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TROPICAL
FORESTRY
PAPERS 41

# *Faidherbia albida*

## MONOGRAPH
## AND
## ANNOTATED BIBLIOGRAPHY

R.D. Barnes and C.W. Fagg

OXFORD FORESTRY INSTITUTE
DEPARTMENT OF PLANT SCIENCES
UNIVERSITY OF OXFORD
2003

FRP
FORESTRY RESEARCH PROGRAMME

## COVER ILLUSTRATIONS

**Front cover**

*Faidherbia albida* on the Gwai River on Chimwara Ranch, Zimbabwe, in August in the middle of the dry season when *F. albida* is in full leaf and provides deep shade for animals in the heat of the day. Nearly all other tree species have lost, or are losing their leaves. The contrast with other species is most marked at this time of the year. Other trees growing among the *F. albida*, but separated by soil differences, or coming after *F. albida* in the succession, include *Acacia tortilis* ssp. *spirocarpa, A. polyacantha, Lonchocarpus capassa, Diospyros mespiliformis, Ziziphus mucronata* and *Kigelia africana.* The *A. tortilis* ssp. *spirocarpa* has already dropped its pods whereas the *F. albida* pods are still green and will fall at the end of the dry season in October-November when other high quality forage is scarce.

**Back cover**

**Above.** *Faidherbia albida* near Zinder in Sahelian Niger where it is one of the few trees to provide vital shade and pods for livestock in the dry season.

**Below.** An unusual population of *Faidherbia albida* at Debre Zeit, in Ethiopia on heavy black vertisols in the central highlands. The trees are preserved and heavily lopped for forage within this highly productive cereal-based farming system. The crop is teff (*Eragrostis tef*).

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# PREFACE

This is the third of four major monographs and annotated bibliographies on African acacia species that are of major importance for human survival and development in many countries of the African continent. Tropical Forestry Paper (TFP) 32 considered *Acacia karroo*, TFP 35 covered *A. erioloba,* while TFP 42 (in preparation) will summarize *A. senegal* and the gum arabic trade. This present monograph covers the genus *Faidherbia albida* which, until recently, was classified in the genus *Acacia* as *A. albida* but is now recognized as a separate, but obviously closely related, monotypic genus.

These publications are the result of a number of research projects financed by the UK Government's Department for International Development (formerly the Overseas Development Administration). They were undertaken by the Oxford Forestry Institute (OFI) and led by Dr Richard Barnes who has outstanding experience and understanding of forests, forestry and acacias in Africa.

As for many other tropical tree species, considerable information has been obtained by professional agronomists, foresters and scientists about the biology, management and uses of the acacias; this has been published in a wide range of books and journals that are not easily available to rural populations, and often not to other scientists and managers. This series of monographs therefore aims to review and bring together all such information in a form that can be easily disseminated and widely understood by the scientist, manager and policy-maker.

The ultimate beneficiaries of such research should be the local populations who depend on woodlands and tree products for their subsistence. The TFP series is therefore accompanied by two other books that are of more immediate value to rural dwellers and to the extension workers who support them – a field guide to the acacias of Zimbabwe, the first in a planned series of field guides for various countries and regions in Africa, and a handbook for extension workers, farmers and teachers. These will assist the integration of the newer, more formal information into the practices of local people to help them use the acacias to the best advantage in a fully sustainable manner.

Professor Jeffery Burley
Director-Emeritus
Oxford Forestry Institute

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# INTRODUCTION

Population pressure and inadequate land management systems have led to deforestation over most of the dry zones of the African continent. Without trees, soil fertility declines, nutritious fodder and forage species cannot be sustained and agricultural production of crops and livestock are drastically reduced. The solution to this problem lies not in the introduction of exotic plants, but in the proper management and cultivation of indigenous species, particularly the pioneer legumes that are the natural colonizers of these disturbed and degraded lands. Most important among these are the acacias.

In recognition of the crucial role that the acacias can play in increasing and sustaining agricultural productivity in the seasonally dry, semi-arid zones of Africa, a number of international agencies, with local collaborators, have over the last 30 years funded projects throughout the continent to study the genetic potential of, and management systems for the most important species. Foremost among these agencies have been CTFT (Centre Technique Forestier Tropical), Division of CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France) now known as CIRAD-Forêt, the Forestry Department of FAO (Food and Agricultural Organization of the United Nations) and the FRP (Forest Research Programme) of the ODA (Overseas Development Administration of the Government of the United Kingdom), now DFID (Department for International Development of the Government of the United Kingdom).

*Faidherbia albida* was recognized as belonging in the genus *Acacia* from 1813, when it was first described, for nearly 180 years before molecular studies tipped the balance in an already weighty case for its being separated into a genus of its own. In the 1980s it became widely accepted as belonging in the monospecific genus *Faidherbia*. Nevertheless, it remains in the Mimosoid legume tribe Acacieae which only contains the two genera, *Acacia* and *Faidherbia*. For all practical purposes, therefore, it is still considered to be an acacia and is almost invariably included among them, particularly where its use in agriculture is concerned, and it has been an important element in the international research and development programmes for the acacias.

The success of afforestation in the semi-arid lands of Africa lies in incorporating trees into farming systems rather than in establishing plantations. The acacias, including *Faidherbia albida*, have an advantage in this respect in that they are armed with thorns against livestock and do not need expensive protection, they compete minimally with, and can enhance crop and grass yields and they provide a wide range of products with cash value. In fact there is often evidence to show that they are the only tree species that have shown an increase in productivity in the degraded agricultural landscapes of Africa. The challenge is to maximize their valuable contribution to agricultural production and to sustain it through the development of management practices that will make them effectively climax species in the agricultural systems.

*Faidherbia albida* is unique among the acacias, and indeed among nearly all tree species, in its reverse phenology; it is leafless during the summer wet season and in leaf in the winter dry season. This attribute gives the species a particular value in both crop and livestock production. Being dormant in summer, the tree does not compete with crops growing beneath it and they benefit from its beneficial effect on soil fertility. Being active in winter, its nutritious pods ripen and fall at the end of the dry season which can often be a critical time for livestock survival when the rains are late in coming and there is no other forage or even roughage.

The value of *Faidherbia albida* in agriculture has been recognized in the Sahelian regions of West Africa, and in parts of Ethiopia, for several centuries and the trees have been incorporated into agricultural systems and very effectively managed in parklands to increase crop and livestock production. More recently, appreciation has dawned of the value of the tree as far south as Malawi and Zambia but this appreciation does not go further south than the banks of the Zambezi river where large trees are still felled in cultivated fields. However, in West Africa increasing population pressures on the land and modern agricultural practices have disrupted the traditional systems and the benefits from the trees are being lost. The extent of this loss has become increasingly apparent with the spiralling costs of agricultural inputs such as fertilizer and animal feed. This situation has stimulated research projects, principally led by CIRAD in the Francophone countries of West Africa since the 1960s, to quantify the beneficial effects of *F. albida* and to formulate management systems to exploit its potential.

*Faidherbia albida* is widely distributed in Africa. It occurs right across the Sahelian zone from West to East, up into Sudan, Ethiopia and Egypt, southwards east of the Rift valley and then across the whole of southern Africa from Mozambique to Angola southwards to South Africa, Botswana and Namibia until frost determines its southern

limit at about latitude 27°S. It is naturally a riverine species but appears to be able to adapt to savanna conditions away from the rivers on a wide range of soils, particularly when historically it has been associated with human agricultural activity. Ecological observations have indicated that there could be considerable genetic variation associated with this ability to adapt to different environments. Recognizing this, the FRP of the ODA funded a sequence of projects at the OFI (Oxford Forestry Institute in the Department of Plant Sciences, University of Oxford) from 1987 to study, assemble and test the genetic resources of *F. albida*, and five other African acacias.

In 1989, the CTFT published a monograph on *Faidherbia albida*. At that time most of the information on the species came from West Africa where almost all the work had been done. By the year 2000, the sequence of acacia projects at the OFI had produced a lot more information on the species across the rest of its range and some interesting genetic information was beginning to emerge. Also during the course of the work, a huge amount of published and grey literature was accessed and abstracted. With funding agencies allocating an increasing proportion of their money upstream, to molecular studies, and downstream, to sociological projects, the mainstream practical research that had become the hallmark of the OFI genetic group was becoming starved of resources and it was decided that it was important to consolidate the information and findings for the acacias in a series of annotated bibliographies and monographs of which this one on *F. albida* is a part.

With *Faidherbia albida* we were fortunate in having the CTFT monograph as a reference for the species and we are appreciative of CIRAD-Forêt's agreement that we could use it as a base on which to build this new updated publication. In some sections where there seemed to be little we could add to a topic, we have repeated the text from the CTFT monograph almost verbatim but in most sections and for most tables a lot more information has become available and this has been re-written and up-dated. While the information from West Africa still forms a major part of the new publication, much more information is given about the species in northern, eastern and southern Africa which we believe makes it a more balanced account of the species over its whole range.

The monographic section has been written as a synthesis of the literature but it also reports some results of original research and incorporates the authors' interpretation of the observations and results of research given in the literature. The annotated bibliography contains full references and abstracts of greater or lesser length, depending on the accessibility and originality of the material, so that the reader can assess the document's likely use before setting about acquiring it. The figures have been grouped in a central section and the captions are fully descriptive so that the reader who wants to get a quick graphic account of the species can do so by reading through the figures section.

This publication has been written and arranged to be useful to a wide range of people. It is hoped that it will provide the scientist with a platform of knowledge from which he can plan his future research, the student with an example of the functions of a tree in an agroforestry situation and an entry into a wide literature on the subject, the extension worker with some specific ideas on how to advise on using the tree in agricultural systems and the farmer himself with the knowledge he or she needs to select a seed source, raise, plant, manage and utilize *F. albida* to his best advantage.

# TAXONOMY, ORIGIN AND DISTRIBUTION

## Nomenclature

The full citation of the species is now:

*Faidherbia albida* (Del.) A. Chev. in Revue de Botanique Appliques Jour. D'Agric. Tropicale 14: 876 (1934). Type: EGYPT, above Philae, Nectoux s.n. (MPU, holotype)

The synonyms, mostly modified from Ross (1979), are:-

- *Acacia albida* Delile in Fl. Aegypte Expl. Planches: 286, t. 52, fig. 3 (1813). Type as shown above
- *Acacia saccharata* Benth. in Hook., Lond. Journ. Bot. 1: 505 (1842). Type: Cayor, Heudelot 391 (K, holo.; FI; OXF; P)
- *Acacia albida* var. *senegalensis* Benth. in Hook., Lond. Journ. of Bot. 1: 505 (1842). Syntypes: Senegal Robert s.n. (K) and Brunner 72 (K)
- *Acacia gyrocarpa* Hochst. ex A. Rich., Tent. Fl. Abyss. 1: 241 (1847). Type: Ethiopia, without locality Schimper 1333 (P holo., BM, E, Fl, K, OXF, Z)
- *Acacia mossambicensis* Bolle in Peters, Reise Mossamb. Bot. 1: 5 (1861). Type: Mozambique, Rios de Sena and R. Chimazo W. of Tete Peters s.n. (B? syntypes)
- *Acacia albida* var. *microfoliolata* De Wild., Pl. Bequaert. 3: 56 (1925). Type: Zaire, Katanga prov., Kala Delevoy 443 (BR, holo.)
- *Acacia albida* var. *variofoliolata* De Wild., Pl. Bequaert. 3: 57 (1925). Type: Zaire, Lubaye Delevoy 227 (BR, holo.)
- *Prosopis? kirkii* Oliv. in F.T.A. 2: 332 (1871). Type: Malawi, Shire river, Kirk s.n. (K, holo.)
- *Faidherbia albida* (Del.) A. Chev. ssp. *albida* in Nongonierma, Bulletin de l'Institute Francaise d'Afrique Noire Serie A 38 (3) 599 (1976)
- *Faidherbia albida* (Del.) A. Chev. ssp. *senegalensis* Benth. var. *senegalensis* in Nongonierma, Bulletin de l'Institute Francaise d'Afrique Noire Serie A 38 (3) 599 (1976) (see plates 1-4)
- *Faidherbia albida* (Del.) A. Chev. ssp. *senegalensis* Benth. var. *glabra* A. Nongo. in Bulletin de l'Institute Francaise d'Afrique Noire Serie A 38 (3) 599 & Planche 7 (1976) Type: Senegal, region de Fleuve, 3 km au nord-est de Ross-Bethio. Nongonierma 3415 (DAKAR holo)
- *Faidherbia albida* (Del.) A. Chev. ssp. *senegalensis* Benth. var. *pseudo-glabra* A. Nongo. in Bulletin de l'Institute Francaise d'Afrique Noire Serie A 38 (3) 599 & Planche 6 (1976) Type: Senegal, presqu'ile du Cap vert, Pout (no number given see plate 6)

[**Bibliography**:- 103, 126, 149, 227, 253, 461, 482, 485, 493, 588, 589, 590, 694]

## Vernacular names

Being so widespread and so much utilized by man, *Faidherbia albida* has a very large number of common names. The number is also swelled by variations in the spelling of the names. Those most commonly found in the literature are listed below. They are given in alphabetical order of language (in brackets after the name(s)). Where the names are common for more than one language, they are given under one language and referred to from the other language in the list.

Anaboom, apiesdoring (**Afrikaans**), gerbi (**Amharinya & Guragenya**), azara, haraz, emil, atasa (**Arabic**), balanzan, balasa (**Bambara**), muchesi (**Bemba**), karaw (**Beriberi**), kwilinti (**Bisharin**), nsangu (**Chichewa/ Nyanja**), gozanga (**Dagati/Dagarti**), puhuri-wooni, puhu-wuni (**Dagbani/Dagomba**), (**Damara** - see Nama), (**Djerma** - see Hausa), bu bilk (**Diola**), ana tree, apple ring thorn, apple ring acacia, winter thorn, white thorn (**English**), cad, kad (**French**), tyahiki, caski, tchaski (**Fulfulde**), gozanga (**Ghanaian**), mjehe, mluma, mujeha (**Gogo**), janwo (**Gonja**), bu lantuabu, gabongu, kanbundisiagu, linkougouable (**Gourmanche**), munjuruf (**Guiziga**), (**Guragenya** - see Amharinya), kwilinseil, kwunti (**Hadendowa**), gao, gawo, (**Hausa/Djerma**), (**Hehe** - see Sango), omue (**Herero**), karage (**Kanuri**), mwiba (**Kaonde**), zizano (**Kassena**), mranda (**Kilango/ Zing**), (**Lara** - see Mundang), munga, mbunga, muUnga (**Lozi**), arav (**Mada**), mokosho (**Mangwato**), ol-erai (**Masai**), zaaga, zaanga (**More**), zangar (**Mossi**), kokoya (**Mundang/Lara**), Musangu (**Nyanga**), anahais, anas (**Nama/Damara**), seretuet (**Nan**), umPumpu, umPumbu, umTungabayeni (**Ndebele**), (**Nyanja** - see Chichewa), derot, garbi (**Orominya**), (**Ouolof** - see Wolof), kababu (**Pare**), caski, cayski, chaski tchayki, thiaski, tieaki, tchaiki, tiaski, tieski, tieaki, tjaiki (**Peul/Fulani**), maman (**Sahonya**), mapogoro, mpogolo, mpogoro (**Sangu/Hehe**), dir (**Sara**), kougnie-sase (**Sarakhohle**), dalyet, duyet (**Sebei**), hak, sas (**Serer**), (**Shangaan** - see Tsonga), mutsangu (**Shona**), garabi (**Somali**), akokoya (**Songhai**), mogabo, mogâhlô (**Sotho**), nanda (**Sukuma**), assana, atens, atheus, athous, atoeuss, att, attehes, habates, hatess (**Tamachek/Tamackeq**), mukababu (**Taveta**), aqba (**Tigre**), garsha, momona (**Tigrinya**), muchangwe, musangu, mujagwe, mutsangu, muUnga (**Tonga**), tari, tehli, teleti, telili (**Toubou**), hlofungu, mmolela,

mukalaunga (**Tsonga/Shangaan**), msangu-sangu (**Tumbuka**), eldurukoit (**Turkana**), muhoto (**Venda**), omuyele (**Wambo**), kad (**Wolof/Ouolof**), chitonya (**Yao**), ege (**Yoruba**), gau, kokoyé (**Zarma**), (**Zing** - see Kilango), umhlalankwazi, umkaya wemfula (**Zulu**).

A list of names generated by the Oxford Forestry Institute's BRAHMS database of the African acacias is given in Appendix 1. The value of this list lies in the association of each name with a herbarium specimen and in its link to a specific locality.

[**Bibliography**:- 24, 149, 173, 215, 235, 342, 457, 485, 493, 523, 586, 648, 663, 666, 670, 671, 691, 714, 747, 748, 749, 750]

## Botanical description

The following botanical description is a composite from selected references in the bibliography given at the end of this section.

**Tree**, up to 30 m. high, sometimes shrub-like in very arid situations. Crown usually rounded in mature trees with spreading branches; young trees can be fastigiate. Trunk usually single, with diameters often up to 2 m. (exceptional cases to 6 m.(White 1962)), multistemmed forms either due to trunk coppicing or root suckering. Wood light: sapwood streaky grey white, heartwood yellow. **Bark** dark brown to dull grey, rough, and deeply fissured and scaly in mature trees, smooth in young trees. Branches greenish-white, sub-glabrous to pubescent, markedly zig-zag, and sometimes fissured to expose a green cortex. **Stipules** spinescent in pairs, moderately thick and straight, up to 3.2 cm long, white to grey with a brown base, rarely the base is slightly enlarged but never inflated into ant galls. Spines usually on new growth, vestigial or abscent on old growth; when young often tipped with orange or brown. **Leaves** bipinnate. **Petiole** 0.5-3.7 cm long, eglandular, Rachis 1.3-7.5 cm long, with a gland at the junction of each of the 2-12 pairs of pinnae, gland round to oval, yellow or reddish-brown to black. **Rachillae** 1.5-8.9 cm long, channelled adaxially. **Leaflets** grey-green, 4-23 pairs per pinna, 2.5-14 mm. long 0.7-5 mm. wide, linear oblong to slightly obovate oblong, with or without marginal cilia, glabrous to densely appressed-pubescent abaxially and/or adaxially. **Inflorescence** spicate produced singly between paired spines or in a leaf axil on current season's growth, spike 3-16 cm. long, on peduncles 0.8-6.3 cm long, terete, olive-green. **Flowers** yellowish white, sessile or to 2 mm. pedicellate. **Calyx** yellow, glabrous to pubescent, 1-2.5 mm long (tube 0.8-2.5 mm. long, 5 triangular lobes, 0.3-0.7 mm. long). **Corolla** yellow, often with a distinctive reddish-pink inside basally, glabrous to pubescent, 3-4.5 mm. long (tube 0.8-2.5 mm long, 5 triangular lobes, up to 3 mm long). **Stamen filaments** numerous (40-+80), up to 7.5 mm long, united and tubular for about 1 mm. at base, yellow. **Anthers** 0.2-0.4 mm across, eglandular, 2 celled, 4 pollen polyads per cell (16-30 pollen grains /polyad). Ovary pilose, shortly stipitate, 0.7-1.4 mm long, style glabrous or subglabrous, up to 7.5 mm long, yellow. **Pollen grains** pollen porate with an areolate tectum and columellae, 3-5 pores, diameter 2.9-5.0 μ; 32 (30-50) grains per polyad which measure 81.1-101.4 x 46.8-62.4 μ and individual cells 20-22 x 16-25 μ; ungrooved monads; thickness of the exine on the distal face 1 μ, two layers of equal thickness, with a very vague and minute pattern of dots; surface granulate. **Pods** orange to reddish-brown, and often coiled, twisted or falcate, 2.5-30 cm long x 1.2-6.7 cm wide, thick and woody to thin and flaky, indehiscent, glabrous or rarely puberulous. **Seeds** up to 29 per pod, light to very dark brown, elliptic-lenticular, 6-12 x 4-8 mm. wide, large distinct areole, elliptic-lenticular, 5-9 x 4-6 mm, seed weight 0.05-0.14 g. **Seedling** epigeal, cotyledons fleshy, sessile, 8-15 mm x 5-10 mm, green upper surface, violet tinted underside, two small oval-elliptical to slightly oblong openings at base. Two bipinnate, twice-jugate, persistent first leaves, one pair of pinnae with 7-8 pairs of hairy, elliptical-ovoid to oblong leaflets with rounded end, can be lightly pubescent but usually glaucescent beneath, mid rib eccentric. Pale green, striated hypocotyl 10-35 mm long.

For botanical illustrations of the morphology of *Faidherbia albida* see Figures 1- 6, 24-31 and 98-101.

[**Bibliography**:- 76, 93, 94, 95, 103, 111, 149, 216, 217, 218, 220, 222, 233, 234, 235, 240, 253, 271, 320, 321, 331, 344, 401, 409, 457, 485, 493, 499, 521, 523, 588, 589, 590, 597, 670, 671, 685, 691, 694, 700, 706, 707, 725, 727, 731, 743, 755, 756]

## Origin

The origin of *Faidherbia albida* is not well understood. It has been suggested (Chevalier 1928; 1934) that it might have originated in the Sahara before desertification and spread to the east and the south and that it was domesticated by man in the Sudanian phytogeographical region. A semi-climax of *F. albida* in the southwestern part of Senegal has been identified, where the species would have been brought in by nomadic peoples and their animals in particularly hard times (Trochain 1969). The human influence developed stable tree populations which replaced the natural open forest climax formations of the Sudanian zone on the lighter, sandier soils. This view is shared by many foresters who believe that the species is not indigenous in the natural forest formations of west Africa where its existence is bound up with pastoralism and agriculture (CTFT 1989). There is also the view that the distribution of the two races across the African continent, and in particular the existence of intermediate forms in west Africa, is an indication of a northern origin for the species (Wickens 1969) which is

supported by its presence in Israel where it is considered to be a relic of the Sudanese flora (Zohary 1962; Halevy 1971; Aloni 1972)). There is, however, a counter view that *F. albida* is an ancient riverine species of east and southern Africa which expanded northwards as a result of the activities of men and animals where it is only found on cultivated or previously cultivated land (Aubréville 1937;1950).

The earliest records of *Faidherbia albida* come from fossil pollen from the middle Pleistocene found in alluvial deposits in the Awash Valley of Ethiopia (Bonnefille 1975). The site is on the banks of the River Awash, 30 km south-east of Addis Ababa at 2000 m above sea level. As the species is pollinated by birds and insects, it produces relatively little pollen and the polyads are not transported very far from their point of origin. *Acacia* pollen in present day mud was much less abundant than *Acacia* was itself in the local vegetation which has led palynologists to believe that the genus is under-represented in the fossil pollen record. The discovery of three polyads of *F. albida* was said, therefore, to be of true significance regarding the presence of this species in the Awash Valley. It was shown that the presence of *F. albida* pollen coincided with a diminution of the number of grasses and an increase in the number of trees and it is taken as indicative of a humid climate. Macro-botanical remains of *F. albida* found near Ghat in Libya in deposits dated 5600 to 3800 BC correspond to the Neolithic humid phase. Other pollen has been found in lake Hula in Israel, dated 60,000 to 70,000 years old (interglacial). It was not possible to date the *F. albida* pollen in the Awash Valley precisely but geological data allow it also to be placed at 60,000-70,000 years old. This evidence of an extension of the geographic range of *F. albida* to Ethiopia in the Quaternary period supports the theory that the species' origins lie in the north of Africa rather than in the east or the south.

The proposal for a northern origin for *Faidherbia albida* has been further supported by a study in which genetic variation was assessed in 30 populations (931 families) of the species from across its entire African range (Harris *et al.* 1997). Six isozyme loci were identified by five enzyme systems. Patterns of genetic diversity that emerged from this study suggested three hypotheses regarding the present distribution of *F. albida:* (i) *F. albida* originated in the Ethiopian/Sudanian region, followed by extensive east-west movement (both by animals and man) along the nomad routes of sub-Saharan Africa and along the east coast of Africa; (ii) *F. albida* originated in West Africa and dispersed through the sub-Saharan region into Ethiopia and then into East Africa; (iii) *F. albida* originated in eastern and southern African and was later spread to West Africa by man and his animals. Evidence from the relative levels of genetic diversity in the three regions of the *F. albida* distribution identified, indicated that a southern African origin of the species is unlikely since genetic diversity is lowest in this area.

In another recent isozyme study of 11 provenances representing the central, western and southern parts of the distribution range of *Faidherbia albida* in Africa, two distinguishable ecological races were identified (Ibrahim 1996a). One, endemic to the southern distribution range of the species, had a low isozyme diversity and the other, endemic to the western and central parts of the species' range, had a high enzyme diversity. Similar patterns were observed in quantitative morphological characteristics. The two patterns were found to overlap in the central distribution range of northeastern Ethiopia. This suggested that the centre of diversity may be in Ethiopia (the Sudan/Ethiopian highlands and the adjacent Lodwar valley in Kenya) and that this was its centre of origin. It is theorized that seed dispersal by animals may have contributed towards its genetic diversity in the Sahelian region whereas dispersal by water along the rivers might explain the lower genetic diversity in the south of its range.

In a trial of 32 provenances of *Faidherbia albida* in Niger, it was found that there were two distinct ecotypes, A, the west African plateau type adapted to severe seasonal drought and deep water tables and B, the east and southern African riparian and lowland type requiring high water tables to survive drought and seasonal dry periods (Vandenbeldt 1991b). It is probable that both ecotypes occur in Ethiopia because there is a distinction between a montaine type that appears to be independent of a perennial groundwater table and a riverine type that has perennial access to water. The results of these trials are taken as evidence that the Sudan/Ethiopia region is the centre of origin of the species and that the two ecotypes diverged when A moved westwards with human pastoral and agricultural activities and B followed the Nile system southwards.

In a study to investigate the diversity and population genetics of *Faidherbia albida* using RAPDs, RFLPs and mtDNA (Rendell 1998), two groups of populations corresponding to northern and southern Africa were identified. Allozyme data suggested that low variation in southern Africa could be explained through recent colonization. A low inter-population pollen:seed flow ratio, estimated for the northern region, indicated that seed is migrating over greater distances than pollen.

*Faidherbia albida* is most closely related to the climbing *Acacias* through the seedling having bipinnate leaves; but it differs from them in that the seedling has only one pair of pinnae, a terete hypocotyl and spinescent stipules (El Amin 1975). There is a theory that the climbing acacias are the ancestral stock of the genus (El Amin 1975). It has also been suggested that *F. albida* and *A. erioloba* might themselves be relicts of a parental stock of the African *Acacia* species (Robbertse, 1974a).

[**Bibliography**:- 15, 34, 80, 83, 102, 149, 220, 310, 315, 334, 345, 459, 482, 570, 572, 591, 682, 694, 730, 757]

## Natural distribution

*Faidherbia albida* is pan-African in its natural distribution. It is widespread in tropical and sub-tropical regions of the continent from Senegal and Gambia in the west to Egypt in the north-east and southwards to kwaZulu in South Africa. It extends into the Middle East and has been recorded from Arabia, Yemen, Israel, Palestine, Oman and Syria. It does not occur south of about 27°30'S, north of the Sahara Desert or in the Guineo-Congolian equatorial region. It has been introduced into India, Pakistan, Nepal, Peru, Cyprus, Cape Verde and the Ascension islands. Localities of selected herbarium specimens are given in the list in Appendix 2 by country, province and locality name. Those that have had their longitude and latitude established have been plotted on the map (Figures 7-11).

[**Bibliography**:- 34, 57, 90, 103, 110, 141, 149, 215, 222, 227, 233, 234, 235, 236, 241, 246, 249, 251, 252, 253, 310, 340, 353, 379, 399, 405, 422, 461, 484, 493, 588, 590, 591, 597, 616, 670, 671, 691, 694, 704, 707, 714, 725, 728, 730, 733, 743, 747]

## Karyotype

*Faidherbia albida* has a chromosome count of 2n=26 (Atchinson 1948; Nongonierma 1976). A polyploid (2n=52) has been recorded from Israel (Halevy 1971). The general conclusion is that *F. albida* is a diploid species (2n=26) over most of its range.

[**Bibliography**:- 16, 30, 31, 233, 235, 310, 493, 708]

## *Faidherbia albida* in the genus *Acacia*

The genus *Acacia* was first described by P. Miller in 1754 based on a specimen of *Acacia nilotica* from Egypt; the name is derived from the Greek word *akis*, meaning a sharp point, descriptive of the thorns that are borne by that species. *Faidherbia albida* was first described by Delile in 1813 from the specimen collected in Egypt and he named it *Acacia albida* Del. The specific epithet is from the Latin word *albidus*, which means whitish, in reference to the pale colour of the branchlets and thorns (see Figure 37). In his revision of the genus, Bentham (first in 1842 then again in 1875) recognized *F. albida* as belonging in the series *Gummiferae* (spinescent species) in *Acacia*, the sole genus in the tribe *Acacieae* in the sub-family *Mimosoideae* of the family *Leguminosae*. However, the species has long been considered as being botanically quite distinct in *Acacia* with no close relatives within the genus (CTFT, 1989). Baillon (1863) was the first to signal the anomalies when he noted that the stamen filaments in *F. albida* are joined at their base whereas the filaments in other spinescent acacias are free. However, it was not until 1934 that Chevalier (1934) used this characteristic among others as a basis to propose that the species should be placed in a monospecific genus which he named *Faidherbia* after a French general, Faidherb, who campaigned in West Africa. Since then, this new classification has been followed by a large number of authorities (CTFT, 1989) including Aubreville (1950), Gilbert and Boutique (1952), Trochain (1969), Vassal (1967 and 1981), Guinet (1964), Nongonierma (1978a), Robbertse *et al.* (1980) and Polhill and Raven (1981 cited in Brenan, (1983)). The move established a link between the *Acacieae* and *Ingeae*, another tribe of the *Mimosoideae,* but there is still some controversy as to which of the two tribes *Faidherbia* should be assigned (Guinet and Lugardon, 1977).

The full list of morphological, physiological and chemical characteristics that set *Faidherbia albida* apart from the other African acacias is given below.

- it has thorns and spicate inflorescences - all other acacias with spicate inflorescences have prickles (Fagg and Barnes, 1990)
- the primordial (first) pair of leaves produced after the cotyledons is bipinnate - all other spinescent acacias produce a pinnate leaf first (Vassal, 1972a & 1972b; 1981)
- it has no petiolar gland (Ross, 1973; Robbertse, 1975c) - it is present in all other African acacias except *Acacia erioloba*
- the stamen filaments are shortly connate (joined) at their bases and thickened on the inner basal part to form a disc-like structure similar to that found in the non-spinescent acacias - all other spinescent acacias have free filaments (Ross,1973; Vassal, 1981)
- it has larger anther sacs than any other species in the genus (Ross, 1973: Hassan and Styles, 1990)
- the anthers are eglandular - the anthers of all other acacias have glands (Ross, 1973; Robbbertse, 1974a; Hassan and Styles, 1990; Tybirk and Jorgensen, 1994)
- the pollen polyads are composed of 26-32 (rarely 16) pollen grains (El Amin, 1973b & 1977) - in most other African acacias there are consistently 16 (except for *Acacia erioloba* which has 26-48 (Zinderen Bakker and Coetzee 1959)
- it has four pollen pores - all other African acacias have more (El Amin, 1973b)
- the surface of the pollen grain has no furrows - the pollen grains of all other spinescent acacias are furrowed (Guinet, 1964)
- it has pollen exine of the *Ingeae* type (Guinet and Lugardon, 1976)
- the cotyledons are sessile - all other spinescent acacias have petiolate cotyledons (El Amin, 1973b, 1975 & 1977)
- the wood has a layered structure and straight rays - no other acacias have the layered structure and no other African species have straight rays (Cutler, 1969; Robbertse *et al*, 1980; Fahn *et al.*, 1986)

- the seed shape is obovate - unlike all other acacias (Horowitz and Baum, 1967)
- the areole is large and conforms to the outline of the seed - in other spicate-flowered species the areole is horseshoe-shaped and occupies the central area of the seed (Ross, 1979)
- the anatomical morphology of the leaf is distinctive - unlike any other acacia which mostly fit into two distinct groups (Robbertse 1975c)
- there is no involucre on the flower peduncle - all other spinescent acacias have one present (Fagg and Barnes, 1990)
- it has both longitudinal and latitudinal fibres in the pod - all other spinescent acacias have only longitudinal or no fibres (Robbertse, 1975b)
- it loses its leaves in the wet season and flushes in the dry season - all other acacias have the reverse of this phenology (El Amin, 1973b, 1975 &1977; Lebrun, 1975)
- the free amino acids that are characteristic of the other African acacias are absent in *F. albida* - the specific free marker amino acid in the seeds of the spinescent acacias is N-acetyldjenkolic acid and those in the non-spinescent acacias are S-carboxyethyl cysteine and an unknown derivative of pipecolic acid (Evans *et al.*, 1977)
- in serological tests, *F. albida* reacts differently from all African *Acacia* species tested, which, among the Gummiferae, reacted identically (El Tinay *et al.*, 1979; Brain, 1987).
- the sequence structure of 5S DNA units in *F. albida* are quite different from other *Acacia* species (Playford *et al.*, 1992)

All agree that *Faidherbia albida* is very distinct, without any close relatives. For example, an analysis of morphological and chemical characters in the Tribe Acacieae has pointed to the paraphyletic nature of the tribe and the unsatisfactory definition of tribal limits between the Acacieae and the Ingeae (Chappill and Maslin, 1995 (not in bibliography)); and a principal components analysis using 51 morphological characters clearly separated it from 12 *Acacia* species in Sudan (Kordofani and Ingrouille, 1991). On the evidence of numerous such studies that provided evidence of dissimilarity from the other acacias, it was inevitable that the species should be reclassified as *Faidherbia albida,* a monospecific genus and the name now almost universally accepted. The closest relative among the African acacias appears to be *Acacia erioloba.* In various characteristics this species is also unique in the genus. Robbertse (1974a) examined the surface structures of pollen grains of *A. erioloba* and *F. albida* in a study to elucidate their taxonomic relationship. *F. albida* was found to be distinct from all other African *Acacia* species except *A. erioloba* in that it has up to 32 cells in the polyad, that it has two peripheral monads on each lateral side of the polyad that undergo a single division to form a double layer and that the petiole is eglandular. In a further study, Robbertse (1975c) found that *F. albida* closely resembled *A. erioloba* (Gummiferae) in the anatomy of the petiole. Both *F. albida* (Nongonierma, 1976) and *A. erioloba* (Robbertse & van der Schijff, 1971) have been stated as being both diploid (2n=26) and polyploid (2n=52). It has been suggested that *A. erioloba* and *F. albida* might be relicts of the parental stock of the African *Acacia* species (Robbertse, 1974a).

[**Bibliography**:- 36, 44, 57, 58, 92, 96, 100, 127, 128, 149, 151, 174, 219, 220, 221, 225, 230, 234, 235, 237, 278, 282, 299, 300, 303, 320, 334, 340, 366, 399, 400, 401, 408, 493, 496, 497, 500, 530, 544, 572, 573, 574, 575, 576, 577, 578, 579, 588, 589, 590, 621, 623, 683, 684, 685, 700, 701, 702, 703, 705, 706, 708, 730, 743, 755, ]

### Sub-specific taxa in *Faidherbia albida*

There is considerable variation in *Faidherbia albida* across its range in both leaf and pod (and seed) morphology. In a detailed biosystematic study, Nongonierma (1976) proposed that the monotypic genus *Faidherbia* A. Chev., should be re-classified with two subspecies *F. albida* (Del.) A. Chev. ssp. *albida* and *F. albida* (Del.) A. Chev. ssp. *senegalensis* Benth., and with three varieties in subspecies *senegalensis*. Subspecies *albida* is described as having a mean of five pinnae pairs and a smaller leaf size and as occurring in north-east Africa and Israel, whereas ssp. *senegalensis* has a mean of 6-8 pairs, larger leaves and occurs only in West Africa. Within ssp. *senegalensis*, var. *senegalensis* is pubescent or villous as a mature plant, with glabrous fruits, var. *glabra* is totally glabrous, and var. *pseudo-glabra* is glabrous except for the seedlings which are pubescent.

Statistically large variations in pod length, width and weight have been noted between individual trees within and between populations (Fagg 1992, Chevalier *et al.*, 1992) with pod length and mass significantly larger in the southern African populations compared to populations from west Africa. Sniezko and Stewart (1989) found significant variation in seed weights between west and southern African populations, the largest from southern Africa, and the smallest from west Africa, with seed of the east African populations being generally intermediate in size. In trials, the larger seeded east and southern African populations have grown faster than the west African populations and have a higher shoot/root ratio, but can fail in the more arid west African sites where water tables are deep (Vandenbeldt 1990b).

Brenan (1959) recognized two distinct geographical races in east Africa, based on the distribution of pubescence on the branchlet and inflorescence axis and the leaflet size. In east Africa, Race A, with smaller more glabrous leaves, occurs from Tanzania to Kenya, Ethiopia and Somalia, whilst Race B, with larger pubescent leaves, occurs from Tanzania southwards to South Africa. A range-wide study of the variation in seedling

leaf peroxidases tended to confirm the distinction between these two races (Harris *et al.* 1997). However, the races are not formally recognized because they both occur together, and there are intermediates between them, from Sudan to north and west Africa (Ross 1979; Brenan 1983). The proposed varieties *Acacia albida* var. *senegalensis*, *A. albida* var. *microfoliata* and *A. albida* var. *variofoliata* were all described from specimens attributable to Race B (Brenan 1983; CTFT 1989). The proposed sub-species *Faidherbia albida* ssp. *albida* was described from a specimen with the smaller leaves (Race A) and the sub-species *F. albida* ssp. *senegalensis* and its three varieties, *sengalensis, glabra* and *pseudo-glabra*, from specimens with the larger leaves (Race B) (Nongonierma 1976).

[**Bibliography**:- 93, 95, 131, 149, 194, 232, 315, 346, 347, 493, 588, 590, 641, 671, 693, 695, 733]

# GENETIC VARIATION

## Sampling genetic variation for testing

Taxonomic studies of specimens from the natural range have resulted in two races of *Faidherbia albida* being described (Brenan 1959). The morphological characteristics are:-

- **Race A** - young branches, inflorescence, peduncle, calyx and corolla glabrous or almost so, leaflets small (6x1.5 mm) and ciliate along margins but otherwise glabrous;
- **Race B** - young branches, inflorescence, peduncle, calyx and often the corolla pubescent and leaflets pubescent on surface and generally larger (12x4 mm) than in race A.

The two races have not been given varietal or subspecific status because of the occurrence of forms that are intermediate in one or more of the characters (Ross 1966). However, the distinctions do hold good at the extremes of the distribution. Race B occurs exclusively from the range south of southern Tanzania whereas Race A is found exclusively from northern Tanzania to Ethiopia. In Sudan and in west Africa, Race B is common, but many specimens combine characteristics of both races; and in Egypt and the northern-most populations, most specimens appear to be intermediate between the two races (CTFT 1989).

In the last decade, a large number of comprehensive seed collections has been made of African acacias and many provenance trials have been established (Corbasson 1987; Fagg and Barnes 1995). This has been in response to an internationally identified need for improved use of the genetic variation in the genus. A major part of this work has been undertaken in a series of projects started in 1987 by the Oxford Forestry Institute, funded by the Overseas Development Agency (later the Department For International Development) of the British Government, to study and assemble the genetic resources of the African acacias including *Faidherbia albida* (Fagg and Barnes 1995). These provenance trials are now making it possible to assess genetic variation in the species free from environmental effects.

Given that there was little to go by from morphological variation described in taxonomic studies, selection of provenances for collection was based initially on sampling the geographical and ecological variation in expectation of correlated genetic divergence, particularly where there was a discontinuous distribution (Figure 12). The first step was to map the natural distribution of the species from herbarium specimens. Areas were then identified by selecting sites with geographical discontinuity and differences in climate, altitude, soils and ecology. *Faidherbia albida* has a more continuous distribution across the Sudano Sahelian belt of west Africa than in its southward extension. In the initial sampling plan, therefore, more weight was given to collecting seed from the isolated populations of east and southern Africa, particularly from outlying and remote populations, such as the Kuiseb and Hoanib river systems in the Namib desert in Namibia, which had been under-represented in previous collections.

Since little was known initially about the patterns of variation within a population, a broad sampling was undertaken when selecting seed trees. Seed was collected from a minimum of 25 individual trees per provenance, spaced at least 100 metres apart. For most provenances, seed lots of individual trees were kept separate. This made it possible to ensure more balanced provenance representation and also enabled assessment of within-population variation through incorporation of half-sib progeny tests within the provenance trials.

Early molecular studies on seedling and leaf material started to show that the discontinuous southern African populations, originally thought to be the most variable, were in fact least variable and that those of west and particularly northeast Africa contained the highest levels of diversity (see below) and that there was a clear division between the southern African populations up to southern Tanzania and those north of this line (Figure 14). The initial sampling strategy was, therefore modified and more collections were made in the west and particularly in the north-western area of its distribution.

The final list of *Faidherbia albida* provenances that were and are being used in the international provenance trials and also being distributed for species trials, agroforestry trials, vegetative propagation studies, screening for salt resistance, chloroplast DNA studies, isozyme studies, nodulation studies and nutrient uptake studies, is given in Appendix 3 (See Fagg and Barnes 1995).

[**Bibliography**:- 49, 50, 51, 93, 96, 141, 149, 232, 233, 234, 235, 253, 365, 588, 694]

## Molecular variation

As collections for provenance testing of *Faidherbia albida* progressed, seed samples were distributed by collecting

agencies to many laboratories for isozyme and DNA testing. The number of populations sampled in each study and the extent to which they represented the range of the species varied greatly with the region of interest and the seed available at the time.

Under a collaborative CEC project, the first large isozyme studies were undertaken on both the west African populations (Joly *et al.* 1992) and on the east and southern African populations (Harris *et al.* 1997). A single seed per tree was used for the genetic diversity studies because of the large numbers of trees and populations. Larger numbers of half-sib progenies (10 seeds per family) were used to study the breeding systems by examining the segregation ratios. Results indicated that there was a high genetic diversity within the species across its range and a marked disjunction between 20 populations from west Africa and two populations from Zimbabwe. Higher levels of diversity were found in the west African populations.

Using the same methodology as Joly *et al.* (1992), six enzyme systems were scored for six putative loci in an OFI study that included 931 individuals from 30 populations of *Faidherbia albida* covering its entire geographical range (Harris *et al.*1997). This study showed that the genetic diversity of *F. albida* (He = 0.127) is somewhat lower than the mean for common tropical tree species (H = 0.211), but is very similar to that recorded for nine species of Australian *Acacia* (He = 0.132). However, this is much lower than that recorded for West African populations of *F. albida* (He = 0.442) (Joly *et al.*, 1992). Both studies used the same standard methodology but part of the discrepancy may have been due to the differences in the numbers of loci scored; only six of the ten loci scored by Joly *et al.* (1992) were used by Harris *et al.* (1997). In the latter study, the mean percentage of polymorphic loci per population was 31.7% and the mean number of alleles per locus 1.6. Genetic diversity was greatest in populations from West Africa and lowest in populations from eastern/southern Africa; the Ethiopian/Sudanese populations were intermediate. The overall degree of genetic differentiation between populations indicated that approximately 56% of the enzyme variation resided within populations. Two major groups were identified, the eastern/southern African and the Ethiopian/West African clusters. Within the Ethiopian/West African cluster, two sub-clusters could be recognized, one broadly corresponding to those populations from Ethiopia/Sudan and the other to those populations from West Africa (Figure 14).

Cluster analyses of Nei's genetic distances confirmed the divergence between West African and southern/eastern African populations of *Faidherbia albida* into two gene pools (Joly 1992) and gave evidence of the third gene pool composed of the Ethiopian and Sudanese populations (Harris *et al.* 1997) (Figure 14). Genetic distance was smallest in those populations from eastern/southern Africa (excluding the Kenyan populations) and greatest in the West African populations. The genetic distance of the Ethiopean/Sudanese populations was intermediate. These results thus paralleled those deduced from the measures of genetic diversity, which were greatest in West Africa and smallest in east/southern Africa.

Within Ethiopia there appears to be a major disjunction in the natural distribution of the species between the north and south of the country; this was borne out in the cluster analysis. The northern populations in Tigray (Rama) and Gonder, which are located along the Mereb and Tacesse rivers, are lower than those in the central highlands and link to the Nile river drainage system (Blue Nile) in Sudan. In Sudan, the species is known in the west along the Red Sea coast and down into Eritrea, in the Nile drainage system and in the east in Darfur (Khor) and Kordofan. From Sudan to Senegal it occurs scattered in the drier parts of the Sudanian and Sahelian zones where the climate and topography are fairly similar right across west Africa (White 1983). Most of this region is relatively low lying (below 750 metres) without pronounced relief. In southern Ethiopia *Faidherbia albida* is found commonly along the Great Rift valley lakes and their drainage systems (Awassa, Koka, Arba Minch) and in the eastern highlands (Gelemso and South Harar). It is also found on heavy vertisols around Debre Zeit in the central highlands near the rift valley. This is an unusual ecotype; through most of its range *F. albida* occurs on sandy alluvium.

The Kenyan populations are weakly linked to the eastern/southern African cluster, but when the Lap-1 locus is excluded they become part of the Ethiopian/Sudanese sub-cluster. Morphologically and geographically they are more closely allied to the southern Ethiopian material; they are also associated with the Great Rift valley drainage systems.

All the other populations analyzed from the eastern and southern populations (excluding those from Kenya) occur from the southern highlands of Tanzania, in the Zambezian regional centre of endemism (White 1983). The dividing line between Zambezian and the Somali Masai regional centre of endemism is at the base of the southern highlands. It is interesting that leaf peroxidase variation in *Faidherbia albida* and *Acacia tortilis* (data produced in ODA/FRP/OFI Project R.5655 and not yet published (see Fagg and Barnes 1995)) showed a similar break in Tanzania between populations from east/south Africa and populations from north/west Africa).

In a similar, but more limited, series of investigations (Ibrahim 1996a and 1996b), variation was examined in genetic material collected from central as well as from the two opposite ends of the range of *Faidherbia albida.* The results suggested that *F. albida* has a bimodal pattern of genetic variation. One variant is confined to the Sahelian range and the other to the southern distribution range. Based on the results, two ecological races were

identified and their geographic distributions were approximately delineated. They overlap only in the area of high genetic diversity in Ethiopia, possibly the species' centre of origin. It is theorized that seed dispersal by animals may have contributed towards its genetic diversity in the Sahelian region whereas dispersal by water along the rivers might explain the lower genetic diversity found in the south of its range.

The diversity and population genetics of *Faidherbia albida* were recently investigated in a study that employed more modern molecular techniques. Random amplified polymorphic DNAs (RAPDs) were used to provide information on overall levels of genetic diversity, and restriction fragment length polymorphisms (RFLPs) in mitochondrial DNA (mtDNA) were used to provide seed-specific markers (Rendell 1998). Cluster analyses identified groups of populations corresponding to three geographic regions; eastern, western and southern Africa. At the regional level, about 80% of variation existed within geographic regions, whilst at the population level about 45% of variation could be attributed to differences within populations.

Patterns of genetic diversity are beginning to emerge from these molecular studies that allow two hypotheses to be proposed regarding the present distribution of *Faidherbia albida*: (i) *F. albida* originated in the Ethiopian region, followed by extensive east-west movement of germplasm in prehistorical (or historical) time by both animals and man, possibly along the nomad routes of sub-Saharan Africa. A lesser north-south movement of germplasm occurred along the east coast of Africa. (ii) *F. albida* originated in west Africa and dispersed through the sub-Saharan region of Ethiopia and then into east Africa, a scenario first proposed by Chevalier in 1928 (Wickens 1969). More data is needed, using other molecular markers and archaeological information, before these competing hypotheses can be tested. Nevertheless, all these findings were used to improve the sampling strategy for making the seed collections for genetic evaluation of the species.

[**Bibliography**:- 73, 103, 234, 315, 345, 346, 347, 365, 366, 367, 368, 570, 565, 728, 730]

## Physiological variation and adaptation

### *Salt tolerance*

Two studies on salt tolerance of *Faidherbia albida* seedlings have been reported. In the first, between and within population variation was assessed for two provenances, Mana Pools (Zimbabwe) and Chawanje (Malawi), at the germination stage (Brown 1998). Overall the results showed that the two provenances were moderately salt tolerant and that the Chawanje provenance was more salt tolerant than Mana Pools. In the second study (Gillespie 1999) the three provenances included, Gona-re-Zhou (Zimbabwe), Debre Zeit (Ethiopia) and Bignonia (Senegal). All were affected adversely by high salinity levels but by the end of the experiment the reduction in growth and the loss of leaves was significantly less in the Bignona provenance. The slower growth and potential drought tolerance of this provenance may explain its greater tolerance of salinity.

### *Nodulation*

In Senegal, *Faidherbia albida* was found to have a low N-fixing potential although some provenances exhibited higher rates (Gueye *et al.* 1997; Gueye and Ndoye 1998). For example, in Senegal, the proportion of nitrogen derived from the atmosphere varied significantly between seven provenances from 0 to 38%. In a test for nodulation in Zimbabwe on 25 provenances of *F. albida* from West, East and southern Africa, all seedlings produced some nodules although West African provenances nodulated less (Sneizko 1987). In a nursery trial of two *F. albida* provenances in Zimbabwe, Mana Pools (Zimbabwe) and Hwange (Zimbabwe), 64% of the seedlings were found to be nodulated (Gwaze *et al.* 1988). There is evidence, therefore, from these seedling studies that nitrogen fixation could be increased through selection.

### *Adaptation*

In Marunda's (1993) greenhouse study of environmental effects on phenology and growth and root morphology in 20 provenances of *Faidherbia albida*, there was evidence of genetic variation between provenances and, to some extent, between families within provenances. There were strong negative correlations between growth traits and those of adaptive significance. Long day-length and water stress caused defoliation to occur most in the Sudan/Ethiopian highlands provenances, next in the those from the riparian ecosystems of southern Africa and least in those from the "upland" (about 750 m altitude) ecosystems of west Africa.

In a trial in Burkina Faso, 36 provenances of *Faidherbia albida* from nine countries across the species' range were planted on two sites, one with and one without a lateritic pan (Billand and Frammond 1990). Eastern and southern African provenances had high initial growth but, after 18 months, suddenly died where the lateritic pan was present while remaining alive at the other site. The central Sahelian provenances from Burkina Faso, Mali and Niger showed the best overall results as they overcame their initial poor performance and, at five years, appeared to be the best choice for planting in Burkina Faso. It was concluded that deaths in the east and southern African provenances were due to their being adapted to the more equitable rainfall distribution, and therefore less severe soil moisture deficits, in the collection sites. In another set of trials in Burkina Faso,

40 provenances were tested on three sites that varied in soil type and annual rainfall (Bongkoungou *et al.* 1988). The growth and survival in the first 30 months varied greatly both between and within provenances. Growth of a provenance was best at sites with conditions most similar to those of the provenance origin.

Twenty-one provenances of *Faidherbia albida* were included in the screening trials of six *Acacia* species which were planted across eight contrasting sites in Zimbabwe (Barnes *et al.* 1999). After the first year, during which there were only light frosts, the species as a whole had done best on granite-derived soils and not so well on the heavier soils and the wind-blown sands. By the fourth year, however, heavy frosts had cut the species back on all but two sites. The species coppiced repeatedly even after being frosted to the ground and the coppicing shoots were very vigorous, especially in the first year after planting. Generally, the southern African provenances did best. The high altitude provenances from Ethiopia did better than all other provenances on the heavier soils and on the frostier sites. The West African savanna provenances were poorest at one year old but, by the fourth year, there was some evidence that they might be taking the lead on the wind-blown fossil dune sites. The conclusion was that the species was best suited to frost-free sites on alluvial soils and sands.

*Faidherbia albida* is exclusively a riverine species in east and southern Africa and regenerates only on newly-formed sand and silt banks after flooding along rivers where there is no frost, or at least where frost is periodically infrequent enough to allow it an opportunity to put on sufficient height growth to get above the frost layer (Figure 44). However, the species can grow and perform extremely well away from the rivers in the right climate and on the right soils where man has removed the competition from grass and woody re-growth during the establishment phase. In Malawi, *F. albida* now grows in cultivated fields away from the rivers round the lake. Here, the artificial weed-free environment and the tree's usefulness to farmers has resulted in a symbiosis that has helped the species to extend out of its natural environment. Very large specimens of *F. albida* are also often seen in gardens and on farms in southern Africa where they have been planted and kept weed-free for a few years (Figures 105, 106). It is possible, therefore, that the species could be used far more widely than it is if it is afforded just a little attention in the first few years. In the medium term, the trials that have been established should show whether this is practicable and, if so, which provenances should be used to achieve fastest growth and greatest pod production (Barnes *et al.* 1999).

Seed and seedling morphology of *Faidherbia albida* have been investigated in conjunction with isozyme analysis. Seeds and seedlings from 19 seedlots representing central, western and southern parts of the distribution range were studied (Ibrahim *et al.* 1997). The bimodal pattern of variation that was shown in the seed and seedling morphology was similar to that shown by the isozyme study. Clines of some morphological traits investigated were also evident in the riparian habitat of the central distribution range. Large-sized seeds were associated with southern African provenances which are in turn associated with riparian habitats. It is argued that, in this situation, greater embryonic capital gives the plants an advantage by favouring rapid establishment of canopies. This is in contrast to the West African populations which evolved under harsher conditions. Small seeds may have been a response to Sahelian habitats where there are greater environmental stresses (Figure 13). Greater heterogeneity in microsite conditions were matched with increased seed and seedling polymorphisms and morphology, and higher root:shoot ratios in the Sahelian provenances compared with the relatively homogeneous southern African populations. The outstanding early performances of the southern African provenances may reflect both potential and liability of these genotypes as a target for achieving maximum productivity at planting sites. The greater root:shoot ratios exhibited by Sahelian provenances may be adaptation to greater water deficits.

The geographic pattern of variation of *Faidherbia albida* in Africa was studied to provide a basis for initiating a genetic improvement strategy (Marunda 1993). The influence of different environments on phenology and growth, and root morphology and size were studied to understand the growth patterns of the species. Twenty provenances were grown in a glasshouse and twenty-four traits assessed to test for the extent of genetic variation. There was strong evidence of genetic variation between the 20 provenances and, to some extent, between families-within-provenances. Most of the traits showed a north to south trend; south-east African provenances had high growth rates (in terms of height, root collar diameter and dry weight production) whereas north-east provenances had qualities of adaptive significance (in terms of late leaf senescence, large root to shoot and leaf to stem ratios). The patterns of variation were strongly related to the temperature of seed origin and the type of ecosystem in which the species grows naturally. There were strong negative correlations between growth traits and those of adaptive significance. The provenances of *F. albida* from Africa could be grouped into three regions, the "upland" (about 750 m altitude) ecosystem of north-west Africa, the riparian ecosystem of south-east Africa and the Sudan/Ethiopian highlands and adjacent Lodwar valley in Kenya. Long day-length and water stress caused defoliation to occur most in the Sudan/Ethiopian highlands provenances, next in those from the riparian ecosystem and lastly, by those from the "upland" ecosystem.

Phosphorus deficiency is a major factor limiting the establishment of most nitrogen fixing trees in many soils of degraded lands throughout tropical Africa. A collection

of *Faidherbia albida* sources was evaluated in a pot trial to examine genetic variation in growth and P uptake at low P levels (Sanginga *et al.* 1990a). Two levels of P were tested. There were significant differences in shoot dry weight among the eleven provenances at both high and low P levels. These results demonstrated genetic variation in the ability of *F. albida* to grow under low P, a variation which could be exploited as a means of alleviating the problem of P deficiency in low P soils in the tropics.

Nitrogen fixed in 13 provenances of *Faidherbia albida* inoculated with *Rhizobium* was measured (Sanginga *et al.* 1990b). On average, *F albida* derived about 20% of its total N from atmospheric N2 fixation. Significant differences in the percentage of N derived from atmospheric N2 (%Ndfa) occurred between provenances (6-37%). Significant interactions occurred between provenances and N treatments and often growth of uninoculated but N-fertilized plants was less variable than that of inoculated unfertilized plants.

[**Bibliography**:- 28, 49, 50, 51, 56, 73, 82, 98, 294, 295, 305, 347, 437, 518, 610, 611, 637, 639, 641, 693, 695, 696, 710]

## Morphological variation

### *Pods*

The indehiscent pods of *Faidherbia albida* are falcate or curled into a circular coil like the peel from an apple and have been recorded to contained from 7 to 29 seeds separated by thin septa (Carr 1976; Chevalier *et al.* 1992; Fagg and Barnes 1995). The size of the pod and the degree of curling are extremely variable with an outside curve length of 112-270 mm, an inside length of 44-112 mm, a width of 12-71 mm and thickness of 7-9 mm (Chevalier *et al.* 1992). Highly significant differences in pod size and weight have been found both within and between provenances (Fagg 1992). The pod surface is convex on one side and concave on the other. Tree to tree variation within populations is conspicuous and consistent and often with no overlap in size and shape so that individual trees can be recognized even from a single pod.

### *Seeds*

The seeds of *Faidherbia albida* are elliptic-lenticular, 6-12 x 4-8 mm. wide with a large distinct areolus or hilum measuring about 8 x 5 mm in an average sized seed (Figures 1 and 13). The extent of variation in seed length, width, thickness and weight within 12 African provenances of *F. albida* was examined in a nursery study at the Kenya Forestry Research Institute (Dangasuk *et al.* 1997). The provenances within a region showed a consistent variation in seed length, seed width and seed weight. The southern African provenances had the largest seeds and west African provenances the smallest. Ibrahim (1997) also found large-sized seeds were associated with southern African provenances which are in turn associated with riparian habitats. It is argued that, in this situation, greater embryonic capital gives the plants an advantage by favouring rapid establishment of canopies. This is in contrast to the West African populations which evolved under harsher conditions. Small seeds may have been a response to Sahelian habitats where there are greater environmental stresses.

### *Seedlings*

In the nursery study of *Faidherbia albida* at the Kenya Forestry Research Institute (Dangasuk *et al.* 1997), seedling height, stem collar diameter and true leaf number differed among the provenances 90 days after germination (Figures 19 and 20). The seedlings from west Africa were shorter, had smaller stem collar diameter and fewer leaves. In contrast, the southern and east African provenances had taller seedlings with bigger seedling diameter and more leaves per seedling. Seedling traits did not show clear-cut divisions between southern and east African provenances, but the west African provenances formed a distinct group. Greater variation was observed for seed and seedling traits among than within provenances.

Ibrahim *et al.* (1997) found that there was a bimodal pattern of variation in the seed and seedling morphology similar to that shown by an isozyme study. Clines of some morphological traits investigated were also evident in the riparian habitat of the central distribution range. Greater heterogeneity in microsite conditions were matched with increased seed and seedling polymorphisms and morphology and higher root:shoot ratios in the Sahelian provenances compared with the relatively homogeneous southern African populations. The outstanding early performances of the southern African provenances may reflect both the potential and the liability of these genotypes as a target for achieving maximum productivity at planting sites.

Kay Nixon (pers. comm.) made observations on the seedling leaves of a large provenance set from the Oxford Forestry Institute collections of *Faidherbia albida*. She found the first leaf to be normally bipinnate with one pinna pair but the proximal pinnules on each pinna were rarely paired. Variations of this were three pinnae all arising from the same point in a digitate fashion or two pairs of pinnae, as in the second leaf of the acacias. Occasionally a pinnate first leaf was also noted. There was no marked provenance variation in the first leaves but some provenances had more aberrant forms of 'bipinnate' than others. The number of pinnule pairs on first leaves varied from a minimum of 4 to maximum of 12, but the variation in the Kuiseb provenance from Namibia alone contained the variation seen in all other provenances. There was very little variation between

provenances in the mean number of pairs of pinnules which varied from six to eight. Generally there was the same number of pairs of pinnules on each pinna, but there were exceptions.

*Leaves*

The bipinnate leaves of *Faidherbia albida* are extremely variable with petiole length 0.5-3.7 cm, rachis length 1.3-7.5 cm with 2-12 pairs of pinnae, rachillae 1.5-8.9 cm with 4-23 pairs of leaflets per pinna each 2.5-14.0 mm long and 0.7-5.0 mm wide. Those provenances from West Africa have the smallest leaves with fewest and smallest pinnae, those from southern Africa, from Malawi southwards, have the largest leaves with most and largest pinnae and leaflets, and those from Tanzania northwards to Ethiopia and Sudan have leaves that vary between these two extremes (Figure 18).

*Stature*

*Faidherbia albida* can grow into a tree up to 30 m high with a bole diameter of over 2 m but more usually grows to 15-20 m in height with a bole of 1 m in diameter. The length of bole is usually 3.0-4.5 m but where elephants browse the pods and foliage, the length of clear bole can be double this. The young trees have a fastigiate habit and the shape of the crown tends to be like an inverted pyramid. As the tree ages and the branches get longer, their weight causes them to sag and the crown eventually becomes rounded and almost hemispherical in shape (Figures 23 to 31).

In arid situations the tree can be bushy and shrub-like (Bertrand and Berthe 1996). Multistemmed forms can develop either due to trunk coppicing or to root suckering. In Sudan, before reaching its limiting altitude, *Faidherbia. albida* exists only as dwarf trees or bushes on the upper slopes of Jebel Marra (Tothill, 1948). A bush form can develop also through browsing by wild or domestic animals or through constant lopping.

*Roots*

A series of observations were made in North Cameroon on the root system and aerial part of *Faidherbia albida* trees to gain information on both the variation in these features and the correlations between them (Eyog Matig 1996). This study showed up major variations in the biomass and distribution of the root system. Although the genetic component of this variation could not be assessed, it is suggested that variation in root architecture might be every bit as important as growth of the aerial part of the tree, especially in relation to competition with crops.

The influence of different environments on a number of traits including root morphology and size were studied in 20 provenances in a glasshouse (Marunda 1993). Provenances from the west African "upland" ecosystem had the largest root length to stem height ratio, showing that they invested more biomass in root extension than those from either the centre of origin in Ethiopia/Sudan or those from the riparian ecosystems of east and southern Africa. West African "upland" sources also had high specific root length values which suggested high root activity. The observations showed that these provenances were better adapted to survive in drought conditions than those from the riparian ecosystems. It is too early to tell from the provenance trials yet to what extent these differences in stature are genetic rather than environmentally induced.

**[Bibliography**:- 49, 70, 72, 73, 82, 103, 105, 111, 131, 141, 149, 163, 231, 232, 235, 236, 347, 365, 437, 496, 641, 675, 693, 695]

## Variation in growth rate

The first estimates of genetic variation in the growth rate of *Faidherbia albida* have been made possible with the establishment of the range-wide provenance trials in the 1980s and 1990s.

Provenance trials of *Faidherbia albida* were carried out at three sites in Burkina Faso using seeds of 23 provenances from Senegal to East Africa (Frammond 1987). No significant differences were found in survival. There were significant differences in the rate of growth at six months and although these persisted to 18 months, they were no longer statistically significant. The most vigorous provenances were from the humid zones in Senegal and Burundi.

In provenance trials in Burkina Faso, 36 provenances of *Faidherbia albida* from nine countries across the species' range showed that eastern and southern African provenances had the highest initial growth but, by five years, they were exceeded by the central Sahelian provenances from Burkina Faso, Mali and Niger (Billand and Frammond 1990). In another set of trials in Burkina Faso, 40 provenances were tested on three sites that varied in soil type and annual rainfall (Bongkoungou *et al.* 1988) . The growth and survival in the first 30 months varied greatly both between and within provenances. Provenances of humid, coastal or altitudinous zones were found to perform best, although it was not known whether these provenances would maintain their advantage after 30 months.

In the range-wide *Faidherbia albida* provenance trials in Zimbabwe there were highly significant differences between provenances for height and diameter growth at 18 months (Barnes *et al.* 1999). The southern and east African provenances were out-performing those from the rest of Africa except for those from high altitude in Ethiopia (Figures 19 to 22). Certain southern Africa provenances were the best performers across sites,

*viz.* Guija (on the Limpopo River near the coast of Mozambique), Sesame, Gwayi and Tambaharta (Zimbabwe) and Chawanje (Malawi). In an earlier trial in Zimbabwe (Wanyancha *et al.* 1994), there were significant differences among the 30 provenances in height growth at 3.5 years. Best performers were Wonji (Ethiopia) and Hwange (Zimbabwe), followed by Bignona (Senegal), Chilanga and Bwanje (Malawi) and Katima Mulilo (Namibia) whose heights did not significantly differ. Overall most west African provenances were the slowest growers.

Early results from all these provenance trials of *Faidherbia albida* have consistently shown the southern African and highland Ethiopian provenances to have grown faster than those from West Africa in the nursery and in the first year or two in the field. However, as discussed in the section on adaptability above, ranking can change as the provenances interact with the environment at the trial site and rainfall, soil type, frost and grass competition exert their influence. The presence of this pronounced genotype-environment interaction augurs well for extending the use of *F. albida* in agricultural systems outside its area of natural occurrence (Barnes *et al.* 1999).

[**Bibliography**:- 49, 50, 51, 56, 73, 81, 82, 147, 231, 255, 305, 312, 313, 347, 349, 351, 365, 518, 569, 608, 637, 641, 694, 695, 696, 710, 716]

# LIFE HISTORY AND GROWTH HABITS

## Phenology

*Faidherbia albida* is unusual in the African arborescent flora in that it sheds its leaves at the start of the rainy season and is in full leaf during the dry season (Figures 37 to 40). Wickens (1969) believes that this habit is fairly consistent and controlled mainly by climatic conditions throughout its range. For example, this behaviour is disrupted in east Africa in areas near the equator where there are two distinct rainy seasons in the year. Here, the tree may flush and flower twice although the pattern may be disrupted by seasonal differences particularly in areas that are transitional between single and double peaks of rainfall (Wickens 1969) (Figures 58 to 60). There are also exceptions where peak groundwater levels do not correspond with peak rainfall as in the Zambezi Valley where high water level is delayed until the end of the rainy season because of the large catchment area. In these situations, the flowering can occur several months late (Wickens 1969; Dunham 1991c). There are, however, contradictory observations and views on how groundwater status affects flushing and flowering. Wickens (1969) relates instances of trees on drier sites flushing both earlier and later than trees on wetter sites and of trees in very different microsites all flushing and flowering together. He comes to the conclusion that leaf fall is controlled by a complex series of factors rather than a single one. Young trees may retain their leaves during the summer (Piot *et al.* 1980).

## Seed production and dispersal

*Faidherbia albida* trees produce huge quantities of pods starting from about the twelfth year. A single mature tree may yield over 1000 kg of pods in a single season (Palmer and Pitman 1972). The pods are heavy and fall straight to the ground (Figures 16 & 57). Wind therefore plays no part in seed dispersal and it is doubtful that water does either as the pods sink and ferment in two or three days (Wickens 1969). Herbivores are the main dispersal agents; the pods are highly palatable and nutritious and eaten in huge quantities (Figures 47 & 48). Wickens reports 66% of seeds passed through a steer undamaged up to six days after ingestion. If the period of retention is similar in an elephant, seed could be dispersed within a radius of over 100 km from the tree.

## Establishment

When a *Faidherbia albida* seed (mass about 0.1 g) absorbs moisture, it swells from the micropylar end and the radicle emerges three to four days after it has received sufficient moisture and daytime temperatures are over about 30°C. The time to germination depends very much on how weakened the testa is (Figure 61 & 62). Germination is epigeal and the cotyledons are sessile.

Normally, very few seedlings survive the first year; seedlings are browsed, eaten by insects or desiccated. Depending on the provenance, height growth of the aerial parts can be up to 2 m (Barnes *et al.* 1996) in 18 months. By three years, trees can grow to 5.5 m (Wickens 1969) and by 14 years trees 15 m high with a breast height diameter of 73 cm have been observed. The cohorts of survivors that form the dense even-aged stands arise episodically when a whole host of environmental factors coincide, for example a newly formed silt bank, copious seed in the soil, sufficient soil moisture to allow the seedling's taproot to reach groundwater before the surface layers dry out and absence of herbivores and frost until the seedlings are above the browse or frost line (Figures 63 to 67).

## Root development

The primary root in *Faidherbia albida* elongates rapidly to reach the perennial moisture zone; the taproot is reputed to be able to grow at 1 cm a day at the seedling stage and up to 5 m in a year (Anon. 1989; Vandenbeldt 1991b) (Figure 32). At three months there is a strong predominance of the tap root over the laterals and a lack of plasticity towards the modifications of the growth conditions (Favre and Traore 1987). At six months the taproot is straight with a swollen, flattened and twisted tip. By 18 months, the taproot has thickened and a system of lateral roots is well-developed (Wickens 1969).

In *Faidherbia albida* seedlings, the dry root matter mass has been found always to be larger than the dry shoot matter (Figure 33) under any soil conditions which was unlike many acacias with which it was compared where shoot mass was frequently higher than root mass (Asakawa and Makino 1989; Asakawa and Harayama 1990). Root systems of *F. albida* can penetrate to a water table at great depth, up to 7.5 m (Roupsard *et al.* 1998), 20 m (Anon. 1989) and even 40 m (Montagne 1984). The tree is generally thought not to compete with shallow-rooted plants for moisture (*e.g.* Bekele 1982) but one researcher (Eyog Matig 1996) found that most of the trees he observed had a considerable proportion of their roots growing horizontally close to the surface and it was suggested that these were likely to be in competition

with crops for water and mineral elements (see Figures 34, 35 & 36). In his work, only a small number of young trees were observed and the large range of variables did not make it possible to determine whether the form of the root system tends to be dependent on climate, soil type, age, genetic origin, or a combination of these factors.

As discussed in the chapter on Reproductive Biology below, *Faidherbia albida* does root sucker when roots are exposed or damaged and a string of trees is often seen that arises from a long root that follows a river bed (Figures 72 & 73).

Alexandre and Ouedraogo (1992) found that roots of *Faidherbia albida* developed differently on different soils. On sandy soils, the taproot penetrated deeply into the soil while root systems in compacted clay soils remained in the upper horizons. When there are changes in the level of the ground water beneath *F. albida* trees, due to man's agricultural activities or to reduced rainfall, established trees are often unable to form new roots deep enough to reach the new water table and so are unable to produce a new flush of leaves and thus suffer from dieback and premature death (Brunck 1972) (Figure 54).

## Crown development

In the first few years of its life, the tree has a fastigiate crown habit but, over the years, the branches gradually sag to give the typical domed or hemispherical shape of mature trees (Figures 23 to 31). Sterck *et al.* (1991) have made a detailed architectural analysis of crown development in *Faidherbia albida* in Mali. They found that every meristem may produce the same kind of axis of which extension growth and secondary thickening are adjusted to available environmental sources. Because of this, trees regenerate easily after damage or environmental stress making them highly adaptable. They recognized eight architectural development phases based on up to seven branch orders. In the first phase, up to one year old, the seedling has an orthotropic axis with a typical zigzag pattern (Figure 23). In the second year, branching starts and extension of the main axis continues (Figure 24). In phase three, the tree remains about 0.6 m high, only the base can be considered part of the main axis and development of some of the first order axes gives the tree a shrubby appearance (Figure 25). In the fourth phase at about seven years, one of the dominating branches becomes a trunk and the others have died (Figure 26). The trunk attains its final height of about 4.5 m in the fifth phase when the tree is about 16 years old (Figure 27). At stage six, at about 30 years, first order axes have reached their maximum extension and maximum crown diameter has been achieved (Figure 28). At stage seven, at 55 years, the tree reaches its maximum height of about 17 m (Figures 29 & 30) and at stage eight, 85 years, some branches at the base of the first order axes have died so that the crown is more open and sub-crowns can be distinguished (Figure 31). A ninth phase covers dieback of trees at the age of about 100 years when no new branch orders develop. Environmental stress and damage is commonly caused by physical factors such as climate and soil, as well as by human factors such as pruning and pollarding and by grazing of cattle but *F. albida* regenerates easily after these setbacks. Werger and Ellienbroek (1982) have observed on the Kafue area of Zambia that *F. albida* trees frequently have asymmetrical crowns that lean in a northerly direction. They attribute this to the fact growth occurs in the dry season when the sun is continually in the north.

Wickens (1969) reported that, as the crown shape begins to develop, the young tree becomes less shade tolerant and will, if necessary, bend sharply, just below the crown, to orientate itself towards the light and he suggests that this growth character is one that would appear to be an adaptation to a closed community, a feature that favours the riverine habitats of East Africa.

The life span of a *Faidherbia albida* tree is thought to be about 70 to 100 years by which time it might be over 20 m high and have a breast height diameter of up to 2 m. The oldest tree on record is believed to be the one at Serdeles in Libya, first noted by a Dr. Oundey in 1822 and it was still alive in the late 1960s (Wickens 1969). The tree consists of a number of trunks and its ability to sucker makes age determination difficult.

[**Bibliography**:- 10, 14, 22, 26, 28, 29, 50, 57, 63, 99, 114, 124, 149, 212, 231, 233, 244, 275, 355, 408, 409, 457, 461, 482, 484, 542, 546, 592, 638, 649, 683, 695, 724, 725, 730, 733]

# ECOSYSTEM

## Climate

*Faidherbia albida* occurs naturally from 270 m below sea level in Israel (Karschon 1961) to 2700 m in Sudan (Anon. 1982a), under a very wide range of meteorological conditions. In south-west Africa it can thrive under desert conditions where the mean annual rainfall is only 20 mm and the mean annual daily temperature 16.8°C (Fagg and Barnes 1995) whereas in West Africa it can also thrive in humid tropical conditions with MAR of 1800 mm (Anon. 1982a) and a MAT of 28°C (Fagg and Barnes 1995) within an absolute range of 0-42°C (Baumer 1983). Where rainfall is low, the tree is only able to survive if there are episodic downpours of rain that allow it to germinate and follow the moisture down to the permanent water table. Under these conditions, its occurrence is therefore generally limited to watercourses where groundwater is present or to wadis where there is residual water in the alluvium following flooding and drying out. (See Figures 41, 42, 46, 64, 65 and 70)

*Faidherbia albida* is susceptible to damage by frost and an annual freeze will limit its occurrence. However, if the climate is characterized by occasional sequences of frost-free winters and the seedlings have the chance to get above the average frost levels, they can develop into very large trees that can eventually survive temperatures as low as -10°C (Figure 44). It is said to tolerate nocturnal frosts in Israel (Anon. 1982a).

The rainfall and temperature data given in Appendix 3 for the international provenance collections give a fuller account of the meteorological conditions under which the species will grow.

[**Bibliography**:- 24, 57, 103, 149, 235, 253, 269, 291, 316, 340, 378, 405, 495, 504, 519, 543, 549, 620, 670, 725, 743]

## Soils

*Faidherbia albida* occurs on a remarkably wide range of soils. Most characteristically, it colonizes deep sandy-clay soils, particularly alluvial deposits along the flood plains of rivers (Ramsay 1958; Marchal 1980; Anon. 1982a; Sturmheit 1989; Teel 1990; Sanusi *et al.* 1992) (Figure 34). It will, however, grow on sandy soils (Anon. 1982a; Acocks 1988; Alexandre and Ouédraogo 1992; Brouwer 1992), on dunes (Karschon 1961), on fossil dunes (Lamprecht 1989) (Figure 53), on gravelly soils (Ouedraogo and Alexandre 1996), on fissured laterites (Harmand and Njiti 1992), on basalts (Karschon 1961) and even on heavy clays (Williamson 1956; Alexandre and Ouédraogo 1992) and vertisols (Sturmheit 1989; Verinumbe and Jarvis 1991; Kamara and Haque 1992; Fagg and Stewart 1994; Laike 1992; Eyog Matig 1996) (Figure 71). It has been reported as being undemanding as to soil structure and nutrient availability (Lamprecht 1989). However, the common requirement throughout this range of soils is that there should be free drainage (Porteres 1967) down to non-standing groundwater (Baumer 1983; Kessler 1990) that is within reach of the tree's roots; the critical depth will vary with annual rainfall and the density of the soil and has variously been reported as 1 to 40 m (Montagne 1984) below the surface. In fact, the presence of *F. albida* is often taken as an indicator of a good siting for a well (Marchal 1980; Willliamson 1956).

Growth rate of *Faidherbia albida* seedlings was studied in a trial over 10 sites in Niger to determine whether the variation among seedlings could be due to microsite variation in soil chemical and physical properties (Geiger *et al.* 1992). It was found that good growth areas had higher clay contents and base saturations, and lower aluminium saturation percentages than poor growth areas within the site. Seedlings planted on sheet-eroded sites, caused by run-off from micro-topographically high areas, performed poorly. The proximity to abandoned termite mounds and other fertile micro-high areas determined the rate of tree growth. Nongonierma (1977a) cites his subspecies *senegalensis* vars. *glabra* and *pseudoglabra* as preferential calcifuges and his subspecies *senegalensis* var. *senegalensis* as a facultative calcifile. *F. albida* is moderately tolerant of saline soils (Timberlake 1980).

The natural occurrence of *Faidherbia albida* is limited by its intolerance of competition rather than by soil type. This is why it is most common on new deposits in river valleys and on other newly deposited soils such as sand dunes (Anon. 1982a) and termite mounds (Geiger *et al.* 1992) (Figures 53 and 64). But it is man's agricultural activities that have enabled the species to establish a widespread presence on the heavier colluvial soils that would otherwise be occupied by grasses and woody species with which it could not compete (Figures 65 and 66).

There has been a huge amount published on the beneficial effect of *Faidherbia albida* on the soil once it

is established. This is discussed below in the Chapter below on *F. albida* and agriculture.

[**Bibliography**:- 2, 14, 24, 25, 57, 97, 103, 149, 231, 236, 246, 252, 268, 279, 312, 313, 340, 376, 378, 385, 403, 405, 409, 431, 461, 479, 494, 504, 549, 553, 557, 560, 616, 620, 626, 652, 666, 670, 671, 675, 698, 709, 724, 725, 740, 742]

**Plant and animal associations**

The following description of the ecology of *Faidherbia abida* in relation to its plant associates is based on the very full account given by Wickens (1969) and this source should be referred to for the numerous personal and published references to which his information is attributed. Personal views and experiences of the authors have been added below and references to information that is additional to that given by Wickens have been given.

*Faidherbia albida* is widespread throughout the drier areas of Africa and is mentioned as being dominant or an associate in five floristic zones (phytochoria): (1) Zambesian, (2) Karoo-Namib and (3) Sudanian regional centres of endemism, and (4) Sahel and (5) Sahara regional transition zones (White 1983). In the Cape Verde Islands, it is now the most characteristic species in pastures up to *c.* 1000 m with *Ficus sycomorus* (CABI 2002; Ferlin 1979). It was possibly introduced, but is now naturalized, although often deformed by wind, and sometimes occurring only as very spiny bushes to 2-3 m high.

Across these zones, *Faidherbia albida* occurs in a wide variety of habitats, ranging from the fringing vegetation on alluvial soils of perennial or seasonal watercourses (Figure 46 and 69) to open savanna woodland and cultivated lands (Figures 66, 83-88 and 90). The trees may occur singly or gregariously and may either dominate the community or be an occasional constituent. The evolution and distribution of the trees are closely associated with wild and domestic herbivores and, by extension, man. The most important of the herbivores are elephant, buffalo, various antelope, cattle, goats and camels (Figures 61, 63, 47, 48, 51, 80 and 108).

In Angola *Faidherbia albida* occurs along the banks of the Cunene River and seasonal streams and inundated areas of the Mossamedes and Huila Districts. It is also found growing in cultivated areas where it is believed to be an anthrophyte.

In Namibia *Faidherbia albida* frequently occurs with *Acacia erioloba* along many of the rivers that flow westwards to the coast such as the Hoanib, the Kuiseb and the Swakop Rivers (Figure 46). The tree is restricted to the alluvial soils on the river banks or actually in the river bed where it has the advantage that it can withstand periodic inundation and have access to underground water in the long dry periods. *A. erioloba*, on the other hand, grows just off the flood plain where it keeps clear of the floods but can still access perennial ground water with its very deep root system. Other associated tree species include *A. tortilis* ssp. *heteracantha, Ziziphus mucronata, Combretum imberbe, Phoenix dactylifera, Ficus sycomorus, F. cordata, Maerua schinzi, Acanthosicyos horrida* and *Colophospermum mopane* in the north. Understorey species include *Salvadora persica, Tamarix usneoides*, and *Euclea pseudebenus, Suaeda plumosa, Eragrostis spinosa, Pechuel-loeschea leubnitziae, Acanthosicyos horrida, Psilocaulon* sp. cf. *salicornioides, Zygophyllum simplex, Z. stapfii* and *Odyssea paucinervis* (Seeley *et al.* 1979; Theron *et al.* 1980).

In Botswana *Faidherbia albida* occurs in the riverine vegetation of the Chobe and Okavango River systems both in closed woodland and on the margins of swamps along the main rivers and in tree savanna, but nowhere is it very common. It is also found along dry sandy watercourses or where there is a high water table (Blair Rains and McKay 1968; Timberlake 1980).

In South Africa *Faidherbia albida* occurs sporadically in forest patches in the Zululand palm veld associated with sandy soils on the coastal plain, in northern kwaZulu in low altitude thornveld along streams with *Acacia* species, and in Lowveld bush within a narrow belt of riverine vegetation of acacias and palms between altitudes 150 and 600 m (Acocks 1988). It also occurs along the rivers in the Limpopo basin.

In Zimbabwe *Faidherbia albida* occurs principally in the well developed fringing forests along the main rivers of the north-west and Zambezi basin (Figures 37 to 40 and 51). The riverine and flood plain forests have a broken canopy and are dominated by *F. albida. A. galpinii, Lonchocarpus capassa, Trichilia emetica* and *Kigelia africana* are the main associates. It also occurs as a sporadic constituent of the *A. tortilis* subsp. *heteracantha* dominant communities of the Sabi and Runde Valley sandy alluvia and other lowveld rivers with the same associates but including *Ficus sycamorus* (Figure 52).

Some of the best-known *Faidherbia albida* in Zimbabwe are on the flood plain of the Zambezi River in the Mana Pools area (Figure 45). Occasional catastrophic flooding of the river has laid down large silty sandbanks that have been colonized by the species which now forms parklands of very large trees with a shrub layer; *F. albida* is a pioneer species on low-lying sandbanks and the woody species richness of stands increases with their height above the Zambezi River. (Alvord *et al.* 1982; Dunham 1989c). The construction of Kariba Dam upstream of Mana Pools in the 1950s has regulated the flow of the river and the rise and fall of the water levels have been minimized. The large sandbanks are no longer created

and *F. albida* regeneration is confined to the much less extensive silt deposits that are laid down by the tributaries that feed in to the Zambezi below Mana Pools. As *F. albida* does not regenerate under its own canopy (Figure 45), the large parklands in this part of the Zambezi Valley will become a phenomenon of the past although it will continue to be common as single trees and in smaller populations (Timberlake *et al.* 1999). The *F. albida* tree population has already been observed to be in decline since the Kariba Dam was built due to low recruitment and the loss of canopy trees at a mean rate of 0.9% per year (Dunham 1989b). Absolute mortality rate of trees was density-dependent and did not vary in relation to temporal changes in the elephant population.

The ecology of *Faidherbia albida* on the Gwai River on Chimwara Ranch is typical of the species in Zimbabwe (Figures 37 to 39 and 69). Silt and sand beds are laid down on the inside curve of the river. Successive populations of *F. albida* establish themselves on these new beds where there is no competition from grass or woody species and the tree's reverse phenology gives it a special advantage in that it makes it possible for it to survive the seasonal flooding during the summer rains (Figure 68). Cohorts of *F. albida* often grow in mosaics with similar populations of *A. tortilis* ssp. *spirocarpa* alongside rivers, each regenerating under the very specific edaphic, climatic and biotic environmental conditions that are favourable to them (Figures 37 to 40); *A. tortilis* colonizes areas disturbed by agriculture such as cultivated lands that have been abandoned, heavily grazed areas when cattle are removed and grasslands that are suddenly protected from fire. There is no *F. albida* established on the outside of the curve where old plant communities are destroyed as the river cuts into new ground and the trees fall into the river and are washed away. On straight sections of river where the bed has remained unchanged for many years, the banks are populated with a mixed community of long-lived hardwoods such as *Combretum* spp., *Diospyros mespiliformis*, *Kigelia africana*. It is possible that these species have succeeded *F. albida* which now occurs only as the odd individual that was probably established on small silt beds that were produced in open spaces in years of exceptional flooding (Figure 71). Sometimes such individuals propagate themselves very successfully into a string of trees from suckers produced by the shallow hose-pipe-like roots that stream out down the bank (Figures 72 and 73).

Also in Zimbabwe, *Faidherbia albida* has been observed to establish itself in the vleis of black vertisols lying in the flood plain of the river where there are the occasional very large isolated specimens even growing amid populations of *A. karroo*. It is possible that the species' reverse phenology again gives it an opportunity to establish itself without competition from both other plants and browsing animals on parts that are waterlogged for several years in succession. Once established, the tree can tolerate the dense grass that covers the area in normal years and the heavy grazing and browsing that often accompanies it. Such isolated individuals, or small groups, are often isolated by as much as 40 km from a main area of occurrence. It seems likely that, in such cases, seed has been transported by large herbivores, such as elephants or buffalo which can travel large distances in a single day, and deposited in their dung on isolated small newly formed sandbanks along small rivers where they have been able to establish themselves but with little opportunity to spread further. Sometimes these trees are in frosty areas where the species would not be expected to survive unless the seed was deposited at the beginning of a rare series of frost-free years which has allowed the trees to survive later severe frosts that would otherwise have killed them, although the crowns may be cut back periodically (Figure 44). There are also instances of small isolated populations, for example at Lion's Den and at Fort Rixon, detached from the rivers, where the species existence is almost certainly due to man's agricultural activities.

In Mozambique, *Faidherbia albida* occurs on the alluvial soils of the Rovuma, Zambezi, Save and Limpopo Rivers, sometimes forming small communities, but usually in association with other *Acacia* species. It also occurs among the *Colophospermum mopane* dominant savanna woodland, and sometimes that of *Brachystegia* spp. on riparian sites.

In southern Zambia *Faidherbia albida* forms fringing forests similar to those in Zimbabwe. There are frequent grove occurrences on the reddish-brown clays fringing shallow watercourse depressions between Mazabuka and Lusaka. It occurs on the margins of the Kafue flood-plain, often standing in three or more metres of water during the period January to April; it occurs in the littoral zone around the southern end of Lake Tanganyika, where the water table is fairly high. *F. albida* is also characteristic of recent alluvia in the Luangwa valley (Feely 1965) where it does not occur randomly distributed, but on seasonally flooded cut-offs or meanders of the river. It shows rapid early growth to avoid complete submergence in following floods. Juvenile trees are not deciduous.

In Malawi, *Faidherbia albida* is common in fringing forests of rivers running into the lake; but it is also widespread throughout extensive areas of cultivated land between the rivers round the lake shore. In this situation it is doubtless anthrophytic in that man's agricultural activities and recognition of its value have recently provided it with a new environment in which it has a competitive advantage over grasses, herbaceous and other woody species (Barnes *et al.* 1995).

In Tanzania *Faidherbia albida* occurs at 750 m. around Lake Tanganyika right up to an altitude of 1850 m. near Mbeya. It is gregarious and abundant in suitable localities in the Lake Rukwa valley and the Usangu plains, and sporadic elsewhere. The soils are well drained, often

alluvial soils with a permanent water table and often there is permanent surface water nearby. These sites also form the bulk of the arable land, so that *F. albida* has come to be regarded as an indicator of fertile soil. In the Usangu plains and Rukwa valley *Diospyros mespiliformis* is probably the most abundant associate, with *Kigelia africana. Acacia tortilis, A. etbaica, Piliostigma lhonningii, Tamarindus indica, Ficus* spp. *Combretum* spp.. *Hyphaene thebaica, Borassus aethiopum* etc. On the hills around Mbeya *Faidherbia albida* may be found occasionally, growing with *A. sieberana, Azanza garckeana, Dombeya rotundifolia,* and *Erythrina abyssinica.*

In Ruaha National Park in Tanzania, *Faidherbia albida* is restricted to alluvial soils along the major rivers. Its fruits are eaten by baboons (*Papio cynocephalus*), vervet monkeys (*Cercopithecus aethiops*), impala (*Aepeyros melampus*), and kudus (*Tragelaphus strepsiceros* and *T. imberbis*) as well as elephants (*Loxodonta africana*). There was a lack of regeneration and 40% of the *A. albida* woodland had been killed by the elephants, and it was concluded that large numbers of elephants needed to be culled to reverse the decline (Barnes 1983, 1985).

*Faidherbia albida* is found on riparian or seasonally inundated areas of Uganda where it is associated with *Tamarindus indica, Acacia tortilis, A. hockii, A. sieberiana* vars. *sieberiana* and *vermoesenii* and thicket vegetation of *Allophyllus africana, Grewia* spp., *Acalypha* sp., *Acacia brevispica, Phyllanthus guineensis* and *Haplocoelum foliolosum.* In Karamoja it occurs up to approximately 1800 m. and may be found in almost pure stands on the deep sandy alluvial soils where the water table is only a few metres below the surface. On the clayey alluviums of the river banks and minor flood plains it is associated in varying amounts with *Acacia gerrardii, A. etbaica* and also *A. tortilis* subsp. *spirocarpa.* In Kenya, *F. albida* is associated with the Great Rift Valley drainage systems.

In Ethiopia *Faidherbia albida* grows in a riparian habitat but there is a major disjunction in its natural distribution between the north and the south of the country. The lower populations in Tigray and Gonder are located along the Mereb and the Tacasse rivers and link to the Blue Nile drainage system in Sudan. In southern Ethiopia, it is found along the Great Rift Valley lakes Awassa (Figure 41), Koka, Arba Minch, and their drainage systems and in the eastern highlands, Gelemso and South Harar. In the area round Debre Zeit in the central highlands, it uncharacteristically grows on heavy soils rather than the usual sandy alluvium, but here it is associated with cultivated land (Figure 86).

In Sudan, *Faidherbia albida* occurs in various habitats, ranging from alluvial soils of perennial or seasonal water courses, to open savanna woodland and cultivated land. The trees occur singly or gregariously, widespread along rivers and water depressions (El Amin 1990). It is associated with the sandy Nile alluvium, but not with the Nile clay plain. It is also found fringing shallow drainage depressions of the *A. Senegal*-dominant savanna thornland on sandy soils to the west of the Nile where it is sporadic in occurrence. The Blue Nile is bounded by banks of deep silt deposits which slope gently on their landward sides down to level basins of silt layers over clay. The natural vegetation in this zone comprises dense *Ziziphus spinachristi* and scattered trees of *F. albida, Ficus sycomorus, Acacia sieberiana* and *Celtis integrifolia* (Jackson 1959; Sudan Forestry Department 1950).

The sandy alluvial soils of the Jebel Marra drainage system in Sudan support the largest population of *Faidherbia albida* recorded in Africa. Pure stands occur in belts up to a mile wide, and in places the communities form an almost closed canopy along the Wadis Kaja and Azum and their major tributaries. The alluvial soils are intensely cultivated and it is also a dry season stock watering and grazing area for the cattle and camels. Therefore there is some doubt as to whether the tree is indigenous or introduced especially as the present dense stand dates from the Mahdist period when the local inhabitants abandoned their lowland cultivation and fled to the safety of the Jebel Marra massif. On Jebel Marra *F. albida* is associated with cultivated areas, often in open stands on derived upland grassland on ash soils of the plateau at 2300 to 2500 m. The dissected, ash piedmont plain at the base of Jebel Marra is mainly dominated by pure stands of *F. albida,* although in some areas this has given way, under pressure of cultivation, to *Balanites aegyptiaca* and *Ziziphus spina-christi* scrub. Further to the north of Jebel Marra it occurs in the saline alluvium of the Malha Crater. Miehe (1988) recognized two provisional alliances in the Jebel Marra Massif, the lower montane *F. albida-Cymbopogon caesius* savanna and the upper montane *Festuca-Andropogon* grassland.

In the eastern parts of the Central African Republic *Faidherbia albida* is more or less confined to riverine habitats in hilly areas and is not necessarily associated with cultivation and grazing; but to the west and north of this, man and his grazing animals appear to play an important role in the distribution of the species.

To the north in Chad, *Faidherbia albida* is considered to be an anthrophyte in some areas, while in others it is as part of the riparian flora, together with such species as *Anogeissus leiocarpus, Tamarindus indica, Diospyros mespiliformis* and *Celtis integrifolia.* It is also recorded as bordering the major drainage channels of Ennedi and Tibesti, both areas isolated from the general distribution by semi-desert. *F. albida* is also found along the wadi banks of the Ahaggar and Tassili des Ajier massifs in Algeria, the mountains of Air in Niger and the Adrar des Iforas of Mali.

In Mauritania it is found on the seasonally inundated alluvial soils of the Senegal River and some of its tributaries

in areas of cultivation. It is present throughout Senegal and is especially concentrated just inland from Dakar and is associated with post-cultivation vegetation. *Faidherbia albida* is a component of the savanna woodlands in Guinea Bissau, rarely of hydromorphic soils and associated mainly with groundnut cultivation.

*Faidherbia albida* occurs in the northern parts of Togo and Benin generally following watercourses and associated with *Acacia polyacantha* subsp. *campylacantha, Balanites aegyptiaca* and *Tamarindus indica* and in areas of cultivation. In Nigeria *F. albida* is widely distributed through the Sudan Zone, both in woodland where it is a dominant in this climax vegetation type and in the Sudan scrub-savanna where it is also dominant (Fairbairn 1939). It also occurs in thorn savanna and thorn scrub but there is little regeneration in these vegetation types. It only occurs sporadically in the Guinea Zone. Although it occurs on a wide range of habitats from riparian vegetation to open savanna (Sanusi *et al.* 1992) it is principally associated with present or past cultivation. Other common trees associated with farmland in the Sudan Zone are *Butyrospermum parkia, Adansonia digitata, Tamarindus indica* and *Balanites aegyptiaca.* It is also an important constituent of the cultivated terraces and plains to the south of Lake Chad in Cameroun, and it also occurs in the Mandaras foothills.

In Egypt, *Faidherbia albida* occurs along the banks of the Nile. There are early records of it on Egyptian oases and the Eastern Desert but they are not known there today. It is not known from Sinai.

In Israel it occurs over a wide range of soils, including dune sand, basalt soils and heavy alluvium, with a preference for good moisture conditions. It is regarded as an alien element in otherwise characteristic associations such as *Ziziphus lotus-Z. spina-christi* association in the Upper Jordan Valley and the *Artemisia monosperma-Cyperus mucronatus* association of coastal sand-dunes, which suggests it is a relic. Stands have been recorded in Nahal Tavor, Shimron (near Migdal Ha'emeq), Nahal Ha'ela, Dor, and around Ashdod (Waisel and Aloni 1980). It has been recorded in Lebanon, in the limestone hills above Saida as well as in the Dog River Valley to the north of Beirut.

Wickens (1969) stated that *Faidherbia albida* in its southern and eastern distribution is invariably a constituent of well-defined riparian communities whereas in West Africa, although it still shows a marked preference for alluvial soils, it also occurs away from the river banks. He pointed out that it is noticeable how the associated trees in West Africa are those normally found on cultivated lands; the inference is that that the species is probably alien to West Africa. Observations made since Wicken's account of its ecology suggest that there are instances in southern (Zimbabwe), east (Malawi) and north (Ethiopia) Africa where the species has been able to establish itself in communities outside its natural niches when the agricultural activities of man present the opportunity. In addition, there are numerous records of large *F. albida* trees in unlikely situations remote from the main populations (*e.g.* Carr 1975). These can only have been established with witting or unwitting help from man.

The natural occurrence of *Faidherbia albida*, in the absence of man, is apparently determined largely by its unique ability to colonize newly formed sand or silt banks along rivers or on their flood plains. The seed is dropped in large quantities in the dung of herbivores either directly on the sandbanks or in the river valleys whence it is deposited with the silt (Figures 48 and 61). The initial growth of *F. albida* is very fast and the seedlings can establish themselves well enough to survive floods in one or two years. Thereafter, periodic inundation and water-logging of the soil can be tolerated because of the species' reverse phenology (Figures 64, 67 and 68). The species can take advantage of very small to very extensive silt deposits; hence its occurrence in the riverine fringes as single trees, small groups or large populations. Once the trees are mature the soil is stabilized and the course of the river may be altered (Figure 69). Pods are produced in huge numbers at the end of the dry season and large numbers of herbivores, domestic or wild, characteristically congregate under trees. The pods are so nutritious that the animals spend most of the day in the shade waiting for the pods to fall, but they also browse any *F. albida* seedlings that might germinate. For this reason, and because of the competition from the exceptionally dense annual grass cover (*e.g. Panicum maximum, Urochloa trichopus* and *Echinochloa colona* in the Zambezi Valley (Dunham 1990a)) that grows in summer below the leafless trees, *F. albida* rarely regenerates under its own canopy (Figure 45). As the trees get old and die, they are succeeded by other species such as *Trichilia emetica, Kigelia africana, Lonchocarpus capassa* and the dense understorey of shrubs (*e.g. Cassia obtusifolia, Diciptera verticilliata, Cassia occidentalis, Indigofera practicola, Cucumis anguria, Ocimum urticifolium, Corchoris olitoris, Ipomoea aquatica* and *Cassia quarrei* in the Zambezi Valley (Dunham 1990a)) provides too much competition for any *F. albida* seedlings to survive.

Despite this very restrictive set of environmental conditions that *Faidherbia albida* seedlings require to establish themselves, the tree is found over an incredibly wide range of soils and climates and with widely varied plant and animal associates. Competition during the establishment phase and access to permanent ground water, even at great depth, are the two critical requirements. Given these, the tree can take advantage of very small to very large niches and, once established, grow to a very large size on a great variety of soils in a range of rainfalls varying from desert to a wet tropical climate. This suggests that with help from man, *F. albida* can be grown in agroforestry

systems in an area that is vastly greater than that of its present distribution.

[**Bibliography**:- 2, 17, 18, 34, 51, 75, 141, 149, 207, 210, 222, 227, 233, 238, 240, 246, 248, 252, 271, 348, 353, 357, 399, 405, 430, 454, 455, 519, 524, 560. 563, 583, 626, 654, 655, 668, 671, 675, 679, 681, 707, 730, 731, 736, 737, 742]

**Rhizobial associations**

*Faidherbia albida,* in common with most other leguminous species, produces root nodules in a symbiotic relationship with Rhizobial bacteria and fixes nitrogen from the atmosphere which enables this species to become established in soils that are poor in combined nitrogen (Figure 92). Rhizobia of the acacias are divided into two groups (Dreyfus & Dommergues 1981a), those of rapid growth (3-4 hours generation time) belonging to the genus *Rhizobium* and regarded as *Rhizobium sensu stricto*, and those that are slower-growing (8-12 hours generation time) belonging to the genus *Bradyrhizobium.* Acacias have been placed into three categories, those that associate with *Rhizobium*, those that associate with *Bradyrhizobium* and those that associate with both (Lajudie *et al.* 1991). Some investigators (*e.g.* Dreyfus & Dommergues 1981a) hold that *F. albida* will only produce nodules with *Bradyrhizobium.* These Rhizobia are more common in African soils than are true *Rhizobium* species. In the Sahelian zone of Senegal, Dupuy & Dreyfus (1992) have isolated 67 strains of *Bradyrhizobium* from soils beneath adult trees. There is, therefore, rarely a need for inoculation. Other investigators (*e.g.* Lesueur *et al.* 1996; Njiti and Galiana 1996) have found that up to 13 *Bradyrhizobium* and *Rhizobium* strains of various origins formed efficient nodules on *F. albida* suggesting that the species is non-specific and nodulates indiscriminately with species of both genera. Conversely, it has been said that *Bradyrhizobium* strains and species are promiscuous in their association with *Acacia* species (Assefa & Kleiner 1998).

Infection of the roots of *Faidherbia albida* seedlings occurs through a characteristic short and curling root hair and the resulting nodules are of two morphological types, one spherical and the other a more indeterminate shape (Gassama 1997). Without inoculation, seedlings form nodules in 60 days (Workman 1986) but with inoculation in nursery experiments, nodulation can occur within 21 days (Mburueu 1994). In a study of the influence of the timing of inoculation on the histological development and nitrogen-fixation of *F. albida*, Gassama (1997) found that symbiosis developed optimally between the seedlings and *Bradyrhizobium* when inoculation occurred during the first 13 days following germination; seedling biomass and total nitrogen content were significantly higher than that of seedlings inoculated at 23 days. Although the seedling taproot elongates very rapidly and independently of nitrogen for at least the first 70 days (Mburueu 1994), the highest densities of *Bradyrhizobium* under adult trees in the Sahelian zone of Senegal were found just above the water table at 30 to 35 metres (Dupuy & Dreyfus 1992).

As with other nitrogen-fixing species, nodulation in *Faidherbia albida* is affected by the physical and the chemical properties of the soil. Soil temperature, pH, moisture, structure and the levels of phosphorus, nitrogen and iron can all be critical factors for nodulation.

In a study in Sudan on the effects of soil moisture, temperature and pH on nodulation and nitrogen fixation of *Acacia* species (including *Faidherbia abida*), growth and nodulation increased to an optimum at 15% soil moisture. A soil temperature of 35°C gave higher nodulation than 30°C. Nodulation occurred best between pH 6.5 and 7.0, hardly at all below 4.6 and very little at 8.0. (Habish 1970; and Habish and Khairi 1970). Lesueur *et al.* (1996) found that the *F. albida*-Rhizobium symbiosis is naturally adapted to acid soils, and is not affected by the presence of high concentrations of aluminium in the nutrient solution. Nodules have been reported to be less numerous on the soils that have higher clay content (Dupuy & Dreyfus 1992). Phosphorus has been found to increase nodulation and nitrogen fixation (Dianda 1988; Mburueu 1994; Masuka 1995). High levels (above 3.0 mol $m^{-3}$) of phosphorus reduced plant growth, nodulation and nitrogen fixation (Mburueu 1994).

Response of *Faidherbia albida* to Rhizobial isolates has been found to be greater in less fertile soils and the more effective isolates tend to produce a response that is comparable to that of plants supplied with nitrogen (Bahry 1998). In fertile soils, uninoculated plants tend to grow as well as inoculated plants but whether this is because the native Rhizobia are active and supplying the plant with nitrogen or whether the plants do not need the rhizobia in fertile soils is not clear. In some nursery experiments, mean root weight per plant has been found to be reduced by nitrogen (Masuka 1995; Dianda 1988 & 1991). In laboratory experiments Mburueu (1994) found that inoculated seedlings of *F. albida* suffered an early period of nitrogen stress. Application of combined nitrogen alleviated early nitrogen stress but reduced nodulation and nitrogen fixation. Combined nitrogen in the form of $NH_{4+}$ had less severe effects on nodulation than $NO_{3-}$ at the three levels of N (0.5, 2.5 and 5.0 mol $m^{-3}$) tested. In an experiment using 5.0 mol $m^{-3}$, N provided as $^{15}NO_{3-}$ (5 atom%) or as $^{15}NH_{4+}$ (5 atom %), it was established that preference for nitrogen form was pH dependent. Nitrate was preferred at low pH (5.5) and ammonium at high pH (6.5). The N form/pH combination resulting in good plant growth also had less severe effects on nodulation and nitrogen fixation.

A marked reduction in nodulation and growth of the *Faidherbia albida* has been found in an iron-free solution;

this suggests that iron is an essential micronutrient for the establishment and/or functioning of the symbiosis (Leseur *et al.* 1996).

Nodules have been noted to appear spontaneously on *Faidherbia albida* growing on dunes (Giffard 1971); this can be attributed to the marked deficiency in nitrogen on the dune soils and the absence of conditions inhibiting nodule formation in this situation.

Controlled laboratory, nursery and early field experiments have shown that there are circumstances in which inoculation with Rhizobium has resulted in increased growth of *Faidherbia albida* seedlings. Leseur *et al.* (1996) found that inoculated plants had a shoot dry weight that was 45-72% higher (depending on the strain) than that of non-inoculated control plants after a two-month growing period under greenhouse conditions. Masuka (1995) found in a nursery experiment that mean shoot weight per plant was greater in the presence of Rhizobium and phosphate but that height growth was negatively affected by *Rhizobium* suggesting that height growth is not a good measure of response.

Despite all the evidence for nodulation in *Faidherbia albida*, a relatively low N-fixing potential has been noted compared with other *Acacia* species although certain provenances of *F. albida* have exhibited higher N-fixation rates than others (Gueye and Ndoye 1998). In Zimbabwe, seedlings of 25 provenances of *F. albida* from West, East and southern Africa all produced some nodules after 12 weeks although West African provenances nodulated less and were poorer growers (Sniezko 1987). *F. albida* is also reputed to produce smaller nodules (1.47 to 2.48 mg per nodule) than many other leguminous species (Sanginga 1988; Sanginga *et al.* 1989). Gwaze (1988) found that seedlings of *F. albida* planted into soil collected from acacia woodland were 64% nodulated at 77 days from sowing and there were 1.1-4.7 nodules per seedling with a mean nodule weight per seedling of 5.7-38.0 mg.

[**Bibliography**:- 30, 32, 42, 105, 119, 142, 143, 149, 189, 190, 193, 199, 200, 201, 214, 233, 234, 235, 261, 263, 264, 274, 293, 294, 295, 305, 307, 308, 309, 375, 404, 414, 438, 447, 457, 480, 489, 507, 508, 609, 611, 612, 613, 614, 616, 622, 631, 634, 639, 745]

## Mycorrhizal associations

Acacias, in common with many other trees, form symbiotic or limited parasitic associations in their roots with mycorrhizal fungi. These associations are divided into two types, ectotrophic, in which the fungus forms a mantle that completely invests the smaller roots, and endotrophic, in which the fungus is within the cortex cells of the root. The association benefits the tree mainly in facilitating the uptake of phosphorus. Phosphorus is also indispensable for rhizobial activity and it has been shown that the presence of mycorrhizae on leguminous trees helps nodulation and the fixation of nitrogen. *Faidherbia albida* is reputed to form mainly endotrophic associations with vesicular-arbuscular mycorrhizal fungi (VAM) although ectotrophic associations have also been reported. VAM fungi of the order Glomales have been collected in samples located at soil depths between 1.5 and 4.5 m in the Sudano-Guinean biogeographic zone and between 16 and 35 m in the Sahel region (Diouf *et al.* 1998). These two soil horizons represent the limits of the water table in the two biogeographic regions.

The response of *Faidherbia albida* to five levels of Kodjari rock phosphate (KRP) (0, 310, 620, 1240 and 2480 ppm P, equivalent to 0, 775, 1550, 3100 and 6200 kg P $ha^{-1}$) and two species of VAM (*Glomus manihotis* and *Glomus aggregatum*) was evaluated in an alkaline sandy soil in Burkina Faso (Ba and Guissou 1996). The *F. albida* seedlings grew poorly without mycorrhizal colonization and without KRP applications. For non-VAM *F. albida*, the maximum growth response and both P and N uptake in shoots was achieved with 620 ppm P. However, even without KRP application, VAM plants generally achieved better results in terms of biomass, and VAM plants with both *Glomus* species had improved growth and increased nutrient contents at any KRP application rate. Although mycorrhizal colonization was comparable at all levels of KRP application, the impact on nutrient content of the shoot varied. VAM plants did not accumulate more biomass than non-VAM plants at 620 ppm P and above, and growth response and mycorrhizal dependency decreased as KRP applied levels increased.

Dianda (1991) pointed out that, in the Sahelian zone, where leguminous trees are frequently used to regenerate the fertility of degraded soils, the advantages of inoculating seedlings with rhizobial and mycorrhizal symbionts are rarely used because competition from indigenous VAM fungi that are nearly always present in the natural habitat can prejudice the performance of the inoculated seedlings. He found that both indigenous (Endo1 and Endo2) and introduced (*Glomus mossae* and *Gigaspora margarita*) VAM fungi greatly stimulated plant growth at three months from inoculation in the nursery but that dual inoculation was up to 50% less effective. It was found that some inoculant combinations produced plants with very much higher levels of N than others and some inhibited growth and had an almost parasitic effect. It is deduced that, as indigenous fungi are often present in the soil, it is important to know the species before selecting the strains with which to inoculate.

In a study on the effects of inoculation with the VAM fungus *Glomus mosseae* on the growth and development of *Faidherbia albida* seedlings in the West African semi-arid tropics (Ducousso and Colonna 1992), heights were found to have increased by 34% in bags and 68% in tubes, shoot dry weight by 82% and 112%, root dry weight by 44% and 57% and nodulation by 30% and

263% after 12 weeks growth. Apart from a slight depressive effect after one week, inoculation had a negligible effect on taproot elongation compared to the control. The majority of endomycorrhizal infections were found in the first 10 cm of soil, and none below 70-80 cm depth.

There is evidence that the beneficial effects of nursery inoculation with VAM fungi are absent or not as pronounced when *Faidherbia albida* seedlings are planted in non-sterile soil. Osonubi *et al.* (1992) found that inoculation of seedlings in pots of sterile soil significantly increased plant biomass but that in the non-sterile soil no significant increase was found due to the indigenous VAM fungi, mainly *Acaulospora dilatata,* in the soil. In this study it was also found that there were significant interactions between VAM inoculation and drought stress indicating that mycorrhizal infection is particularly beneficial to P uptake and plant growth under drought-stressed conditions. Reddell and Warren (1987) also suggested that both ecto and VA mycorrhizal types may reduce the effects of drought and transplantation stresses on seedlings.

Like most mycorrhizal studies, these with *Faidherbia albida* show that although mycorrhizae are important for the healthy growth of the tree, very much more needs to be known about genetic variation between and within species, interaction between species, interaction with the structure, chemical composition and moisture status of the soil and interaction with rhizobia before sound advice can be given on the economic benefits of inoculation.

[**Bibliography**:- 40, 189, 190, 192, 193, 201, 375, 517, 565]

# REPRODUCTIVE BIOLOGY

## Breeding system

Knowledge of the breeding systems of multipurpose trees is very limited, but essential to breeding progress (Brewbaker 1990). Among the objectives of the series of ODA-funded projects at the Oxford Forestry Institute on the study and assembly of the genetic resources of the African acacias was the supply of materials for the investigation of selfing levels and breeding systems in the species. These were to be used, firstly for use in improving the precision of sampling the natural range of the species, and secondly for use in designing effective selection and breeding strategies (Fagg and Barnes 1995).

*Faidherbia albida* is an insect-pollinated species and was initially thought to be self incompatible and out-crossing. In one study, isozymes in seed from trees in 18 West African populations were used as genetic markers to investigate the breeding system of *F. albida* (Joly 1991b). The out-crossing levels of the four populations from Niger were very high (0.893-0.996) for an insect-pollinated species especially considering the morphology of the inflorescence and the dynamics of flowering which would favour selfing. There was variation between individuals in out-crossing rates and isolated trees have been found to produce very little seed (Joly 1992) so the species does not possess a strict self incompatibility system. Flowering of individual trees is not synchronous, so the rate of self fertilization within a stand may vary from tree to tree. In a later study, northern Cameroon populations showed levels of out-crossing from 50-100 % with variation in the population throughout the growing season; this indicates a mixed mating system.

In a study of the diversity and population genetics of *Faidherbia albida* (Rendell 1998), allozyme data indicated a low inter-population pollen:seed flow ratio for provenances in the northern part of the species' range, *i.e.* seed is migrating over greater distances than pollen. The multilocus out-crossing rate for an Ethiopian population was about 50%, with a high level of correlated matings.

This research suggests a flexible breeding system involving only some degree of self-incompatibility.

[**Bibliography**:- 96, 235, 365, 367, 570, 754]

## Flower and fruit phenology

*Faidherbia albida* starts to flower from around eight to ten years of age, older than most African acacias. Detailed information on the phenological variation between populations requires regular observations in many populations over long periods of time, such as those undertaken at the Mana Pools population by Dunham (1991c). He found that leaf flush occurred towards the end of the rainy season with flower buds occurring soon afterwards on current season's wood. Ripe fruit fell in the late dry season. The seasonal timing of peaks in ripe fruit-fall and the mass of fruit produced from individual trees fluctuated from year to year.

Using the information about *Faidherbia albida* on the BRAHMS database, which includes the flowering and fruiting status of the herbarium specimens and the date of collection, three phenology diagrams were produced to cover the wide distribution of the species (Figures 58 to 60). The area of natural distribution in Africa was broadly divided into the southern and western unimodal rainfall regions and the bimodal rainfall region of eastern Africa. Some broad trends can be interpreted but, given the range of countries and climates that exist in each region, it is not surprising that the variation clouds the pattern. It should be noted that in collecting herbarium specimens collectors will search out a tree to find a fruit even if it is out of the main flowering season, or a tree that is flowering when the majority are still vegetative. Pruning the tree can also affect the flowering phenology. In any one population the variation in phenology between trees can be considerable. Fruit drop can be spread over a number of months.

In southern Africa (all countries south of Tanzania) the peak of flowering of *Faidherbia albida* appears to be between June/July and the peak of fruiting around October/November. In eastern Africa the trend is complicated by bimodal rainfall for flowering but two peaks of fruiting were recorded, one in February and one in October. In western Africa flowering peak is in October/December and fruiting peak in February/March.

[**Bibliography**:- 212, 216, 222, 241, 310, 484, 638, 753, 754]

## Pollinating agents

*Faidherbia albida* is insect-pollinated (Horowitz and Baum 1967). The flowers in the spicate inflorescence usually open progressively from the proximal end and remain open for 24-48 hours (Figure 56). The whole inflorescence may have open flowers over a period of

three days. A sourish odour is produced in the androecium of the flower. A wide range of insects from the *Lepidoptera, Coleoptera, Hymenoptera* and *Diptera* have been recorded visiting the flowers (Tybirk and Jorgensen 1994) (Figures 55 and 91).

[**Bibliography**:- 26, 334, 685]

## Seed production and dispersal

Pod production of *Faidherbia albida* was measured over two consecutive years in ten seed trees at Watinoma, Burkina Faso (Depommier 1996). Harvests were affected by climate, soil, genetics, and human intervention and varied from 0.3 to 23.0 kg per tree per year. Seed viability was greatly affected by attacks from spermatophagous insects, in particular the Bruchidae (up to 100% of the seeds can be damaged), and by other destructive agents such as granivorous birds; in Zimbabwe, hornbills and parrots have been observed breaking open unripe pods to feed on the seeds before the coat hardens. In the Burkina Faso study, virtually none of the indehiscent pods, and therefore seeds, escaped the mouths of livestock roaming through parklands in the dry season. Feeding tests were carried out with cattle, sheep and goats to assess the amounts of seeds contained in their faeces. The indications were that most healthy seeds were digested to close on 90% by cattle and goats, and to almost 99% by sheep and the conclusion was that the sexual regeneration potential of the species was very small and perhaps even reduced to nothing by these agencies. This conclusion tends to support a finding by Tybirk *et al.* (1992) who, in a study of soil seed banks of African acacias in Senegal, Kenya and Zambia, found very few seeds of *F. albida* in the upper 3-5 cm of soil beneath the trees and they question what happens to the few hundred to several million seeds produced annually by each large *F. albida* tree. In contrast, seeds of other acacias, *e.g. Acacia mellifera* and *A. seyal*, were found in profusion in the soil beneath the trees. It may be relevant that seed of *F. albida* has been found to lose its viability in storage sooner than many of the acacias (Asakawa and Makino 1989; Nixon pers. comm.); this possibly indicates a less resistant testa and therefore greater vulnerability to the digestive juices of the herbivores.

*Faidherbia albida* pods are an important component of the diet of elephants, buffalo, eland, waterbuck and kudu in the Zambezi valley at the end of the dry season when there is very little other browse available (Dunham 1990b) (Figures 47, 48 and 51). Huge quantities of *F. albida* seed pass through the digestive systems of these herbivores undamaged, especially through elephant and buffalo (Figure 61). It is possible that, having evolved with these animals, the seed of *F. albida* is better adapted to passing safely through their digestive tracts than it is through those of domestic livestock. Certainly this applies to sheep which grind the seed with their molars; in Australia, episodic regeneration of exotic *Acacia nilotica* occurs in ranges where there are cattle but not where sheep are grazed. On the other hand, Coe and Coe (1987) examined the testa of *F. albida* seeds and found the mass of testa to be 29% that of the total seed weight and suggested that the seeds were thick and robust and could resist the damage caused when passing through the herbivore's buccal cavity; and Gwynne (1969) estimated that 80-90% of seeds would survive passage through the gut of cattle in Kenya. These contradictory findings might be explained by an initial variation in bruchid damage; those seeds that have been holed by bruchids, even if not killed, can be crushed more easily or digested because the digestive juices can enter the seeds through the exit holes and destroy them.

Notwithstanding the damage done to the seeds of *Faidherbia albida* in the animal's gut, herbivores are the principal agents of dispersal for the species. The pods are brightly coloured and have a strong aroma which can attract animals from a distance (Gwynne 1969) (Figure 16). Tybirk *et al.* (1992) suggest that the most important positive effect of mammalian dispersal is the removal of seeds from the parent plant, for seedlings will rarely develop under its canopy (Figure 45). Seeds may be defecated in more suitable places for germination, for instance in abandoned goat or cattle enclosures where important new tree populations can develop. Fresh seeds of animal-dispersed species are able to germinate during the first rainy season but, if seeds are kept dry, they will remain dormant in the soil for several years.

In southern Africa, anomalous single large specimens of *Faidherbia albida,* or very small groups, can be found along some rivers 50 kilometres or more distant from the nearest area of the species' general occurrence. These isolated trees or populations have been attributed to seed dispersed by elephants which can move many miles in 24 hours and probably dropped the seeds in their dung on a small sandbank that offered a suitable microsite for the tree (Figure 44).

[**Bibliography**:- 29, 138, 180, 209, 306, 686, 730]

## Asexual reproduction

*Faidherbia albida* has been reported widely to coppice vigorously (Lamprecht 1989; Maydell 1979; Sturmheit 1990) although the growth of coppice shoots has been said to be very irregular for the first few years (Giffard 1971) and may even be prostrate initially (CTFT 1989). When the coppice shoot is freed it may grow in the same way as a free-standing tree (CTFT 1989) although it has been reported from Senegal that if the shoots are to develop into well-formed trees, they must be pruned and straightened until they are capable of developing a crown (Pelessier 1967). There is no indication from the literature cited here as to how rapidly the coppicing power of

a stump declines with age of the tree. In provenance trials in Zimbabwe, trees have coppiced vigorously after severe frost has killed the seedling or coppice shoots to ground level for two to three years running and one or two coppice shoots have almost immediately assumed the growth form of the seedling (Barnes *et al.* 1996 & 1999). This was to be expected given the existence of large *F. albida* trees in frosty valleys in Zimbabwe which must have been able to survive repeated frosts until they got above frost level in a sequence of milder years.

Root-suckering is a feature of *Faidherbia albida* but it appears that this form of reproduction is far more common in the north of its range, particularly in Israel (Karschon 1976), but also in Sudan (CTFT 1989) than in the west, east or south of the continent. It has been suggested that the reasons for this are that seed is heavily parasitized in the north and few seeds are viable and that low temperatures prejudice the survival of seedlings (Aloni 1973). In southern Africa, the wild and domestic herbivores that congregate under *F. albida* trees to feed on the falling pods at the end of the dry season also browse on any root-suckers (Figure 50). At Mana Pools in Zimbabwe, the ground under *F. albida* woodland on the flood plain of the Zambezi River is kept completely bare year after year by the congregating wild animals. When a patch of this woodland was protected from browsing animals with an electric fence, there was a massive development of a woody under-storey that included root-suckers from the large *F. albida* trees, but no seedlings (Figure 45). The root suckers were within the radii of the crowns of the trees. In Israel, suckers are said to emerge in a circle of 22m diameter from 50- 60-year-old trees. In Zimbabwe and Namibia, *F. albida* can produce long, shallow, hose-pipe-like roots that extend down the sandy river beds and give rise to suckers that develop into trees at even greater distances from the original seedling (Figures 72 and 73).

[**Bibliography**:- 16, 50, 51, 149, 274, 380, 405, 443, 531, 653]

## Natural regeneration

The Natural regeneration of *Faidherbia albida* has been described by many authors throughout its range. There is a consensus on what conditions are required for it to be successful in the initial stages; these are:- scarification of the hard seed coat; dissemination to a suitable environmental niche; sufficient moisture to allow water to be imbibed, germination to occur and extension of the roots to a permanent source of moisture in the soil; freedom from early competition, particularly from grasses; and protection from browsing animals (Figures 61 to 68).

Fresh seed of *Faidherbia albida* is reputed to germinate readily (Anon. 1982) but, soon after the pods fall, the testa hardens and becomes impermeable to water. Thereafter germination is dependent on the seed coat being scarified by passage through the gut of a herbivore. There is a number of wild vectors, for example elephants (*Loxodonta africana*), buffalo (*Synceros caffer*), eland (*Taurotragus oryx*), kudus (*Strepsiceros strepsiceros and T. imberbis*) and impala (*Aepyceros melampus*) (Dunham 1990b), which provide this service and at the same time deposit the seed in a suitable environment for its germination establishment and growth. Domestic animals (cattle and goats, but not sheep which grind the seed before swallowing it) have fulfilled a similar function especially in the north and west of its range (Giffard 1974a; Baumer 1983; Montagne 1984); Bongkoungou 1987; Anon. 1992a; Depommier 1996).

After germination, seedlings of *Faiherbia albida* will only survive if there is adequate moisture and if they are relatively free of competition. The most common niche, particularly in the riverine populations of east and southern Africa, is newly-formed, low-lying sandbanks where the species is a pioneer (Dunham 1989c; Timberlake *et al.* 1999). Elsewhere, natural regeneration has become intimately associated with any of man's activities, mainly agricultural, that have removed the tree cover and reduced grass competition long enough for the tree to establish a substantial root system, usually by the end of the first season (Anon. 1982a; Baumer 1983; Montagne 1984; Bongkoungou 1987; Bertrand and Berthe 1996). There have also been reports of natural regeneration of *F. albida* being associated with fertile microsites associated with termite mounds (Vandenbeldt and Geiger 1991).

Once established, the principle hazard for the seedlings of *Faidherbia albida* is browsing by herbivores (Giffard 1974a; Bongkoungou 1987; Rocheleau *et al.* 1988; Clive-Cole *et al.* 1990; Depommier 1996). This is most serious if it occurs during the first year of establishment (Delwaulle 1979). Once the root system has developed, and this can be even after just one to three years if there has been no grass competition, the seedlings can withstand a considerable amount of browsing and are able to coppice repeatedly and grow fast until they escape for a long enough interval for a shoot to get above the browse line (Baumer 1983). In Niger, saplings die from overgrazing by cattle and this starts the process of desertification (Montagne 1984). Trampling by domestic animals is a problem. Goats uproot and sheep sever seedlings at the collar. In the dry season, this will kill young plants, but mild successive grazing stimulates root growth and plants are able to re-shoot each year provided the roots have already reached the water table. Eventually one shoot gets away to form the tree. Without cattle and man *F. albida* would not be able to survive in Niger.

If elephants are present in any numbers, the trees are unlikely to survive and it has even been suggested that elephants would have to be culled in Ruaha National Park in Tanzania if *Faidherbia albida* stands are to regenerate (R.F.W Barnes 1983). In the riverine populations of

*F albida* in southern Africa, elephants congregate in large numbers beneath the trees at the end of the dry season to feed on the pods and, while they are waiting for the pods to fall, they will pull up every seedling within browsing distance of the old trees. The species' regeneration, therefore, is dependent upon the herbivores carrying the seed to sites well away from the parent trees. In fact, being a pioneer, the species does not regenerate under the canopy of old trees; other species follow in a progression to a climax tree community in which *F. albida* does not occur (Dunham 1989c).

Fire and frost also affect the natural regeneration of *Faidherbia albida*. The effects of annual early burning, annual late burning and grazing on the seedlings and saplings of *F. albida* among other savanna forage plants were investigated in Nigeria (Nwaigbo 1989). Only complete protection from fire resulted in an increase in the initial population of seedlings and saplings; early and late burning both led to progressive loss of the species whereas uncontrolled grazing and burning resulted in a more resilient and stable ecosystem, with rates of seedling and sapling destruction equal to the regeneration rate in the protected area.

Natural regeneration can occur through root suckering particularly where surface roots are damaged but development of the suckers is dependent upon their being able to get above the browse line.

[**Bibliography**:- 16, 24, 45, 52, 57, 70, 80, 108, 137, 149, 174, 180, 207, 209, 215, 275, 306, 310, 380, 386, 443, 454, 458, 461, 503, 531, 540, 586, 620, 671, 686, 698, 714, 733]

# PESTS, DISEASES AND HARMFUL PHYSICAL AGENCIES

## Fungi

Very few fungal pests have been reported on *Faidherbia albida*. Baumer (1983) goes as far as to say that no fungal diseases have been reported. This is surprising given the intense interest in the species and the extent to which it has been raised in nurseries. It has been suggested that the absence of fungal pests is due to its inverse phenology (CABI (19?? Forest Compendium??). In an intensive study to find a cause for the dieback of *F. albida* in the parklands round Magaria and Matameye in southern Niger, it was noted that there were no signs of fungal attack (Brunck 1972). A leaf blight, *Rhizoctonia solani*, has been reported on *F. albida* seedlings in a nursery in India (Mehrota 1990).

[**Bibliography**:- 57, 103, 99, 233, 450, 730]

## Plants

*Faidherbia albida* is occasionally parasitized by *Ficus thonningii*. This plant grows as an epiphyte and kills its host by strangulation. Another epiphytic plant, *Tapinanthus dodoneifolius* of the family Loranthaceae is more common and weakens the affected host trees (CTFT 1989). There is a brief reference to a mistletoe (*Loranthaceae*) being found on a 13-month-old *F. albida* plant growing at Maidugari, Northern Nigeria (Parker 1964)

[**Bibliography**:- 149, 524]

## Nematodes

Like most plants, the acacias are attacked by many species of nematodes particularly in the nursery. Plants affected by gall nematodes can be identified through the presence of large cells within the roots (Cadet *et al.* 1998). These authors listed *Faidherbia albida* as being among the trees more resistant to attack by nematodes and resistance was found to increase with tree age. Prot (1986), on the other hand, found *F. albida* to be a good host for the root knot nematodes *Meloidogyne javanica* and *M. incognita* in moist conditions in the nursery in Senegal but resistant to infestation by *Scutellonema cavenessi* and *Dolichorhynchus elegans.*

The effect of inoculation with gall nematodes (*Meloidogyne* sp.) was to stimulate nodulation in *Faidherbia albida*. Phenolic compounds in roots of this species suggest a resistance mechanism. Nematode attack, nodulation (and nitrogen fixation) and plant vigour may be interrelated.

The leaves of *Faidherbia albida* have been shown to exhibit moderate toxicity to the multiplication of *Pratylenchus zeae* population on *Capsicum frutescens* (Khan 1990).

[**Bibliography**:- 104, 118, 119, 149, 233, 387, 555, 561, 562]

## Insects

The most serious pests of the *Faidherbia albida* tree itself are defoliating caterpillars. The most extensive damage to trees of all ages seems to be caused by the widespread Noctuid, *Crypsotidia conifera,* and the Psychid, *Cryptothelea junodi* (Monod 1968; Roberts 1969; Giffard 1974a; Dunham 1991c; Fagg 1995) with 50% defoliation of adult trees and complete defoliation of young trees reported (Anon. 1982b). Dunham (1989a) observed that insects consumed about 26% of leaf production in the Zambezi Valley. Cochineal bugs can cause benign deformations of the foliage and crickets and grasshoppers can cause serious defoliation of young plants (Giffard 1974a; Anon. 1982a). Insect galls occur sporadically (Fagg 1995) and those that have been found in the inflorescence have contained Homopterous nymphs (Wickens 1969). Normally, the tree can recover from defoliation but where it is under pressure from increased livestock numbers and cultivation, the effects of attacks are more severe and can lead to the eventual death of the tree (Brunck 1972).

Although the occasional termite damage has been found on *Faidherbia albida* seedlings, the species is generally resistant to these insects and damage is only likely to be severe where it is a secondary cause (Wickens 1969; Timberlake 1980; Stewart 1989). Montagne (1984) reports a 24% failure of seedlings, most of which were attributed to termites. Mitchell (1989) found that *F. albida* was among the most resistant of tree species with less than 10% of deaths caused by termites. There is evidence that the presence of termite mounds enhances the survival and growth of *F. albida* (Vandenbeldt and Geiger 1991, Brouwer *et al.* 1992).

Several bark and wood-boring beetles, some of which penetrate to the heartwood, have been recorded on

*Faidherbia albida* but most of them only affect dead, dying and felled trees (Duffy 1967; Roberts 1969).

It is the Bruchid beetles that exert the greatest influence on the life cycle of *Faidherbia albida* (Southgate 1983; Sary and Some 1990; Depommier 1996). These beetles lay their eggs in the flowers and pupate in the ripe seed after feeding on the endosperm. The beetle bores its way out of the mature seed and emerges through a small round hole. Over 50% of the seeds is frequently destroyed although the presence of an emergence hole does not necessarily mean that the seed is not viable. Many Bruchid species have been recorded as living on *F. albida* seed. In a study of the seed-attacking insects found in the pods of 41 *Acacia* species growing in South Africa, 3,300 bruchids of 23 species were found (van Tonder 1981). Some *Acacia* species were not attacked at all and some were heavily attacked; *F. albida* was among the less severely attacked species.

Cerambycid beetles also attack seeds and pods of *Faidherbia albida*. *Sophronica calceata* and *Enaretta castelnaudi* have been recorded feeding on seeds and *Sophronica testacea* on pods (Duffy 1967).

Leaf galls have been seen on *Faidherbia albida* in Namibia and Ethiopia (Monod 1968). Leaflets form small bladder-shaped cavities in which a homopterous insect was found.

Table 1 gives a list of insects that feed on *Faidherbia albida* with indications of their importance and the parts of the plant on which they feed. The base information for this table was provided originally by Brunck (1972) for CTFT (1989).

[**Bibliography**:- 99, 138, 139, 149, 180, 202, 212, 233, 275, 358, 457, 458, 482, 529, 580, 618, 644, 645, 646, 650, 670, 672, 673, 720, 730]

## Animals and birds

*Faidherbia albida* has evolved with the large herbivores of Africa and is entirely dependent upon them for dispersal of its seed as described above in this publication. In feeding on the pods and foliage, however, the larger herbivores can do extensive damage to the trees. If the young tree is exposed to browsing from animals such as elephants, buffalo, impala, waterbuck, kudu and eland (Dunham 1989b) and domestic livestock, the seedling can be destroyed, particularly by sheep and goats (Montagne 1984) if it is cropped before reaching permanent ground water when it has not developed sufficient lateral roots to utilize surface water (Anon. 1989). Once the tree has reached the water table, it can coppice from repeated cropping by animals.

As the *Faidherbia albida* trees get older and start to produce pods, large animals like elephants pull down branches to browse while waiting for the pods to fall (Figure 47). Elephants can also strip bark off the trunk, often almost ring-barking even very large trees (Figure 49). Livestock and elephant have, in many instances, been identified as causes of population decline of *F. albida* (Boulhol 1950; Feely 1965; Weber and Dulansey 1978; New 1984; Dunham 1989b;). In some cases, it has even been suggested that elephant populations should be culled to reverse the decline of *F. albida* (R.F.W. Barnes 1983 and 1985). However, there are records of elephants being shown to have had no marked effect on the decline of *F. albida* and of human and livestock population pressure bearing positively on the survival of the trees, despite agricultural intensification, because farmers were undertaking better protection and management of their natural resources (Viljoen and Bothma 1990). Generally, once established, *F. albida* exhibits remarkable powers of recovery after damage by herbivores. It rapidly produces new foliage after browsing and it responds to de-barking by producing a ridged bole with intact bark in the crevices that an elephant cannot remove with its tusks and which saves the tree from death by complete ring-barking (Figure 49).

There are animals and birds that feed destructively on the seed of *Faidherbia albida* before the pods fall. Granivorous birds, including parrots and hornbills and parakeets (Depommier 1996; Wickens 1969) pick the seeds out of the pods in the trees before the coat has hardened as do baboons. Fallen pods are eaten by rodents (*Tatera leucogaster*). Flowers are eaten by Nyasa lovebirds (*Agaporins lilianae*) (Feely 1965).

[**Bibliography**:- 26, 52, 53, 89, 138, 149, 180, 206, 246, 461, 483, 504, 523, 549, 711, 720, 730]

## Drought

The ability of *Faidherbia albida* to grow in areas of very low rainfall is due to its propensity to develop and maintain a root system that keeps in touch with permanent moisture zones in the soil rather than to any physiological attribute that might enable it to regulate water use under stress (Roupsard *et al.* 1996 & 1998). This is doubly important because of the tree's inverse phenology; the tree is leafless in the wet season and in leaf in the dry and cannot therefore take advantage of seasonal moisture and it is dependent on the baseline winter water table. Therefore, provided the seedling's taproot can keep up with the receding groundwater level in the dry season following germination (Maydell 1979; Montagne 1984) and develop a root system that is deep enough to be permanently in touch with the water table, the tree will be able to survive fluctuations in seasonal rainfall. Should the seedling roots be unable to keep contact with the ground water level or should the water table suddenly drop due to severe environmental conditions such as a long series of droughts, water extraction, river diversion or severe competition from other woody species, the tree will die (Ward and Breen 1983;

**Table 1.** Insect pests of *Faidherbia albida* (Modification and expansion of Table 27 in CTFT (1989)).

| Family | Species | Damage | Severity | Area | Reference |
|---|---|---|---|---|---|
| **Orthoptera** | | | | | |
| Acridiidae | *Kraussaria angulifera* | Seedlings | * | | Brunck 1972 |
| | *Tylotropidius gracilipes* | | * | | Brunck 1972 |
| | *Anacridium melanorhodon* | Leaves and twigs | * | | Brunck 1972 |
| | *Anacridium werherellum* | Leaves | * | BUR | CTFT 1989 |
| **Lepidoptera** | | | | | |
| Noctuidae | *Crypsotidia conifera* | Leaves | **** | NIG+ | Brunck 1972 |
| | *Crypsotidia mesonema* | Leaves | | NIG | CTFT 1989 |
| | *Crypsotidia wollastoni* | Leaves | | NIG | Brunck 1972 |
| | *Pandesma anysa* | Leaves | | NIG+ | Brunck 1972 |
| Psychidae | *Cryptothelea junodi* | Leaves | ** | NIG+ | Brunck 1972 |
| Pyralidae | *Phycitines* sp. | Young growth | *** | | Brunck 1972 |
| Cossidae | (*Salagena transvena*?) | Decortication of bole | * | NIG | Brunck 1972 |
| Lycaenidae | *Chilodes eleusis.* | Leaves | | BUR | CTFT 1989 |
| **Coleoptera** | | | | | |
| Curculionidae | *Ischotrachelus spinicollis* | Young leaves | | NIG+ | Brunck 1972 |
| | *Stasiastes glabratus* | Platypodid predator? | | NIA | Roberts 1969 |
| | *Sinoxylon cerateniae* | Platypodid predator? | | NIA | Roberts 1969 |
| | *Sinoxylon senegalense* | Platypodid predator? | | NIA | Roberts 1969 |
| Cerambycidae | *Sophronica calceata* | Seeds | | | Duffy 1957 |
| | *Sophronica testacea* | Seeds | | | Duffy 1957 |
| | Enaretta castelnaudi | Seeds | | ZAM | Duffy 1957 |
| Platypodidae | *Doliopygus bohemanni* | Borer in dying trees | | NIA | Roberts 1969 |
| | *Doliopygus malkini* | Borer in dying trees | | NIA | Roberts 1969 |
| | *Doliopygus terebrans* | Borer in dying trees | | NIA | Roberts 1969 |
| Scarabaeidae | *Schizonycha sp.* | | | NIG | CTFT 1989 |
| Bruchidae | *Caryedon* sp. | Seeds | *** | BUR | CTFT 1989 |
| | *Meloidogyne javanica* | Seeds | *** | | Fagg 1995 |
| | *Meloidogyne incognita* | Seeds | *** | | Fagg 1995 |
| | *Pachymerus pallidus* | Seeds | *** | | Peake 1952 |
| | *Pachymerus longus* | Seeds | *** | | Baumer 1983 |
| | *Callosoburchus maculatus* | Seeds | *** | | Southgate 1983 |
| | *Bruchidius albidus* | Seeds | *** | RSA | v. Tonder 1981 |
| | *Bruchidius auratopubens* | Seeds | *** | RSA | v. Tonder 1981 |
| | *Bruchidius silaceus* | Seeds | *** | | Baumer 1983 |
| | *Bruchidius rufulus* | Seeds | *** | | Baumer 1983 |
| Brenthidae | *Allagogus brunneus* | Platypodid predator | | | Roberts 1969 |
| Histeridae | *Teretrius kraatzi* | Dead stems & branches | | | Roberts 1969 |

(continued)

**Table 1.** (continued)

| Family | Species | Damage | Severity | Area | Reference |
|---|---|---|---|---|---|
| Lyctidae | *Acantholyctus cornifrons* | Dead branches | | NIA | Roberts 1969 |
| Scolytidae | *Xyleborus ferrugineus* | Branches of dying trees | | NIA | Roberts 1969 |
| | *Xyleborus torquatus* | Branches of dying trees | | NIA | Roberts 1969 |
| **Hemiptera :** Homoptera | | | | | |
| Lecaniidae | *Ceroplates* sp. | Young shoots | ** | | Brunck 1972 |
| | *Diaspine* sp. | Young shoots | | | Brunck 1972 |
| Diaspididae | *Lepidosaphes* sp. | Young shoots | ** | | CTFT 1989 |
| Coccidae | *Gascardia mimusae* | Young shoots | ** | | CTFT 1989 |
| Membracidae | Unidentified | Young shoots | | BUR | CTFT 1989 |
| Psyllidae | Unidentified | Young shoots | ** | BUR | CTFT 1989 |
| **Hemiptera**: Heteroptera | | | | | |
| Coreidae | *Anophocnemis curvipes* | Young shoots | | | Brunck 1972 |
| Pentatomidae | *Piezodorus* sp. | | | | CTFT 1989 |
| **Isoptera** | | | | | |
| Termitidae | *Ancistrotermes latinotus* | Stem base and roots | * | ZIM | Mitchell 1989 |
| | *Macrotermes michaelseni* | Stem base and roots | * | ZIM | Mitchell 1989 |

BUR – Burkina Faso; NIG – Niger; NIG+ - Niger and Nigeria; NIA – Nigeria; ZAM – Zambia; RSA – South Africa

Williams 1990) (Figure 54). The considerable variation that has been found between provenances in apparent drought resistance (Vandenbeldt 1991b; Joly 1992; Marunda 1993; Ibrahim 1996a) is due to a difference in allocation of relatively more biomass to the root system (Kireger and Blake 1994). The provenances from the riparian ecosystems of southern and eastern Africa produce more above-ground biomass and use more water than do the provenances from the west African savannas which invest more in root development during early growth. The higher transpiration rate of the former, associated with a limited water reservoir for juvenile trees that have not yet found the groundwater would be a disadvantage because the length of the period of soil-related drought would be extended (Roupsard *et al.* 1996). Although the latter authors did find that seedlings regulated their transpiration and their growth for very moderate levels of drought, they concluded that, in natural conditions, adult trees have not developed resistance strategies, and only grow properly if they have access to substantial water reserves.

[**Bibliography**:- 28, 41, 99, 365, 392, 437, 443, 460, 461, 479, 512, 514, 517, 591, 592, 593, 688, 695, 717, 738]

**Frost**

*Faidherbia albida* is a frost-tender species (West 1950; Palmer and Pitman 1972; Geldenhuys 1975; Carr 1976; Palgrave 1977; Timberlake 1980; Davidson and Jeppe 1981). Frost is the factor that determines the species' natural southern limits in Africa and its exclusion from the riverine vegetation in the highveld of southern Africa. Seedlings can coppice vigorously and repeatedly after being killed back to ground level by frost and produce shoots 2-3 metres high in the subsequent summer. If a series of frost-free winters follow, these shoots can attain heights of 3-4 meters and they can then survive quite severe frosts (Barnes *et al.* 1999). It is in these circumstances that very large trees can occasionally be seen in areas where there are periodically quite severe frosts that might otherwise be expected to be limiting for the species (Figure 44). Trees in such environments acquire a rather stag-headed appearance (West 1950) because the new shoots and sometimes smaller branches are periodically killed back by the more severe frosts soon after leaf flush at the beginning of winter; and they rarely bear good pod crops because the flowers are also killed even by relatively light early frosts.

In trials of 21 wide-ranging provenances of *Faidherbia albida* in Zimbabwe, frosts were heavy enough to cut the species back on six of eight sites (Barnes *et al.* 1996; Barnes 2000). The trees coppiced repeatedly even after being frosted to the ground and the coppicing shoots were very vigorous, especially in the first year after planting. The high altitude provenances from Ethiopia did best on the frostier sites; the Malawian provenances were least tolerant.

[**Bibliography**:- 49, 50, 51, 111, 167, 269, 521, 522, 670, 725]

## Fire

*Faidherbia albida* is stated in the literature both to be sensitive to fire (Delwaulle 1973; Baumer 1983) and to be fire-hardy (Oboho 1984) and even as forming part of the fire-climax vegetation of the West African savannas (Fagg 1995). Bush fires have been cited as a factor in the decline of the *F. albida* parklands in the Sahelian zone of West Africa (Delwaulle 1973) but only 5% of tree loss was attributed to fire in a study in Chad (Weber and Dulansey 1978). Neither is it clear what role fire plays in stimulating germination of *F. albida* seed in the soil. Fire affects the soil seed bank by breaking the seed coat and bringing about germination of many tree species, particularly acacias, but a particular paucity of *F. albida* seed has been found in the soil in areas where a large annual seed production of the species might lead one to expect otherwise (Tybirk *et al.* 1992).

It is likely that these very different views of the fire-hardiness of *Faidherbia albida* arise from the great differences in fuel load that can exist beneath the trees. Man dominates this factor, both in the direct effects of his agricultural activities and in his effect on the populations of large wild herbivores that congregate under the trees (see *e.g.* Dunham 1989b). If the heavy grass growth that grows beneath and between the canopies is not grazed and trampled at the end of the dry season, fierce fires could damage even large trees in *F. albida* parkland. This view is supported by the results of a study to determine the effects of annual early burning, annual late burning and grazing on the seedlings and saplings of *F. albida*, among other species, at Mokwa, Nigeria (Nwaigbo 1989). Only complete protection recorded an increase in the initial population of seedlings and saplings. Annual late burning destroyed seedlings and saplings at twice their regeneration rate and annual early burning resulted in only 1.5 times that regeneration rate. Uncontrolled grazing and burning on the other hand showed a more resilient and stable ecosystem, with rates of seedling and sapling destruction equal to the regeneration rate in the completely protected area.

Regeneration of *Faidherbia albida* is dependent upon an absence of competition, particularly grass, and therefore it is assumed that an absence of fire in the first year or two is required for the species to become established. Young *F. albida* trees would not therefore be expected to have evolved to be resistant to fire. Neither is fire likely to be an important factor in stimulating germination of *F. albida* in the soil seed bank since natural regeneration is usually on newly formed silt banks or cultivated areas where fire is not a precursor. In which case, *F. albida* seed in the soil may not be resistant to damage by fire; this would explain the paucity of *F. albida* seed in the soil seed bank found by Tybirk *et al.* (1992).

[**Bibliography**:- 57, 170, 204, 233, 444, 450, 503, 505, 686, 720]

# WOOD PROPERTIES

## Anatomy

The following description of the wood anatomy of *Faidherbia albida* is taken from CTFT (1989). This is in agreement with other authors who have described the wood (Seabra 1957; Kromhout 1975; Robbertse 1980).

- Wood yellowish beige, sometimes dark brown in the heart of old trees, coarse and always cross-grained.
- Growth rings absent or only slightly visible, sometimes detectable by variations in the arrangement of the parenchyma.
- Vessels scattered, isolated or grouped radially in twos or threes, few (2-5 $mm^{-2}$), and of variable size (average tangential diameter 100-200 µm). Perforations only on the vessels, inter-vascular ornate, average size 7-10 µm.
- Parenchyma in wide bands, slightly sinuous, in line with the vessels. Line of cells generally of two elements, occasionally four, with some fusiform cells. Layered structure. Chains of crystals in the separate parenchyma bordering the fibres.
- Rays layered, uniseriate, or uni- and bi-seriate, 14-18 $mm^{-1}$ with procumbent single cells. Perforations as in the vessels.
- Fibres 0.8-1.5 mm long, 20-25 µm wide, walls of medium thickness, 10-13 µm. Bending coefficient about 50. Simple perforations.

The anatomical features of the wood in transverse, tangential and radial sections are shown in Figure 77.

A detailed description of the vegetative anatomy of twig wood, leaf and root, as well as a description of the mature wood, was given by Cutler (1969) who found that *Faidherbia albida* belongs to the group of species in the genus with narrow rays. Cutler's diagrams and captions are given in Figures 74 and 75.

In a study of 37 *Acacia* species, nine anatomical wood characteristics were found to vary sufficiently among them to be useful for differentiating the species by principal component analysis (Robbertse *et al.* 1980). This examination of morphological characters, however, revealed *Faidherbia albida* to be so different from other *Acacia* species that it threw doubt on whether it should be classified as an acacia at all.

In a description of the fossil wood anatomy of *Faidherbia albida*, it was found that no growth rings were discernable, vessels were solitary or in small clusters with simple perforations, parenchyma was confluent-banded, rays homogeneous, composed of long, procumbent cells, uni- and bi-seriate and storeyed. The wood was easily distinguished from that of other North African acacias by the banded parenchyma and the uni- and bi-seriate and storeyed rays (Neumann undated).

[**Bibliography**:- 149, 154, 402, 482, 579, 624, 662, 663, 664, 712, 733, 752]

## Growth rings

The age of most temperate tree species can be estimated accurately by counting the annual rings formed as concentric circles in the wood of the stem. In the tropics and sub-tropics, this regular periodic growth is seldom clearly found.

In the first reported study to determine whether or not *Faidherbia albida* exhibited growth rings, Mariaux (1966) took the annual ring boundary as the point where there was a sudden change in the appearance of the parenchyma associated with the vessels and a ring of closely spaced vessels showed what was taken to be the start of the next growing season. The width of a growth ring could vary greatly round the circumference of the stem and where it became very narrow it was difficult to distinguish the boundary between seasons. Although this was a very laborious process, the number of rings so defined did correlate with the known age of the trees.

Research has more recently been undertaken to investigate whether any other wood anatomical feature might delimit annual growth periods more precisely in the African *Acacia* species including *Faidherbia albida* (Gourlay and Kanowski 1991; Gourlay 1992; Fagg and Barnes 1995). Unlike most past work where the wood samples were from natural stands, those for this study were taken from trees of known age. Narrow bands of marginal parenchyma were found to be associated with annual growth periods. These bands were not associated with the vessels and were filled with crystal chains. The crystals were subsequently identified through the use of a scanning proton microprobe, as calcium oxalate ($CaC_2O_4$). The number of bands formed annually corresponded to the number of peaks in the annual rainfall distribution. Where the rainfall pattern was unimodal, one crystalliferous band was also laid down during the dry season; at lower latitudes where the rainfall pattern was bimodal, two crystalliferous bands were formed annually. Ring widths were correlated with the rainfall recorded in each wet season although the correlation between the

**Table 2.** Physical wood characteristics of *Faidherbia albida* (CTFT 1989).

| Trait | Sample 1 | Sample 2 |
|---|---|---|
| Wood | Pale yellow | Yellow-beige with a large brownish zone round the heart |
| Sapwood | Not discernible | Not differentiated |
| Rings | Continuous, distinct, wavy | Continuous, distinct, very wavy |
| Heartwood | Very knotty | Very knotty |
| Hardness | Moderately hard | Moderately hard |
| Specific gravity at 12% moisture content | Light | Moderately heavy |
| Hygroscopic potential in air | Normal | Normal |
| Moisture content when tested | Dry | Dry |
| Fibre saturation point | Low | Low |
| Total volumetric shrinkage | Average shrinking | Average shrinking |
| Volumetric shrinkage | Very unstable | Very unstable |
| Tangential shrinkage | Average | Average |
| Radial shrinkage | Low | Average |

width of the annual growth rings in *F. albida* was much higher for the preceding than the current year, which might be expected given the species' deep rooting habit. Ring width was also well correlated with the annual minimum temperature for this species. These results suggest that the presence of marginal parenchyma bands and crystalliferous chains define growth phases in *F. albida*, and can be used for age determination.

In common with the African acacias, *Faidherbia albida* shows banded parenchyma of two types, apotracheal (independent of the vessels) and paratracheal (associated with the vessels). Both types can be broad and, in *F. albida* in particular, obscure the fine lines of terminal parenchyma that are independent of the vessels and relate to annual growth periods. In *F. albida*, however, the paratracheal bands produce patterns of decreasing and increasing frequencies at a growth ring boundary and, in this case, the feature can assist in identifying a growth ring zone. The growth rings are illustrated in Figure 78.

[**Bibliography**:- 235, 288, 289, 290, 432]

## Physical properties

The wood has been generally described as light coloured, yellow to white, coarse-grained, uneven-textured with

**Table 3.** Strength properties of *Faidherbia albida* at 12% moisture content (Banks *et al.* 1977).

| Parameter | Unit | Value |
|---|---|---|
| ***Mass*** | | |
| Mass | kg $m^{-3}$ | 562 |
| ***Static bending*** | | |
| Modulus of rupture | MPa | 64 |
| Fibre stress at P.L | MPa | 35 |
| Modulus of elasticity | MPa | 7652 |
| ***Compression parallel to the grain*** | | |
| Max. crushing strength | MPa | 37.6 |
| ***Compression perpendicular to the grain*** | | |
| Stress at 2.54 mm deflection | MPa | 11,9 |
| Stress at P.L. | MPa | 6.1 |
| ***Shear parallel to the grain*** | | |
| Max. shearing strength | MPa | 10.3 |

**Table 4.** Strength properties of *Faidherbia albida* at green, air-dried and 12% moisture content (Nigerian Federal Department of Forest Research 1967).

| Parameter | Unit | Moisture content | | |
|---|---|---|---|---|
| | | Green | Air-dried | 12% |
| Moisture content | % | 72.5 | 12.5 | 12 |
| Specific gravity | | 0.51 | 0.55 | - |
| Weight | lb $ft^{-3}$ | 48[1] | - | 39 |
| ***Static bending*** | | | | |
| Equivalent fibre sress at max load | lb ft $in^{-3}$ | 6580 | 9740 | 9950 |
| Modulus of elasticity | 1000 lb ft $in^{-2}$ | 660 | 850 | 870 |
| Work to max load | lb ft $in^{-3}$ | 21.3 | 15.6 | 15.4 |
| Total work | lb ft $in^{-3}$ | 34.3 | 25.3 | 24.9 |
| ***Impact bending*** | | | | |
| Max drop | in | 47 | 31 | 30 |
| ***Compression*** | | | | |
| Max compressive strength | lb ft | 3170 | 4570 | 4650 |
| *Hardness (side)* | | | | |
| Indenting load | lb ft | 780 | 1030 | 1050 |
| *Shear stress* | | | | |
| Radial | lb ft $in^{-2}$ | 1130 | 1630 | 1660 |
| Tangential | lb ft $in^{-2}$ | 1200 | 1760 | 1780 |
| *Cleavage* | | | | |
| Radial | lb ft $in^{-2}$ | 68 | 96 | 98 |
| Tangential | lb ft $in^{-2}$ | 75 | 105 | 107 |

[1] at 50% MC. (lb ft $in^{-2}$ x .006894757 = Mpa; lb ft x 4.448222 = N; in x 2.54 5 cm; lb x 0.4535924 = kg; $ft^3$)

no clear distinction between sapwood and heartwood (Fanshawe, 1962; Timberlake, 1980; Wickens *et al.*, 1995) (Figure 76). Table 2, modified from CTFT (1989), gives verbal descriptions of physical wood characteristics of two samples of wood of *Faidherbia albida.*

The strength properties of the wood of *Faidherbia albida* are given from two independent sources, one from South Africa (in metric units) in Table 3 and the other from Nigeria (in Imperial units) in Table 4. The values for shrinkage are given in Table 5.

*Shrinkage from green to oven dry*

The wood of *Faidherbia albida* is unlike most of the acacias in being lighter in colour, less dense, softer and less durable. Table 6 (from CTFT 1989) shows a comparison of the wood of *F. albida* with three well known West African timber species, *Triplochiton scleroxylon*, a low density tropical hardwood used for plywood, *Entandrophragma utile*, the industry standard for a high quality mahogany-like tropical hardwood, and *Lophira alata*, a strong, dense, durable tropical hardwood with

**Table 5.** Shrinkage and density of *Faidherbia albida* (van Vuuren *et al.* 1980).

| Parameter | Unit | Value |
|---|---|---|
| ***Moisture content*** | | |
| Green | % | 109 |
| ***Density*** | | |
| Green | g cm$^{-3}$ | 0.70-1.02 |
| 10% M.C. | g cm$^{-3}$ | 0.40-0.58 |
| ***Shrinkage from green to oven-dry*** | | |
| Volume | % | 9.40 |
| Radial | % | 2.86 |
| Tangential | % | 5.90 |
| Longitudinal | % | 0.24 |
| ***Shrinkage from green to 10% M.C.*** | | |
| Radial | % | 1.79 |
| Tangential | % | 3.56 |
| Mean of radial + tangential | % | 2.68 |

strength properties comparable to reinforced concrete. In density and hardness, *F. albida* compares well with *E. utile*. Although radial shrinkage is acceptable for sawn timber, tangential and volumetric shrinkage are high and imply instability in service. Values for compression strength, static bending and modulus of elasticity are all considerably lower for *F. albida* than they are for *E. utile* indicating a much weaker timber. The timber is unusual in that the radial splits that occur in stem discs during drying are usually contained within the disc and seldom extend to the periphery (See Figure 76).

[**Bibliography**:- 46, 149, 242, 474, 485, 554, 659, 661, 662, 663, 664, 670, 712, 733, 752]

## Pulping properties

The following account of the pulping qualities of *Faidherbia albida* is based on CTFT (1989) and draws on reports from Seabra *et al.* (1957), Giffard (1971 & 1974b), FAO (1980) and Anon. (1982a). It was found that the species could be pulped using the Kraft process although it required 22-26% alkali to obtain a pulp with satisfactory fibre separation and the yield was not good. The levels of alcohol extractives was high, that of water soluble extractives very high and the cellulose content low. Bleaching was straight forward, brightness satisfactory and stability average. The amount of chlorine used was normal for the amount of delignification needed. The mechanical

**Table 6.** Wood properties of *Faidherbia albida* compared to *Triplochiton scleroxylon*, *Entandrophragma utile* and *Lophira alata*. From CTFT (1989).

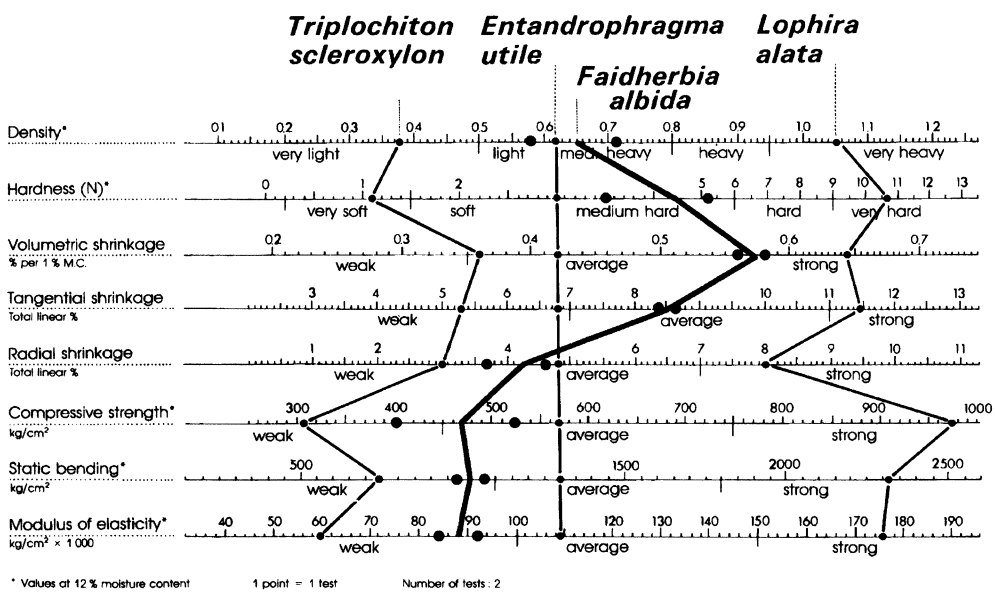

**Table 7.** Chemical composition of the wood of *Faidherbia albida* (From CTFT (1989)).

| | |
|---|---|
| Alcohol (%) | 4.2 |
| Boiling water extract (%) | 8.7 |
| Solubility in 1% NaOH (%) | 14.8 |
| Lignin (%) | 33.0 |
| Pentosans (%) | 15.6 |
| Celluslose (%) | 34.7 |
| Ash at 425 °C | 2.9 |

**Table 8.** Fibre dimensions and ratios of wood of *Faidherbia albida* (from CTFT (1989)).

| | | |
|---|---|---|
| Fibre length (μm) | L | 1 080 ± 150 |
| Fibre width (μm) | I | 23.4 ± 3.5 |
| Cavity size (μm) | C | 11.4 ± 3.5 |
| Wall thickness (μm) | 2P | 11.7 ± 2.7 |
| Suppleness coefficient (%) | C/I | 50 ± 14 |
| Runkel ratio | 2PC | 1.02 |
| Felting coefficient | L/P | 45.1 |

characteristics of the pulp were poor. The retention of fibres on calibrated grids was poor and, as a result, the papers produced were porous and of low strength. The results from other processes were even less encouraging. Reduction of sulphur during the cooking process produced a dark pulp, poorly de-lignified and with slightly inferior properties. The pulp produced by the sulphite process was dark and poorly delignified and gave a low yield of poor quality bleached pulp. The calcium bisulphite process was more promising but the yield was only slightly better, the pulp a dark colour and the strength properties poor. Cold treatment with soda gave a dark unbleached pulp and a poor yield. Mechanical pulping showed no promise.

The chemical composition of the wood of *Faidherbia albida* is given in Table 7 and the dimensions of its fibres in Table 8.

[**Bibliography**:- 24, 149, 242, 274, 624]

# PRODUCTS AND USES

## Wood

The wood of *Faidherbia albida* has been described as light yellow to white in colour and is reputed to be of good quality, soft and easy to work (Dancette 1968; Giffard 1974a; Anon. 1982a; Lamprecht 1989; Wickens *et al.* 1995) although it is also said to be coarse-grained, uneven-textured, weak and of poor durability (Fanshawe 1962; Goldsmith and Carter 1981; Timberlake 1980; Lamprecht 1989). Reports vary as to its value from being a very useful timber to being practically useless depending obviously on what products are required and what other timbers are available rather than on any regional differences in the quality of the wood (Giffard 1974b). For example, it is the main source of wood in the dry parts of West Africa (Louppe 1990). The wood, however, is said to have been favoured in ancient Egypt in the third century BC and a yoke and a group of five cats (in the Louvre) have been identified as having been made of *F. albida* (CTFT 1989).

Quite apart from its inferior physical characteristics, the wood of *Faidherbia albida* suffers from being subject to insect and fungal attack. Pinhole borers and termites are mentioned among the most prevalent causes of damage and fungi cause discolouration as well as rot when the timber is green (Kerr 1942; Hughes 1957). However, the practice of soaking in water by submergence for several months prior to use to remove the sap is an effective treatment for improving durability (Dancette 1968; Giffard 1974b; Anon. 1982a). The wood is said to be easily preserved (Wickens *et al.* 1995).

The wood of *Faidherbia albida* is combustible with a calorific value of 4 720 kcal $kg^{-1}$ or 19 740 kJ $kg^{-1}$ (Doat 1977) and easily carbonized with yields of 17% (Giffard 1966; Louppe 1990). Generally it is considered to be an inferior firewood (Lamprecht 1989) except where there is nothing else available when it is described as burning well (Dancette 1968). It makes an average quality charcoal (Anon. 1982).

The wood can be used for light construction but it is weak and should be used oversized for beams, both because of its lack of strength and because of the large amount of shrinkage that occurs on drying (Fanshawe 1962; Hughes 1957; Goldsmith and Carter 1981; Mergen undated).

The tree bole is widely used for the construction of dugout canoes (Figure 79), boats and paddles and the sawn planks for furniture (Kerr 1942; Fanshawe 1962; Goldsmith and Carter 1981; Anon. 1989; Louppe 1990; Wickens *et al.* 1995).

Other uses for the wood include bowls, kitchen utensils, art objects, tool handles, pestles and mortars, framing, crates, wood wool, oil presses, drums, boxes, saddles, troughs and fencing (Hughes 1957; Fanshawe 1962; Giffard 1974a & 1974b; Goldsmith and Carter 1981; Anon. 1982; Lamprecht 1989; Louppe 1990, Wickens *et al.* 1995).

The branches are used for huts, granaries and sheds (Giffard 1974b; Anon, 1982).

The wood ash is used for soap and as a depilatory (Wickens 1980; Anon. 1989; Lamprecht 1989; Wickens *et al.* 1995).

The wood is not suitable for pulping; the Kappa number is far above the acceptable range for hardwood pulp and the yield of unbleached pulp is very low (Food and Agriculture Organization 1980) (see under wood properties above).

The physical and anatomical characteristics of the wood of *Faidherbia albida* are described and discussed in the chapter on wood properties above.

[**Bibliography**:- 3, 21, 24, 26, 35, 46, 57, 78, 103, 129, 137, 149, 157, 195, 217, 233, 240, 241, 250, 252, 253, 254, 272, 274, 275, 276, 283, 321, 331, 342, 343, 353, 359, 364, 384, 405, 409, 418, 422, 451, 461, 463, 474, 523, 537, 546, 554, 624, 670, 671, 690, 694, 707, 732, 733, 740, 752]

## Bark

The bark of *Faidherbia albida* is used to make beehives and as saddle stuffing (Wickens 1980) and it is also used in the construction of huts (Wickens *et al.* 1995).

The bark is also said to be used as a fish poison in Botswana (Timberlake 1980). It does contain the compounds (-)-epigallocatechin-7-gallate and (-)- epigallocatechin-5, 7-digallate which have molluscicidal properties, better known in the fruits and bark of *Acacia nilotica,* which are used against *Bulinus truncatus* and *Biomphalaria pfeifferi*, vectors of schistosomiasis in Sudan and Egypt (Ayoub 1985). Spray-dried powder from *Faidherbia albida* has been found to be active at 100 ppm and could be used as a cheap molluscicide (Ayoub *et al.* 1987).

Methanolic extract of *Faidherbia albida* contained hydrolysable and condensed tannins and showed algicidal activity when tested in ponds (Ayoub *et al.* 1985). The tannins acted by precipitating algal proteins.

The old bark of *Faidherbia albida* contains 20-29% tannins (Eggeling 1940; Dale and Greenway 1961; Irvine 1961; Kerharo and Paccioni 1974; Zambia Forest Department 1979b; Lamprecht 1989) which are probably the active components that explain the widespread medicinal use of the bark described in the section on medicinal uses below.

[**Bibliography**:- 37, 38, 39, 149, 155, 418, 217, 353, 383, 405, 522, 670, 732, 733, 752]

### Gum

The gum of *Faidherbia albida* has medicinal properties that have been described in the section below on medicines. There is a mention of the species providing a gum for commerce (Baillon 1863) and of its yielding a good gum (Williamson 1956; Hughes 1957; Zambia Forestry Department 1979b) but no quantitative or monetary values were found to support these statements.

[**Bibliography**:- 44, 342, 740, 752]

### Foliage, flowers and pods

*Faidherbia albida* produces an excellent, highly nutritious fodder (Dancette 1968; Cisse and Kone 1992). Both the foliage and the fruits are used as a fodder resource by herdsmen throughout its range in Africa. The pods are traded commercially in the markets of the Sahelian and Sudanian countries where they are also used for stall-fed sheep, to fatten livestock, for prestige animals, for dairy animals to enhance milk production and as a tonic to rehabilitate lean and weakened or sick animals (Giffard 1974a; Delwaulle 1977; Grainger and Esbenshade 1978; Dancette and Niang 1979; Baumer 1983; CTFT 1989). In eastern and southern Africa *F. albida* fodder is not so directly recognized although its contribution to the condition and even survival of livestock and wild animals is very considerable because the green leaves are produced in the winter and the pods ripen at the end of the dry season when there is a paucity of all other fodder, especially in drought years. In fact, it is said that, in the absence of grass, *F. albida* fodder constitutes the best possible stock feed (Baumer 1983).

Unripe pods can be poisonous due to their containing prussic acid (Fanshawe 1972). If the pods are collected after they fall and dried, they can be stored for feeding later. Particularly in the south of its range, pods are usually picked up by cattle and game from the ground beneath the trees. If large numbers of pods have fallen, cattle can be very selective and choose first only pods that are darker and more strongly scented (Wickens 1969).

The foliage of *Faidherbia albida* is fair in fat and high in protein (Montagne 1984). The leaves are soon out of reach of browsing animals as the tree grows rapidly in its early years and a browse line is soon formed at a height depending on the species of browsing animal, about two metres for goats up to seven metres for elephants. Access to the foliage for domestic livestock is therefore dependent on lopping the branches. The tree reacts well to heavy and repeated lopping (Depommier and Guerin 1996) but it can cause a heavy nutrient drain on the tree (Lulandala 1989) and on the environment and, if overdone, it can weaken and kill the tree. Lopping always prejudices pod production (Montagne 1984).

Studies have shown that 20 *Faidherbia albida* trees per hectare increases beef production by up to three times. Put another way, one hectare of *A. albida* parkland with 20 trees supplies enough fodder in the dry season (*c.* 1 950 kg) to feed six head of cattle (Raison 1988). It has, however, been suggested that there is an incompatibility between *A. albida* and large cattle; success is thought to be dependent on the functional symbiosis between small cattle and this classical tree of the Sudanese parks.

A full discussion of *Faidherbia albida* fodder and livestock, including palatability, consumption, nutritional value, digestibility and its effects on production, and a discussion on management of the tree for forage production can be found below in the chapter on *Faidherbia albida* and agriculture (*q.v.*).

*Faidherbia albida* also provides good bee fodder (Figure 89). Bee-keeping is important in Southern Darfur, particularly around Kubbum which is a major production site of honey in Sudan (Garcia and Gasma 1986). The vegetation in the area is dominated by *F. albida* and the tree is a major honey source. A beekeeper with six hives can produce 50 to 60 kg of honey per year. *F. albida* also has the advantage that it flowers at the end of the rains and provides a source of nectar and pollen when other plants have finished flowering.

The powdered pods and seeds are widely used to stupify or poison fish in pools (Miller 1948; Irvine 1961; Pardy 1953; Wickens 1980; Timberlake *et al.* 1999).

[**Bibliography**:- 26, 57, 103, 134, 149, 157, 161, 172, 183, 241, 262, 275, 291, 421, 461, 527, 548, 559, 671, 694, 713, 730, 733, 750, 752]

### Medicine

*Faidherbia albida* has many medicinal properties (Watt and Breyer-Brandwijk 1962; Dancette 1968; Fanshawe

1972; Lamprecht 1989). Extracts of the bark, gum and roots are the main parts used to treat many ailments.

Extracts are used as astringents to treat gastrointestinal disorders, particularly diarrhoea (Williamson 1956; Watt and Breyer-Brandwijk 1962; Kokwaro 1976; Timberlake 1980; Wickens 1980; Muhammad *et al.* 1998).

There is widespread use of the bark to prepare a broncho-emollient for respiratory diseases (Wickens 1980; Anon. 1982a; Bonkoungou 1987). For example, it is used in the traditional preparation of Joal's remedy, an old Senegalese herbal medicine for all chest ailments. All the constituents in this preparation are known to be pharmacologically active although some are not recognized for chest ailments by modern medicine (Kerharo and Paccioni 1974).

Bark and root preparations are also said to have anti-febrile (anti-malarial) properties (Irvine 1961; Wickens 1980; Anon. 1982a; Bongkoungou 1987). For example, they are used as an emetic for fever by the Masai (Watt and Breyer-Brandwijk 1962).

In Ivory Coast, root-bark is used for leprosy and as a liniment for pneumonia, and a bark infusion is used as a febrifuge for coughs and to assist in difficult childbirth (Irvine 1961).

Extracts of bark, gum and roots are used as a gum wash to stop bleeding (Muhammad *et al.* 1998) and to treat toothache (Hughes 1957; Hedberg and Edwards 1989). The leaves are used as an astringent for the teeth and may contain fluorine (Wickens *et al.* 1995).

Other ailments that are treated with preparations from the bark include liver complaints, wounds, ulcers, psychological disorders, kidney diseases, post-partum complications, haemorrhage, opthalmia, rheumatism, ear-ache and deafness, colds and gripe (Irvine 1961; Anon. 1982a; Wickens et al. 1995).

Medicinal uses specifically for the gum are given as an emollient for inflammation, haemorrhage, diarrhoea and opthalmia (Wickens *et al.* 1995)

[**Bibliography**:- 24, 80, 149, 157, 233, 241, 301, 321, 331, 342, 353, 382, 383, 398, 405, 456, 465, 470, 491, 525, 669, 670, 671, 694, 718, 732, 733, 740]

## Food

There are numerous reports from many parts of Africa of the seeds of *Faidherbia albida* being eaten by humans as famine food (Pardy 1953; Palmer and Pitman 1972; Pullan 1974; Grainger and Esbenshade 1978; Marunda 1992; Wickens *et al.* 1995; CABI 19??). The pods are crushed and the seed separated from the chaff in winnowing baskets. The seed is boiled in water; drained and the seed coat removed, boiled again for several hours with wood ash and washed with fresh water. This process is repeated several times and finally the seed is boiled again without ash. Salt is added. If preferred the seed can be pounded and baked into cakes or mixed with maize meal. Legumes are known to contain toxins such as trypsin inhibitors, hemagglutins, goiterogenic factors, cyanogenic glucosides lathyric factors and compounds that cause favism and flatulence, the latter possibly caused by a gram positive anaerobic bacterium, present in the intestinal tract, that is stimulated by unknown substances in the dry seed (Marunda 1992). There are also reports of people using the ground pods as food (Marunda 1992) or even being eaten or used as a condiment (Wickens *et al.* 1995).

The macro nutrient composition (g $100g^{-1}$) of seeds is given by Wickens *et al.* (1995) as:- moisture B 6.5; ash B 3.9; protein B 24.8; fat B 2,2; fibre B 6.8; carbohydrate B 55.8; thiamin B 0.9; riboflavin B 0.17; nicotinic acid B 2.04; energy (kJ $100g^{-1}$) B 1437. The inorganic constituents (mg $100g^{-1}$) are given as:- Ca B 252; Mg B 276; Fe B 6.81; Na B 18.3; K B 1125; Cu B 1.57, Zn B 2.55; P B 390.

Seed oils extracted from *Faidherbia albida* contained 3.64% total lipids (Akhtar *et al.* 1988). The oils were fractionated by TLC into 39% neutral lipids and 60.9% polar lipids. Further fractionation of the neutral lipids revealed hydrocarbons, wax-esters, triglycerides free fatty acids, 1:3-diglycerides, 1:2-diglycerides and monoglycerides. Margaric acid was detected in the seed oil.

In a study to determine free amino acids in *Faidherbia albida*, the following were identified:- 4-OH and 5-OH pipecolic acid, djenkolic acid, diaminopropionic acid (weak); amino-acetylaminopropionic acid, amino-oxalyaminopropionic acid (medium); albizziine (strong) (Evans *et al.* 1977).

Farooqui *et al.* (1987) found that coronaric acid made up 7.8% of *F. albida* oil triglycerides. Direct acetolysis of the oil followed by saponification gave cis-9,10-dihydroxy-octade-cis-12-enoic acid.

Grindley (1945) found generally that the fixed fatty acids of a number of *Acacia* species, including *Faidherbia albida,* contained a high percentage of unsaponifiable matter and no linoleic acid could be detected. The mixed unsaponifiable matter from these oils had an iodine value of 115.

[**Bibliography**:- 9, 103, 230, 243, 291, 292, 436, 522, 523, 556, 733]

# *FAIDHERBIA ALBIDA* AND AGRICULTURE

## History of use in agricultural systems

The history of *Faidherbia albida* in agriculture has been described comprehensively in the CTFT monograph on the species (CTFT 1989). The account below is taken from that work with slight modification.

For several centuries a number of different African peoples have nurtured *Faidherbia albida* on their cultivated land and created a park-like landscape. The presence of the tree in these agricultural systems has resulted from demographic pressure that has made it necessary for the people to use the land without fallows. In this situation, where most of the land is cultivated and free pasture is limited, an agro-pastoral system has evolved based on *F. albida*, millet, sorghum, maize and livestock. It is an example of the traditional farmer-herder interaction leading to the evolution of an ecologically sound productive system (Franke 1987).

The system has developed independently within civilizations in both west and north-east Africa. It is found among:- the Mandingue people of Casamance and the Sereres of Senegal; the Brame and the Mandjak of Guinea Bissau; the Bissas in the south and the Mossi of Yatenga in the north of Burkina Faso; the Hausa of Niger and northern Nigeria; the civilizations of the Jos plateau of Nigeria and the Mandara Mountains of the Nigeria-Cameroun border; the Fur people of the Jebel Marra and the Nuba Mountains of southern Kordofan Province of Sudan; the people of the upper Jordan valley in Israel; and the Gallas and Arusi of the rift valley of Ethiopia. In the southern hemisphere there is the more recent use of *Faidherbia albida* over the coffee plantations of the southern highlands of Tanzania and in the cultivated land round Lake Malawi and in the Kafue floodplain in southern Zambia. More recently still, subsistence cultivation has been practised beneath the trees on fertile flood plains in the Zambezi Valley. There is no record of its value to agriculture having been exploited by the indigenous peoples further south than the Zambezi River.

As these systems have developed in different communities, laws aimed at protecting the trees have evolved. Among the Fur farmers of the Sudan, the law forbids the felling of *Faidherbia albida*; only dead trees may be utilized for their wood. Another well known example is that of the old Hausa Sultans of Zinder in Niger who were self-appointed protectors of the "gao", and enacted draconian conservation measures. For instance, around 1860 Sultan Tanimoun decreed that anyone who cut a gao without permission would be decapitated; anyone who mutilated one would have his arm severed. Perhaps the proverb "Fao daya tafi da rafani bokway" dates from this time ("a gao is worth more than seven maternal uncles"). Since inheritance is through maternal uncles this indicates a fortune, but the fortune gets spent, whilst the gao remains. This action of the Sultans of Zinder led to the establishment of closed stands of the tree with densities reaching 100 to 120 stems per hectare in the regions of Magaria and Matameye. As a result, bush fallows disappeared completely. These laws no longer exist; the power of the state has replaced that of the customary authorities, and in many places one can see degradation of the *F. albida* parkland as a result of excessive lopping, as well as the general ageing of the trees with no replacement. Increasing population pressure, modern, high input cultivation practices, and disruption of the closed communities have compounded the destructive forces threatening the *F. albida* system with deleterious effects on the sustainability of agricultural production in many of these areas.

This particular agro-pastoral system with its beneficial effects on maintaining soil fertility has been the subject of detailed research covering agriculture, soil science, microbiology and bioclimatology. The principal results of their work are summarized in the sections below. (See Figures 80 to 96).

[**Bibliography**:- 22, 23, 26, 27, 47, 54, 55, 67, 68, 79, 80, 81, 86, 101, 103, 105, 106, 107, 108, 113, 123, 124, 135, 149, 161, 173, 175, 178, 179, 213, 215, 223, 247, 252, 256, 266, 274, 286, 297, 316, 322, 326, 332, 333, 335, 339, 340, 362, 363, 384, 385, 386, 391, 392, 395, 403, 411, 413, 419, 424, 426, 427, 429, 431, 439, 440, 441, 442, 443, 444, 445, 448, 449, 451, 453, 454, 464, 466, 471, 473, 476, 478, 481, 491, 492, 505, 509, 516, 520, 522, 531, 532, 535, 539, 545, 547, 548, 549, 552, 556, 558, 566, 567, 581, 582, 584, 592, 598, 599, 602, 604, 616, 617, 665, 667, 687, 689, 691, 694, 709, 721, 723, 726, 738]

## Influence on microclimate

This section is modified and updated from CTFT (1989) which was drawn largely from a number of bioclimatic studies carried out at Bambey in Senegal (Dancette 1966). These studies have shown that the microclimate created by a stand of *Faidherbia albida* is favourable to

crops beneath them. The effects on the various climatic parameters are as follows.

- *Potential evapotranspiration* (PET), the sum of the evaporation from the soil plus the transpiration from the vegetation, is a climatic parameter that is closely related to global radiation, temperature, moisture saturation deficit and wind. In a traditional field planted with standards of *F. albida* at a density of 25 to 30 trees per hectare, observations and calculations indicated a considerable reduction of PET of the order of 50% in the dry season and 10% in the wet season compared with a field unprotected from the wind. (Schoch 1966; Charreau and Nicou 1971).
- *Relative humidity* (RH) is higher under a canopy of *F. albida* than on bare ground. Thus the soil dries out more slowly, which is important in where soils are denuded (Schoch 1966). When the first intermittent showers of the rains arrive they decrease the saturation deficit of the air, leading to a reduced PET at the level of the cultivated plants, thus helping them to survive until the next shower.
- *Soil moisture* in the top four metres of soil in the summer in West Africa has been found to be identical under the trees and in the open. However, the distribution in the soil differs; under the trees there is more moisture in the top 120 cm and less below this level. The higher moisture content found in the upper layers of the soil may be due to a reduction in evaporation under the tree canopy and the lower moisture content measured lower down the profile may be due to the uptake of water by the tree's root system.
- *Air temperature* beneath the canopy of *F. albida* trees is reduced in range, *i.e.*, the maximum temperature is lower (*c.* 3.4°C) because the canopy reduces incoming radiation, and the minimum temperature is higher (*c.* 0.6°C) because the canopy reflects infrared radiation from soil. It has also been noted in the mountain regions of the Sudan that the risk of frost is greatly reduced under the trees.
- *Soil temperature* (daytime) at a depth of 0.05 m beneath the canopy has been found to be reduced by as much as 6°C (Payne *et al.* 1998).
- *Precipitation* is increased beneath the canopy of *F. albida* during heavy showers or in windy conditions; the converse is true in light showers and still conditions. However, this is due to the mechanical effect of the tree's crown on the rainfall, a phenomenon common to all isolated trees.
- *Insolation*, the transmitted sunlight essential for growth, remains high during the rainy season because of the inverse phenology of *F. albida*.
- *Irradiance* has been found to be reduced inside the canopy by 0.5 to 1.0 kW $m^{-2}$ (Payne *et al.* 1998).

[**Bibliography**:- 6, 24, 112, 124, 149, 156, 157, 161, 173, 215, 274, 461, 403, 484, 515, 528, 621, 699, 739]

**Effects on soil fertility**

The traditional inter-cropping of grain crops with *Faidherbia albida* has stimulated a great deal of interest in the effects of the tree on soil fertility and, as a result, there has been a considerable amount of experimental field work done to investigate them. Reports of these assessments form a major part of the published information on the species. Many investigators have found that tree cover increases water infiltration and also has a beneficial effect on bulk density, structural stability and chemical and biochemical properties.

The relationship between rooting, plant growth and production were investigated by Charreau and Nicou (1971) in West African rain-fed systems. They concluded that where *Faidherbia albida* is maintained in the cropping area, the plough layer is enriched by the trees' exploitation of the deep soil horizons that brings nutrients up from depths not accessible to herbaceous plants. The surface horizons are then enriched with decomposing leaf litter at the start of the rains and the soil nutrient status is improved, particularly with increased N, but also with C, Ca, Mg, K, P and humus. The biological activity in the topsoil is also increased. The improvements are found particularly in sandy soils but also in clay-rich soils. Foliar analysis showed increased mineral uptake, especially N, in plants grown under *F. albida*. This could explain the increase in growth noted in the crops.

Other authors have made similar general claims. For example, Saka and Bunderson (1989b) attributed high soil fertility under *Faidherbia albida* to nitrogen-fixation; during leaf shedding, the tree deposits a fine mulch of litter which rapidly decomposes and enriches the topsoil in plant nutrients whilst improving soil moisture conditions, soil porosity and root penetration. Charreau (1982) suggested that *F. albida* can compensate millet and groundnut crops for the absence of mineral fertilizers as it brings leached nitrates to the surface in the organic matter that it drops beneath its crown. Kamara and Haque (1992) found that *F. albida* trees on a vertisol in Ethiopia had higher organic matter on the west side than the east due to the accumulation of wind-blown litter on the leeward side of the tree. Organic matter, N, P and K levels were higher under the tree canopy than outside for all directions and depths studied. Soil pH, exchangeable Na, Ca, and Mg under the canopy and outside were similar. Available water capacity was 1.5 to 2 times greater under than beyond the individual trees. Noticeable increases in the silt fraction under the tree were recorded. In Nigeria, *F. albida* is said to improve soil fertility slightly more than *Parkia biglobosa*, and both these species improve soil fertility more than *Eucalyptus camaldulensis* (Jaiyeoba 1996). In Nigeria, Alexander (1986; 1989) found that *F. albida* was more effective in increasing the morphological, chemical and biological differentiation of unclaimed mining spoil than eucalypts or pines. Observation of the ground vegetation

growing in the vicinity of a number of isolated *F. albida* indicated that the ground vegetation growing below the canopy was taller, more lush and a darker green than that growing outside the influence of the tree. Organic carbon, total nitrogen, pH, percentage base saturation and exchangeable Ca, Mg, Na and K were all significantly higher in soils from beneath the canopy than in those from beyond it. Giffard (1974a) found that the soil beneath *F. albida* also had a better-developed and more robust structure and a more active population of soil fauna. The tree had beneficial effects on the soil, including a higher level of activity of soil micro-organisms, though N is only fixed in areas lacking in this mineral. Rapid decomposition of the litter led to tight mineral cycling through the system, notably of K, Mg, and Ca, but not P. The greatest return of minerals to the soil occurred in December-January with leaf fall and then in March-April when pods fell. These effects have long been exploited in Senegal, Mali and neighbouring regions and in the drier areas around Debre Zeit in Ethiopia.

Several authors have conducted experiments to quantify the effects of *Faidherbia albida* on the soil; others have interpreted and summarized the published research with a varying amount of reference to the basic work. The most prominent of both these types of publication are quoted below. Neither site conditions nor experimental methodology are included in these abstracts; the variations in both complicate the overall picture and the reader is better advised to go to the original references if a deeper understanding is to be sought. Results are given in percentages without reference to base levels because these, and season, have frequently not been given in the publication. The purpose here is to give the reader an introduction to the subject, an overall assessment of the effects of *F. albida* on the soil and an entrance into the literature, not a critical review of the status of research on the subject.

Jung (1966 and 1970) investigated soil microbiological characteristics under *Faidherbia albida* in Senegal. Soils under the trees showed greater biological activity in all seasons of the year than soils without tree cover. In the vicinity of *F. albida* trees, the soils were more fertile but they also showed greater seasonal fluctuations in physiochemical and biological characters. There was a clear increase in invertase, dehydrogenase, asparaginase and respiratory $CO_2$. Carbon dioxide released upon soil moistening was also increased by 54%. Increased levels of fungi and actinomycetes, major decomposers of lignin, cellulose and organic matter, implied faster rates of organic decomposition, nitrification, and nutrient availability. *Bacillus circulans* was found to fix nitrogen and to have a 20-fold higher population under *F. albida*. Measurements were also made on physical changes in the soil; a 52% increase in clay and a 51% increase in water holding capacity were found. Assessments were also made of chemical changes; a 120% increase in cation exchange capacity, a 91% increase in total soil carbon and a 110% increase in total soil nitrogen were found.

Delwaulle (1977) summarized the results of research on the soil improvements under *Faidherbia albida* in Senegal. He quoted the following rates of increase:- 7% in clay content; 134% in assimilable P; 60% in total C; 43% in equivalent moisture (and therefore water retention); 100% in N; 100% in exchangeable Ca; and 70% in exchangeable Mg. The reasons for the beneficial effects of *F. albida* on the soil are given as:- active decomposition of leaves when crops beneath the trees are beginning to sprout; fertilization by livestock seeking shade under the trees; diminution of evapotranspiration, leaching and fluctuations in temperature; possibility of fixation of N; and bringing nutrients to the surface from deep down in the soil.

In Ethiopia, Bekele (1982) investigated the effect of *Faidherbia albida* on the silt-loam to sandy soils near Awasa in the summer. He found the overall values under the trees to be:- moisture content - 68%, 4.2 t $ha^{-1}$ of vegetation under the tree, texture index - 7, and rate of infiltration - 5.8 l $hr^{-1}$; the respective overall mean values for the open areas were:- 57%, 4.2 t $ha^{-1}$, 4, and 5.8 l $hr^{-1}$. Results of laboratory analyses of soil samples from under the *F. albida* were:- organic matter - 4.3%, N - 0.17%, pH - 6, and C:N ratio - 26.4; the respective mean values for the open were:- 4.1%, 0.2%, 7, and 13.2. As biomass is a good indicator of soil fertility, and since the biomass under *F. albida* was greater than the biomass in the open, it was concluded that the fertility was higher under the trees.

Montagne (1984) reported for Niger as follows. There is little variation in soil humidity under the canopy compared to the open site throughout the year. Rainfall infiltration under the canopy increases in heavy and oblique rain and decreases in light vertical rain. There is no effect on the percentage of clay and silt but there is an increase in the percentage of organic matter to 2 m depth. Soil humidity is maintained under the canopy all year due to lower evapotranspiration. Relative humidity under the canopy increases above a wilting point of 2.8; otherwise there is no difference compared to the open. When relative humidity is below 2.8, water is no longer limiting to plant growth. There is a rise in pH and exchange capacity as a result of the increase in organic matter under the trees. K and Na are little influenced; Ca and Mg, which provide 95% of the exchange cations, both increase under the canopy; P increases in the dry season. The C and N content under the canopy doubles. The greatest increase in C under the canopy occurs in at the end of the wet season when microbial activity is high and the leaf litter is rapidly broken down. Greatest concentration of ammonium under the canopy occurs at the end of the dry season, while nitric compounds are most abundant after the first rains. Biological activity in the soil increases under the canopy by 2.5 times (with seasonal variation) though only specialized fungi increase in abundance

(*e.g.* N fixing). Mineral elements increase 20-40% under the canopy depending on the season, *e.g.* $P_2O_5$ increases by 2-3 times.

In Senegal it has been found that about 50 trees to the hectare give the equivalent of 300 kg organic nitrogen, 50 kg of potassium chloride (24 kg K), 80 kg of dicalcium phosphate (31 kg of soluble $P_2O_5$ and 25 kg Ca), 125 kg of dolomite (15 kg Mg and 25 kg Ca) and 100 kg of agricultural lime (Baumer 1983).

A study in Malawi on the impact of *Faidherbia albida* on nitrogen mineralization and soil moisture from the time of crop planting until harvest included both large and small trees to determine whether the effects change as trees mature (Rhoades 1995). During the first month of the rainy season, a seven-fold difference in net N mineralization was recorded beneath large tree canopies compared to rates measured in open sites. However, both N mineralization and soil moisture were decreased below young trees. The impact of *F. albida* on these soil properties therefore appears to change with tree age and size and the author concluded that, while maize yields were not depressed below young *F. albida*, it is important to realize that the full benefits of this traditional agroforestry system may require decades to develop.

From the foregoing, it is clear that there is overwhelming evidence that the soil beneath the canopy of a *Faidherbia albida* tree undergoes significant changes and that the overall effect of these changes is to increase fertility. The effects attributed to the various authors above are incorporated in an edited version of the summaries given in CTFT (1989) *q.v.* below.

*Physical properties of the soil.* Generally, the clay and silt contents of sandy soils appear to be little influenced by the presence of *Faidherbia albida*, though increases of 7-52% have been recorded in the topsoil. Nevertheless, even small effects can have an appreciable influence on other soil properties, notably on cation exchange capacity and on humus content with less significant effects on cohesion, bulk density and porosity. The influence of the trees on the physical properties of the soil, particularly porosity, might be greater if cultivation before sowing crops were deep enough to incorporate the organic debris into the soil; subsistence farmers practise only light surface cultivation which leaves a high proportion of the debris on the surface of the soil. The compaction of the soil by livestock attracted by the fodder and the shade of the trees is an undesirable factor.

*Organic and biological soil characteristics.* The organic and biological soil features are, in contrast to the physical properties, greatly influenced by the presence of *Faidherbia albida.* This is mainly due to the organic debris dropped in the neighbourhood of the tree canopy. The agricultural crops or natural under-storey species grow better under the trees and also contribute more to the soil in the form of residues and litter. The soil changes are greatest near the trunk of the tree and least towards the edge of the canopy. Similar unevenness could also be caused by the prevailing wind which can affect the distribution of litter falling from the tree.

Under the *Faidherbia albida* canopy, total carbon has been found to be increased by 60-91%, mineralizable carbon by 73%, humus content by 40-47% (significant for total humus and labile humus but not for non-labile humus) and nitrogen by 100-110%. The magnitude of nitrogen increase is greater than that of carbon and therefore the C:N ratio is diminished under the tree. The lower C:N ratio may be a favourable sign since it indicates a more rapid mineralization of organic matter.

Biological activity has been found to be two to five times higher under *Faidherbia albida* than in the open during the period of cultivation. An increase under the tree crowns is indicated whether it is determined by measuring $CO_2$ production, the glucose index, the level of saccharose, or dehydrogenase or asparaginase activity. Activity is at a maximum at the end of the dry season, except for asparaginase which peaks during the rainy season. The presence of *F. albida* does not influence the quantity of micro-organisms, except for the cellulose-decomposing and denitrifying fungi which are more abundant under the crown. There is, rather, a basic microflora little affected by the tree and a more specialized microflora which is favoured by its presence. The rainy season is the most favourable time for microbiological activity. In the month of August, for instance, the number of bacteria can increase by 90% , actinomycetes by 75% and basidiomycetes by 40 -70%.

*Chemical characteristics of the soil.* The pH of the soil has, in some studies, been found to be higher under a *Faidherbia albida* fallow than on open land at all seasons of the year. The difference varies from 1.3 at the soil surface to 0.3 at 140 cm depth. The conductivity of the aqueous extract reaches a maximum just before the first rains. The conductivity of soil under *F. albida* fallow has been found to be 135% higher than on open land. On cultivated lands the conductivity could be as much as 90% higher under the trees than on open lands.

The cation exchange capacity in the top 10 cm of soil has been found to range from 28.1 to 41.3 me $kg^{-1}$, that is a rise of 47% at the area near the trunk compared with the area outside the zone of *Faidherbia albida.* Of the exchangeable cations, Ca shows the largest increase (100%) followed by Mg (78%), Na and K at 30 to 40%. The sum of exchangeable cations, mainly influenced by Ca and Mg, rose from 22.5 me $kg^{-1}$ to 42.7 me $kg^{-1}$, an increase of 90%. Under the trees the saturation level (100 x sum of exchangeable ions/exchange capacity) was 100% compared with a value of 80% beyond the canopy. The soil mineral reserves of cations have also been found to be marginally higher under *F. albida* trees, *i.e.* the level

of cations has been increased to a lesser degree than their availability for saturating the base complex.

There are indications that the total level of phosphorus in the soil increases by about 28% under *Faidherbia albida* trees. However, available phosphorus has been found to increase by as much as 134%.

*Soil improvements in terms of fertilizer and manure equivalents.* The soil-improving action of *Faidherbia albida* has been quantified in general terms for the top 10 cm of the soil in equivalent inputs in kg $ha^{-1}$ on the assumption that the whole hectare is covered by *F. albida* trees planted at 50 stems $ha^{-1}$ (CTFT 1989) .

- *carbon* - an increase of 55 tons dry matter $ha^{-1}$ $yr^{-1}$ which is equivalent, in organic matter only, to 120 tons of farmyard manure per hectare
- *nitrogen* - an increase of up to 460 kg $ha^{-1}$, equivalent to 1.15 tons of urea
- *calcium* and *magnesium* (exchangeable) - an increase that is equivalent to an application of 450 kg of magnesium limestone and 800 kg of slaked lime perhectare
- *potassium* (exchangeable) - an increase equivalent to 23 kg of potassium oxide or up to 50 $kgh^{-1}$ of KCI fertilizer per hectare
- *phosphorus* - an increase in total phosphorus equivalent to 67 kg of $P_2O_5$ or 168 kg of double superphosphate per hectare; or an increase in available phosphorus equivalent to 48 kg of $P_2O_5$ or 120 kg of double superphosphate per hectare.

These figures indicate the level of benefits to the soil from *Faidherbia albida.* The increases in carbon and nitrogen represent very large amounts of fertilizer, the increases in lime and magnesium are at the level of normal applications, the increases in potassium are comparable to an annual application and the increase in phosphorus amounts to a light top dressing. The imbalance of these increases does not appear to affect cereal crops but might have to be corrected by artificial applications for other crops.

[**Bibliography**:- 11, 12, 13, 24, 25, 57, 58, 63, 69, 80, 103, 108, 118, 123, 124, 125, 146, 148, 149, 157, 159, 161, 173, 184, 198, 210, 211, 213, 215, 224, 233, 247, 271, 272, 274, 275, 276, 277, 316, 331, 336, 341, 350, 360, 361, 363, 369, 370, 371, 372, 373, 374, 376, 391, 394, 406, 457, 461, 484, 486, 511, 513, 515, 516, 528, 546, 548, 550, 551, 571, 598, 599, 601, 603, 617, 631, 656, 665, 677, 691, 698, 709, 738, 739]

## Source and cycling of nutrients

This section contains a modified and up-dated version of the section on the soils in CTFT (1989).

The mineral elements accumulated in a tree are returned to the soil in the leaf, flowers, pods, dead wood, decomposition of roots and exudates from them, and from nutrients leached from the crown in rainwater. All these mechanisms tend to concentrate the mineral elements under the crown of the tree. Most tree species are in full leaf during the wet season and crops cannot be grown in the shade beneath them. *Faidherbia albida* is leafless in the wet season and, as there is no need to remove them or lop the crowns to grow crops, the tree's soil improvement potential can be realized. Furthermore, the deep, extensive nodulated root system helps to ensure that a large amount of the nutrients concentrated under the tree do not come from the surface layers of the soil, but from deeper horizons and the atmosphere and this results in a net gain to the arable soil layers.

Jung (1970) measured and analyzed the annual production of organic debris under *Faidherbia albida.* The results are shown in Table 9. The mineral content of *F. albida* litter compared well with the litter of other common tropical trees of the fallows as it did in the microbiological activity of the soil beneath it.

The reverse phenology of *Faidherbia albida* means that the leaf litter is dropped at the end of the dry season when the soil is being cultivated in preparation for planting crops and it is thus incorporated into the soil in readiness to coincide with the increase in microbiological activity as the soil becomes moistened by the rains.

Another factor in nutrient cycling is the effect of animals, domestic and wild, that seek fallen pods and shade beneath the canopy of the trees in the dry season and deposit dung and urine. There is no doubt that the effect of this is to increase fertility beneath the trees but there is said to be no close relationship between any such increase and the numbers of animals, and animals are not an essential part of the system; in fact it is said that the effect of *Faidherbia albida* is less in systems that incorporate animals than in situations protected from livestock (Poulain 1970) (Figure 108).

The presence of trees in fields reduces wind speed over the landscape and reduces loss of topsoil through wind erosion. *Faidherbia albida* is particularly effective in this since it is in leaf when the soil is dry and high winds, such as the harmattan, occur. It is also possible that dust is captured on the leaves and eventually finds its way down to the soil although analysis of water collected under the trees has not shown this to be significant in the fertilizing action in regard to nitrates.

There are two unanswered questions on the contributions that *Faidherbia albida* makes to the fertility of the soil.

1. Does the tree's extensive root system, which can exploit an area of up to six times that of the canopy (Dunham 1991b), mine the surface layers of the soil beyond the reaches of its crown and, in so doing,

**Table 9.** Analysis of annual litter fall under *Faidherbia albida* in Senegal (After Jung 1970). Maximum = 44 stems $ha^{-1}$, all debris, including pods, returned to the soil. Average = 20 stems $ha^{-1}$, pods consumed by animals, 50% of the nitrogen and 90% of the minerals returned to the soil. Minimum = 10 trees $ha^{-1}$, with complete removal (collection) of all pods.

| | Litter | N | $P_2O_5$ | $K_2O$ | CaO | MgO |
|---|---|---|---|---|---|---|
| | | | *per tree* (kg) | | | |
| Leaves | 97 | 2.06 | 0.06 | 0.47 | 3.21 | 0.95 |
| Wood & bark | 46 | 0.58 | 0.02 | 0.14 | 3.26 | 0.39 |
| Pods | 125 | 1.66 | 0.12 | 1.48 | 0.73 | 0.25 |
| Total | 268 | 4.30 | 0.20 | 2.09 | 7.20 | 1.59 |
| | | | *per hectare* (kg) | | | |
| Maximum | 11 583 | 8.9 | 8.9 | 91.3 | 311.01 | 69.5 |
| Average | 5350 | 3.8 | 3.8 | 38.8 | 111.6 | 31.3 |
| Minimum | 1 428 | 0.8 | 0.8 | 6.1 | 64.7 | 13.4 |

redistribute the nutrients in the litter that then falls beneath its canopy rather than increase the nutrients on a unit area basis by accessing sources of nutrients that are out of reach to the crops and grasses? This has been put forward as a possibility by Kessler (1990) who even suggests that *F. albida* trees establish themselves in the first place on fertile spots, rather than bring about an increase in soil fertility. There has also been a study to determine whether areas of good growth in a *F. albida* plantation near Niamey might be associated with higher levels of previous termite activity (Brouwer *et al.* 1992). Data taken on a transect from a poor to a good growth area in the trial showed a positive correlation between growth of *F. albida* and level of termite activity at 0.5-1.0 m depth. In Malawi, studies along the lake shore plain revealed the general pattern to be for maize yields to be highest from 5 to 10 m from the bole of *F. albida* trees, to decline to 20 m and then to level out and sometimes even to increase slightly to 30 m (Saka *et al.* 1994). This latter finding suggests that mining of the open areas is occurring.

2. Is *F. albida* any more effective in increasing soil fertility than other tree species in the ecosystem? Soil nutrient concentrations under *F. albida* trees growing free from human influence in Zambezi riverine woodlands were compared with soils in the open, beyond the tree canopies (Dunham 1991b). Concentrations of N, C, P and K were higher under the tree canopies but Ca and Mg were unchanged. The soils were slightly more acid than open soil. The conclusion was, however, that *F. albida* is probably no more efficient at increasing soil fertility than are other savanna trees.

In summary, *Faidherbia albida* draws upon nutrients at great depths as well as from surface soil layers in the surrounding open ground and from the soil atmosphere and from trapped dust. When taken in combination with the benefits of the interaction between its unique phenology and agriculture, there is good evidence for it making a remarkable contribution towards amassing and conserving nutrients for the benefit of both natural and managed ecosystems. What remains unclear is the extent to which the fertility of the cropping zone of the soil beneath the canopy is the result of nutrient redistribution in the top layers of the soil in the area as a whole rather than of the introduction of nutrients from a source that is otherwise inaccessible to the system. To answer this important question, more comprehensive studies are needed to quantify the effect of the tree on soil fertility on a unit area basis.

[**Bibliography**:- 97, 149, 196, 211, 372, 385, 550, 692, 667]

### Effects on crop yields

There are numerous published accounts of the effects of *Faidherbia albida* on crop yields. Most record significant increases in crops growing beneath or near the trees but the scale of the increase varies greatly and there are some instances of crop yields being reduced. This variation is no doubt a function of crop species, tree size and shape, soils, crop management by the farmer, and proximity to neighbouring trees (Saka *et al.* 1994; Sanginga *et al.* 1995). The relative contributions of these factors are not well known; in fact, most experimental work to investigate the effects are local and information such as

tree size and spacing, soil type, rainfall *etc.* are not in a consistent form and comparisons cannot be made.

There are many reports of spectacular increases in grain yield of unfertilized millet (*Pennisetum glaucum* and other species) crops grown under *Faidherbia albida* in West Africa. These vary from marginal to 250% (Charreau and Videl 1965; Baumer 1983; Anon. 1989; De Montgolfier-KouÈvi and Le HouÈrou 1980; Moussa *et al.* 1998; Payne *et al.* 1998; Sarlin 1963; Vandenbeldt 1990a; Williams 1990). The increase in yield is more due to an increase in the number of flower heads than to the weight of grain per head (CTFT 1989). There is the odd report of millet grain yield being unaffected or even decreased below the trees (Sarlin 1963). Artificial fertilizers are reputed to increase yields further but not to an extent greater than would be expected on the control soil (Montagne 1984); in other words, the effect of the trees on yield is equivalent to that obtained after extensive inputs of organic and inorganic fertilizers and of soil working (CTFT 1989). The increase in grain yield has generally been found to be highest close to the bole of the tree and to decrease to the base yield level at 4 to 8 m from the bole, depending on the size of the trees (Delwaulle 1977; Louppe *et al.* 1996). Grain yield tends to be higher on the southern and eastern side of the bole (Moussa *et. al* 1998); as these studies were in the northern hemisphere this suggests that partial shade from the bole and bare branches of the tree is prejudicial. Protein yields of the grain have been reported to be increased under the trees by as much as 300-400% (Charreau and Videl 1965). When this qualitative effect is taken together with the rise in yield, the increase in protein yield is very substantial. There are indications that millet stover yield is unaffected by the trees (Moussa *et al.* 1998). (See Figure 83).

Increases in yield have been reported for sorghum (*Sorghum bicolor* and other species) grown under *Faidherbia albida* in various parts of Ethiopia, sub-Saharan Africa and in India. In the African studies, yields were greater under the tree canopies than in the open by amounts varying from 36 to 250% (Poschen 1986; Moussa *et al.* 1998; Payne *et al.* 1998; Radwanski and Wickens 1967; Saka and Bunderson 1989b; Vandenbeldt 1990a). In India, sorghum yields of grain and dry fodder were found to be reduced by three species of tree in an inter-cropping system (Suresh and Rao 1998); *F. albida* affected yield less than did *Albizia lebbek* or *Acacia ferruginea*. In this instance the trees may have been too young to give the expected benefit to the crops. No effects on direction have been reported for this crop.

Maize (*Zea Mays L.*), the most widely grown grain crop in Africa, also benefits from being grown under *Faidherbia albida*. Increases of grain yield of between 6 and 100% and more have been recorded (Poschen 1986; Saka and Bunderson 1989b; Khonje 1989; Williams 1990; Vandenbeldt 1990a; Saka *et al*, 1994; Rhoades 1995; Moussa *et al.* 1998). Grain yield directly under the tree canopy can be 5 to 10 times that in the open; unlike millet, it is highest on the northern and western sides of the tree north of the equator (Moussa *et al.* 1998). A steeper yield gradient has been recorded in maize than in millet, sometimes to the extent that the difference was between a respectable yield under the tree and no yield at all in the open (Payne *et al.* 1998). There have been a number of findings of maize yield being unaffected by *F. albida* (Chamshama *et al.* 1998; Lulandala 1989) but, in these, the trees were either immature or were annually lopped (Rhoades 1995). However, it has been suggested that the low Nitrogen (N) recovery in maize is partly caused by lack of synchronization between N release by the trees and the associated food crop N demand. The N not taken up by the associated crop can be immobilized in soil organic matter or assimilated by the trees and thus remain in the system. This N can also be lost from the system through denitrification, volatilization or leaching beyond the rooting zone (Sanginga *et al.* 1995).

In Zambia, the profitability of a sole maize cropping system was compared to growing maize under indigenous *Faidherbia albida* in an agroforestry system (Sturmheit 1989). On sloping ground, the agroforestry system was far more profitable than the existing maize monocropping practice and even on level ground the *F. albida* system was found to be a more profitable option at low discount rates. Research conducted in Malawi indicated that *F. albida* has effects on maize similar to those reported in the Sahel, Sudan and Ethiopia (Saka *et al.* 1994). Yield and soil chemical trends were evaluated along transect lines at increasing distances up to 30 m from individual trees in different orientations extending away from the tree canopy of mature trees found in cultivated land. The general pattern was for yields to be highest from 5 to 10 m from the bole of the tree, to decline to 20 m and then to level out and sometimes even to increase slightly to 30 m. Exploratory studies showed that yields of local maize under traditional management with *F. albida* were more than double the yield away from the trees. However, the soil fertility status changed little over the length of the transects. Differences in effect appeared to be a function of variability in tree size and shape, soils, crop management by the farmer, and proximity to neighbouring trees. The relative contributions of these factors are not known. (See Figures 81 and 82). Olsen (1992) also found in southern Zambia that some farmers complained of an apparent incompatibility between *F. albida* and hybrid maize cultivation expressed as excessive vegetative growth with depressed crop yields whereas the crop yields were increased in local maize varieties.

Studies on combined maize and sorghum production under *Faidherbia albida* trees were conducted in eastern Ethiopia (Poschen 1986 in CTFT 1989). The cropping pattern was 50% to 60% sorghum and 5% to 20% maize.

Average overall yields were 1.55 t $ha^{-1}$ in the open and 2.42 t $ha^{-1}$ under *F. albida*, a general increase of 56%. The increase was greater for the maize (76%) than for the sorghum (36%). The increase was due to the greater seed weight, the number of seeds per plant (49% higher in the case of maize) and denser plant populations under the trees.

The effect of *Faidherbia albida* on groundnut (*Arachis hypogaea*) yields is dependent on the nitrogen status of the soil under the trees. If it is high, the yields can be depressed (Baumer 1983). A depressive effect has been observed on the yield of pods in the first 3 m around the trunk, then an increased yield but still lower than in the open, and then a drop in production between 8 and 10 m just outside the canopy (Louppe 1983). In contrast, the production of haulms in relation to pods was greatly increased by the tree. The substantial increases in yield of nuts by 35 to 100% that have occasionally been observed (*e.g.* Dancette and Poulin 1968; Saka and Bunderson 1989b; Vandenbeldt 1990a) occur no doubt where the base level of N in the soils is low.

The effect of the tree on groundnut production has been the subject of comprehensive studies in Senegal both with and without the application of fertilizers (CTFT 1989). The presence of *Faidherbia albida* was found to have a highly significant effect on the production of pods in the absence of fertilizer, but was not significant when fertilizer had been applied. The differences were more marked on the production of other plant residues but the effects of addition of extra nitrogen on the production of straw were not significant. A slight depression of yield of pods was recorded with and without fertilizer where there was a deficiency of phosphorus and this was more marked under the trees. Application of fertilizer in conditions of water scarcity resulted in lower pod production but more vegetative growth. Overall, the yield improvements arising from the presence of *F. albida* trees approached 44% for pods and 47% for straw. This research included an experiment in which the soil from under *F. albida* trees was transported to a site away from the tree cover. The conclusions were that the effect of the litter was most important because, despite the removal of the surface layer of the soil, the plot under the trees still performed better although the removal of the soil did reduce the yield under the trees. Taking the soil to a new site with no trees produced increases in yield of 36% of pods and 26% of straw compared with an untreated site without trees. Foliar analysis of groundnut plants under *F. albida* trees and in the open showed that the further the plants were from the trunk of the tree, the more the levels of P and K diminished.

A series of studies were undertaken of the *Faidherbia albida/Gossypium hirsutum* (cotton) association in the parklands in the Sudano-Sahelian zone of northern Cameroon (Libert and Eyog Martig 1996). The density in the 38-hectare plot was 5.5 trees $ha^{-1}$ with a mean basal area at breast height of 1.8 $m^2$ $ha^{-1}$. Crown cover was 8.7% of the area, average height 12 m and average diameter 0.56 m. The first study focused on the effect of isolated trees on the growth of cotton and compared the part beneath *F. albida* crowns and the part up to 20 m from the outer edge of the crown. Beneath the crown, the density of cotton plants was 20% lower, but the plants were larger and more evenly sized. The average capsular weight for them was higher. The cotton yield was higher beneath the trees in less fertile soils, and lower in more fertile soils. A second study was a comparison between a dense parkland area with young *F. albida* trees (37 trees $ha^{-1}$, average diameter 34 cm, 26% crown cover, average crown area 70 $m^2$) and a nearby zone where trees were very sparse. Although yields were high (1.61 t $ha^{-1}$) in the part outside the parkland, they increased by 32% in the parkland. The effect of dense parkland on cotton plant yield was found to be more favourable than the effect of an isolated tree although the soil parameters seemed to have been more markedly changed under the old trees. The third study dealt with the availability of water for the cotton plants under old trees. Cotton plant roots reached a maximum depth of 80 cm. In this zone, no *F. albida* roots were found and the available water reserve at this soil depth was found to be greater beneath the crowns at the start and at the end of the crop cycle. The phenology of the individual trees differed greatly, the earliest being totally in leaf by mid-July and the latest not starting to form leaves until mid-August. Two out of four trees intercepted more than 50% of the light throughout the cotton plant's vegetative period. Beneath the canopy, cotton plants flowered later and the plants were larger. At the same time, weeds developed better beneath crowns, but were less diversified, and weeding was more laborious. The authors concluded that the influence of *F. albida* on the cotton plant has to do with the station, that the effect of a stand on cotton production is greater than that of isolated trees, that water availability for the cotton is greater at the start and end of the crop cycle, that there is no competition for water and mineral elements between tree and crop and that any depressive effect is due to shade.

Increases in yield of other crops have been recorded when grown under *Faidherbia albida*. In an arid region of India, the yield of barley (*Hordeum vulgare*) was increased by 58% (Anil *et al.* 1998) and yields of castor (*Ricinus communis*), sunflower (*Helianthus annuus*) and redgram (*Cajanus cajan*) were all increased when alley-cropped with *F.albida* (Bheemaiah *et al.*1992). In Ethiopia, an increase in yield of 63% was reported in a mixed crop of teff (*Eragrostis tef*) and wheat (*Triticum aesticum*) grown under the canopies of *F. albida* trees (Jiru 1988). (See Figures 84 to 87 and 94 to 96).

The foregoing indicates the impressive extent of the evidence that crop yields are increased under *Faidherbia albida* trees. The size of this increase is determined by a complex interaction of factors and is no doubt a function

of variability in tree size and shape and proximity to neighbours, soils, water availability and crop management by the farmer. The relative contributions of these factors have not generally been quantified. It remains important to determine whether the trees mine the surrounding open areas for nutrients and water thereby effectively reducing crop yields in the open and perhaps negating the gains in yield made under the trees. It is known that the trees root well beyond their canopies and there are indications that crop yields in open areas do start to rise again when they are sufficiently distant from the trees (Saka *et al.*1994). The open areas can also be mined through livestock which deposit their dung and urine beneath the canopies when they seek the shade cast by the trees in the dry season (Radwanski and Wickens 1967) (Figure 108).

[**Bibliography**:- 20, 25, 26, 57, 71, 103, 122, 125, 146, 149, 157, 161, 162, 173, 184, 215, 247, 267, 270, 275, 336, 363, 364, 385, 389, 415, 419, 421, 431, 451, 457, 459, 462, 463, 467, 509, 510, 511, 513, 528, 547, 557, 571, 598, 599, 601, 615, 617, 652, 656, 677, 691, 692, 699, 738]

## Nutritional value and digestibility for livestock

### *Nutritional value*

The chemical composition of the leaves, flowers, pods and seeds of *Faidherbia albida* are given in Table 10. The table is modified from CTFT (1989) which was in turn constructed from Boudet (1972), Le Houérou (1980a), Miehe (1986) and Touzeau (1973). Russell (1947), Grainger & Esbenshade (1978), Baumer (1983), Cissé & Koné (1992) and Wickens *et al.* (1995) were additional sources used in the construction of this table. In many of the published data the degree of maturity and desiccation of the material were not the same, or not given, which could account for some of the more extreme variation in values shown. Outlier values have been excluded from the table to avoid obscuring the median values. Many of these measures are not mutually exclusive.

The units used as measures of the various parameters in Table 10 and text below are not always made clear in the publications on the subject. In addition, much of the research was done in West African countries with French associations using procedures that sometimes differed from those used in countries in Africa with British associations. Some of these problems were discussed in CTFT (1989) and the explanation of terms and the procedures used in that publication in their determination are repeated, with modifications and additions, below.

- **Dry Matter** (DM) (%) - measured after drying the sample in an oven overnight at 105 °C; (dry weight/fresh weight x 100) = % dry matter.
- **Moisture Content** (MC) (%) - calculated as 100 = % DM
- **Crude Protein** (CP) ($g\ kg^{-1}$ DM) - estimated by the Kjeldahl method; proteins on average contain about 16% nitrogen; therefore, CP = nitrogen x 100/16 or % nitrogen x 6.25. This is taken as an acceptable estimate but the assumption in the analysis is that all nitrogen comes from protein, which is not so as some comes from DNA, RNA and urea and some proteins, *e.g.* oil seed proteins, contain 18.5% nitrogen.
- **Crude Fibre** (CF) ($g\ kg^{-1}$ DM) - cell wall constituents (cellulose + hemicellulose + pectin + lignin). A dried sample is boiled in weak sulphuric acid and filtered, boiled in weak alkali, and the residue dried and ashed. The difference between the filtered dried sample and the ashed sample is CF. The two boiling processes simulate pH conditions in the stomach and small intestine. (For the values given in Table 10, it is not clear if the method used included the initial step of extraction in diethyl ether before the boiling stage)
- **Crude cellulose** (CC) ($g\ kg^{-1}$ DM) - obtained as the residue after boiling the sample for 30 minutes with a concentrated mixture of three acids, acetic, trichloracetic and nitric; this procedure differs from the detergent fibre system now used in Britain which would obtain values for CF, acid detergent fibre (ADF), neutral detergent fibre (NDF) and non-starch polysaccharides.
- **Acid Detergent Fibre** (ADF) ($g\ kg^{-1}$ DM) - insoluble residue following extraction of herbage with acid detergent; cell wall constituents minus hemicellulose, *i.e.* consists of cellulose, lignin, bound protein, and acid insoluble ash. Since these constituents are quite indigestible, ADF is a negative indicator of energy level in forages and grains, *i.e.*, as ADF increases, digestible energy is decreased.
- **Acid Detergent Lignin** (ADL) ($g\ kg^{-1}$ DM) - lignin in the residue determined following extraction with acid detergent.
- **Neutral Detergent Fibre** (NDF) ($g\ kg^{-1}$ DM) - that portion of a forage that is insoluble in neutral detergent; synonymous with cell wall constituents. In addition to the components which make up ADF, NDF contains hemicellulose, a bulky, more digestible fibre fraction, which makes NDF a good predictor of dry matter intake.
- **Ether extract** (EE) ($g\ kg^{-1}$ DM) - sample boiled in organic solvent (ether) for four hours. Since fats are soluble in ether, EE is equivalent to fat.
- **Nitrogen-free extractives** (NFE) ($g\ kg^{-1}$ DM) - NFE represents soluble carbohydrate (basically glucides); CF is insoluble carbohydrate. NFE contains accumulated error from CP, CF, EE and MIN because it is calculated as 100 - (CP + CC + EE + MIN).
- **Digestible crude protein** (DCP) ($g\ kg^{-1}$ DM) - calculated as 0.929(CP) - 3.52. DCP is often queried for ruminants because so much 'digested' N can appear in urine; the key figures are CP and degradability (solubility). There are two needs, that of the rumen microbes and that of the animal. Rumen microbial need depends on CP and compatible breakdown

**Table 10.** Chemical composition and forage value of *Faidherbia albida* flowers, leaves, pods and seeds. Modified from CTFT (1989).

| Part Sampled → | | Leaves | | | Pods | |
|---|---|---|---|---|---|---|
| Parameter ↓ | Flowers | Juvenile | Mature | Whole | Pulp | Seeds |
| % dry matter | 17.8 | 30.6-37.3 | 30.7 | 86.4-94.0 | 94.6 | 90.6-95.5 |
| • *Chemical composition g kg$^{-1}$ dry weight* (DW) | | | | | | |
| Crude protein (CP) | 190 | 171-200 | 120-200 | 88-171 | 56 | 260-280 |
| Crude cellulose (CC) | 572 | 124-182 | 147-196 | 144-331 | 218 | 104-222 |
| Crude fibre (CF) | - | - | 16 | 14-15 | - | - |
| Carbohydrates (CH) | - | - | 72 | 37-63 | - | 558 |
| Neutral detergent fibre (NDF) | - | 355 | 309 | 670 | 474 | 458 |
| Acid detergent fibre (ADF) | - | 221 | 197 | 419 | 364 | 146 |
| Acid detergent lignin (ADL) | - | 79 | 97 | 88 | 121 | 24 |
| Ether extract (EE) | 16 | 23 | 22-51 | 09-15 | 25 | 19-25 |
| Ash (MIN) | - | - | - | - | - | 39 |
| Nitrogen-free extractive (NFE) | 125 | 584-597 | 495-562 | 500-665 | 655 | 453-560 |
| • *Composite measures of quality (DCP - g kg$^{-1}$ DW; NE - MJ kg$^{-1}$ DM; NC - g DCP kg$^{-1}$)* | | | | | | |
| Digestible crude protein (DCP) | 141 | 123-136 | 128-137 | 45-109 | 17 | 197-215 |
| Net energy (NE) | - | 7.0 | 6.1 | 6.1-7.2 | 6.6 | 8.1 |
| Nutritional coefficient (NC) | - | 125-132 | 150 | 59-87 | 18 | 184 |
| • *Vitamin B complex – g 100g$^{-1}$ DW* | | | | | | |
| Thiamin | - | - | - | - | - | 0.90 |
| Riboflavin | - | - | - | - | - | 0.17 |
| Niacin | - | - | - | - | - | 2.04 |
| • *Macro-elements – g kg$^{-1}$ DW* | | | | | | |
| Total minerals | 9.7 | 6.3-8.4 | 6.4-8.1 | 3.3-12.6 | 4.7 | 3.8-4.2 |
| Silicon | 1.9 | 0.5-0.6 | 0.5 | 0.2-0.7 | 0.9 | 0.1 |
| Phosphorus | - | 0.19 | 0.10-0.20 | 0.12-0.28 | 0.05 | 0.38-0.40 |
| Calcium | - | 1.13 | 1.13-1.80 | 0.23-0.73 | 0.50 | 0.25-0.40 |
| Magnesium | - | 0.26 | 0.26 | 0.10-0.29 | 0.10 | 0.28 |
| Potassium | - | 1.20 | 1.20 | 1.20-1.30 | 1.10 | 1.07-1.13 |
| Sodium | - | - | - | - | trace | 0.018 |

(continued)

**Table 10.** (continued)

| Part Sampled → | | Leaves | | Pods | | |
|---|---|---|---|---|---|---|
| Parameter ↓ | Flowers | Juvenile | Mature | Whole | Pulp | Seeds |
| • *Ratios* | | | | | | |
| Calcium:phosphorus | - | 5.9 | 5.9-18.0 | 1.5-3.7 | 10.0 | 0.8-1.0 |
| Calcium:magnesium | - | 4.3 | 4.3 | 2.3-3.5 | 5.0 | 1.1 |
| Potassium:sodium | - | - | - | - | 275 | - |
| • *Micro-elements – mg kg$^{-1}$ DW* | | | | | | |
| Copper | - | - | - | 0.1 | 3.0 | 0.016 |
| Cobalt | - | - | - | 1.4 | 0.2 | - |
| Manganese | - | - | - | 10.7 | 13.0 | - |
| Zinc | - | - | - | 11.8 | 10.0 | 0.026 |
| Iron | - | - | - | 21.4 | 194.0 | 0.070 |

with the fermentation rate of energy (hence efficiency of urea combined with molasses) to form microbial protein (thus minimizing urine N); the animal may also need some 'bypass' protein to top up microbial supply, especially young rapidly growing animals and milking cows (T. Smith pers. comm.).

- **Gross energy** (GE) (MJ kg$^{-1}$ DM) - is the total calorific content, i.e. the fuel value, of the feed. It is measured as the energy given off when the feed sample is combusted.
- **Digestible energy** (DE) (MJ kg$^{-1}$ DM) - is GE minus the energy lost in faeces.
- **Metabolizable energy** (ME) (MJ kg$^{-1}$ DM) – is DE less the energy lost as methane from the rumen plus that lost in urine. The energy nutrients differ in the amount of ME they provide to the animal. Digestible protein (DCP) provides 4.5 kcal g$^{-1}$; the ME content of digestible fat (DCF) is about 9.5 kcal g$^{-1}$; while digestible carbohydrate (DCH) provides 4.2 kcal g$^{-1}$. The DCP, DCF and DCH values are multiplied by the respective ME factors to calculate the ME.
- **Net energy** (NE) (MJ kg$^{-1}$ DM) – is ME less the heat lost in heat increment. This figure represents about half the metabolizable energy (ME). In the case of barley grain, for example, GE = 17.5 MJ kg$^{-1}$ DM, ME = 13.3 MJ kg$^{-1}$ DM and NE = 6.9 MJ kg$^{-1}$ DM. NE depends on the level of crude cellulose compared with the ash content and it varies inversely with the level of the two constituents. NE depends both on the feed and on the animal consuming it; the value is higher for maintenance, slightly less for milk production and lower for growth. NE is not often used because it is difficult to measure and is therefore usually an estimate. ME is more commonly used in the UK.
- **Fodder unit** (FU) - one FU corresponds to the energy content of 1 kg of barley grain. The figures are given in megajoules (MJ) kg$^{-1}$ DM: 1 MJ = 239 kcal = 0.145 FU.
- **Nutritional coefficient** (NC) = (DCP/FU) is an index of fodder value of a sample. It is expressed as grams of digestible protein or FU kg$^{-1}$: 1 FU = 6.9 MJ = 1,650 kcal. This is for adult ruminants consuming coarse fodder.
- **Total minerals** or ash (MIN) (*g kg*$^{-1}$ DM) - the residue after calcining a sample at 600 °C.
- **Silicon** (S) (*g kg*$^{-1}$ DM) - that portion of the ash which is insoluble in hydrochloric acid.
- **Phosphorus** (P) (*g kg*$^{-1}$ DM), **calcium** (Ca) (*g kg*$^{-1}$ DM), **magnesium** (Mg) (*g kg*$^{-1}$ DM), **potassium** (K) (*g kg*$^{-1}$ DM) and **sodium** (Na) (*g kg*$^{-1}$ DM) - these macro-elements have been assessed by spectrophotometry or complexing and spectrophotometry.

Proximate analysis is a basic system of nutritional analysis which divides the food into six fractions:- moisture (MC), ash (MIN), ether extract (EE), crude protein (CP), crude fibre (CF), and nitrogen-free extractives (NFE). As indicated above, NFE is calculated by subtraction, so it includes the errors in all the other estimates; it also includes a lot of different components of the food, including sugars, starch, pectins, resins, tannins, pigments and water-soluble vitamins. This form of analysis is used less and less as time goes by because it generally has little relevance to practical feeding; CF is rarely quoted now. ADF and NDF are what are required today, together with CP and ME.

A summary of (approximately) median values from the literature of DM, CP, ADF, NDF and ME for flowers,

**Table 11.** Nutritional composition of flowers, leaves, pods and seeds of *Faidherbia albida,* maize grain, silage and stover and veld hay. Approximate median values from the literature.

| Plant part | DM % of fresh mass | CP | ADF g kg$^{-1}$ DM | NDF | ME MJ kg$^{-1}$ DM |
|---|---|---|---|---|---|
| *Faidherbia albida* | | | | | |
| Flowers (fresh) | 18 | 190 | - | - | - |
| Leaflets (fresh) | 36 | 170 | 221 | 355 | 14 |
| Leaves (fresh) | 41 | 140 | 197 | 309 | 12 |
| Pods (green) | 28 | 110 | - | - | - |
| Pods (dry) | 68 | 140 | 419 | 670 | 12 |
| Pod pulp | 95 | 56 | 364 | 474 | 13 |
| Seeds | 93 | 260 | 146 | 458 | 16 |
| *Zea mays* | | | | | |
| Maize grain | 93 | 96 | 90 | 180 | 13 |
| Maize silage | 41 | 91 | 229 | 436 | 11 |
| Maize stover | 94 | 54 | 428 | 670 | 5 |
| *Grass* | | | | | |
| Veld hay | 95 | 42 | 472 | 701 | 5 |

DM – dry matter, CP – crude protein, ADF – acid detergent fibre, NDF – neutral detergent fibre, ME – metabolizable energy

leaves, pods and seeds of *Faidherbia albida* is given in Table 11. Also given in the table are equivalent values from the literature for maize grain, silage and stover and for veld hay. The value of CP for all parts of *F. albida* except the pod pulp is considerably higher than all parts of maize and veld hay. The value of CP of 56 g kg$^{-1}$ DM for pod pulp is a bit suspect especially in view of its high ME. The values for NDF are generally *c.* 50% higher than those for ADF for all plant parts except for *F. albida* pod pulp where it is only *c.* 30% higher, maize grain and maize stover where it is *c.* 100% higher and seeds of *F. albida* where it is *c.* 200% higher. This implies that the proportion of fibre that is digestible is lowest in *F. albida* pod pulp and highest in *F. albida* seeds. ME is also highest for *F. albida* seeds, slightly lower for everything else except maize stover and veld hay in which it is very much lower. The general conclusion from these data is that the leaves, pods, seeds and, probably, flowers of *F. albida* have a much higher nutritional value than maize stover or veld hay, and higher CP and equivalent or higher ME than maize grain or stover.

The general quality of fodder in terms of energy and protein content are shown in Table 12. These estimates are based on the assumption that an animal consumes a daily average of 2.5 kg DM 100 kg$^{-1}$ body weight. The minimum requirements of adult cattle are thus 3.1 MJ (0.45 FU) kg$^{-1}$ DM containing 2.5% of DP. This gives a nutritional coefficient of 25/0.45 = 55 (CTFT 1989). The estimates are probably on the low side for Zebu cattle which consume about 3 kg DM 100 kg$^{-1}$ live weight, and the figure is said to be low for sheep; for goats the figure would be more than double (CTFT 1989). However, average figures for intake are difficult to estimate because so many factors are involved and the figures given above may be high for animals on dry season grazing when the diets can be very low in CP (T. Smith pers. comm.).

*Faidherbia albida* rates as excellent fodder in terms of NE, DCP and NC in all its parts except perhaps for pod pulp. This can be seen by comparing the values for these parameters in Table 12 with those for *F. albida* in Table 10. However, it is more relevant to compare the value of *F. albida* fodder with that of the grasses available in the same area in the dry season, since this is the time when foliage of woody species is most sought for livestock. Baumer (1983) gives the NE of the leaves and pods of *F. albida* as 6.2-6.9 MJ kg$^{-1}$ and 5.5-6.2 MJ kg$^{-1}$

**Table 12.** Fodder quality in terms of energy and protein content. (Table derived from CTFT (1989)).

| Fodder quality | NE (*MJ kg$^{-1}$ DW*) | DCP (*g kg$^{-1}$ DW*) | NC (*g DCP FU$^{-1}$ kg$^{-1}$ DW*) |
|---|---|---|---|
| Poor | NE < 3.1 | DCP < 25 | NC < 55 |
| Moderate | 3.1 < NE < 3.45 | 25 < DCP < 34 | 55 < NC < 68 |
| Good | 3.45 < NE < 4.15 | 34 < DCP < 53 | 68 < NC < 88 |
| Excellent | NE > 4.15 | DCP > 53 | NC > 88 |

NE - net energy, DCP - digestible crude protein, NC - nutritional coefficient, DW - dry weight, FU - forage unit

**Table 13.** Macro-element daily requirements of cattle and the corresponding forage content. (Table from CTFT 1989 (after Boudet 1972)).

| Macro-element | Animal requirements (*g 100kg$^{-1}$ live weight*) | Fodder content (*dry weight*) | Fodder content of *Faidherbia albida* (*% dry weight*) | | |
|---|---|---|---|---|---|
| | | | Leaves | Pods | Pod pulp |
| Na | 0.5 | 0.08 | - | - | 0.004 |
| Ca | 5.0 | 0.2 | 1.30 | 1.0 | 0.500 |
| P | 3.0 | 0.12 | 0.16 | 0.17 | 0.050 |
| Mg | 5.0 | 0.2 | 0.26 | 0.15 | 0.100 |
| K | 10.0 | 0.4 | 1.20 | 1.3 | 1.1 |
| K:N ratio | - | 4 to 6 | - | - | 275.0 |
| Ca:P ratio | - | 1.0 to 1.7 | 10.0 | 6.0 | 1.0 |
| Ca:Mg ratio | - | 3 to 4 | 4.3 | 2.6 | 5.0 |

respectively. The NE of dry grasses (2.8 MJ kg$^{-1}$) is less than half those values. The protein content of the leaves of *F. albida* ranges from 15 to 20% and the pods (plus seeds) 10 to 15% whereas the dry grasses are about 3.1%.

The daily macro-element requirement of cattle are compared with the fodder composition of *Faidherbia albida* in Table 13. The macro-elements in the fodder (except for the fruit pulp) of *F. albida* are, in general, adequate in calcium, potassium and phosphorus. There does, however, appear to be a deficiency of sodium in the fruit pulp, as well as a very high potassium:sodium ratio, although this is general for tropical fodder plants, woody or herbaceous (CTFT 1989). The Ca:P ratio is likewise very high in all parts of the plant, and so is the Ca:Mg ratio in the leaves and the fruit pulp but this is not thought to pose a problem in nutrition.

Trace elements are equally necessary for animal nutrition; both an excess and a deficiency can cause problems. The values for fruit pulp of *Faidherbia albida* are compared with animal requirements in Table 14. These analyses indicate a deficiency of copper and zinc, like most of the dry grasses. Millet straw generally contains sufficient zinc, and groundnut straw has enough copper to enable these deficiencies to be remedied. On the other hand, the deficiency in manganese in the pod pulp could result in a drop in milk production and a reduction in fertility. Some herbaceous supplement must therefore be offered to supply additional manganese. An estimate of trace elements in *F. albida* leaves and seeds is not currently available from the literature but, if the superiority of macro-elements in leaves and pods plus seeds over the pod pulp is any indication, the deficiencies in micro-elements copper, zinc and manganese may well be made good by inclusion of these parts

**Table 14.** Estimates of trace element ruminant requirements compared with contents of the pulp from pods *Faidherbia albida*. Table from CTFT 1989 (after Boudet (1972)).

| Trace element | Quantity required from forage (*mg kg*$^{-1}$ *DW*) | Content of pulp of pods of *F. albida* (*mg kg*$^{-1}$ *DW*) |
|---|---|---|
| Cu | 10 | 3 |
| Co | 0.10 | 0.16 |
| Mn | 40 | 13 |
| Zn | 50 | 10 |
| Fe | 8 | 194 |

of the tree in the diet. The excess of iron does not normally present a problem except under conditions that restrict excretion thus causing overload, a condition referred to as hemochromatosis (V. Mlambo pers. comm.)

The daily needs of carotene per tropical livestock unit, equivalent to an animal of about 250 kg, have been estimated as 100 mg, containing 45,000 IU of vitamin A. The content of carotene in dry grasses in the Sahelian zone in the dry season is nil, and even if the animals can store vitamin A in their fat in the wet season, they still need a supply in the dry season. There are few records of the exact levels of carotene in woody fodder, but some studies carried out by Granier (1977), cited by Le Houérou (1980a), in Niger on exclusively herbaceous pasture are of interest. A herd kept in these conditions developed such severe deficiencies of vitamin A that blindness resulted and they could not survive on the diet, whereas a neighbouring herd that was given mixed herbaceous and woody forage did not develop the symptoms.

In summary, the forage of *Faidherbia albida* is of very high quality and, especially in the dry season, provides a necessary and adequate supplement to the herbaceous fodder of digestible protein, phosphorus and carotene. Straw of groundnuts and of grasses, especially millet, may be necessary to supply the animal needs of the trace elements zinc, copper and manganese in the dry season.

*Digestibility*

Unlike a grain such as maize, the protein in woody forage is not totally digestible. The reduced digestibility has been linked to two complementary factors (Cissé and Koné 1992). The first is the inhibiting effect of tannins on protein breakdown in the rumen and *in vitro*. The pods of *Faidherbia albida* contain 36.5% phenolic substances and 0.27 (absorbance units @ 550 nm g$^{-1}$ NDF) of insoluble proanthocyanidins (condensed tannins). Tannins have been thought to affect digestive enzymes negatively and to have a prejudicial effect on ingestion and, as a result, on animal growth. The second factor is inter-specific variation of protein distribution between the cellular contents and the paries (cell wall). The non-digestible proteins are to a large extent linked to the acid detergent fibre (ADF) because of the high lignin content.

The extent to which the proteins are degraded in the rumen varies both with the type of food and the animal (Cissé and Koné 1992). In sheep, the *Faidherbia albida* pod proteins are more soluble and less degradable than those of the leaves. In goats, however, the intra-ruminal breakdown of leaf proteins was higher than that of pods. The digestibilities for leaves and pods have been found to be:-

- leaves – dry matter digestibility = 14 to 53%; total protein digestibility = 67 to 72%
- whole pods – dry matter digestibility = 50 to 57%; total protein digestibility = up to 73%

It has more recently been appreciated that the theory that tannins negatively affect animal growth is just one side of the coin. Tannins could protect proteins in the rumen and result in higher nitrogen utilization (T. Smith pers. comm.)

Digestibility is also affected by the hard coat of the *Faidherbia albida* seed which can prevent the animal's access to its nutrient-rich contents in its passage through the gut. If the seed coat is unbroken, only the pod pulp is digested and the seeds are ejected in the faeces. When whole pods are fed to steers, 66% of the seeds are said to pass through the animal's rumen intact (Wickens 1969). It is likely that this proportion varies with the species of ruminant. Sheep are reputed to grind the seeds with their teeth and far fewer seeds are likely to pass through them undigested. The nutritional value of the pods would be increased for goats and cattle if they were milled to crush the seed which would make the nutrients within them more available. Complete milling of the seed may not be necessary. It would probably be sufficient (and less costly) merely to crack the seeds which can then absorb water rapidly and become digestible.

**Table 15.** Forage preference for *Faidherbia albida*, *Acacia senegal* and five grass species in Darfur Province, Sudan (Table after Bourreil (1968)).

| | Sheep | Goat | Cow | Donkey | Horse | Camel |
|---|---|---|---|---|---|---|
| *Acacia senegal* leaves | 0 | 1 | 0 | 0 | 0 | 4 |
| *Acacia senegal* pods | 3 | 3 | 1 | 0 | 0 | 4 |
| *Faidherbia albida* leaves | 0 | 2 (3) | 0 | 0 | 0 | 5 |
| *Faidherbia albida* pods | 2 | 4 | 5 | 0 (1) | 0 | 5 |
| *Aristida adscensionis* | 1 (2) | 0 | 2 (3) | 2 (3) | 1 (3) | 4 |
| *Aristida funiculata* | 1 (2) | 0 (1) | 2 (3) | 2 (3) | 1 (2) | 3 (4) |
| *Aristida pallida* | 0 (1) | 0 (1) | 0 (1) | 0 (1) | 0 (1) | 1 (3) |
| *Cenchrus ciliaris* | 3 (4) | 3 | 5 | 4 (5) | 5 | 4 (5) |
| *Eragrostis aspera* | 2 | 1 | 2 (3) | 2 (3) | 2(3) | 1 (2) |

Range of coefficients – 5 = very browsed to 0 = not browsed at all. Figure in brackets indicates that the animal consumes more when there is restricted choice

[**Bibliography**:- 1, 57, 85, 124, 134, 141, 149, 173, 183, 187, 205, 215, 233, 236, 337, 239, 247, 271, 275, 276, 291, 306, 318, 319, 331, 337, 340, 341, 364, 406, 436, 454, 457, 483, 484, 501, 502, 515, 542, 546, 557, 559, 568, 596, 660, 676, 677, 678, 713, 725, 730, 733, 734, 741, 744]

## Consumption and effect on livestock production

### *Palatability*

The leaves, flowers and pods of *Faidherbia albida* are attractive to domestic animals, including camels, cattle, goats and sheep. Horses have rarely been recorded as eating *F. albida* forage (Baumer 1983) although Palgrave (1977) states that it is a valuable fodder for these animals. The amount of woody forage that an animal consumes is extremely variable and is dependent on the type of husbandry, the type of animal and available plant cover. A study was undertaken of the preferences of different domestic herbivores for a range of fodder species in the pastoral areas of Darfur province in Sudan in an area that was dominated by the grass genus *Aristida*. Camels were most partial to leaves and pods of *F. albida*, cows and sheep consumed pods but not leaves, goats ate pods and leaves. Horses were not recorded as eating either the leaves or the pods of *F. albida* and donkeys only ate pods when other forage was not available (Table 15) (Bourreil 1968).

### *Consumption*

Le Houérou (1980a) has shown that the protein needs of animals can be met from herbaceous sources during the rainy season and at the start of the dry season. During the dry season, however, the herbaceous fodder contains only 1–3% of crude protein and no digestible protein so that the protein needs must be met from woody sources. The following conclusions have been drawn in CTFT (1989).

- If it is accepted that the daily protein needs are 1 g $kg^{-1}$ live weight for maintenance, survival and growth, 275 x 250 g = 68.7 kg of crude protein are required for an animal weighing 250 kg (a conventional tropical livestock unit (TLU)) during the 275 days of the dry season in west Africa). The average crude protein content for all the woody forage species of west Africa is 125 g $kg^{-1}$ dry matter (for *Faidherbia albida* this figure is 170 g for the leaves and 120 g for the pods). One TLU would thus consume 250/125 = 2 kg of tree forage per day. Assuming that an animal consumes daily 2.5 kg of dry matter per 100 kg body weight (see above), this constitutes 2/(250/100 x 2.5) = 32% of the daily fodder requirements, assuming that the remainder of the intake includes digestible proteins, which is by no means always the case. Each TLU must therefore consume, during the course of the dry season, 2 x 275 = 550 kg of woody forage for each 1168 kg of herbaceous fodder. These figures have been confirmed experimentally by Blancou *et al.*, (1978) cited by Le Houérou (1980a) in Senegal for fistulated cattle. The studies indicated that the average consumption of woody forage was 25% of total intake during the dry season, ranging from 5% to 45%. These figures match well with the value of 32% derived above, bearing in mind that herbaceous fodder is not totally deficient in nitrogenous material.

*Production*

Using the same data, the number of TLU per hectare that could be supported using only the pods of *Faidherbia albida* during the dry season have been estimated (CTFT 1989) as follows.

- Assuming an average stocking of 20 stems per hectare, with each tree producing an average of 20 kg (dry weight) of pods per year plus the same amount of leaves, and taking the value of 1 g $kg^{-1}$ live weight as the protein requirement, one UBT would consume 400 kg of leaves or 570 kg of pods (dry) per dry season. Therefore 1.7 TLU could be supported, or two adult animals if crop residues are also eaten. In reality, leaves and pods of *F. albida* are not available throughout the entire nine months of dry season, nor will livestock accept solely woody forage, nor eat all that is made available to them. In practice in the dry season plant residues make up the bulk of the intake, and woody forage provides the nitrogenous supplement. Moreover, optimal exploitation of the trees cannot be guaranteed and therefore 20 trees of *F. albida* could probably only support a single TLU per hectare.

This estimate is in close agreement with Anon. (1982a) who stated that fields cleared for cultivation in summer and a pasture with *Faidherbia albida* can support 1.3 beef cattle $ha^{-1}$.

Giffard (1974b) records that the needs of a working ox have been estimated at 1500 FU and *Faidherbia albida* as having the potential to nourish 1.3 animals $ha^{-1}$ without affecting farm production. A daily ration of 7 kg of pods to a cow of 250 kg is sufficient to obtain a daily gain of 0.7 kg of live weight or to supplement daily production of 5 l of milk.

[**Bibliography**:- 24, 57, 58, 86, 91, 124, 146, 149, 153, 161, 191, 208, 210, 247, 276, 297, 318, 336, 337, 340, 434, 457, 502, 521, 542, 547, 559, 652, 729, 734]

# ESTABLISHMENT, MANAGEMENT AND YIELD

## Direct seeding

Direct seeding of *Faidherbia albida* can be successful provided the conditions are right, otherwise it is risky and likely to fail (Anon. 1982a). Montagne (1984) reported 70% germination from direct seeding but low survival after five months due to competing vegetation and drought. Samba (1992) conducted a trial to compare direct seeding with out-planting potted seedlings in the Sahelian zone of Senegal where there was an annual rainfall of 400 to 500 mm. Germination and survival after three months was high in both treatments, but after six months, 13% of potted seedlings had died whereas there was no mortality in the direct seeded seedlings. Seedlings from direct seeding also showed significantly higher growth in all parameters measured compared to the potted seedlings. This favourable result however was dependent upon keeping the soil moist to over 50 cm depth and keeping the seedlings well weeded. Cazet (1987a) also found advantages in direct seeding in the Sahelian zone in Senegal. Although it was not recommended as general practice, direct sowing, when carried out with certain precautions, provided much better results than planting in balls of earth. The plants were more resistant to drought and their vegetative development, at least in the juvenile stage, was superior; the dry weight of the stem at six months was increased 17-fold over nursery-raised plants while that of the roots was 24 times as great. Beckman (1992), in Niger where the mean annual rainfall was 172 mm, reports that the best survival after direct seeding *F. albida* into a field was 26% which was achieved through nicking the seed with nail clippers and sowing at 15 mm depth in the soil; much poorer results were obtained with sowing at 10 mm.

It appears, therefore, that proper seed scarification, appropriate soil preparation, sufficient soil moisture, the right sowing depth and the absence of grass competition are all crucial for success in direct seeding *Faidherbia albida*. What this means in practice is that throwing handfuls of seed about is not likely to be a successful way of establishing trees unless conditions precisely resemble those rare situations where cohorts are established under natural conditions. In fact the conditions required for successful direct seeding are exactly those required for the successful establishment of potted seedlings, *viz.* carefully scarified seed, tilled soil, moist soil down to permanent water, sowing depth of about 15 mm, and removal of grass competition. Nevertheless, it appears from some of the research cited above that, given these conditions, a direct seeded seedling might have at least an initial advantage in survival and growth rate over a seedling raised in the nursery. However, the costs of maintaining the correct environmental conditions in the field rather than in the nursery in the early stages are probably unacceptably high and not crucial to successful establishment.

[See under reproductive biology above for natural regeneration]

[**Bibliography**:- 24, 61, 117, 148, 457, 461, 605, 651]

## Raising seedlings

*Faidherbia albida* seed requires pre-treatment to stimulate rapid and uniform germination unless the seed is fresh or has passed through animals (Baumer 1983). Adeola and Dada (1985) tested five pre-treatments. These were:-

- manual scarification and soaking for 24 hours
- covering with boiling water which then cooled for 24 hours
- placing in 96% sulphuric acid for 10 minutes then soaking in water for 24 hours
- placing in 96% sulphuric acid for 20 minutes then soaking in water for 24 hours
- soaking for 24 hours in water (control).

The first and third treatments were the most successful and gave 99% germination after four days. These findings have been more or less confirmed in other studies. For example, Baumer (1983) recommends that seed should be soaked in 66° Baume sulphuric acid for four minutes, then washed and dried, or soaked in water just come off the boil for five minutes then left to soak for 24 hours. Bebawi and Mohamed (1985) suggest that the seed should be manually scarified and then soaked in tap water for 32 minutes although they warn that boiling water is detrimental and kills most of the seed. Diallo *et al.* (1996) tested ten methods and found that sulfuric acid, manual scarification and scarification by hot wire were best. Halliday and Nakao (1984) recommend mechanical scarification or immersion in concentrated sulphuric acid for 10 minutes. Sniezko and Gwaze (1987) found that treating seed with concentrated sulphuric acid for 40 minutes and then washing and manually nicking gave highest germination rates. Bebawi and Mohamed (1985) found that manual scarification and then soaking in tap water for only 32 minutes gave the

best overall germination (85%). Boiling water was particularly detrimental with only 3% average germination response over all boiling treatments. On balance, the most successful and safest procedure is clearly scarification, or nicking, of the individual seeds followed by soaking in water. Diallo *et al.* (1996) suggest that nicking individual seeds could be too labour intensive and that a seed gun method could be developed to treat a large quantity of seed quickly.

However, Barnes *et al.* (1996) came to the conclusion that, for the international provenance trials of *Faidherbia albida*, despite the very large numbers of seedlings that had to be raised (about 30,000 per year), it was practicable to nick every seed, allow it to imbibe water, pre-germinate in a controlled temperature cabinet and sow each seed separately in a dibbled hole in the nursery container once the radicle had appeared (Figures 98 to 101). The procedure adopted was as follows:-

- the seeds were first washed to remove any residual fungicide/insecticide, then placed on racks to air dry for about 10 to 15 minutes;
- after drying, the seed was nicked, using nail cutters, at the micropylar end taking great care not to damage the embryo; there would be less risk of damage to the embryo if the seed were to be nicked at the end opposite the micropyle but it was found that, if this was done, the testa tended to be retained over the cotyledons after emergence and this led to contortion and fungal infection of the cotyledons; during nicking, it was easy to tell whether a seed was sound or not by the colour and feel of the endosperm - if the latter was white and firm it almost invariably germinated; if it was discoloured and spongy it would not;
- the seeds were then soaked in water for 3 to 12 hours. The precise amount of time depended on the rate of water imbibition; the faster the rate of imbibition, the shorter the soaking time needed to be;
- once the seeds were fully imbibed, they were placed in a petri-dish on moist filter-paper and placed in a germination cabinet set to run at 25°C during the night and 30°C during the day; time to emergence of the radicle varied from 48 to 72 hours;
- when the radicles emerged, the seeds were transferred, using tweezers, direct into a pre-dibbled hole in the nursery container, radicle downwards, and then covered with very fine sand
- the hypocotyl emerged above ground in three days from sowing in the container;
- using this method of pre-germination, it was possible to achieve close to 100 % success.

The use of this procedure comes as close as possible to ensuring that a robust seedling is established in every container within the first four or five days from sowing. The seed can be sown soaked or sown direct into dibbled holes before germination. The latter is less labour-intensive but it will not be possible to screen out non-viable seeds that imbibe water but fail to germinate, as, for example, those where the embryo has been damaged by bruchids.

A study was made in the nursery of the effect of seed weight on early growth characteristics of *Faidherbia albida* among other species (Oboho and Ali 1985). Germination time did not vary with seed weight but seedling height at time of appearance of leaflets was positively correlated with seed size. The number of leaflets, biomass production and growth rate was also positively correlated with seed size. Seedlings from the low weight class had the highest root/shoot ratios.

Black polythene tubes are used for sowing *Faidherbia albida*; tubes are preferable to bags because the latter can cause root spiraling. A 10 x 20 cm (flat width x depth) tube has been used for the international provenance trials (Barnes *et al.* 1996). The soil mix was 1 part black clay, 2 parts river sand, 2 parts of well rotted powdered cow dung and 10 parts of a light sandy-clay loam. The latter was collected from acacia woodland to ensure the inclusion of rhizobia. Other workers have recommended similar mixes (*e.g.* Bahugunu *et al.* 1987) and excess clay has been said to hinder development (Montagne 1984). The mix was heaped, covered with polythene sheeting and sterilized with methyl bromide to kill weed seeds. This treatment did not seem to kill the rhizobia because copious nodules subsequently developed on the seedling roots during the period in the nursery. It was found that, on mild compaction during pot-filling, this mix remained permeable and supported good growth of the seedling without addition of any fertilizer. In India, best results were obtained with polythene bags filled with a 1:1 soil/sand/ farmyard manure mixture (Bahuguna *et al.* 1987).

Inoculation with rhizobia has been found by some workers to increase seedling growth (*e.g.* Bahry 1988; Montagne 1984) but it is likely that inoculation with soil collected from beneath local acacias and application of nitrogen in the form of manure to the soil mix is sufficient to ensure good seedling growth in the nursery (Mburueu 1994). Nodules start to develop naturally in about 21 days from sowing.

The taproot of *Faidherbia albida* can grow extremely fast and can emerge through the bottom of the container in 18 days from sowing (Louppe and N'klo Ouattara 1992). Root pruning should therefore start soon after this and be done every two or three weeks throughout the nursery period; A tap root has been recorded as growing to 7 m long in a seedling which was nine months old and only 6 cm high (Baumer 1983). Manual root pruning has been compared with air pruning (Louppe and N'klo Quattara 1992). Air-pruned seedlings proved as successful in development after planting out as manually pruned seedlings. They also developed 50% more secondary roots and 28% more nodules than manually pruned seedlings and suffered less transplant shock. All treatments developed effective taproots after planting in the field.

A large enough seedling for planting out can be produced in three to four months (Baumer 1983; Montagne 1984) when, depending on the provenance, the height can be between 16 and 24 cm (Gwaze *et al.* 1988). Watering should be once or twice a day during the period of rapid growth but should be reduced at the end of the nursery period to check growth and harden the seedling off. Bebawi and Mohamed (1982) found that maximum germination and root and shoot yields were obtained with daily irrigation. The containers should be weeded regularly and the soil surface turned to increase water penetration (Montagne 1984).

[**Bibliography**:- 4, 24, 42, 43, 50, 57, 59, 60, 61, 117, 118, 120, 148, 149, 188, 197, 215, 233, 269, 275, 285, 304, 305, 311, 324, 325, 331, 338, 381, 393, 420, 447, 457, 461, 506, 594, 605, 607, 635, 640, 643, 648, 651, 666, 709, 719, 720, 725]

## Vegetative propagation

Although *Faidherbia albida* suckers readily from damaged roots (Fagg 1995), success in striking cuttings (macropropagation) from material of any age has been variable. For example, Gosseye (1980) recorded strike rates of 63% for *F. albida*) with root cuttings but 0% with stem cuttings.

Studies on propagation of *Faidherbia albida* by shoot and root cuttings have been carried out in Burkina Faso (Nikiema and Tolcamp 1992) (Figure 103). The optimal period to collect cuttings was during rains (June to September) when the trees are most likely to be leafless. Rooting of branch cuttings took 2-3 months to root; cuttings from young plants rooted more readily. Basal treatment of 1% indole butyric acid gave better rooting than other hormone treatments. Overall rooting rates were low (38%), due, in part, to unresolved problems with temperature and fungus attacks.

Experiments have also been carried out in India (Parvez 1987) using 20-cm branch cuttings (diameter 0.5-1.5 cm) taken in the last week of February. Sprouting was observed in nearly all cuttings within four weeks but successful rooting occurred in only 65% of cuttings. The best medium was found to be a mixture of sandy loam plus farmyard manure and the thicker cuttings (1.0 to 1.3 cm) gave the best results.

Air-layering has been found to be very much more successful for propagating *Faidherbia albida* in India than cuttings (Syed *et al.* 1995). Best results were obtained with air-layering in the summer when all branch cuttings failed to root. IBA increased rooting of the air layers at all concentrations but 2500 or 5000 ppm were best. Ground layering was also successful and was best improved with IBA 1000 ppm.

Main shoot, axillary shoot of coppice and root cuttings were compared in a study in Burkina Faso (Yameogo undated). After two months, all of the axillary cuttings had died. Best results were obtained with main shoot cuttings treated with IBA which had 70% survival. Root cuttings also gave good results, with 51.7% survival.

In another study in Burkina Faso, the success of rooting cuttings from young and old material of *Faidherbia albida in vitro* was compared (Bongkoungou *et al.* 1988). Cuttings from young shoots produced their maximum root growth within five weeks with indolbutyric acid (IBA) while the older material took more than 10 weeks due to slower rooting and no effect of hormone additions. IAA produced longer roots while IBA produced denser rooting. The best time for root growth for young stock is outside November-December and for old stock outside September-January.

It is possible to raise *Faidherbia albida* with more consistent success using micropropagation (Davies 1984, and Duhoux and Davies 1985 in CTFT 1989). "The technique used was to take the cotyledons with about 5 mm of root and 2 mm of stem, from young plants aged 20 to 25 days with 4 or 5 leaves. The explant is put into a tube containing a medium of appropriate composition, buds in the cotyledons develop, multiply, and each one gives rise to a small branchlet with leaves similar to those of plants raised from seed. In some tubes it is possible to count up to six newly-formed branchlets. These secondary explants consisting of segments of 10 to 12 mm with one bud and one leaf are separated from the branchlets and planted out into a rooting medium. The microcuttings which have been rooted *in vitro* are then removed and transplanted into a greenhouse before being taken out into the natural environment." Micropropagation is more successful when material is taken from young plants than when it is taken from mature trees. However, trials using vegetative material from sprouts and, particularly suckers from mature trees (Gassama and Duhoux 1986)) showed that it is possible to regenerate whole plants using the same technique.

There has also been some success in what has been called chain micrografting (Detrez *et al.* 1992). In this technique, the meristems from vegetative buds (apical or axillary) were collected from branches of a 50-year-old tree and 1-2 month old seedlings of *Faidherbia albida*. These were grafted *in vitro* on two-day-old seedlings. Grafts began elongating after 10 days in culture, and these shoots were used for second and third generation micrografting cycles. These micrografted seedlings developed well after acclimatization, and enabled the rapid multiplication of selected individuals on root stock derived from seed.

In more recent work, Ruredzo and Hanson (1993) describe the *in vitro* culture of *Faidherbia albida* shoot tips taken from seedlings and the successful rapid multiplication and transfer of the rooted cultures to the soil.

The most vigorous growth and rooting was achieved on Murashige and Skoog-based medium supplemented with $10^{-7}$M α-naphthaleneacetic acid (NAA) only, where 87% of shoots formed roots. Seventy-one percent of the plantlets that were transferred to the soil established and nodulated with the native *Rhizobium*.

As it is so easy to raise seedlings of *Faidherbia albida,* vegetative propagation is likely, for the present at least, to be used mainly as a tool in the genetic improvement process rather than for raising operational planting stock. Long term topophytic effects in trees propagated vegetatively have not yet been mentioned in the literature. However, there seems to be little doubt that successful and practical procedures for vegetative propagation could be evolved and used to propagate genetically superior individuals once the traits of interest have been shown to be under genetic control.

[**Bibliography**:- 7, 8, 82, 103, 148, 149, 186, 204, 233, 263, 265, 285, 317, 352, 487, 526, 595, 608, 616, 658, 694, 746]

## Planting out

*Faidherbia albida* seedlings sown singly in 10 x 20 cm black polythene tubes (Barnes *et al.* 1996; Nimbkar *et al.* 1996) are about 25 cm tall after three months in the nursery and they are then ready for planting out (Figure 102). The seedlings ideally will have been root-pruned a number of times and the root mass will be well developed and will have bound the soil. Planting stations will have been planned before planting out in the field; this and spacing of the plants is discussed under the section on spacing below.

It is best to prepare and mark the planting spot for each tree before the planting operation, and also to prepare the planting hole, particularly on heavy soils (Anon. 1982a). Montagne (1984) however, says that no ground preparation is necessary. It is important that the pit is dug deeper than the polythene tube; if it is not, pressure of time on planting day can result in seedlings not being planted deep enough and subsequent wash will expose the roots and lead to failure of the plant. The soil should be worked to a minimum of 30 x 30 x 30 cm. The pit should be re-filled and, if there is a slope on the ground, a semi-circular mound created below the pit to direct run-off into it so as to build up moisture reserves in the planting hole before planting. If there is an indurated horizon in the soil, sub-soiling is advisable and this should be done a year ahead of planting to allow water to penetrate (Le Houérou 1980b). If the trees are to be planted into land that is being cultivated for an annual crop, the soil will have been ploughed and/or harrowed and will be weed free. If they are to be planted into land that is not being cultivated, it may be wise to harrow the ground before preparing the pits to ensure initial weed control. If harrowing is not possible, then an area at least one metre in diameter should be scalped clean round the planting hole when it is dug.

There is a great advantage to planting early in the season so that the seedlings have the maximum time to establish themselves before the dry season and so that they can get ahead of competition from weeds. However, before planting, re-charging of soil moisture following the previous dry season should be to a depth of at least 50 cm. Seedlings should be planted with the soil in the field at the original level of the soil in the container, *i.e.* at the seedling's root collar. It is better to plant the seedling too deep than too shallow. The polythene container should always be removed to allow for free root development. There have also been recommendations, however, to plant on mounds and just to cut the base off the container (Anon. 1982a). Provided the container is removed, the taproot will be re-formed and penetrate to depth as it does in a naturally established seedling (Louppe and Ouattara 1992).

Fertilizer applications appear to have little benefit (Nimbkar *et al.* 1996) but out-planting *Faidherbia albida* on fertile microsites would improve its growth and survival (Geiger *et al.* 1992).

Although plants that survive the first dry season will be established (Anon. 1982a; Montagne 1984) (Figure 104), above ground growth, particularly in the West African provenances, can be slow until the roots have reached the permanent ground water; this might take 3-4 years (Anon. 1982a). Weeding and protection from browsing animals is important during this period.

[**Bibliography**:- 5, 24, 50, 116, 157, 174, 228, 233, 268, 275, 313, 338, 351, 381, 393, 420, 425, 457, 461, 488, 490, 636, 650, 651, 697, 709]

## Spacing

The most commonly recommended plant spacing for *Faidherbia albida* parklands is 10 x 10 m, or 100 trees $ha^{-1}$ (Delwaulle 1977b; Anon.1982a; Montagne 1984; Harmand and Njiti 1992; Harmand *et al.* 1996). This appears to be the minimum required if mechanical or animal drawn cultivation equipment is to be used (Casey 1987). Closer spacing down to 4-5 m square has been recommended to achieve more rapid site capture (Anon. 1982a) but thinning to 10 x 10 m by year six will be necessary and this will mean taking out trees that have not yet produced pods. Wood yields, however, have been found to be higher at six years at closer spacing; for example wood yields at 4 x 4 m (22 $m^3$ $ha^{-1}$) were found to be double those at 6 x 6 m (10.3 $m^3$ $ha^{-1}$) (Lulandala 1989). In a similar experiment Okorio and Maghembe (1994) obtained similar results at six years with 24.9 $m^3$ $ha^{-1}$ produced at 4 x 4 m and 9.9 $m^3$ $ha^{-1}$ produced at 6 x 6 m; tree diameter but height was reduced at the 4 x 4 m spacing.

Final spacing in the parklands varies between 12 and 50 trees $ha^{-1}$ (Giffard 1974a; Delwaulle 1977; Raison 1988). A stocking of 50 trees $ha^{-1}$ is said to cover the soil but lower stockings are used to encourage pod production (Le Houérou 1980b). Density can also be varied with different crown management regimes. For example, the tree can be maintained in a bush form by regular lopping to improve integration into the agricultural system and higher stocking rates can be used (Raison 1988).

Spacing need not be systematic on a square or rectangular pattern. Trees can be planted along contours in the field to facilitate cultivation of the crops by ox-drawn or mechanical equipment (Casey 1987). It has also been suggested that the high fertility under *Faidherbia albida* trees might precede the establishment of the tree and that young trees should be planted in fertile micro-stations, pre-identified during the previous subsistence crop, rather than at the conventional 10 x 10 m spacing with the expectation of maximizing yields from the cash crops which would be grown beneath the trees (Vandenbeldt 1996).

Studies that have been conducted to evaluate the yield of agronomic crops in the immediate vicinity of *Faidherbia albida* should provide the information needed to determine the optimum spacing of *F. albida* from information on yield responses. For example, Jiru (1988) measure yield of wheat at four distances from the bole, 1.7, 6, 10, and 14 m. Overall, an increase in crop yield of 63% was found for a crop mixture under the tree Yield decreased as the distance from *F. albida* increased in ratio 100:88:77:71. What is not clear from this experiment is what happens to yields beyond the influence of the tree canopy. If the tree is mining nutrients from the surrounding area, a rise in yields should be seen beyond the influence of the trees roots. An extension of this type of experiment under trees planted at more extreme spacings could provide useful data for determining optimum spacings for *F. albida* parklands.

[**Bibliography**:- 24, 88, 113, 124, 157, 161, 173, 198, 247, 275, 297, 312, 313, 338, 363, 415, 418, 419, 421, 461, 471, 511, 559, 602, 630, 652, 680, 697, 725]

## Lopping and pruning

Lopping branches from the green crowns of *Faidherbia albida* at the end of the dry season is common practice in West and north-east Africa (CTFT 1989; Vandenbeldt 1990a; Cissé and Koné 1992). Browsing livestock soon produce a browse line on the trees and lopping becomes necessary if the animals are to derive any benefit from the green leaves. The practice is rarely seen in east and southern Africa, which is surprising given that, towards the end of the dry season, fresh fodder becomes increasingly scarce and the foliage of *F. albida* is the only green material available; and it has a high nutritional value.

The traditional practice of pollarding *Faidherbia albida* in the Dossi and Watinoma village farmlands in Burkina Faso was studied over a three-year period (Depommier and Guerin 1996). The Peul livestock farmers demonstrated considerable expertise with pollarding techniques. Practice varied from pollarding mature trees twice per season, which affects more than 50% of their canopy, to moderate pollarding of just a few trees. Total pollarding tests repeated over two years showed that the trees continued to produce vigorous shoots. The youngest trees remade their canopy in one year. The leaf biomass produced was well correlated with the ground-projected area of the canopy, but less so with the stem circumference. Yield of fodder ranged from 10 to 15 kg of dry matter for small trees, and from 20 to 40 kg of dry matter for large trees. But pollarding severely restricted fruit production; it was more influential in this than climatic fluctuations and insect attacks and it could limit pod production to just a few kilograms per tree, and sometimes there were no pods produced at all. Firewood, a valued by-product of pollarding, was assessed at around 100 kg $yr^{-1}$ of dry matter from totally pollarded adult trees, and about a third to a quarter of this amount for smaller trees. The conclusion was that *F. albida* has relatively poor production levels for leaves and pods but that the tree is still a fodder species of prime importance because of its reactions to heavy and repeated pollarding and because of the good quality of the dietary supplement it gives in the dry season.

In Burkina Faso, young uneven-aged *Faidherbia albida* trees are often heavily trimmed and pruned for fodder (Depommier 1998). In unpruned trees, leaf flush and fall occur regularly, synchronized with the wet and dry seasons; site and size of tree were not significant factors. In contrast, trees that were experimentally pruned exhibited disturbed phenophases. Pruning at the end of the dry season extended the period of leaf retention, or stimulated an additional foliage development cycle. This pruning treatment had negative effects on the frequency and abundance of flowering and on fruiting.

In West Africa, the practice is for the herdsmen to lop branches and leave them under the tree within reach of the livestock (CTFT 1989). The ideal is for:-

- only small branches to be cut (Baumer 1983)
- no more than 30% of the green crown to be removed (Montagne 1984)
- branches to be severed cleanly so that strips of bark are not torn from the stem below the cut (CTFT 1989)
- lopping to be carried out at the beginning rather than at the end of the dry season (CTFT 1989)
- lopping to be carried out to minimize damage to the potential pod crop (Giffard 1974a; (Depommier and Guerin 1996))
- lopping to be carried out so as to raise the canopy to improve conditions for crops being grown beneath the tree (Vandenbeldt 1990a)

- the tree to be lopped only every other, and preferably only every three or four years (CTFT 1989)
- lopping to be carefully controlled during drought years when high demand for fodder may result in permanent damage to the trees (Lulandala 1989)
- the branches to be cleared from under the tree after the animals have eaten the leaves, before they become a fire hazard or a hindrance to cultivation, and used for brush fencing and firewood (CTFT 1989).

Sustainable leaf fodder yield from mature trees managed in this way might amount to 300 kg $ha^{-1}$ (Fagg and Stewart 1994; Depommier and Guerin 1996). More intensive fodder harvests can lead to a heavy nutrient drain that could amount to an annual rate of 87 kg N, 42 kg K, 20 kg Ca, 8 kg Mg, and 5 kg P (Lulandala 1989).

[**Bibliography**:- 57, 74, 132, 133, 134, 149, 177, 181, 183, 205, 224, 236, 257, 258, 259, 275, 314, 323, 328, 338, 363, 403, 418, 419, 421, 422, 461, 540, 546, 547, 548, 559, 652, 692]

## Pod production

Pod production from *Faidherbia albida* trees varies enormously depending on the age, size and management of the tree, the soil, the climate and the meteorological conditions from the time of initiation of the flower buds to the maturation of the pods. For example, trees can live for over 100 years and pod production increases as their crowns expand but environmental conditions can limit maximum height to about 9 m (CTFT 1989) in the Jebel Marra in Sudan whereas in southern Africa trees can reach heights of 25 m (West 1950). The widely used management practice of lopping the crown for fodder can severely reduce pod production. Unseasonal frosts or dull weather during the flowering period, heavy rain and wind or hail when flowers or young pods are vulnerable can all prejudice pod production and it is likely that there will be a cyclic pattern to the size of the pod crop depending on the amount of resources the tree had to use to bring the cop to maturity in the previous year.

*Faidherbia albida* has been said to start fruiting between two and four years under exceptional circumstances (Baumer 1983), has been observed to start at eight years (Felker 1978) but more usually it starts at about 15 years (Baumer 1983). Pod production increases only gradually and is not regular and profuse until the tree reaches about 25 years (De Montgolfier-Kouévi and Le Houérou 1980). It is said that a single tree can produce 1000 kg of pods in a year in South Africa. However, the most commonly reported range of average production from a mature tree is 100 to 150 kg per year (Wickens 1969; Jung 1970; Charreau and Nicou 1971; Giffard 1974b; Grainger and Esbenshade 1978; Anon. 1982a; Baumer 1983; Anon. 1989) with yields in individual years varying from 40 to 300 kg per year (CABI 19??). This yield per tree is usually translated into a unit area production of about 2000 to 3000 kg $ha^{-1}$ on the assumption that there are about 20 mature trees per hectare (Giffard 1974b; Anon. 1982a) but higher yields up to 5400 kg $ha^{-1}$ have been cited (Marunda 1992). The lower yields that have been reported are usually explained by there having been some lopping of the trees. Lopping usually brings the annual yield down to less than 20% of that from unlopped trees (CABI 19??) or about 10 to 20 kg per tree (Baumer 1983; CTFT 1989). In some areas lopping is thought to have an adverse effect on village economy because of its effect on pod production (Montagne 1984; Louppe 1990).

[**Bibliography**:- 24, 26, 57, 103, 124, 134, 149, 175, 180, 183, 209, 210, 233, 236, 247, 276, 291, 372, 405, 412, 418, 422, 436, 457, 459, 463, 625, 725, 730]

## Rotation and growth rate

*Faidherbia albida* is invariably used for the production of fodder and for its amelioratory effects on the environment in agricultural systems in Africa. Therefore rotation age is determined by a decline in fodder production rather than by size or wood production. Environmental stress and damage caused by physical factors such as climate and soil as well as by human factors such as pruning and pollarding and by browsing animals are likely to affect the life span of the tree (Sterck *et al.* 1991). There is general consensus that the tree lives to a maximum age of about 80-100 years in favourable undisturbed conditions (Baumer 1983; Sturmheit 1989; Sterck *et al.* 1991).

In the southern Sudanian zone of Burkina Faso, a broad cross section of *Faidherbia albida* trees with circumferences between 50 and 250 cm were sampled with an increment borer to identify annual rings and to evaluate the age and growth rate of the trees (Depommier and Detienne 1996). The growth rate was influenced by site, lopping and pruning but the annual growth rate was estimated to be 7.2 to 10.9 mm in trees that were 10-30 years old. It was of interest that the best average annual growth rates were paradoxically recorded at the driest station. The authors put forward the hypothesis that the longer period of foliation at the dry site, because of the longer dry season, permits better tree growth. They also theorize that lopping at the end of the dry season, with consequent refoliation at the beginning of the rainy season, prolongs the foliation period and therefore perhaps does not prejudice wood production as much as one would expect. They conclude that trees have reached a diameter of 50 cm in 27 years and that, if the trees are well managed, more than 3 cm of annual diameter growth could be achieved and that substantial timber production can be added to the tree's other agronomic and pastoral advantages. These annual growth rates in breast height diameter are similar to those estimated for *F. albida* in Senegal, 1-3 cm (Mariaux 1966), in Kenya, 1.5-2.5 cm

(Rocheleau 1988) and in Zimbabwe, 1.4-4.0 cm (Gourlay 1995). Very much higher growth rates can be expected from individual trees when they are on a good site with no competition. For example the senior author has seen a 14-year-old tree of 15 m in height and 73 cm diameter at breast height in Namibia. (See Figures 105 and 106).

For more information see under Life history and Genetic variation above, Figures 23 to 31 and Figures 105 and 106.

[**Bibliography**:- 57, 182, 270, 289, 349, 361, 388, 418, 432, 457, 459, 416, 432, 472, 476, 511, 586, 648, 649, 652]

# THE FUTURE

The size and quality of the bibliography included in this publication is ample evidence on its own of the importance that has been attached to *Faidherbia albida* in its agroforestry role. It is one of the very few trees in Africa that has "sold" itself well enough on its inherent merits to have been used by subsistence farmers in rare agricultural systems that are designed to work the land sustainably on a continent where nomadic and slash and burn practices have been the rule. These systems are all the more impressive for having emerged from the indigenous communities themselves without influence from agriculturalists from developed countries. In fact, apart from population pressure, it has been western agricultural practices of clearing trees for crops and pastures, high inputs of fertilizer and the use of machinery that have led to the demise of the *F. albida* parklands in West Africa. High input costs are just not self-sustaining in the agricultural economies of rural communities in the semi-arid zones of Africa. The only long term solution to this problem is to use trees in the systems to maintain soil fertility and produce forage. *F. albida* has the potential to be intimately established in this role not only in the areas where it has been traditionally used but over a very much greater part of Africa than its natural distribution would suggest.

There is no doubt that it is *Faidherbia albida*'s unique reverse phenology that makes it so compatible and productive in agricultural systems. There are other acacias that have equivalent environmental benefits and produce as much nutritious fodder but, because they have normal phenology, they compete with the crops for sunlight and water and do not produce their forage at such critical times for domestic and wild anumals. It is for this reason that there is a temptation to push *F. albida* for use beyond the boundaries of its natural distribution into areas where other acacias might seem the obvious choice. To move a tree species out of its environment would normally be fraught with risks of failure. However, with *F. albida,* there are indications that it is not always climatic or edaphic factors that limit its natural occurrence but rather the competitive environment in the first few years of life. There is practical evidence of this in parts of Africa in the way it has voluntarily reached out of its riverine environment into land that is cultivated annually for crops where it is released from grass competition. It is possible therefore that *F. albida* does have the potential to be used in agricultural systems over a far greater part of the African savannas than might be expected.

This review of *Faidherbia albida* has drawn on all available published and unpublished information and it is unlikely that any major research results have been missed. It is possible and useful therefore to summarize the main topics that have been highlighted in the text as needing further research to add to the body of information on which recommendations can be based and agroforestry systems devised. These are listed below.

- When *F. albida* is established away from its riverine environment, what are its requirements in regard to ground water, will it flower and fruit normally and are there long term differences in this regard between the west and the east/southern African provenances? Range-wide provenance trials must cover a wide range of sites and be long term to make any advance in answering this important question.
- Is the increase in soil fertility under *F. albida* trees due to its utilizing otherwise inaccessible water and nutrients at depth and fixing nitrogen, is it due to livestock congregating under the tree and depositing manure, or is it due to the tree using its extensive root system to mine the topsoil in the open far beyond its canopy? These effects need to be quantified before management systems can be optimized.
- To what extent do the tannins in the pods of *F. albida* affect their nutritional benefits to livestock, are there universal or local tannin-binding chemicals or alkaline substances that can be added to the pods to increase nitrogen retention and, if the pods are used as a supplement, should they be milled and what proportion of various diets should they constitute? Many more empirical and basic studies are required to understand how the foliage and pods can be used to gain the maximum nutritional advantage.
- What effects do *F. albida* pods and foliage have on weight gain, milk production, conception rates and mortality of livestock compared with traditional feeds? These effects need to be quantified.
- To what extent is pod production under genetic control and what is the potential to increase this by selection? This needs to be studied in long-term progeny tests designed to partition the environmental and genetic effects and the influence of the previous years' pod production on that of the current year.

This is a short list of what the authors see as the most important research topics that need to be addressed for *Faidherbia albida*, a tree that arguably has a greater potential than any other to increase the productivity of both arable and non-arable land in the semi-arid and dry savannas of Africa.

# FIGURES

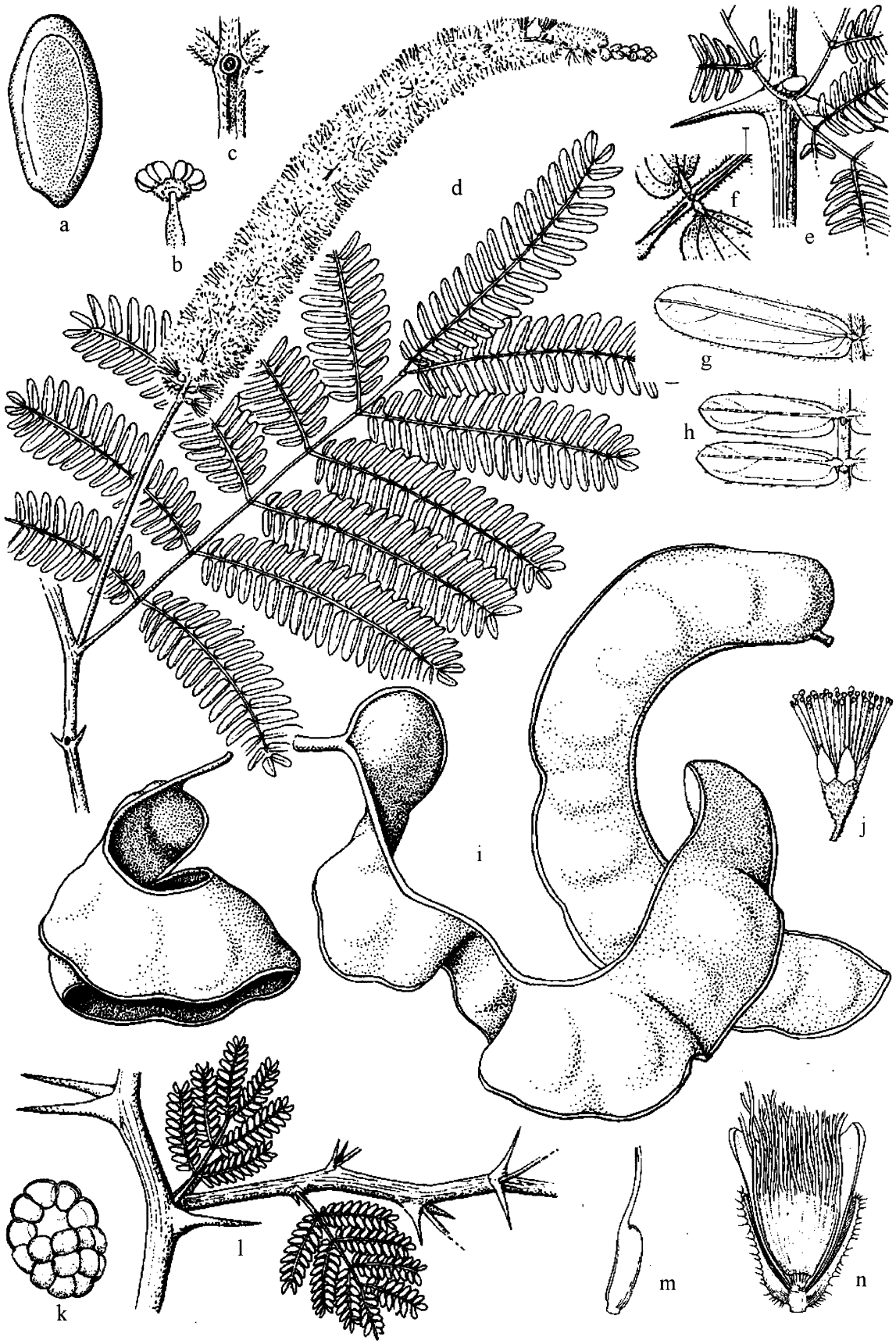
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**Figure 1**. ← Botanical drawing of *Faidherbia albida*. a – seed (x4); b – anther (x25); c – inter-pinnae gland (x3); d – branchlet with flower and leaf (x1); e – spines and leaf base (x1); f – inter-rachillae gland (x10); g – leaflet Race B (x6); h – leaflet Race A (x6); i – pods (x1); j – flower (x5); k – pollen polyad (x35); l – branchlet with spines and leaves (x1); m – ovary (x20); n – longitudinal section of flower showing anthers connate at base (x7). Drawings by Rosemary Wise except for b, f and n (Francis in Wickens (1969)), k (Zinderen, Bakker and Coetzee in Wickens (1969)), and f (Wickens 1969), all drawn by Mary Grierson.

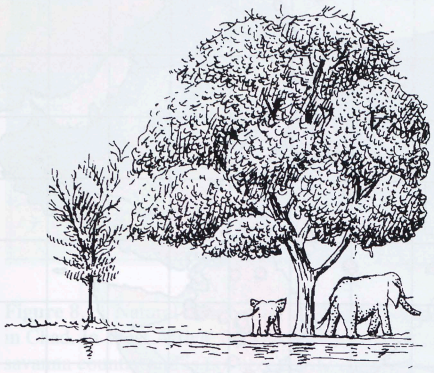


**Figure 2**. ↑ Habits of young and old *Faidherbia albida* trees. The crowns of young trees are fastigiate, the shape of an inverted vase, and they become hemispherical with age.

**Figure 3**. ↑ Bark slash colour of *Faidherbia albida*. The underbark is a deep orange-red.

**Figure 4**. ↑ Bark of *Faidherbia albida*. On a mature tree, the bark is fissured and scaly. The pale colour of the bark and twigs give the species its name.

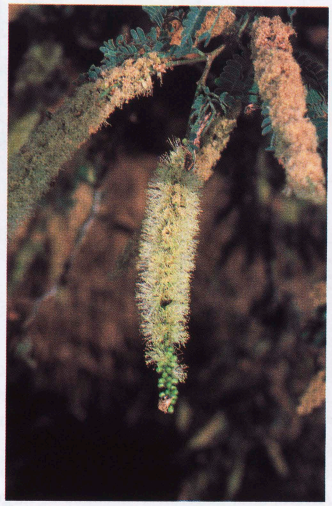


**Figure 5**. ↑ Inflorescence of *Faidherbia albida*. The flowers are spicate and pale cream tinged green and attract many insects.

**Figure 6**. ↑ Ripe pod of *Faidherbia albida*. The coiled indehiscent pods vary greatly in size and colour from pale yellow through orange to deep red.

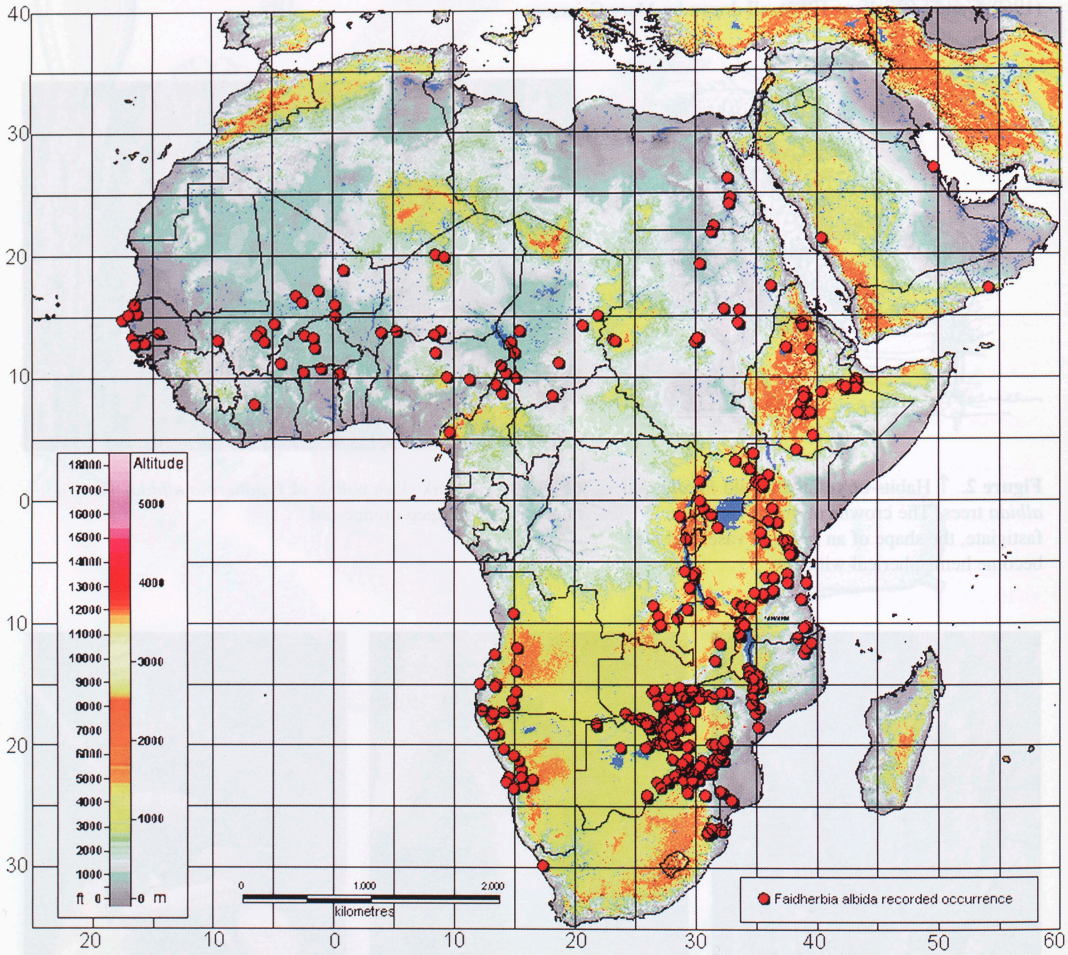



**Figure 7**. ↑ Natural distribution of *Faidherbia albida*. The species is widespread in tropical and sub-tropical Africa from Senegal and Gambia in the west to Egypt in the northeast and southwards to kwaZulu in South Africa. It extends into the Middle East and has been recorded from Arabia, Yemen, Israel, Palestine, Oman and Syria. It does not occur south of about 27°30', north of the Sahara Desert or in the Guineo-Congolian equatorial region. Factors that limit the species' distribution are frost in the southern tip of Africa, extreme aridity in the Sahara, luxuriance of competing vegetation in the Congo basin and the coastal region of equatorial West Africa, and, generally, absence of large rivers and groundwater elsewhere. The distribution in this map is based on verified herbarium specimens for which latitude and longitude are also available. The density of dots on the map does not necessarily indicate more common occurrence; this is caused by there being more herbarium specimens for some regions than for others. For example, in Zimbabwe, more botanical collections have been made than elsewhere.

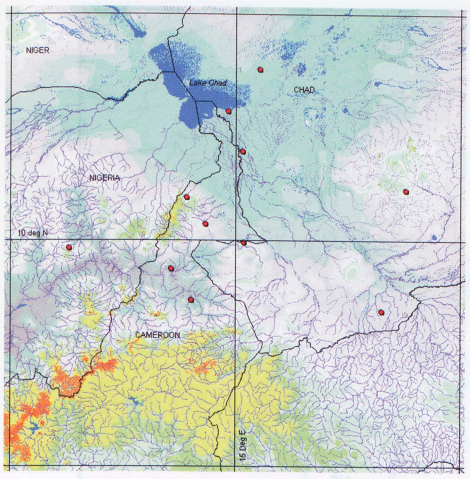



**Figure 8**. ↑ Natural distribution of *Faidherbia albida* in Chad. In West Africa, the species occurs in lowland savanna country and is not necessarily confined to alluvial soils along the rivers. It is thought that man and his livestock have provided an environment in which the species has been able to establish itself and then adapt to the savannas.

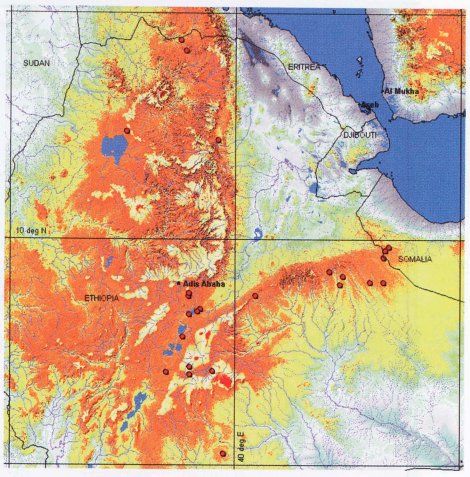



**Figure 9**. ↑ Natural distribution of *Faidherbia albida* in Ethiopia. In northeast Africa, the species is associated with human cultivation up to 2000 metres above sea round lake basins. It occurs naturally between the high and low water marks where its reverse phenology enables it to withstand periodic flooding.

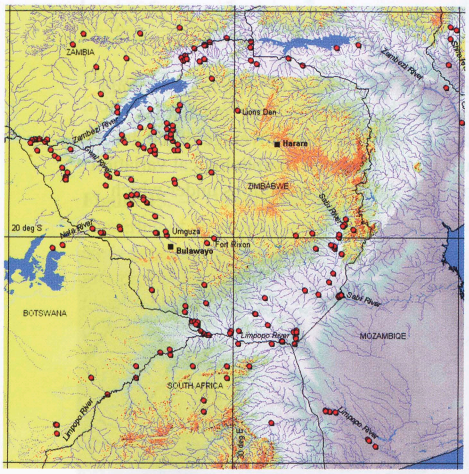



**Figure 10**. ↑ Natural distribution of *Faidherbia albida* in Zimbabwe. In southern Africa, the species is mainly confined to the large rivers over a range of altitudes from sea level to 1500 metres but there are numerous anomalous natural and man-facilitated occurrences on a wide range of soil types where there is freedom from early competition and permanent groundwater occurs, even if it is at great depth.

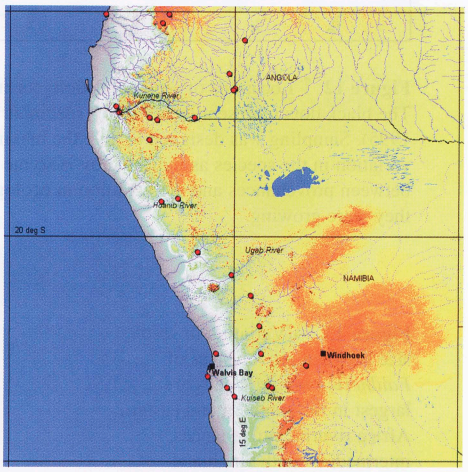



**Figure 11**. ↑ Natural distribution of *Faidherbia albida* in Namibia. In southwest Africa, the species is strictly confined to the larger rivers that run through the very arid Namib desert. Periodic floods that originate from rain that falls far inland provide new alluvium for germination and establishment of seedlings, and permanent groundwater beneath the river beds maintains the mature trees throughout the year where rainfall can be less than 50 mm per year.

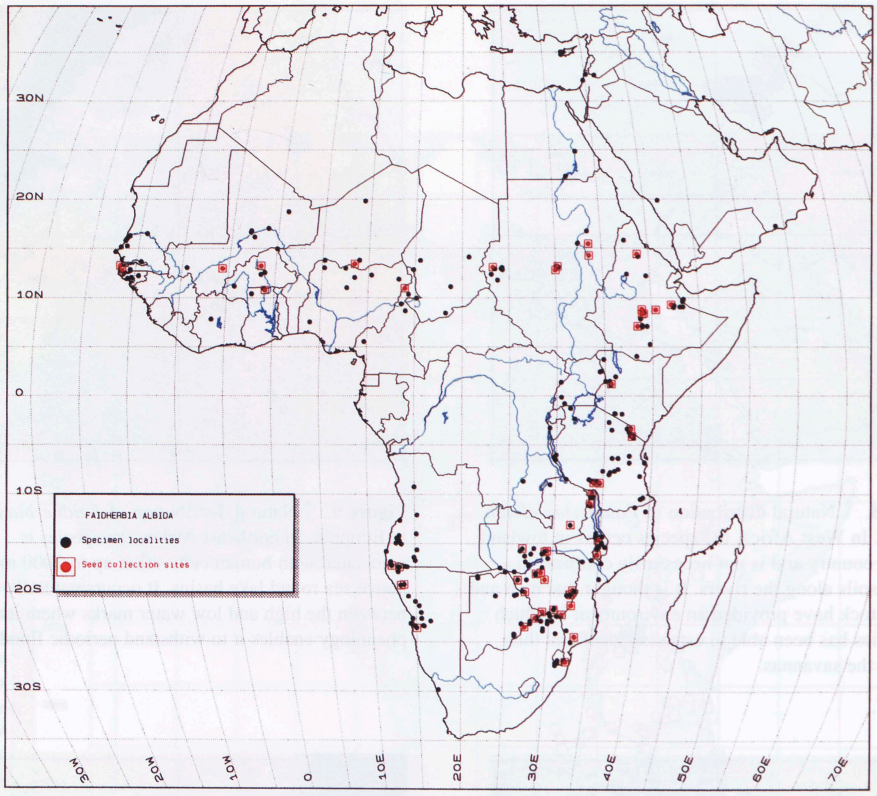



**Figure 12**. ↑ Locations of seed collections for international provenance trials of *Faidherbia albida*. The black dots represent locations of specimen collections for herbaria (from Fagg and Barnes 1995). Sampling was designed to give the maximum chance of attaining good coverage of the genetic variation in the species as indicated by isozyme studies and by the observed morphological variation between provenances and the variation in ecological, climatic and edaphic conditions under which they were growing.

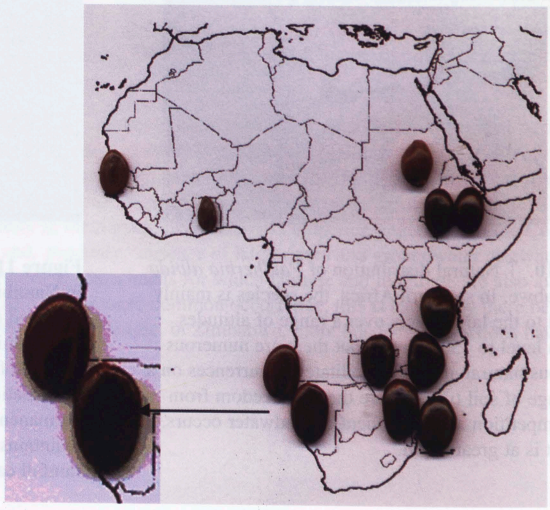


**Figure 13**. → Variation in seed size between provenances of *Faidherbia albida*. Seeds are largest in the southern and eastern Africa riverine provenances, intermediate in the highland provenances of Ethiopia and Sudan and smallest in the lowland savanna provenances of West Africa. Greater embryonic capital may be an advantage in riparian situations and smaller seeds a response to the greater environmental stress in the West African savanna. The seeds on the full map of Africa are about life size.

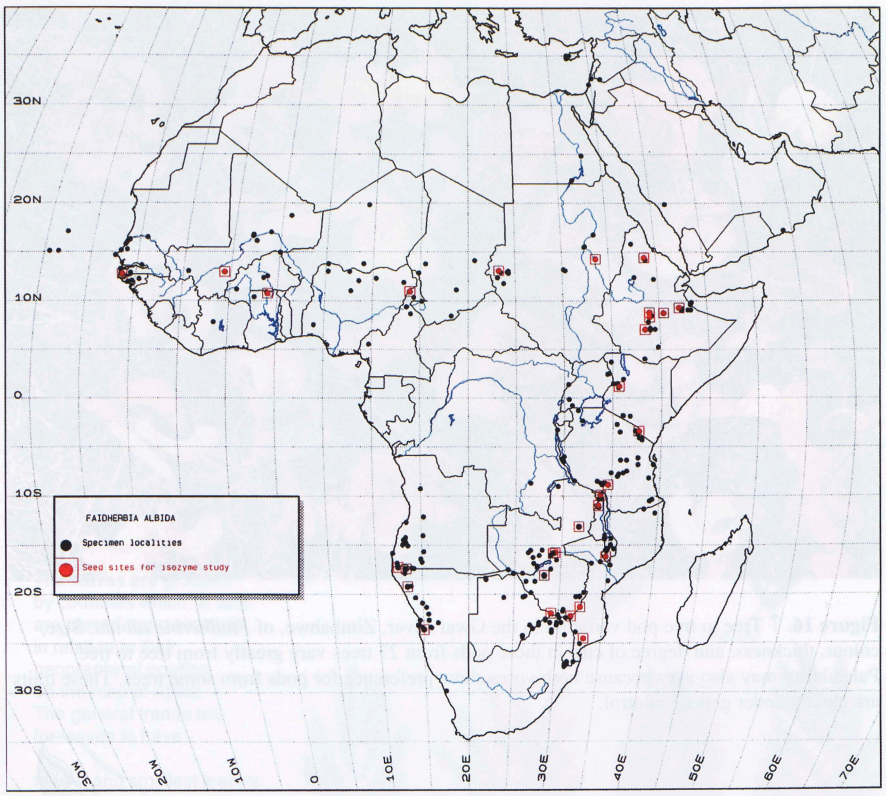



**Figure 14**. ↑ Locations of seed collections for an isozyme study of *Faidherbia albida*. The black dots indicate the localities of specimen collections for herbaria (from Fagg and Barnes 1995). Sampling was designed to give an early indication of how the species varied genetically over its entire distribution.

**Figure 15**. → Unweighted pair-group mean analysis clustering of 30 populations of *Faidherbia albida* based on Nei's genetic distance. These data indicate divergence of three groups, the Southern and eastern Africa cluster, the Ethiopian (and Sudanese) cluster and the West African cluster. For precise localities of the provenances see Appendix 3.

| | |
|---|---|
| Chinzombo<br>Shashi River<br>*etc.* | Southern and eastern African provenances |
| Rama<br>and Khor<br>*etc.* | Ethiopia Sudanian provenances |
| Bolgatonga<br>Bignona<br>*etc.* | West African provenances |

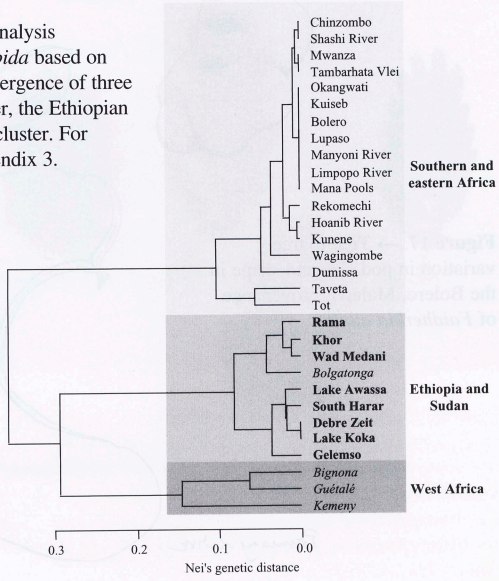


**Figure 16**. ↑ Tree to tree pod variation in the Gwai River, Zimbabwe, of *Faidherbia albida*. Size, colour, thickness, and degree of curl in these pods from 23 trees vary greatly from tree to tree. Palatability may also vary because herbivores show preference for pods from some trees. These traits are clearly under genetic control.

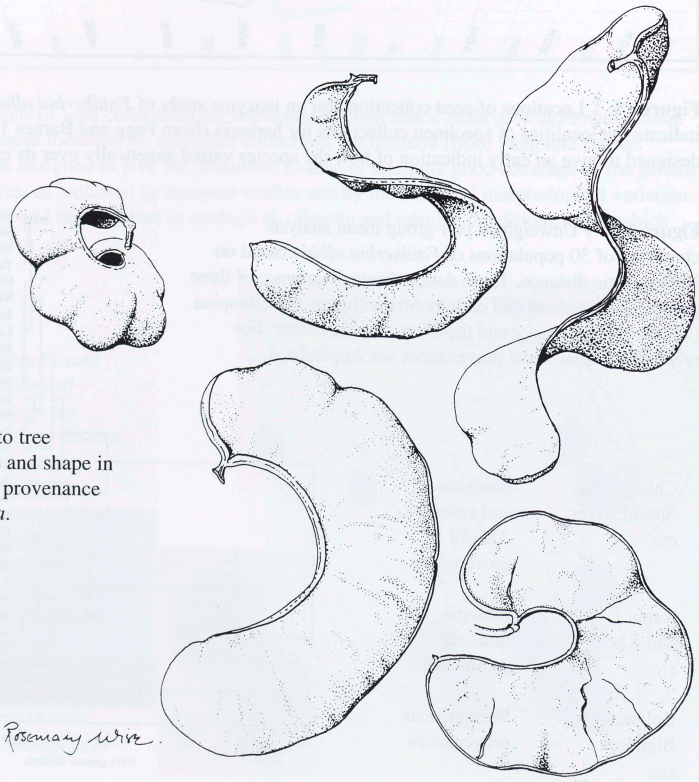



**Figure 17**. → Tree to tree variation in pod size and shape in the Bolero, Malawi, provenance of *Faidherbia albida*.

**Figure 18.** ↑ Leaves typical of 19 range-wide populations of *Faidherbia albida* growing in a provenance trial in Zimbabwe.

**Figure 19**. ↑ Seedlings typical of 11 southern provenances of *Faidherbia albida* six months from sowing. These are provenances from Malawi, Zimbabwe, South Africa and Namibia and generally reflect the lack of variation between the southern sources. From left to right they are:- Wagingombe (Tanzania), Bolero (Malawi), Chawanje (Malawi), Chawanje (Malawi), Mana Pools (Zimbabwe), Gona-re-Zhou (Zimbabwe), Kapula (Zimbabwe), Kuiseb River (Namibia), Hoanib River (Namibia), Pongola River (South Africa).

**Figure 20**. ↑ Seedlings typical of four range-wide provenances of *Faidherbia albida* eight weeks after sowing. From the left the provenances are:- Bolutanga (Ghana), Bignona (Senegal), Khartoum (Sudan) and Kuiseb (Namibia). The slow growth rate of the West African provenance, the fast growth of the southern Africa provenance and the intermediate growth of the north eastern provenance are typical of populations in those the regions. The sessile cotyledons are conspicuous on each seedling as are the first pair of bipinnate leaves. In both these characteristics, *F. albida* is different from the spinescent acacias all of which have petiolate cotyledons and once pinnate first leaves.

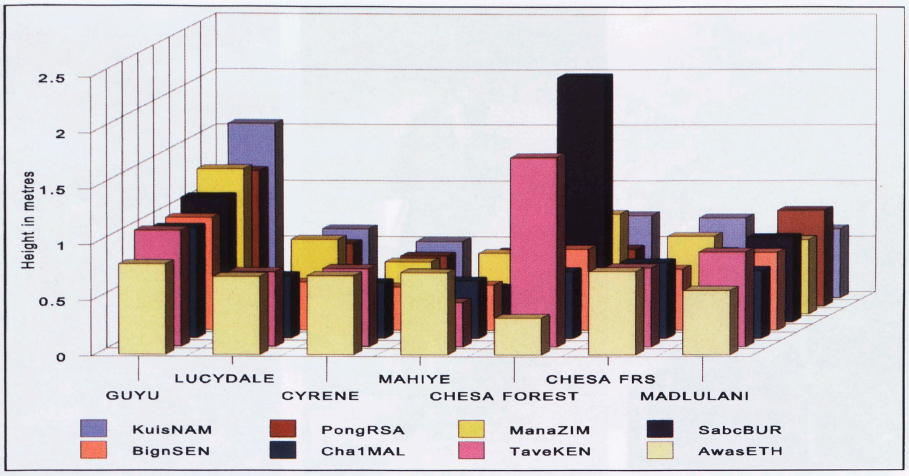



**Figure 21**. ↑ Fourth-year heights of eight provenances of *Faidherbia albida* over seven sites in Zimbabwe. These data are from screening trials of 72 provenances of six Acacia species in Zimbabwe (Barnes *et al.* 1996). KuisNAM - Kuiseb, Namibia; PongRSA - Pongola, South Africa; ManaZIM - Mana Pools, Zimbabwe; SabcBUR - Sabce, Burkina Faso; BignSEN - Bignona, Senegal; Cha1MAL - Chawanje 1, Malawi; TaveKEN - Taveta, Kenya; AwaETH - Awassa, Ethiopia. The southern African provenances of *Faidherbia albida* grew faster than those from North and West Africa with the exception of those from high altitudes in Ethiopia which did better than all other provenances on the heavier soils and the frostier sites. The West African provenances were the poorest performers but, by the fourth year, appeared to be catching up on the frost-free, wind-blown Kalahari sands.

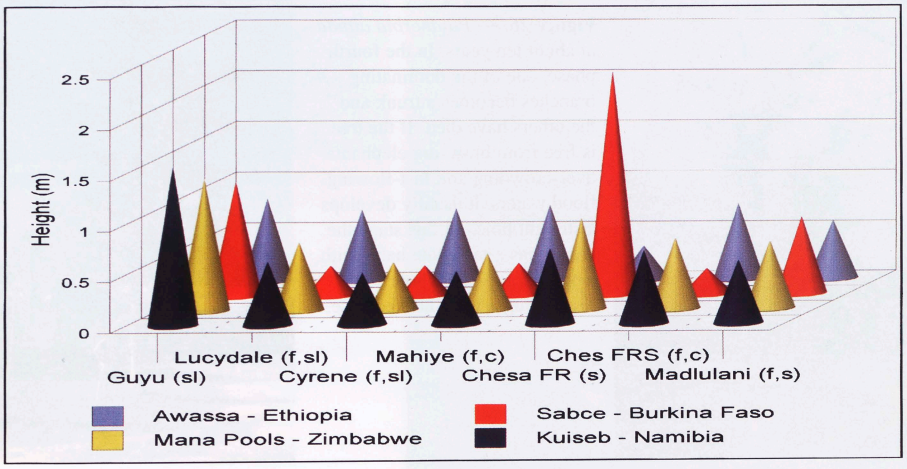



**Figure 22**. ↑ Fourth-year heights of a sub-set of four provenances of *Faidherbia albida* over eight sites in Zimbabwe. These four provenances are representative of the northeast, west, southwest and southern provenances in the screening trials in Zimbabwe. The most significant site factors were frost (f) and soil type, sand (s), sandy loam (sl) or clay (c). As would be expected, Awassa, from heavy soils at high altitude, did best on loams and clays and was little affected by frost; Sabce, from low altitude sandy savannas did best on frost-free sands; Mana Pools and Kuiseb, both from riverine silt beds, did best on frost-free sandy loams.

**Figure 23.** ↑ *Faidherbia albida* at six weeks. In the first phase, up to one year old, the seedling has an orthotropic axis with a typical zigzag pattern. There are no branches. Spines are present and the tree has not shed its cotyledons and is still producing the characteristic bipinnate seedling leaves with one pair of pinnae.

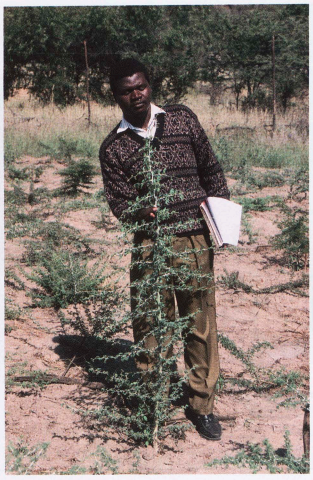


**Figure 24.** ↑ *Faidherbia albida* at 18 months. In the second phase, branching starts and extension of the main axis continues. The height attained at this age depends on provenance. The tree illustrated here is of one of the southern African sources which maintain a much higher shoot:root ratio in the early stages of development.

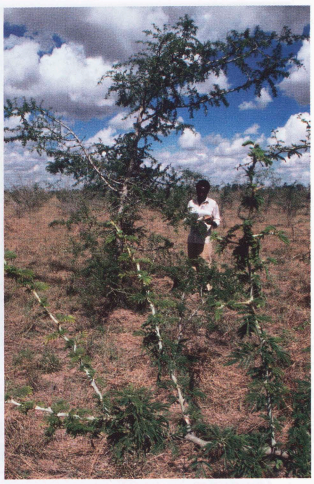


**Figure 25.** ↑ *Faidherbia albida* at about four years. In the third phase, only the base can be considered as part of the main axis. Development of some of the first order axes gives the tree a shrubby and often ragged appearance. There is no apical dominance and several major branches lean outwards with no indication of the clear bole to come.

**Figure 26.** ← *Faidherbia albida* at about ten years. In the fourth phase, one of the dominating branches becomes a trunk and the others have died. If the tree is free from browsing elephants, over-crowding and fast-flowing flood waters, it usually develops a straight bole. At this stage the crown has a fastigiate habit with a broader top, the whole resembling a wide-necked vase.

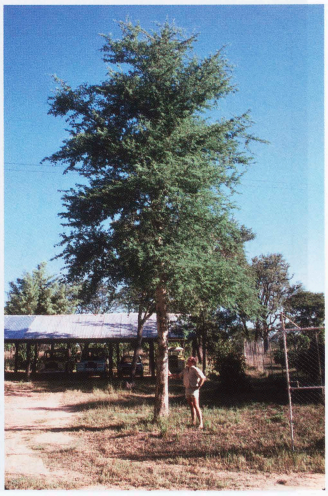


**Figure 27.** ↗ *Faidherbia albida* at about 15 years. In the fifth phase the trunk attains its final height of about 4.5 m, long enough for a dugout canoe. The first order branches above this height develop strongly and break up the apical dominance. The tree starts to lose its open-necked vase appearance but the general habit remains fastigiate.

**Figure 28.** ↑ *Faidherbia albida* at about 30 years. The tree maintains a semi-fastigiate habit but with an overall more rounded appearance.

**Figure 29.** ↑ *Faidherbia albida* at about 40 years. In the sixth phase, first order axes have reached their maximum extension and maximum crown diameter has been achieved. The length and weight of the branches is causing them to droop and the tree loses its fastigiate habit. If elephants are present, the tree has a very much higher browse line than the one illustrated here which is imposed by livestock only.

**Figure 30.** ↑ *Faidherbia albida* at about 70 years. In the seventh phase, the tree reaches its maximum height of about 17 m and the crown becomes dome-shaped.

**Figure 31.** → *Faidherbia albida* at about 85 years. In the eighth phase, some branches at the base of the first order axes have died so that the crown is more open and sub-crowns can be distinguished. A ninth phase covers dieback of trees at the age of about 100 years when no new branch orders develop.

**Figure 32.** ← *Faidherbia albida* seedling showing the strong taproot development typical of the species although this seedling has been root pruned. The primary root elongates rapidly to reach the perennial moisture zone. The taproot may grow at 1 cm a day at the seedling stage and extend to 5 m below the surface in a year. At three months there is still a strong predominance of the tap root over the laterals. By 18 months, the taproot has thickened and a system of lateral roots develops. The tap root must be able to keep in touch with the retreating groundwater level for the seedling to survive. Once the permanent water table has been reached, the tree can adopt its reverse phenology and remain in full leaf for the whole of the dry season.

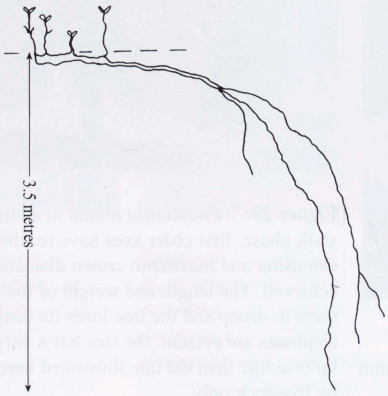



**Figure 33.** ← Rooting habit of coppice of *Faidherbia albida* on clay over limestone at Mount Mukulu, Zambia (Timberlake and Calvert 1993). From the illustration, it appears that these are root suckers from a coppicing seedling. The massive investment in root development compared with the aerial parts is obvious from this drawing. There are very large provenance differences in the root:shoot ratio of seedlings. The riverine provenances, particularly those from southern Africa, have a far lower shoot:root ratio in the first few years of their life than do the west African provenances which are much better adapted to savanna conditions. When there are changes in the level of the ground water beneath *F albida* trees, due to man's agricultural activities or to reduced rainfall, established trees are often unable to form new roots deep enough to reach the lowered water table and so are unable to produce a new flush of leaves and thus suffer from dieback.

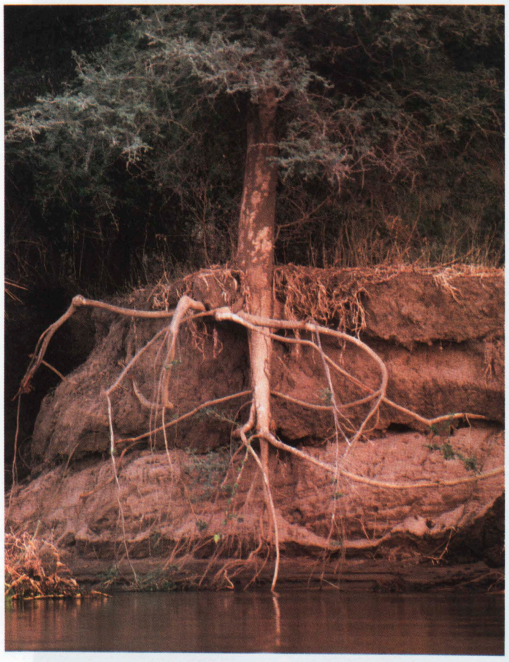


**Figure 34.** ← Revealed roots of a *Faidherbia albida* tree on a sandbank on the Zambian bank of the Zambezi River downstream of its confluence with the Kafue. These long hose-pipe-like lateral roots are typical of the species and are revealed when silt beds and sandbanks are eroded away by the flood waters. These roots can often extend far beyond the tree's crown and may enable it to mine a very large area for nutrients which then contribute to the increased fertility beneath the canopy, and to a decrease in fertility in the open spaces beyond. In this photo it is conspicuous that the lateral roots are concentrated in the siltier strata rather the pure sand layers, suggesting that these roots are seeking nutrients rather than water.

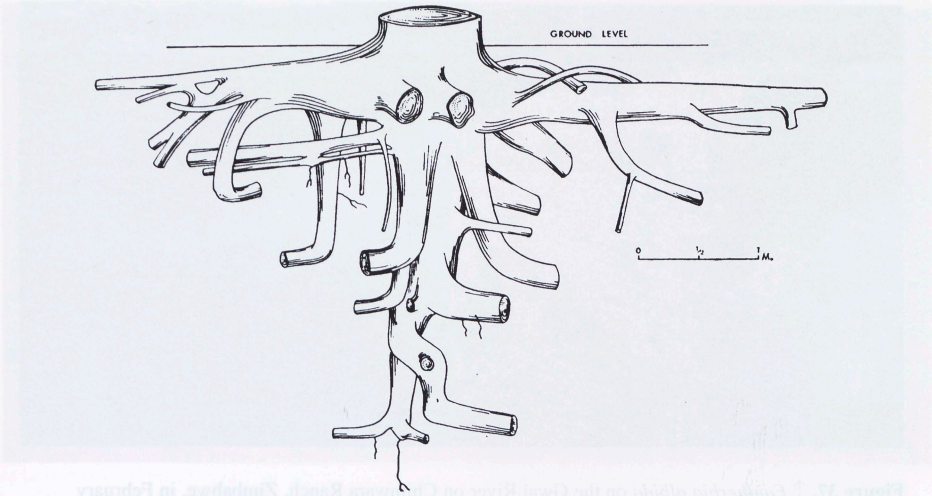



**Figure 35.** ↑ Drawing of excavated root system of *Faidherbia albida* tree growing in loamy sand alluvium of the Wadi Aribo lower terrace soils at Zalingei, Darfur Province, Sudan (from Wickens 1969). In this case it looks as though the taproot has leveled out at about 4 m depth and it is likely that this was the depth at which there was permanent ground water.

**Figure 36**. ↑ Root system of *Faidherbia albida* tree revealed by gully erosion at Mana Pools, Zambezi Valley, Zimbabwe. The similarity between the root architecture of this tree and the tree illustrated in Figure 35 is striking given that they are growing in different environments thousands of kilometres apart. Both these trees show much greater development of a lateral system near the soil surface than might be expected given the tree's reputation for not competing with crops growing beneath the canopy. Root development of *F. albida* is reputed to differ according to the soil. On sandy soils, the taproot is said to penetrate deeply while root systems in compacted clay are said to remain in the upper horizons. This illustration suggests that the tree will root intensively at shallow or deep levels wherever the opportunity exists.

**Figure 37.** ↑ *Faidherbia albida* on the Gwai River on Chimwara Ranch, Zimbabwe, in February (29-02-2000). Chimwara (*c*. 18.45 °S, 27.28 °E; altitude 925 m) lies half way between Bulawayo and Victoria Falls in western Zimbabwe. This photograph was taken from the same point as Figures 38, 39, and 40 at the height of the wet season when the trees were flooded. Pale and leafless, they stand out starkly and show the aptness of the specific name, alba. The mopane (*Colophospermum mopane*) woodland on the outside of the bend in the river is in full leaf. Other species growing with the *F. albida* but separated by soil differences or succession include *Acacia tortilis*, *A. polyacantha, Lonchocarpus capassa and Kigelia afrciana*.

**Figure 38.** ↑ *Faidherbia albida* on the Gwai River on Chimwara Ranch, Zimbabwe, in May (05-05-1999). This photograph was taken from the same point as Figures 37, 39, and 40 at the end of the rainy season when the trees were fully flushed and flowering. Most of the *F. albida* crowns look pale because of the flowers although those nearest the river are greener because they are not flowering so heavily, probably because they are younger having been established on the more recent silt beds. At this time of the year, the trees are almost the only source of pollen and nectar for insects, particularly honey bees.

**Figure 39.** ↑ *Faidherbia albida* on the Gwai River on Chimwara Ranch, Zimbabwe, in August (23-08-2001). This photograph was taken from the same point as Figures 37, 38, and 40 in the middle of the dry season when *F. albida* is in full leaf and provides deep shade for animals in the heat of the day. Nearly all other tree species have lost, or are losing their leaves. The contrast with other species is most marked at this time of the year. The autumn colours of mopane (*Colophospermum mopane*) are conspicuous. The mopane is growing on the colluvial soils on the outside of the river bend whereas the *F. albida* is confined to the alluvial soils deposited on the inside of the river bend.

**Figure 40.** ↑ *Faidherbia albida* on the Gwai River on Chimwara Ranch, Zimbabwe, in November (15-11-1999). This photograph was taken from the same point as Figures 37, 38, and 39 at the end of the dry season when the *F. albida* is dropping its pods and other species are in their final stages of flushing. The pods are a vital source of protein for herbivores at this time of the year particularly if the rains are late in coming. If the rains come early, herbivores disperse to feed on the new grass and many of the *F. albida* pods go uneaten - unless they are collected and kept dry for stall feeding later in the following dry season.

**Figure 41.** ↑ *Faidherbia albida* on the shores of Lake Awassa in Ethiopia. Populations of the species are common around the Rift Valley lakes of África. Here, on sandy loam soils, they withstand having their roots in water during the wet season. During the dry season, the waters retreat and the trees, being in full leaf, can grow normally.

**Figure 42.** ↑ The Okangwati provenance of *Faidherbia albida* in Northern Namibia. This population follows a dry river bed. Settlements are concentrated around the trees in this remote dry sandy location. Rivers cross the Namib Desert from the better watered areas inland to the sea. *F. albida* is the provider of shade and the principal source of food for herbivores, and hence predators, which can thus traverse the desert along them. This leads to extraordinary sights like lions and elephants on the desert sea shore

**Figure 43.** ↑ Giraffe under *Faidherbia albida* in the dry bed of the Hoanib River in northen Namibia. These animals browse on the trees and eat fallen pods, one of the few sources of food in the arid stretches of the Skeleton Coast.

**Figure 44.** → An outlying, regularly frosted population of *Faidherbia albida* in Zimbabwe. This small group of large trees on the Umguza River many kilometres distant from the main populations, may have originated from seeds in migrating elephant droppings left on a suitable sandbank. A succession of frost-free winters must have followed for the trees to have become big enough to survive the regular sub-zero temperatures that are common in the river valley. The crowns have been misshapen by regular frosts.

**Figure 45.** ↑ Natural understorey in protected *Faidherbia albida* parkland at Nyamepi, Zimbabwe. On the left, the *F. albida* parkland has been protected from wild herbivores by an electric fence. A dense understorey of herbs, shrubs and successor tree species has established itself while the area outside the fence remains exclusively a *F. albida* parkland that has dense grass cover in the wet season but is stripped bare of all vegetation in the dry season by herbivores seeking the trees' shade and browse and waiting for the pods to fall. There is no regeneration of *F. albida* itself in either the protected or in the unprotected area.

**Figure 46.** ↑ ***Faidherbia albida*** along the Kuiseb River at the Gobabeb Desert Research Station in Namibia. The species grows along the larger rivers that flow through the Namib desert where annual rainfall is less than 50 mm. Periodic floods that originate from rain that falls far inland create ideal silt beds and sandbanks for the tree to regenerate and maintain permanent groundwater at depth. *F. albida* grows in and nearest to the river bed where its unique reverse phenology makes it able to withstand the floods whereas species such as *Acacia erioloba*, which can root even deeper but cannot withstand submergence, grow further from the river.

**Figure 47.** ↑ Elephant browsing on *Faidherbia albida*. Elephants can reach to over five metres for foliage and pods and they create a high browse line on the trees which means all other herbivores have to wait for the pods to fall before feeding.

**Figure 48.** ↗ Elephant picking up *Faidherbia albida* pods. Huge quantities of pods are consumed by elephants, and other animals such as buffalo, and impala, and most of the seed passes through the animal and emerges undamaged in the dung, as shown by the huge number of seeds in the ball of dung in the insert, and ready to germinate when dropped, often many miles away.

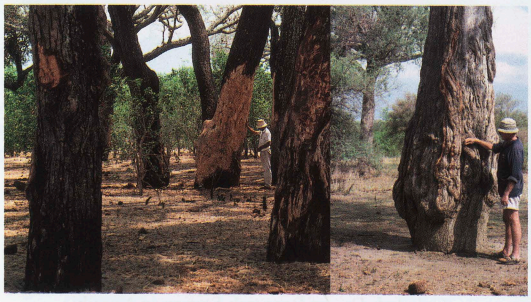


**Figure 49.** ↑ *Faidherbia albida* trees debarked by elephant. While waiting in the shade beneath the trees waiting for the pods to fall, elephants debark the boles but the trees respond by producing a convoluted calloused regrowth, shown in the insert, which prevents them from being completely ring-barked by repeated visits.

**Figure 50.** ↗ Elephant digging for *Faidherbia albida* roots. This elephant is levering up large roots to chew. The tree's response is to produce a sucker from the damaged root but the elephants eat the suckers, and any seedlings too. There is therefore rarely regeneration beneath the trees unless the herbivore pressure is reduced.

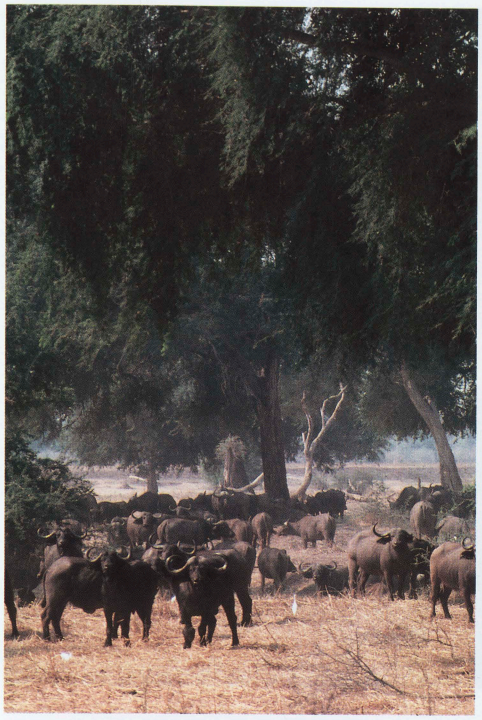


**Figure 51.** ← Buffalo resting and browsing under *Faidherbia albida* in the Zambezi Valley, Zambia. These animals spend many hours of the day under the trees during pod-fall at the end of the dry season.

**Figure 52.** ↑ *Faidherbia albida/Trichelia emetica* woodland near the Savi-Rundi confluence in Zimbabwe. Elephants create a high browse line on the *F. albida;* they do not eat the *T. emetica* which kudu and impala keep at a lower level.

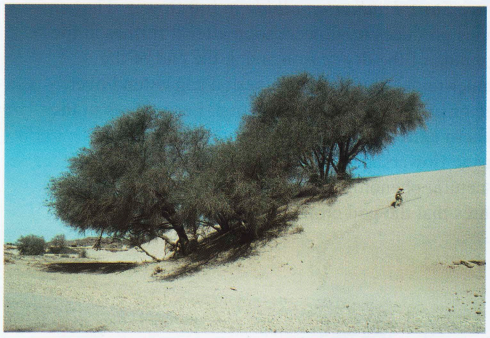


**Figure 53.** ↑ *Faidherbia albida* stabilizing sand dunes on the banks of the Hoanib River in Namibia. Sufficient rain very occasionally falls in the desert for the *F. albida* seed to germinate in the sand and send a taproot down to groundwater beneath the river bed.

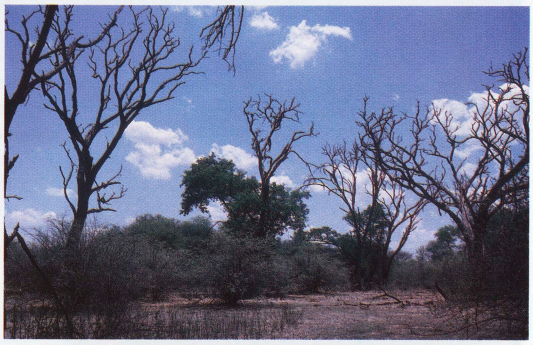


**Figure 54.** ↑ *Faidherbia albida* dying from drought near the Gwai River in Zimbabwe. Mature trees are unable to adapt to keep in contact to receding groundwater. As the trees die, other species succeed as the animal pressure is reduced when there are no longer pods to be picked up.

**Figure 55.** ← Moth visiting *Faidherbia albida* flowers. The species has many insect pollinators, including honey bees. The flowers are produced at the end of the summer when most other plants have finished flowering. The weather at this time of the year is usually dry, it is not too hot and the cold, and occasional frost, of the winter months are yet to come. These conditions are ideal for insects and efficient pollination therefore takes place most years which contributes to the regular and copious pod crops.

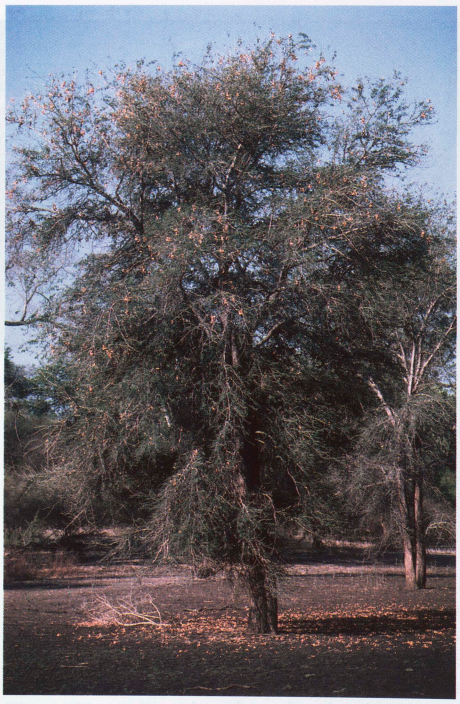


**Figure 56.** ↑ *Faidherbia albida* in full flower. The species produces its flowers soon after it flushes at the beginning of the dry season and at the end of the summer rains. The flowering period can extend over three or four weeks on a single tree. Early frosts in the southern extremes of the species' distribution can damage flowers and reduce pod production although the natural phenological variation between trees usually ensures that the pod crop is not all lost.

**Figure 57.** ← Ripe pods falling from a *Faidherbia albida* tree. The pods ripen and fall from the tree at the end of the dry season just before the summer rains begin, about four months after it has flowered. The length of the pod fall period from a single tree can be as long as five to six weeks but early thunderstorms accompanied by high winds can cause most of the pods to fall in a few hours.

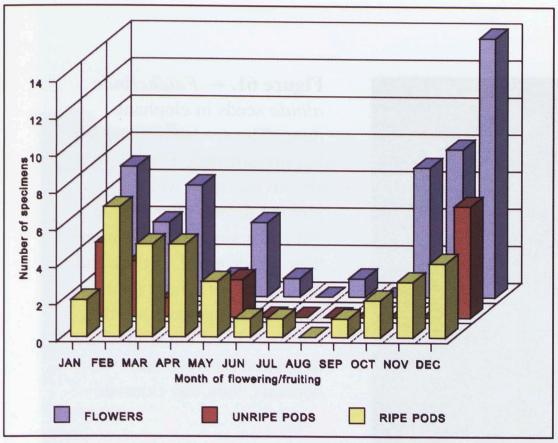
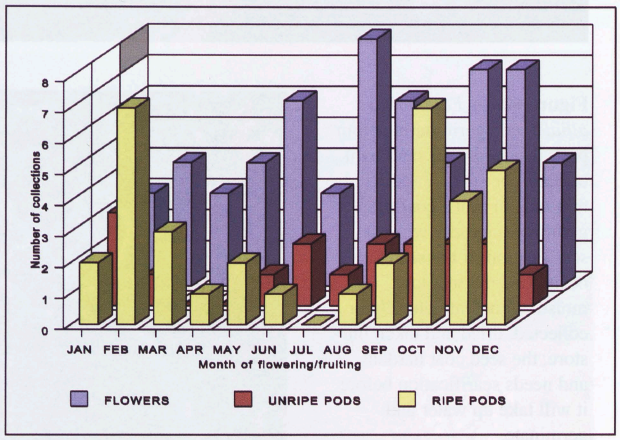



**Figure 58.** ← Flowering/fruiting phenology of *Faidherbia albida* in western Africa (data from Fagg and Barnes, 1995). Details of specimens in the BRAHMS database collected in the unimodal summer rainfall zone of Africa north of the equator were used to construct this diagram. The flowering peak is in December and the peak of pod production in February. The peaks are not as pronounced or as far apart as might be expected compared with those for southern Africa in Figure 60 below but this effect might be due to the very much more variable habitats that the species occupies north of the equator from riverine through savanna to high altitude agricultural environments.

**Figure 59.** → Flowering/fruiting phenology of *Faidherbia albida* in eastern Africa (data from Fagg and Barnes, 1995). Details of specimens in the BRAHMS database collected in the bimodal summer rainfall zone of Africa round the equator were used to construct this diagram. The double peaks of pod production in February and October are clear as are the flowering peaks in November and July. Whether the dual peak is due to individual trees flowering twice or whether the effect is an artefact of the manner of defining the data set cannot be determined from the specimens and needs further research for clarification.



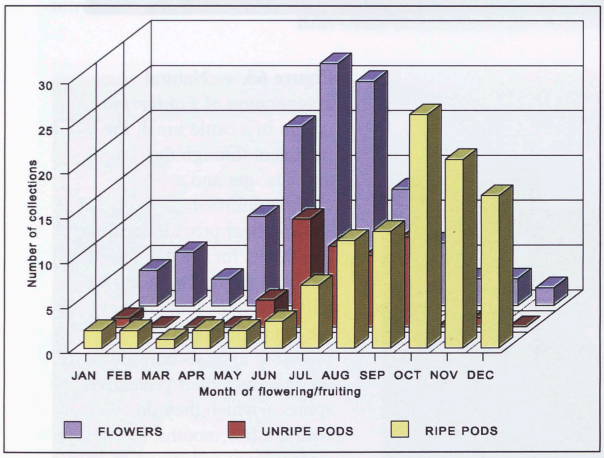




**Figure 60.** ← Flowering/fruiting phenology of *Faidherbia albida* in southern Africa (data from Fagg and Barnes, 1995). Details of specimens in the BRAHMS database collected in the unimodal summer rainfall zone of Africa south of the equator were used to construct this diagram. The flowering peak is in June and the peak of pod production in October. The peaks are pronouced and the four-month period for pod ripening is about right. The rather drawn out flowering and fruiting periods are caused by the effects of annual climatic variation on the tree's phenology and also perhaps by anomalous behaviour of trees that have established themselves outside their normal natural habitats.

**Figure 61.** ← *Faidherbida albida* seeds in elephant dung. The seeds are scarified but not crushed. They absorb moisture when passing through the animal's gut and soon germinate after they are dropped. If they end up in grass or where there is heavy grazing pressure, they are short lived but if they are deposited on fresh silt deposits, they can flourish.

**Figure 62.** → *Faidherbia albida* seed germinating from pods dropped on a sand bank beneath the trees. Fresh seed that falls in moist conditions germinates rapidly without scarification. If the seed has been dried out to a low moisture content naturally or collected, dried and taken into store, the seed coat hardens and needs scarification before it will take up water and germinate.

**Figure 63.** ← Natural regeneration of *Faidherbia albida* in a cattle kraal. Pre-treatment through the animals' gut and a competition-free environment provide ideal conditions for the tree to establish itself. The trees will survive as long as they are not pulled up by browsing animals before they produce their protective spines – which they do within a few months.

**Figure 64.** ← *Faidherbia albida* colonizing the sandy bed of the Bubi River in Zimbabwe. With its early and rapid growth of a penetrating taproot, the tree is able to establish itself as the water level drops in the dry season free of competition from any other plant. These trees are about two years old and have survived one or two wet seasons when the flood levels have not been high enough to wash them out.

**Figure 65.** → Gully colonization by *Faidherbia albida* in Malawi. The absence of competition from grasses gives the tree an ideal opportunity to establish itself in this degraded landscape where it is subsequently able to survive because of the speed with which its taproot follows the moisture down to the water table enabling it to use nutrients from depth and fix atmospheric nitrogen.

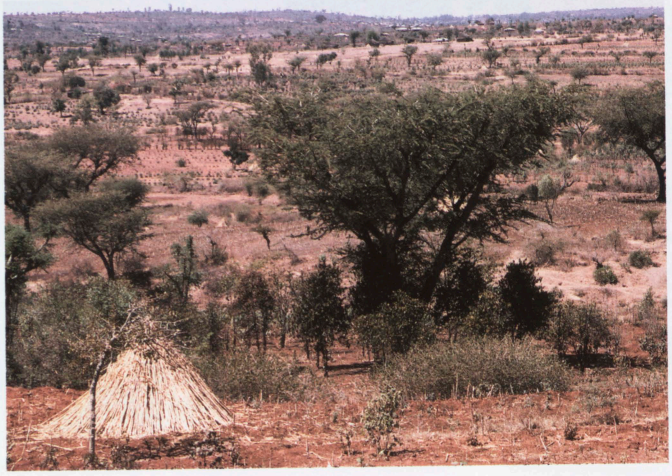


**Figure 66.** ← Natural regeneration of *Faidherbia albida* in an agricultural landscape in Ethiopia. If the seedlings are protected from browsing livestock in the early stages, they grow on to create a productive parkland provided the roots can keep in touch with a permanent source of moisture in the dry season. Human agricultural activities like this have enabled the species to spread out of its normal riverine.

**Figure 67.** ← *Faidherbia albida* regenerating in the Bubi River bed in Zimbabwe. A flood lays down silt beds that allow the species to germinate free from competition. If several years of low rainfall follow, the seedlings grow rapidly and are able to withstand later floods. The flood debris can be seen here; The young trees have been deformed, but not uprooted.

**Figure 68.** → *Faidherbia albida* established in the Gwai River bed in Zimbabwe. Once established, the trees can withstand very severe floods and long periods of inundation in the summer when the trees are leafless. The severity of the floods can be seen here from the wash in the reeds (*Phragmites* sp.) and the debris left high up in the trees.

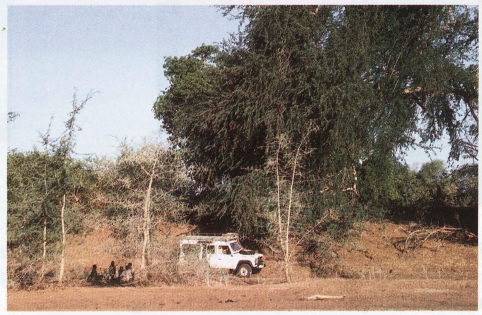
**Figure 69.** ← *Faidherbia albida* that has succeeded in colonizing a section of the Gwai River bed in Zimbabwe. This pure population of the species has slowed the flood waters down and caused the river to shift its bed. In due course, 50 to 100 years, the *F. albida* itself will be succeeded by mixed deciduous forest with species such as *Trichelia emetica.*

**Figure 70.** ↑ Colonization of a dam edge by *Faidherbia albida* in Zimbabwe. The tree's reverse phenology enables it to exploit the area between wet and dry season water levels.

**Figure 71.** → *Faidherbia albida* colonizing black clay vertisols. The species can take advantage of denuded patches on almost any soil type and is successful if it can reach permanent water.

**Figure 72.** ← A *Faidherbia albida* root sucker. Trees can originate from surface roots when they are damaged for example by elephants when they dig up the roots to eat.

**Figure 73.** ↓ A string of *Faidherbia albida* root suckers. Lines of trees can originate from long, hose-pipe-like lateral roots that may extend many metres beyond the parent tree's canopy down a sandy river bed.



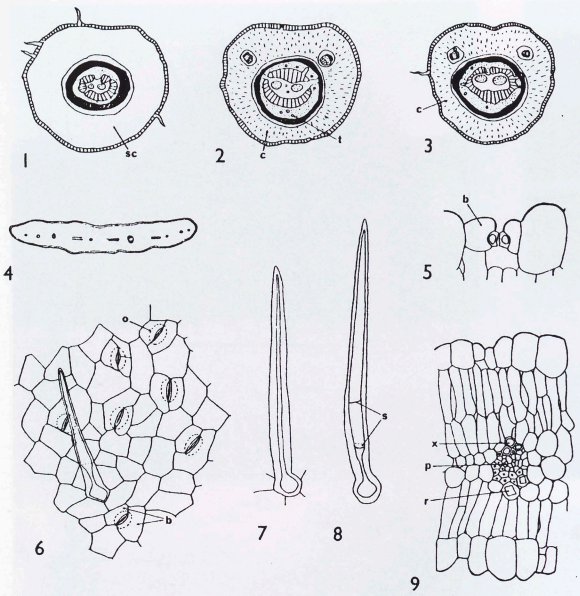
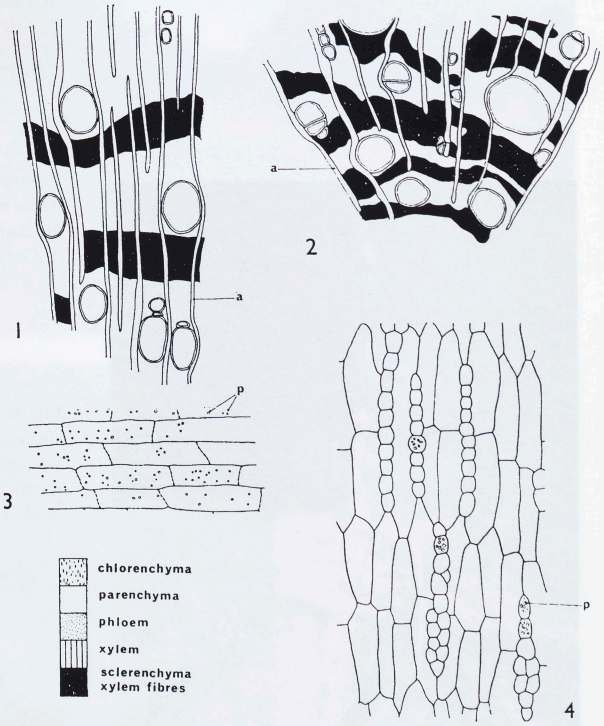



**Figure 74.** ← Leaf anatomy of *Faidherbia albida.* 1 – T.S petiole near base (x50); 2 – T.S. petiole mid section (x50); 3 – T.S. petiole near first pair of pinnae (x50); 4 – T.S. leaflet (x12); 5 – stomata (x320); 6 – leaf surface (x200); 7 – non-septate hair (x320); 8 – septate hair (x320); T.S. leaflet (x200). b = subsidiary cell; c = chlorenchyma; o = guard cell outline; p = phloem; r = rhombohedral crystal; s = septa; sc = sclerified parenchyma; t = tannin cell; x = xylem;. For shading key see next figure. Diagram from Cutler (1969).

**Figure 75.** → Twig and root wood anatomy of *Faidherbia albida*. 1 – T.S. of twig wood (x50); 2 - T.S. of root wood (x50); 3 - R.L.S. ray of twig wood (x200); 4 – T.L.S of twig wood showing storied parenchyma (x200). a = narrow ray; p = pit in ray cell wall. Diagram from Cutler (1969).



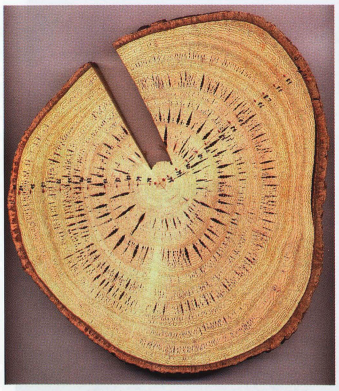



**Figure 76.** ↑ Stem disc of 14-year-old *Faidherbia albida*. Shrinkage in drying has been accommodated by cracks within the circumference which remains intact without the usual radial cracks to the edge. This may make the tree particularly suitable for dugout canoes.

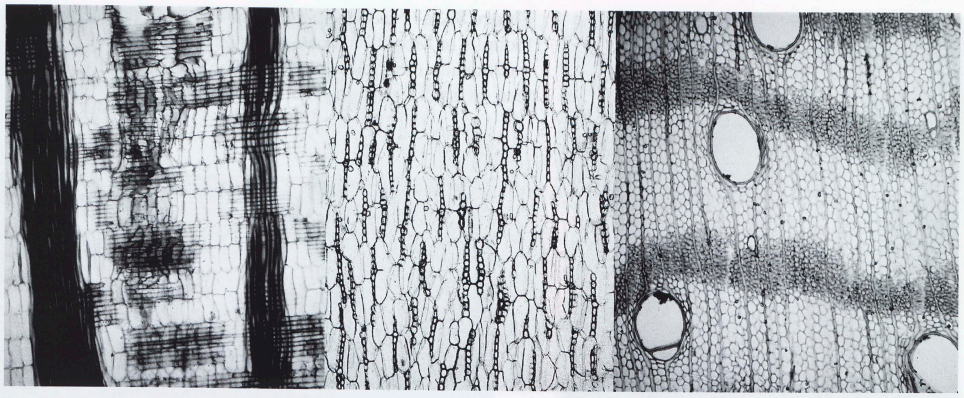


**Figure 77.** ↑ Stem wood anatomy of *Faidherbia albida*. Radial, tangential and cross sectional photographs of the wood are shown in this composite figure. The fibres are short to average, the rays are layered, uniseriate or uniseriate and biseriate, the parenchyma is in wide slightly sinuous bands, and the vessels are scattered, isolated or grouped radially in twos or threes.

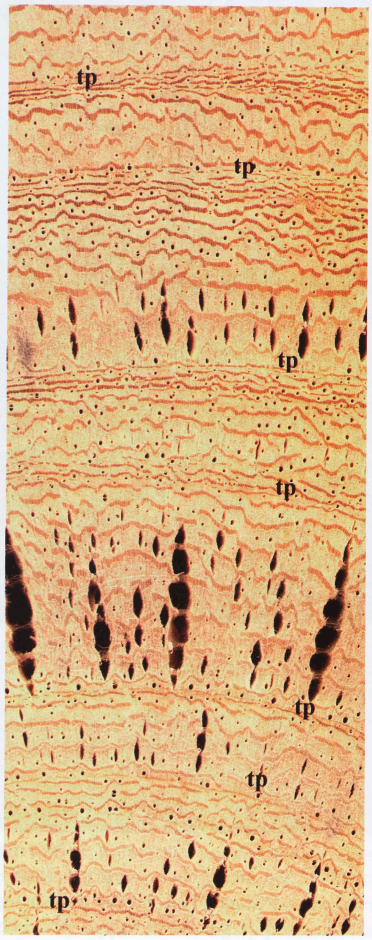



**Figure 78.** ← Growth rings in *Faidherbia albida*. Stem disc showing changing frequency and size of the broad paratraechal parenchyma bands with numerous radial drying cracks, both converging on the growth ring boundaries. The thin unwavering lines of marginal parenchyma (tp) laid down at the end of the growing season are independent of the vessels and are a mark of annual growth.

**Figure 79.** ↑ Dugout canoe in Malawi made from a bole of *Faidherbia albida*. Anatomical features that accommodate drying cracks and the light weight of the wood make the tree particularly suitable for canoes. The timber otherwise is of low quality with high shrinkage, low density and poor strength properties. It is used for light construction and for cheap furniture. The wood is used as fuel but has a low calorific value.

**Figure 80.** ← *Faidherbia albida* at Taveta in the Kenyan foothills of Mount Kilamanjaro, Bamboo stems are traditionally used to knock down mature pods for livestock to feed on, such as the goats in the foreground.

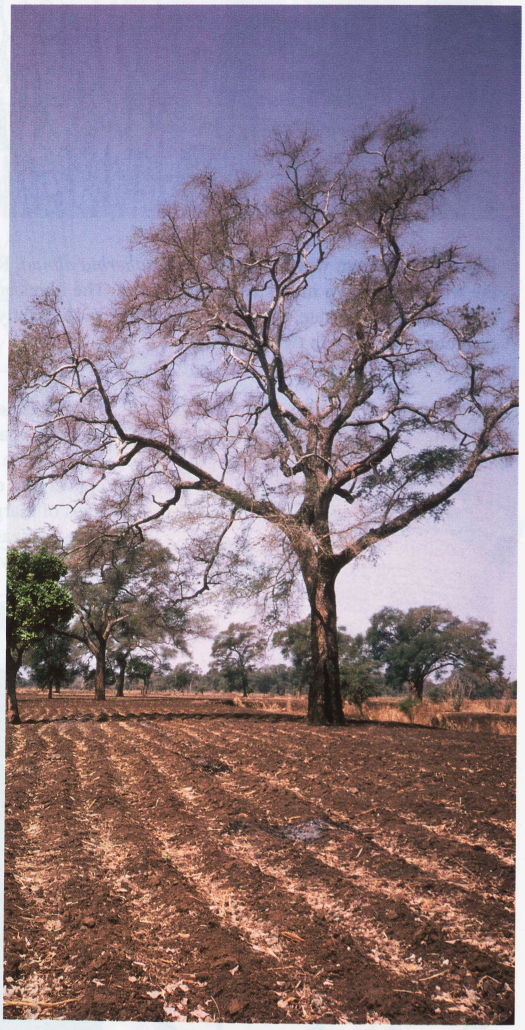


**Figure 81.** → Fields being prepared for planting maize with *Faidherbia albida* in Malawi. The trees are leafless at the beginning of summer just before the rains. Cattle will have picked up the pods from beneath the trees before the crops were planted.

**Figure 82.** ← Maize growing in association with *Faidherbia albida* near Lake Malawi. The crop plants are larger and darker green under the trees. Here the maize has matured and the tree has just flushed.

**Figure 83.** ↑ Bulrush millet cultivated under leafless *Faidherbia albida* at Kokologo, in the Sudanian belt of Burkina Faso. This is a summer, wet season, crop.

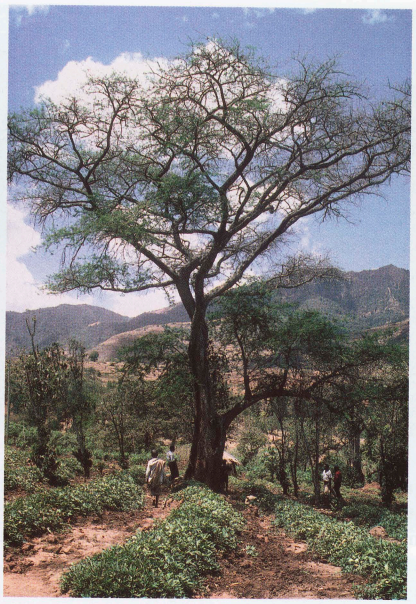


**Figure 84.** ↑ Mature trees of *Faiherbia albida* retained in the sweet potato fields at Gelemso, in the eastern highlands of Ethiopia.

**Figure 85.** ↑ *Faidherbia albida* in cultivated fields south of Harar, in the eastern highlands of Ethiopia. The trees are sometimes pollarded for fodder and fuel; sometimes a large crown is encouraged in order grow coffee beneath as shown in the centre of this photo.

**Figure 86.** ↑ An unusual population of *Faidherbia albida* on the black vertisols around Debre Zeit, in the central Ethiopian highlands. In this unusual population, the trees are preserved and heavily lopped in this highly productive cereal (tef) based farming system.

**Figure 87.** ↑ Maize and cassava growing in association with *Faidherbia albida* near Tot in the Kerio valley, Northern Kenya. The Sharp escarpments of the Cherangani hills in the background.

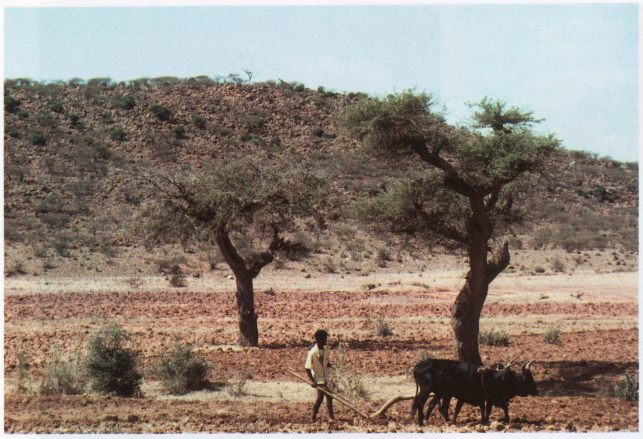


**Figure 88.** ↑ *Faidherbia albida* in farmed land at Rama, Ethiopia, two km south of the border with Eritrea. Pollarded trees are retained in the farmers' fields as are bushy regenerating seedlings as seen in the photo.

**Figure 89.** ↑ Log beehives in the crown of *Faidherbia albida* near Harar, Ethiopia. Fodder for bees is produced after most other plants have flowered and the tree can, therefore, make a critical contribution to honey production.

**Figure 90.** ↑ Seedlings of *Faidherbia albida* in the highlands of Malawi, near Bwanje. The trees are planted and pruned to form a higher canopy in the cultivated farmland.

**Figure 91.** ↑ Bee on *Faidherbia albida* flowers. Bees are important for pollination in the species and contribute to the regular copious pod crops.

**Figure 92.** → Rhizobial nodules on the roots of a *Faidherbia albida* seedling. Bacteria infect the roots of the trees through the root hairs. In response, the tree produces nodules within which the bacteria reside and, in a symbiotic relationship, use the tree's photosynthates to fix nitrogen from the soil atmosphere. This eventually finds its way into the cropping zone through the tree's leaf litter and thence into protein production in crops and livestock.

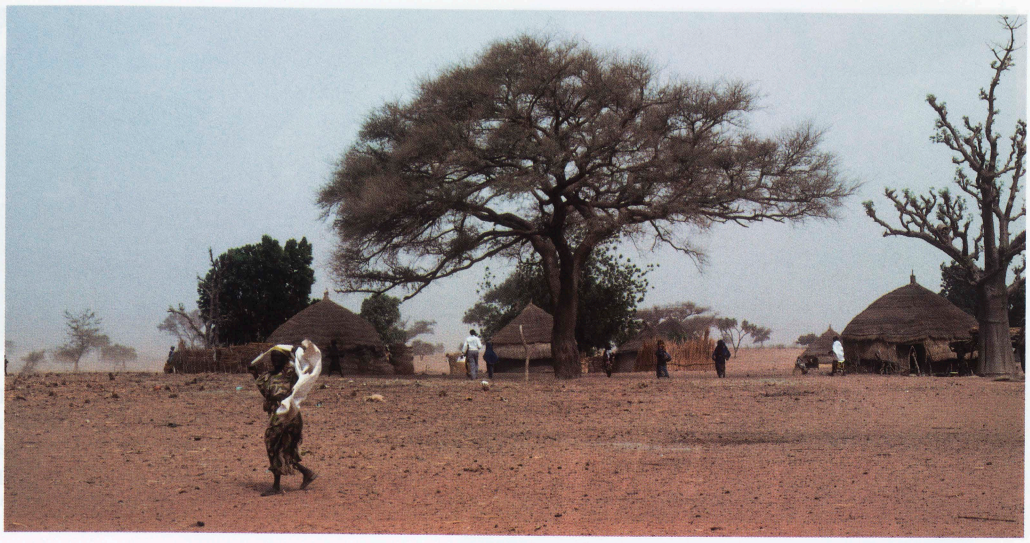


**Figure 93.** ↑ *Faidherbia albida* in a village in Niger. In the sandy soils of the Sahelian Niger, the F. albida are one of the few tree species that survive beside settlements. The foliage may be lopped for green leaf fodder or the crowns can be left untouched to provide shade and pods.

**Figure 94.** ↑ *Faidherbia albida* in the Kerio valley of northern Kenya. Here bananas are among the crops that are grown in association with the trees.

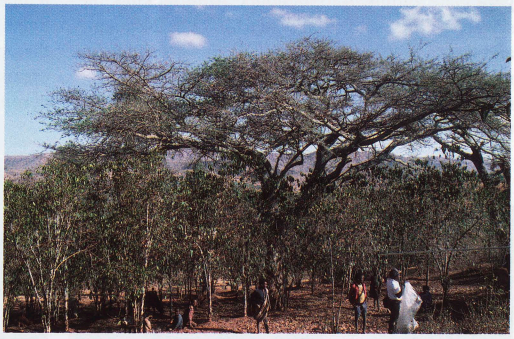


**Figure 95.** ↑ *Faidherbia albida* in South Harar, eastern highlands of Ethiopia. Arabica coffee originates from this area and it is traditionally cultivated under the trees.

**Figure 96.** ↑ *Faidherbia albida* near Bambey in the central plains of Senegal. Livestock are left to browse freely in extensive stands after the millet harvest.

**Figure 97.** ↑ Extracting seed from *Faidherbia albida* pods at Morogoro, Tanzania. If pounding is prolonged, it can fracture the seed coat and release protein in the meal.

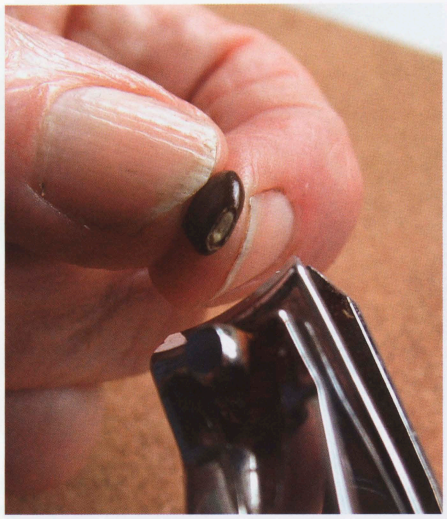


**Figure 98.** ↑ Nicking a *Faidherbia albida* seed. Clipping a very small part of the testa with nail clippers allows the seed to imbibe water and germinate within 24 to 48 hours. After nicking, the seed should be soaked in water for 12 to 24 hours and then sown in containers. Only a very small nick is necessary for the seed to take up water; nicking too large a patch of seed coat can damage the embryo.

**Figure 99.** ↑ Germinating seeds of *Faidherbia albida* in a petri dish. Instead of sowing directly into the pots after soaking, the seeds can be pre-germinated on a moist substrate with the temperature at 25-30°C. The radicle emerges within 24 - 48 hours. The seed can be nicked at the micropylar (top seeds) or the opposite (bottom left seed) end. If nicked at the end opposite the mycropyle, the testa tends to be retained after germination and damping-off fungi can be troublesome.

**Figure 100.** ↑ Sowing a pre-germinated *Faidherbia albida* seed. The seeds are dibbled into the containers after germination. This procedure leads to more uniform seedlings and, provided after-care is good, ensures that all containers are filled.

**Figure 101.** ↑ *Faidherbia albida* seedling with first pair of leaflets. The first pair of leaves in the species is bipinnate, one of the characteristics that contributed to it being removed from the genus *Acacia.*

**Figure 102.** ↑ *Faidherbia albida* seedlings five months after sowing for provenance trials in Zimbabwe. These seedlings are an ideal size for planting out. They are in polythene tubes and have been root pruned regularly. A new taproot is produced after planting out.

**Figure 103.** ↑ *Faidherbia albida* cuttings at the National Tree Seed Centre, Ouagadougou, Burkina Faso. The species can be propagated from cuttings but rooting success is generally low. Best results have been achieved with cuttings collected when the tree is leafless.

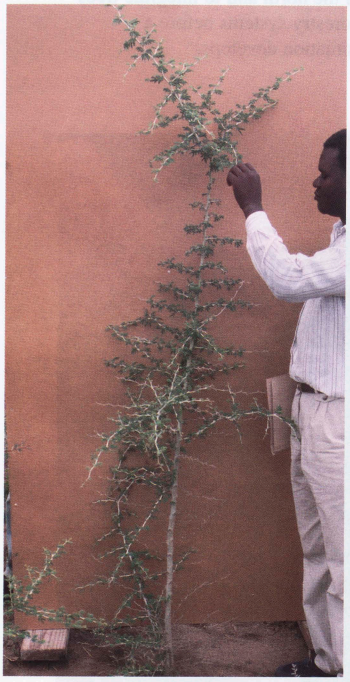


**Figure 104.** ↑ One-year-old *Faidherbia albida* seedling of the Kuiseb, Namibia, provenance. This tree is in a provenance trial in Zimbabwe, one year from planting in the field, 1.5 years from sowing in the nursery.

**Figure 105.** ↑ *Faidherbia albida* planted out of its natural environment in Namibia. This 14-year-old tree on Jena Farm would have been unable to establish itself in this location without human help in the early stages.

**Figure 106.** ↑ *Faidherbia albida* planted at Chitedzi Agricultural Field Station in Malawi. Although this tree is only 11 years old, it is already 40 cm in diameter because it has grown free from competition and is probably in contact with the water table.

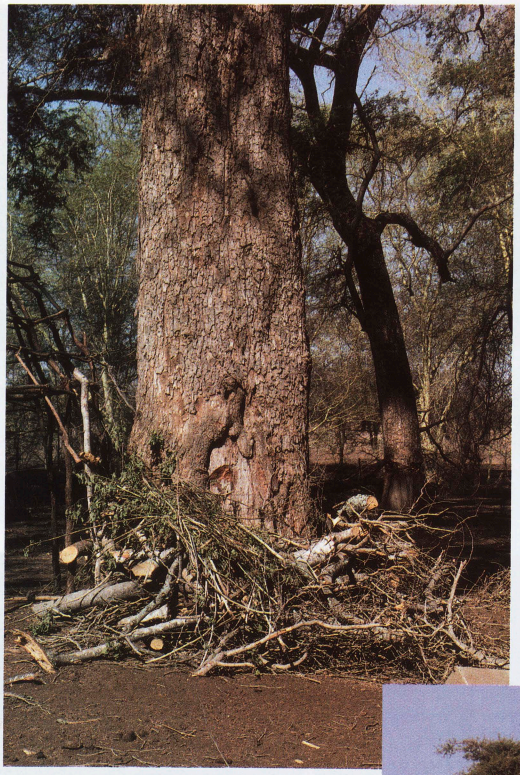


**Figure 107.** ← *Faidherbia albida* about to be felled by fire in the south of Zimbabwe. Brushwood is piled round the base of the tree and lit and the fire eventually burns through the bole. The further south one moves in Africa, the less appreciation there has been in the rural communities of the value of trees in crop and livestock production. Huge trees that yield many pods, improve soil fertility and often produce more protein than crops or grass are often felled to make way for short-term cultivation of annual grain crops. The reason for this is probably that there has been less population pressure towards the south of Africa and therefore no need to use trees in agricultural systems to sustain yields from the same piece of land year after year. Now that those pressures are being felt in the south, there is great potential to learn from the north and to integrate trees into agroforestry systems before a Sahelian situation develops.

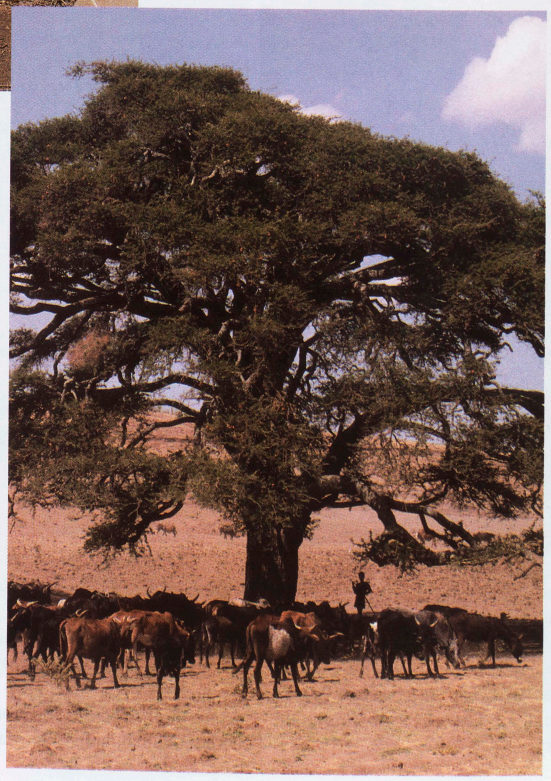


**Figure 108.** → A mature *Faidherbia albida* tree retained in cultivated fields near Debre Zeit in the central highlands of Ethiopia. *F. albida* serves to produce fodder and shade for livestock and enhances the fertility of the soil for crops that are grown round and beneath it in the summer. The value of trees in agricultural systems in the Sahelian zones, particularly in West Africa, has been recognized for centuries and communities have instituted very severe penalties on those who damage or fell a *F. albida* tree. In recent years, modern agricultural systems have been introduced that have threatened the place of these trees in production but high input costs of fertilizer and machinery have proved to be unaffordable for small farmers and a return to the use of trees like *F. albida* in agroforestry systems is indicated if agricultural production is to be sustainable.

# APPENDICES

**APPENDIX 1.** List of common names for *Faidherbia albida* from herbarium specimens linked to a locality.

| Common name | Language | Country | Region | Gazetteer |
|---|---|---|---|---|
| Adurko (pod) | Turkana | Kenya | Northern Frontier | Katilo |
| Ahetes | | South Africa | Unknown | Tit |
| Anadoring | Afrikaans | Namibia | Damaraland | |
| Anadoring | Afrikaans | Namibia | Swakopmund | |
| Aspro spalathia | Cypriot | Cyprus | Unknown | Paphos |
| Balanzan | Bambarra | Mali | Unknown | |
| Balasan | | Mali | Kayes | Kita |
| Balasan | | Mali | Segou | Segou |
| Baransao | Mandinga | Guinea Bissau | Bissau | Bissalanca |
| Barasango, Bubirikab | Mandings | Gambia | Unknown | |
| Bubissikabo | | Gambia | Unknown | |
| Cad | Oloff | Senegal | Saint Louis | Makhana |
| Camudo | Bijago | Guinea Bissau | Formosa | Sae |
| Condenso | Ajaua | Mozambique | Rovuma | Lugenda river |
| Dhahamo | Mbulu | Tanzania | Unknown | Mbulu |
| Dzumgua | Sena | Mozambique | Sofala | |
| Edruknet | | Uganda | Northern | Kangole |
| Esanya (plant) | Turkana | Kenya | Northern Frontier | Katilo |
| Espinheiro branco | Portugese | Cape Verde | Ilha de Santiago | Belem |
| Garabi | Somali | Somalia | Woqooyi Galbeed | Dila |
| Garbi | Gallinia | Ethiopia | Shewa | Arussi |
| Gawo | Hausa | Nigeria | Kano | Kano |
| Gawo | Hausa | Nigeria | Zaria | Zaria |
| Haraz | Arabic | Sudan | Unknown | El Shellab, Garsila, Shendi |
| Ikese | Kitongwe | Tanzania | Mpanda | Mahali mountains |
| Messango | | Mozambique | Niassa | Maniamba |
| Mgunga | Pare | Tanzania | Tanga | Gonja Maore |
| Mokosho | Setswana | Botswana | Central | Nata river |
| Molele | | Mozambique | Gaza | Canicado |
| Mpogoro | Hehe | Tanzania | Unknown | Mporogoro |
| Mpumbu | Ndebele | Zimbabwe | Nyamandhlovu | Maintengwe Dam |

(continued)

**APPENDIX 1.** (continued)

| Common name | Language | Country | Region | Gazetteer |
|---|---|---|---|---|
| Msangu | Chichewa | Malawi | Dedza | Mua Livulezi Forest |
| Msangusangu, Msangus | Tumbuka | Malawi | Mzimba | Lake Kazumi |
| Mu he | Mundimba | Angola | Huila | Chitado |
| Mucuampongue | Mulondo | Angola | Huila | Mulondo |
| Mujehe | | Tanzania | Central | Mvumi |
| MuKosho | | Botswana | Central | |
| Munhele | Mumuila | Angola | Huila | Huila |
| Munhele | Muhumbe | Angola | Huila | Namuculungo, Mulondo |
| Munhele, Omuhe-muhe | Muila, Mucubal | Angola | Mocamedes | Caitou |
| Munhem | Cuando | Angola | Mocamedes | Lucira |
| Musangu | Chikanga | Zambia | Southern | Sikasondasima |
| Mutsangu | | Zimbabwe | Hurungwe | Rekomechi/Zambezi con |
| N'sango | Sena | Mozambique | Tete | Pandocane |
| Nunhere | Cuanhama | Angola | Huila | Preira d'Eca |
| Nzungua | Sena | Mozambique | Manica e Sofala | Rio Urema |
| Omuene, omunhe | Mundimba | Angola | Cunene | Chicusse |
| Sangak | | Kenya | Turkana | Sigor |
| Sango | Tete | Mozambique | Tete | Chioco |
| Sangoa | | Mozambique | Tete | Tambara |
| Seshwa | Elgeyo | Kenya | Rift valley | Chesoi |
| Tadecka | Gallinya | Ethiopia | Shewa | Maki |
| umPumbu | Ndebele | Zimbabwe | Hwange | Chimwara ranch |
| Ussimpulo | Papel | Guinea Bissau | Bissau | Bissalanca |
| White Rashia | | Cyprus | Papho | |
| Zizano | Kassena | Ghana | Unknown | Navrongo |

**APPENDIX 2.** Herbarium specimen list for *Faidherbia albida* (Del.) A. Chev.

**ANGOLA.** Baixo Cunene, **Chiepeque** (17 Jul 1970), *Mendes Dos Santos R et Barroso E 2753, (LISC);* Benguela, *12° 06'S 15° 17'E* (1910), *Gossweiler J 3624, (K, LISC);* (1910), *Gossweiler J 1709, (K);* **Benguela** *12° 40'S 13° 27'E* (19 Feb 1974), *Dechamps R Murta F & Da Silva M 1116, (LISC);* **Benguela** (1910), *Gossweiler J 1719, (K);* Cunene, **Chicusse** (13 Jun 1971), *Borges A 280, (LISC, SRGH);* **Chiepeque** (17 Jul 1970), *Dos Santos R & Barroso E 2753, (SRGH);* Huila, (1900), *Antunes Vel Dekindt 930, (LISC);* **Bandeira** *14° 01'S 15° 11'E* (Aug 1937), *Humbert N 16303, (P);* **Chitado** (15 Jan 1962), *Menezes A et Henriques C 13, (LISC);* **Forte Rocadas** *16° 43'S 15° 01'E* (2 Jun 1937), *Gossweiler J 11031, (K);* **Huila** *15° 04'S 13° 33'E* (16 Dec 1956), *Teixeira JB 1687, (LISC);* **Inha** (14 Nov 1959), *Teixeira e Figueira 3952, (LISC);* **Mucope** (28 Nov 1963), *Henriques C 259, (K, LISC, SRGH);* **Mulondo** *15° 39'S 15° 14'E* (21 Nov 1963), *Azancot De Menezes 781, (K, LISC, SRGH);* **Mulondo** *15° 39'S 15° 14'E* (25 Jun 1965), *Azancot De Menezes 1785, (LISC);* **Namuculungo** (14 Jun 1957), *Teixeira JB 2445, (LISC);* **Namuculungo** (23 Oct 1956), *Teixeira JB 1414, (LISC);* **Preira d'Eca** (4 Apr 1960), *Grandvaux Barbosa & Correia Rui 9022, (LISC, SRGH);* Loanda, **Cazengo** (1911), *Gossweiler J 4932, (K);* Mocamedes, **Assuncao** (12 Sep 1955), *Mendes EJ 54, (LISC);* **Assuncao** (11 Sep 1955), *Mendes EJ 366, (LISC);* **Bibala** (10 Sep 1951), *Teixeira JB 470, (LISC);* **Bibala** (18 Jun 1959), *Teixeira e Andrade 4001, (LISC);* **Bruco** (30 Nov 1955), *Mendes EJ 930, (LISC);* **Caitou** (Sep 1956), *Teixeira JB 1300, (LISC);* **Camucuio** (1 Sep 1959), *Teixeira e Andrade 447?, (LISC);* **Capangombe** (Jul 1956), *Teixeira JB 980, (LISC);* **Iona** (15 Oct 1968), *Brito Teixeira J et al 12756, (LISC);* **Lucira** (5 Aug 1967), *Menezes A Henriques C et Brites M 3027, (LISC, SRGH);* **Montipa** (19 Jun 1959), *Teixeira & Santos 3851, (LISC);* **Pirangombe** (28 Mar 1956), *Teixeira JB 780, (LISC);* **Pirangombe** (28 Mar 1956), *Teixeira JB 779, (LISC);* **Porto Alexandre** (30 Dec 1955), *Mendes EJ 1190, (LISC);* **Posto de Munihiero** (23 Jul 1956), *Torre AR 8280, (LISC);* **Vila Arriaga** (10 Jun 1959), *Teixeira e Andrade 4087, (LISC, SRGH);* Unknown, (1800), *Welwitsch SN, (P);*

**BOTSWANA.** Central, *23° 29'S 27° 14'E* (3 Sep 1988), *Barnes RD 529,* **Mahalapye** *23° 07'S 26° 52'E* (18 Jun 1978), *Camerik AM 244, (PRE);* **Makarikari basin** (Aug 1930), *Van Son G TM 28876, (PRE);* **Martins Drift** (Jun 1962), *Yalala AM 167, (K, SRGH);* **Nata** *20° 11'S 26° 13'E* (19 Sep 1988), *Barnes RD 539,* **Nata river** *20° 15'S 26° 00'E* (9 Apr 1983), *Smith PA 4221, (SRGH);* **Nata river delta** (21 Apr 1976), *Ngoni JF 523, (K, PRE, SRGH);* **Baines Drift** *22° 30'S 28° 36'E* (16 Dec 1976), *Mott PJ 1052, (SRGH);* **Baines Drift** *22° 30'S 28° 36'E* (12 Oct 1978), *Timberlake & Kabelo 1809, (SRGH);* Chobe, **Kazungula** (15 Jun 1944), *Kokot D 1, (PRE);* **Makalamabede** *20° 18'S 23° 53'E* (1 Sep 1962), *Yalala AM 226, (K, SRGH);* **Nyungwe Hot Springs** (2 Aug 1950), *Robertson & Elffers 100, (K, PRE);* **Panda forest** (May 1986), *Mutakela ML 50, (SRGH);* Kgatleng, **Mochudi** *24° 10'S 26° 05'E* (Feb 1914), *Harbor CC 6610, (FHO, K);* **Mochudi** *24° 22'S 26° 07'E* (Aug 1914), *Harbor WAH TM 14094, (PRE);* **Mochudi** *24° 10'S 26° 07'E* (Jan 1914), *Rogers FA 6610, (K, PRE);* Ngamiland, **Kachikan** (11 Jul 1937), *Erens J 392, (K, PRE);* **Katima Mulilo** (25 Nov 1972), *Smith PA 288, (K, SRGH);* **Okavango** *18° 20'S 21° 52'E* (19 Feb 1979), *Smith PA 2694, (K, PRE, SRGH);* **Samocina camp** (29 Apr 1975), *Muller & Biegel 2291A, (SRGH);* **Shakawe river** *18° 20'S 21° 52'E* (6 Oct 1973), *Smith PA 716, (PRE, SRGH);* **Xaoga** *18° 30'S 21° 54'E* (22 Feb 1979), *Smith PA 2715, (K, PRE, SRGH);*

**BURKINA FASO.** Centre, **Ouagadougou** (7 Aug 1910), *Chevalier A 24676, (P);* **Tin Akof** (Dec 1970), *Gaston A 2864, (P);* Unknown, **Koua** *11° 10'N 4° 16'W* (5 Dec 1963), *Mariaux A 415, (P);* **Ziga** (7 Jun 1962), *Leeuwenberg AJM 4383, (K);*

**BURUNDI.** **Rusizi plaine** *3° 15'S 29° 17'E* (6 Jun 1977), *Reckmans M 6345, (EA, K);*

**CAMEROON.** Benoue, **Natsari** *8° 40'N 14° 01'E* (7 Mar 1933), *Lhote H 87, (P);* **Ouro Haoussas** *9° 22'N 13° 34'E* (16 Dec 1964), *Raynal J & A 12564, (P);* Diamare, **Waza** *10° 21'N 14° 20'E* (23 Nov 1969), *Hepper FN 3989, (K, P);* Dikwa, **Bara** *5° 32'N 9° 43'E* (24 Dec 1954), *McClintock A 116, (K, P);* Logne et Chari, **Ft. Foureau** (May 1939), *Jacques Felix H 3682, (P);* Magdeme, (23 Jan 1966), *Leeuwenberg AJM 7499, (K, LISC);* Unknown, (1938), *Jacques Felix H 1147, (P);* **Tchastei** (20 Mar 1954), *Recherchs Forestieres Du Cameroun 19229, (P);*

**CAPE VERDE.** Ilha de Fogo, **Brandao** (4 Nov 1985), *Cardoso De Matos 6013, (LISC);* **Pico da Veiga** (12 Jan 1956), *Barbosa G 6314, (LISC);* Ilha de Maio, **Alcatraz** (11 Nov 1964), *Malato-Beliz & Guerra 253, (LISC);* Ilha de Santiago, **Achada Palmarejo** (3 Nov 1988), *Cardoso De Matos 6351, (LISC);* **Belem** (13 Mar 1983), *Barbosa LG & Magalhaes 14432, (ISC);* **Caniche** (21 Mar 1961), *Barbosa G 9200, (LISC);* **Praia** (23 Jun 1934), *Chevalier A 44498, (P);* Ilha de Santo Antao, (1900), *Cardoso J A, (COI);* **Ilha de Santo Antao** (Sep 1893), *Cardoso J Junior 18, (LISU);* **Santa do Sol** (Jul 1887), *Cardoso J s.n., (COI);* Ilha de Sol, **Algodoerio** (1934), *Chevalier A 44304, (P);*

**CHAD.** Chari Baguirmi, **Hadjer el Hamiz** *12° 51'N 14° 50'E* (2 May 1935), *Zolotarevsky B Murat M Dupont L M 14, (P);* **Hadjer el Hamiz** *12° 51'N 14° 50'E* (2 May 1935), *Zolotarevsky B Murat M Dupont L M 15, (P);* Guera, **Ogol** *11° 07'N 18° 47'E* (15 Dec 1968), *Fotius 1310, (P);* Kanem, **Mondo** *13° 47'N 15° 32'E*

(4 Feb 1964), *Mosnier 1962, (P);* **Mayo Kebbi, Folmaye** *9° 57'N 15° 11'E* (11 Jan 1968), *Gaston A 1448, (P);* **Moyen Chari, Moussoro** *8° 26'N 18° 15'E* (19 Jul 1964), *Gaston A 88, (P);* **Ouaddai, Foundou** *14° 08'N 20° 44'E* (16 Nov 1979), *Klein D 129, (P);*

**CYPRUS. Papho,** (24 Sep 1933), *Foggie A 314, (FHO);* **Unknown,** (6 May 1934), *Foggie A 327, (FHO);* **Khrysokhou valley** (Aug 1900), *Lascelles AG & Lescelles ME 8/00, (K);* **Khrysokhou valley** (1964), *Forestry Dept Nicosia SN, (K);* **Paphos** (6 May 1934), *Chapman E 145, (K);* **Polis Tis Chrysochou** (12 Jun 1934), *Syngrassides AI 843, (K);* **Skoulli** (28 Oct 1981), *Meikle RJ 5024, (K);*

**EGYPT. Aswan, Aswan** (9 Nov 1926), *Drar M 4221, (K);* **Aswan** (31 Jan 1917), *Walsingham FG 36, (K);* **Aswan** (14 Nov 1916), *Walsingham FG 35, (K);* **Saluga island** (7 Dec 1943), *Davis PH 6016B, (K);* **Saluga island** (10 Dec 1943), *Davis PH 6056B, (K);* **Saluga island** (10 Dec 1943), *Davis PH 6068B, (K);* **Siheil Island** (14 Feb 1927), *Simpson ND 4449, (K);* **Unknown,** (20 Mar 1881), *Cosson M 5/83, (K);* (1829), *Baddi J SN, (K);* (1846), *Pinard SN, (K);* (1881), *Letourneux A sn, (OXF);* **Abu Simbal** (14 Mar 1963), *Sa'ad F 1546, (K);* **Abu Simbal** *22° 19'N 31° 38'E* (7 Feb 1963), *Hepper FN 3026, (K);* **Tauhah** (27 Apr 1910), *Muschler R 2.06, (K);* **Wadi Eigat** (Jan 1963), *Tackholm V & Kassas et al 161, (K);*

**ERITREA.** (24 Oct 1896), *Bent J TH SN, (K);* **Beni Amer** (6 Nov 1902), *Pappi A 389, (K, P);* **Sahada Custan** (26 May 1902), *Pappi A 391, (EA, K, P);*

**ETHIOPIA. Gamo Gofa,** (22 Dec 1981), *Mesfin T & Tewolde BGE 2820, (ETH);* **Arba Minch** (29 Dec 1981), *Tadesse M & Tewolde BGE 2820, (ETH);* **Gojam, Gojjam** (2 Jan 1976), *Getahun A 160, (ETH);* **Gondar, Chengaye** *12° 23'N 37° 35'E* (22 Jul 1988), *Friis I & Lawesson J 5373, (ETH);* **Maksagnit** (9 Jul 1989), *Mercier 1831, (ETH);* **Harerge,** *9° 00'N 42° 20'E* (17 Dec 1976), *Corra M JF 32A, (ILCA); 9° 36'N 43° 18'E* (20 Jun 1976), *Le Houerou HN 01A, (ILCA); 9° 03'N 43° 00'E* (17 Dec 1976), *Corra M 32, (EA, ILCA); 9° 03'N 43° 18'E* (20 Jun 1976), *Le Houerou HN 20 06 76, (EA);* **Bedeno Awraja** (16 Feb 1990), *Demel & Assefa 959, (ETH);* **Dire Dowa** (Jan 1958), *Imperial Ethiopian College AX3, (EA);* **Togo-Wouchale** *9° 36'N 43° 18'E* (20 Jun 1976), *Le Houerou HN 20-6-76 01, (ILCA);* (18 Jan 1987), *Tekelay Demel 207, (ETH);* **Idli valley** *9° 11'N 42° 24'E* (13 Jul 1963), *Burger W 3018, (K);* **Idli valley** *9° 11'N 42° 24'E* (21 Jul 1961), *Burger W & Getahun A 341, (K);* **Shewa,** *8° 27'N 39° 14'E* (17 Feb 1993), *Fagg CW 605, (FHO, ILCA);* **Alem tena** *7° 10'N 39° 00'E* (24 Dec 1980), *Kahurananga J & Abdul Kadir A 3722, (ILCA);* **Arussi** *7° 50'N 38° 50'E* (Aug 1976), *Alemayehu Haile 1096, (ETH, K);* **Debre Zeit - ILCA station** *8° 44'N 38° 58'E* (15 Oct 1976), *Boulos L 9966, (EA, ILCA);* **Lake Zuai** (8 Mar 1944), *Bally PRO 3124, (EA);* **Maki** *8° 10'S 38° 50'E* (16 Jun 1968), *Desta Hundessa 61, (EA);* **Addis Ababa** (15 Jul 1953), *Mooney HF 5106, (K);* **Sidamo,** *5° 15'N 39° 45'E* (9 May 1980), *Thulin M Hunde A & Tadesse M 3474, (K);* **Awasa** (19 May 1966), *De Wilde WJJ & De Wilde-Duyfjes BE 11031, (K);* **Awassa** *7° 00'N 39° 00'E* (17 Jan 1977), *Froment D SN, (EA, ILCA);* **Awassa** *7° 05'N 39° 30'E* (15 Aug 1971), *Ash J 1109, (K);* **Mega** *4° 02'N 38° 20'E* (26 Sep 1980), *Kahurananga J 2938, (ILCA);* **Tigray,** (24 Oct 1991), *Tadesse Mesfin 8571, (ETH); 14° 24'N 38° 47'E* (), *Fagg CW 611, (FHO, ILCA);* **Adoam** (1 Dec 1837), *Schimper 33, (K, OXF, P);* **Adowa** *14° 10'N 38° 54'E* (1844), *Quartin-Dillon & Petit 80, (P);* **Adowa** (1839), *Quartin-Dillon & Petit sn, (P);* **Adowa** (1 Dec 1837), *Schimper MW 1813, (P);* **Adowa** (1 Dec 1837), *Schimper MW 33, (P);* **Unknown,** (1858), *Schimper MW 12, (P);* (18 May 1856), *Schimper MW 1679, (P);* **Nil Blanc** (1840), *D'Arnaud sn, (P);* **Welo,** (26 Nov 1988), *Tadesse Mesfin 7087, (ETH); 12° 12'N 39° 37'E* (21 Feb 1993), *Fagg CW 606, (FHO, ILCA);* **Tis - Aba- Lima** (25 Oct 1987), *Tadesse Mesfin 6302, (ETH);* **Yegof mountain** (29 Oct 1987), *Tadesse Mesfin 6626, (ETH);*

**GAMBIA. Unknown,** (28 Feb 1921), *Dawe 80, (FHO, K);* **Kombo** (7 Feb 1984), *Lock & Boonmalison 84/14, (K);*

**GHANA. Navrongo** (Nov 1938), *Vigne C 4658, (K, P);* **Navrongo** (Apr 1935), *Vigne C 4758, (FHO);* **Tokali** (1 Mar 1927), *Kitson A 713, (K);* **Wogu village** *10° 24'N 2° 23'W* (2 Nov 1958), *Rose Innes R 30795, (K);*

**GUINEA BISSAU. Bafata, Dandum** (3 Nov 1932), *Espirito Santo 256, (LISC);* **Bissau, Bissalanca** (11 Jan 1945), *Espirito Santo 1634, (K, LISC, P);* **Bissalanca** (1972), *Sanguineo C Dr s.n., (LISC);* **Formosa, Sae** (27 Apr 1945), *Espirito Santo 1981, (K, LISC, P);* **Mansoa, Mansoa** (30 Dec 1960), *Alves Pereira J 1112, (LISC);* **S. Domingos, Cabo Roxo** (25 Jan 1955), *Espirito Santo 3254, (LISC);* **Unknown, Pecixe** (7 Nov 1962), *Alves Pereira J 3461, (LISC);*

**IVORY COAST. Nord, Barana** *7° 49'N 6° 28'W* (May 1932), *Aubreville M 1443, (P);*

**KENYA. Coast, Lake Chala** *3° 19'S 37° 42'E* (1966), *Gilbert VC D62, (EA);* **Masai, Kajiado** *1° 51'S 36° 47'E* (1900), *Bainbridge WR B60/60, (EA);* **Northern Frontier, Katilo** (4 Dec 1978), *Hughes P 61, (EA);* **Rift valley, Chesoi** *1° 04'N 35° 36'E* (31 Aug 1992), *Fagg CW 589, (EA, FHO);* **Naivasha** (Sep 1933), *Van Someren 2721, (EA);* **Taita, Taveta** *3° 24'S 37° 42'E* (7 Sep 1992), *Fagg CW 595, (EA, FHO);* **Turkana, Kakuma** *3° 43'N 34° 52'E* (Dec 1978), *Ohta I 9, (EA);* **Kiriamet** *1° 29'N 35° 03'E* (Jan 1962), *Tweedie 2288, (EA);* **Lokori** *1° 57'N 36° 06'E* (10 Aug 1970), *Gwynne MD SN, (EA);* **Sigor** *1° 30'N 35° 29'E* (Aug 1974), *Museums KN 193, (EA);* **Unknown,** *1° 48'S 36° 04'E* (11 Mar 1993), *Fagg CW 631,*

*(EA, FHO);* **Kalemma** (Sep 1933), *Glover PE & Cooper MG 3521, (EA);* **Rombo** (10 Oct 1973), *Mumiukha P 244, (EA);* **Rombo** *1° 47'S 36° 02'E* (13 Dec 1970), *Horne J Mrs 1, (EA);*

**MALAWI.** **Blantyre,** *15° 36'S 34° 48'E* (6 Dec 1988), *Fagg CW 445, (FHO); 15° 24'S 34° 56'E* (7 Nov 1989), *Fagg CW 475, (FHO);* **Chikwawa,** *16° 10'S 34° 46'E* (1 Nov 1989), *Fagg CW 467, (FHO);* **Mwanza river** *16° 10'S 34° 46'E* (15 Nov 1991), *Fagg CW 561, (FHO);* **Pradze river** (29 May 1959), *Young A 30, (MAL);* **Chitipa, Chipome valley** *10° 17'S 33° 45'E* (19 Aug 1972), *Synge AHM WC 268, (K, MAL, SRGH);* **Dedza, Mua** *14° 17'S 34° 31'E* (1 Sep 1965), *Banda EA 656, (MAL, SRGH);* **Mua Livulezi Forest reserve** *14° 23'S 34° 32'E* (24 Apr 1964), *Banda EA 584, (LISC, MAL, SRGH);* **Mua Livulezi Forest reserve** *14° 23'S 34° 32'E* (9 Mar 1985), *Salubeni & Kaunda 4017, (MAL);* **Karonga,** *9° 55'S 33° 53'E* (22 Oct 1989), *Fagg CW 462, (FHO); 10° 16'S 34° 02'E* (Jun 1896), *Whyte ??, (K);* **Lilongwe, Lilongwe Nature Sanctuary** (9 Nov 1984), *Patel Salubeni & Banda 1672, (MAL);* **Machinga,** *14° 59'S 35° 13'E* (3 Dec 1988), *Fagg CW 441, (FHO);* **Liwonde** *15° 03'S 35° 13'E* (5 Jul 1986), *Balaka & Kaunda 1629, (MAL);* **Mwanza, Kasamba village** *15° 20'S 34° 48'E* (11 Aug 1984), *Balaka Tawakali Nchamba 528, (MAL);* **Mzimba, Lake Kazumi** *11° 08'S 33° 38'E* (17 Oct 1973), *Pawek J 7394, (DSM, K, MAL, SRGH);* **Nsanje,** *17° 02'S 35° 19'E* (Jul 1859), *Kirk OK ??, (K);* **Rumphi,** *10° 58'S 33° 43'E* (24 Oct 1989), *Fagg CW 464, (FHO);* **Runyina river bridge** *11° 10'S 33° 46'E* (20 May 1970), *Brummitt RK 10931, (K, MAL, SRGH);* **Salima, Chipoka** *13° 59'S 34° 31'E* (26 Jul 1978), *Salubeni AJ 2288, (MAL);* **Nfunde river** (15 Jun 1985), *Kwatha Salubeni & Kaunda 218, (MAL);* **Salima** (12 Aug 1970), *Hall Martin AJ 927, (SRGH);* **Unknown, Mtile** (Oct 1930), *Tophamii 688, (MAL);* **Palm Beach** *14° 18'S 35° 13'E* (16 Jul 1962), *Leach LC & Schelpe EA 11391, (K, SRGH);* **Shire river** (6 Jun 1938), *Pole Evans IB & Erens J 576, (K, P, SRGH);* **Zomba, Kachoka research station** *15° 23'S 35° 34'E* (1 Jun 1970), *Brummitt & Williams 11204, (K, MAL, SRGH);*

**MALI.** **Gao,** (19 Jan 1936), *Wailly M De 5401, (P);* **Hamgoundji** *17° 03'N 1° 08'W* (Feb 1915), *Gironcourt De 73, (P);* **Hariboro** (21 Nov 1935), *Wailly M De 4912, (P);* **Tachdait** *18° 44'N 0° 53'E* (27 Feb 1964), *Chudeau M SN, (P);* **Tombouctou** (22 Jan 1928), *Mission Saharienne Augieras Draper 20610, (P);* **Kayes, Kita** *13° 03'N 9° 29'W* (17 Oct 1934), *Dubois R 213, (K, P);* **Mopti, Korioume** *16° 40'N 3° 02'W* (19 Jul 1899), *Chevalier A 1190, (P);* **Korioume** *16° 40'N 3° 02'W* (15 Jul 1899), *Chevalier A 1191, (P);* **Segou, Sansanding** (28 Sep 1899), *Chevalier A 3378, (P);* **Segou** (1899), *Chevalier A 3377, (P);* **Segou** (5 Oct 1937), *Roberty G 3026, (P);* **Sikasso, Sanga** (14 Jan 1938), *Ganay S De 7, (P);* **Unknown,** (16 Feb 1915), *Gironcourt De 179, (P);* (20 Oct 1935), *Wailly M De 4843, (P);* (Apr 1945), *Irvine FR 3200, (FHO);* **Songhai** (31 Aug 1899), *Chevalier A 3373, (P);*

**MAURITANIA.** **Brakna, Bogue** (27 Jan 1908), *Chudeau M sn, (P);*

**MOZAMBIQUE.** **Cabo Delgado, Macondes** (20 Sep 1948), *Barbosa 2227, (K);* **Gaza,** (11 Apr 1972), *Myre Lousa et Rosa 5751, (LMA);* **Canicada** (8 Jul 1969), *Correia MF & Marques A 938, (COI, LMU, SRGH);* **Canicado** (20 May 1948), *Torre AR 7885, (COI);* **Guija** (6 May 1944), *Torre AR 6581, (K, LISC);* **Lagoa Nova** (25 Jul 1969), *Correia MF & Marques A 1071, (COI, LISC, LMU, SRGH);* **Massingir** (26 Jun 1980), *Schafer PA 7159, (K);* **Muianga** (Jul 1948), *Torre AR s.n., (LISC);* **Limpopo, Limpopo** (Jul 1939), *Smuts JC 2195, (K);* **Manica e Sofala, Ilha da Inhangoma** (7 Jul 1949), *Grandvaux Barbosa & Carvalho MF 3764, (SRGH);* **Rio Urema** (1 May 1964), *Torre AR & Paiva J 12195, (LISC);* **Ilha de Inhangoma** (27 Jul 1949), *Grandvaux Barbosa & Carvalho MF 3764, (K, LMA);* **Maputo, Macaene** (24 Jun 1969), *Correia MF & Marques A 824, (COI, LISC, LMU);* **Magude** (12 May 1941), *Torre AR 2647, (LISC, LMA);* **Sabie** (2 May 1944), *Torre AR 6548, (LISC, SRGH);* **Sabie** (7 Jun 1948), *Torre AR 7950, (LISC);* **Sabie** (16 Feb 1948), *Torre AR 7333, (LISC);* **Umbeluzi** (25 Sep 1968), *Balsinhas A 1322, (LISC, LMU);* **Umbeluzi** (28 Jul 1965), *Carvalho De MF 771, (LISC);* **Umbeluzi** (17 Jun 1968), *Myre M e Rosa N 4920, (LMA, LMU);* **Niassa, Maniamba** (10 Oct 1942), *Mendonca FA 767, (LISC);* **Nairoto** (20 Sep 1948), *Andrada 1378, (COI);* **Nairoto** (20 Sep 1948), *Barbosa G 2227, (LISC);* **Mueda** *11° 45'S 39° 40'E* (20 Sep 1948), *Grandvaux Barbosa LA 2227, (LMA);* **Mueda** *11° 45'S 39° 40'E* (17 Sep 1948), *Pedro & Pedrogao 5265, (LMA);* **Nuanetsi river,** (Jul 1932), *Smuts JC P326C, (K);* **Rovuma, Lugenda river** *11° 20'S 38° 30'E* (10 Nov 1959), *Gomes A e Sousa 4512, (COI, K, SRGH);* **Sofala,** (6 Nov 1963), *Torre AR & Paiva J 9077, (LISC);* **Canxixe** (5 Jul 1947), *Simao J 1376, (LMA);* **Chilamo** (Jul 1907), *Braga C 93, (COI);* **Sulo do save,** (4 Jun 1947), *Pedrogao J 240, (COI, K, LISJC);* **Tete, Ancuaze** (19 Jun 1949), *Barbosa G e De Carvalho MF 3162, (K, LISJC, LMA, SRGH);* **Changara** (18 Aug 1943), *Torre AR 5773, (LISC);* **Chioco** (31 Oct 1965), *Myre M e Rosa N 4758, (LMA);* **Chioco** (26 Sep 1942), *Mendonca FA 449, (LISC);* **Kaimba island** (1860), *Kirk J SN, (K);* **Magoe** (18 Feb 1970), *Torre AR & Correia MF 18028, (LISC);* **Mutarara** (25 Nov 1971), *Haffern JK 109, (SRGH);* **Pandocane** (19 Jun 1949), *Andrada 1608, (LISC);* **Rio Mazoe** (17 May 1966), *Neves Rosa F 268, (LISC);* **Rio Sanangoe** (28 Mar 1972), *De Aguiar Macedo JM 5108, (K, LISC, SRGH);* **Sinjal** (16 Aug 1947), *Simao J 1485, (LISC);* **Tambara** (24 Sep 1949), *Pedro & Pedrogao 8359, (LISC);* **Tete** *18° 38'S 35° 13'E* (21 Jun 1966), *Myre M e Rosa N 4857, (LMA);* **Unknown,** (Jul 1932), *Smuts JC P326B, (K);* **Zambezia,** (21 May 1943), *Torre AR 5349, (K, LISC, LMA);*

**NAMIBIA.** **Caprivi,** **Caprivi strip** (Oct 1945), *Curson HH 1185, (PRE);* **Lisikili** (17 Sep 1952), *Codd LEW 7100, (K, PRE);* **Nakabolelo district** *17° 52'S 24° 52'E* (27 Aug 1969), *Macferren D 82, (PRE);* **Damaraland,** *22° 00'S 15° 35'E* (27 Aug 1989), *Barnes RD 2056, (FHO, PRE, SRGH); 21° 19'S 15° 23'E* (28 Aug 1989), *Barnes RD 2061, (FHO, PRE, SRGH); 20° 52'S 14° 57'E* (28 Aug 1989), *Barnes RD 2064, (FHO, PRE, SRGH); 20° 21'S 14° 12'E* (28 Aug 1989), *Barnes RD 2065, (FHO, PRE, SRGH); 19° 10'S 13° 45'E* (30 Aug 1989), *Barnes RD 2071, (FHO, PRE, SRGH);* **Sesfontein** (10 Jul 1951), *Hall HM 497, (PRE);* **Tsoaxaub** (30 Nov 1885), *Schenck A 456, (PRE);* **Kaokoland,** **Etanga** *17° 52'S 13° 07'E* (8 Apr 1957), *De Winter B & Leistner 5455, (PRE, WIND);* **Hoanib river** *19° 14'S 13° 23'E* (2 Dec 1992), *Fagg CW & Maggs GL 73, (FHO, WIND);* **Kunene river** *17° 15'S 12° 26'E* (16 Aug 1956), *Story R 5803, (FHO, PRE, WIND);* **Okangwati** *17° 25'S 13° 17'E* (30 Nov 1992), *Fagg CW & Maggs GL 71, (FHO, WIND);* **Ombazu** (28 May 1957), *De Winter B & Leistner 5895, (PRE, WIND);* **Omuhonga river** *17° 22'S 13° 07'E* (16 Jul 1976), *Leistner Oliver Steenkamp Vorste 197, (PRE, SRGH);* **Otjinhungwa Kunene** *17° 15'S 12° 26'E* (25 Nov 1992), *Fagg CW & Maggs GL 27, (FHO, WIND);* **Otjinhungwa Kunene** *17° 14'S 12° 26'E* (26 Nov 1992), *Fagg CW & Maggs GL 29, (FHO, WIND);* **Otjinungua** *17° 07'S 12° 22'E* (15 Sep 1968), *Giess W 10512, (PRE, WIND);* **Karibib,** **Ameib farm** (1965), *Giess W 8457, (WIND);* **Otjimbingue** (May 1886), *Marloth RH 1124B, (PRE);* **Swakop rivier** (1900), *Le Roux PJ 916, (WIND);* **Swakop rivier** (May 1886), *Marloth RH 1194, (OXF);* **Usakos** (15 Aug 1919), *Pole Evans IB H19303, (PRE);* **Wilsonfontein** *22° 37'S 15° 37'E* (Jul 1975), *Watmough R 894, (PRE);* **Okahandja,** **Gross Barmen** (1900), *Gibson G 133, (WIND);* **Okahandja** (1900), *Dinter D 7800, (WIND);* **Outjo,** **Sorris-sorris** (11 Apr 1955), *De Winter B 3151, (PRE, WIND);* **Owambo,** **Ruacano** (1900), *Kotze TJ 8, (WIND);* **Ruakana falls** *17° 22'S 14° 07'E* (29 Apr 1962), *Kotze T 8, (PRE, WIND);* **Swakopmund,** **Gaub river valley** *23° 22'S 15° 52'E* (11 May 1976), *Oliver & Muller 6573, (PRE);* **Goanikontes** (1900), *Craven P 2414, (WIND);* **Gonekontes** (15 Jan 1929), *Bradfield RD 553A, (PRE);* **Kuiseb delta** *23° 07'S 14° 22'E* (10 Jan 1979), *Ward CJ 9239, (PRE, WIND);* **Kuiseb river** *23° 22'S 15° 52'E* (21 Aug 1977), *Brink E 564, (PRE);* **Kuisebrivier** *23° 22'S 14° 52'E* (Jul 1977), *Theron GK 3715, (PRE, WIND);* **Swakop** *22° 37'S 14° 37'E* (25 Oct 1980), *Evrard C 9254, (PRE);* **Swakop district** (10 Aug 1948), *Farmers Association 313, (PRE); 23° 20'S 15° 47'E* (23 Aug 1989), *Barnes RD 2041, (FHO, PRE, SRGH); 23° 34'S 15° 02'E* (24 Aug 1989), *Barnes RD 2048, (FHO, PRE, SRGH);* **Unknown,** (2 Sep 1962), *Seydel R 3168, (EA, ILCA, SRGH);* **Haikamchab** (26 Jan 1907), *Pearson & Galpin 7609, (PRE);* **Otjitambi** (1900), *Walter H et E 1040, (WIND);* **Windhoek,** **Kuiseb** *22° 52'S 16° 37'E* (18 Sep 1971), *Balsinhas A & Kersberg H 2001, (PRE, WIND);* **Kuiseb** *22° 52'S 16° 37'E* (6 Jul 1950), *Strey RG 2635, (PRE);* **Otjisewa farm** (28 Dec 1947), *Wiss HJ & Kinges H 750, (PRE);* **Rostock-south reh 41** *23° 22'S 15° 52'E* (19 Jun 1964), *Giess W 8229, (PRE, WIND);*

**NIGER.** **Air mountains,** **Greboun wadi** (11 Mar 1970), *Bradley PN 40, (K);* **Filingue,** **Tarkannous** (1900), *Bartha R 108, (K);* **Tahoua,** **Birni N'Koni** *13° 48'N 5° 15'E* (16 Dec 1935), *Wailly M De 4939, (P);* **Unknown,** (31 Jan 1928), *Mission Saharienne Augieras Draper 673, (P);* **Azanyares** *19° 49'N 9° 17'E* (14 Mar 1979), *Newby JE ZP31, (K);* **Matankari** (30 Oct 1968), *Boudet G 5353, (P);* **Yobe** (17 Apr 1963), *White F 8906, (FHO);* **Zinder,** **Zinder** *13° 48'N 8° 59'E* (18 Nov 1964), *Peyre De Fabreues B 1171, (P);*

**NIGERIA.** **Benue Plateau,** **Zanwa** (21 May 1974), *Okeke Latilo & Odewo FHI 69303, (K);* **Bornu,** **Komadufu Waube** (9 Dec 1904), *Eliott R 142, (K);* **Ibadan,** **Ibadan aerodrome** (23 Jun 1973), *Jackson G 2/23673, (FHO);* **Kano,** **Kano** (Mar 1909), *Dudgeon GC 4, (K);* **Katsina,** **Katsina** (22 Feb 1950), *Meikle RD 1214, (K);* **Maiduguri,** **Maiduguri** (1936), *Kennedy JD 2978, (FHO);* **Northern,** **Katagum** (1908), *Dalziel JM 53, (K, P);* **Sokoto** (1900), *Dalziel JM 314, (K, P);* **Sokoto,** **Fafara river** (14 Apr 1946), *Keay RWJ FHI 15670, (FHO);* **Sokoto** (Dec 1935), *Kennedy JD 2840, (FHO);* **Unknown,** **Zing** (2 Feb 1976), *Chapman JD 4080, (FHO, K);* **Zaria,** **Zaria** (17 May 1930), *MacGregor WD 467, (FHO);*

**OMAN.** **Unknown,** **Jebel qara** *17° 14'N 54° 06'E* (29 Jan 1986), *Lawton RM 2563, (K);*

**PALESTINE.** **Lower Galilee,** **Shimron** (31 Aug 1945), *Zohary M 6309, (K);* **Tel Aviv,** **Tel Aviv hospital** (10 Nov 1925), *Herbarium Palestinum sn, (FHO);* **Unknown,** **Beisan - Samakh** (11 Oct 1931), *Shinuely 6, (K);* **Kabbara** (15 Jun 1943), *Zohary M 6305, (K);*

**SAUDI ARABIA.** **Baljurshi** (14 Mar 1985), *Collenette JS 5164, (K);* **Baljurshi** (17 Oct 1983), *Collenette JS 4640, (K);*

**SENEGAL.** **Dakar,** **Dakar-Pointe de** *14° 40'N 17° 25'W* (6 May 1960), *Raynal J & A 5785, (P);* **Kolda,** **Salikenie** *12° 51'N 15° 33'W* (24 Jan 1931), *Trochain J 1327, (P);* **Louga,** **Cayor** *15° 15'N 16° 15'W* (1837), *Heudelot 591, (K, P);* **Mbao** *15° 48'N 16° 31'W* (Jun 1950), *Berhaut RP 14 BIS, (P);* **Saint Louis,** **Gandon** *15° 57'N 16° 27'W* (Dec 1935), *Lynseud sn, (P);* **Makhana** *16° 05'N 16° 22'W* (25 Sep 1965), *Audru J 2732, (P);* **N'Dombo** (3 Jan 1934), *Trochain J 2319, (P);* **Ross Bethio** (5 Jan 1966), *Audru J 3038, (P);* **Tambacounda,** **Silame** *13° 39'N 14° 28'W* (12 Dec 1966), *Diallo AK 822, (P);* **Thies,** **M'Boro** (18 Apr 1934), *Trochain J 3073, (P);* **M'Boro** *15° 09'N 16° 54'W* (18 Apr 1936), *Trochain J 3074, (P);* **M'Boro** *15° 09'N 16° 54'W* (25 May 1935), *Wailly M De 4627, (P);*

**Unknown,** (), *Bosc M SN, (P);* (21 Jan 1825), *Perrottet 52, (P);* (10 Jun 1828), *Perrottet 261, (P);* (1836), *Robert M sn, (P);* (19 Jul 1930), *Trochain J 29, (P);* (), *Trochain J 117, (P);* (), *Richard sn, (P);* (Mar 1828), *Perrottet SN, (P);* (Mar 1825), *Perrottet SN, (P);* **Cayon** (1839), *Heudelot 391, (K, OXF);* **Ramarion** (27 Nov 1930), *Trochain J 970, (P);*

**SOMALIA. Woqooyi Galbeed, Dila** *9° 50'N 43° 25'E* (17 Apr 1987), *Hassan AS 9, (FHO, MOG);* **Dila** (14 Jan 1945), *Glover PE & Gilliland HB 579, (EA, FHO);* **Hendesa Tug** *9° 45'N 43° 20'E* (10 Jan 1933), *Gillett JB 4839, (EA, K, P);*

**SOUTH AFRICA. Cape, Kommagas** *29° 50'S 17° 22'E* (22 Jan 1979), *Van Der Westhuysen PM 64/79, (PRE);* **Natal, Dongolo river** (15 Jul 1965), *Moll EJ 1751, (PRE);* **Kosi road** *27° 07'S 31° 22'E* (23 Nov 1967), *Moll & Strey 3770, (PRE);* **Makanes bridge** *27° 22'S 31° 07'E* (1 Jul 1973), *Moll EJ 5730, (PRE);* **Makanis pont** *27° 07'S 31° 07'E* (13 Nov 1969), *Venter HJT 5139, (PRE);* **Ndumu game reserve** *26° 52'S 31° 22'E* (24 Feb 1964), *Ross JH 698, (LISC, PRE);* **Ndumu game reserve** *26° 52'S 31° 22'E* (24 Feb 1964), *Ross JH 699, (LISC, PRE);* **Ndumu game reserve** *26° 52'S 32° 07'E* (28 Aug 1957), *Ward CJ 3151, (PRE);* **Otoboteni** *27° 22'S 31° 07'E* (27 Sep 1964), *Ross JH 1145, (LISC, PRE);* **Otobotini p.o.** (17 Oct 1946), *Codd LEW 2085, (PRE);* **Shemulaspont** (18 Jul 1954), *Ward CJ 2360, (PRE);* **Umfongoti drift** (10 Jul 1935), *Gerstner JJ 2869, (PRE);* **Zululand** (Jul 1936), *Verdoorn IC 1683, (PRE);* **Makanes Drift** (6 Mar 1970), *Ross JH 2377, (PRE, SRGH);* **Transvaal,** (20 Aug 1967), *Biegel HM 2220, (SRGH);* (1948), *Gerstner JJ 6626, (PRE);* **Beauty** *23° 07'S 27° 52'E* (26 Sep 1972), *Mogg AOD 36863, (PRE);* **Blaauwberg** (10 Jan 1955), *Mogg AOD 24421, (PRE);* **Buffelsdrift** (15 Dec 1965), *Vahrmeijer J 1282, (PRE);* **Groblersdal border** *22° 52'S 27° 52'E* (21 Aug 1977), *Venter S 2037, (PRE);* **Kalkbank** *23° 37'S 29° 22'E* (3 Dec 1946), *Codd LEW 2274, (PRE);* **Limpopo** (15 Jul 1940), *Verdoorn IC 2088, (PRE);* **Limpopo river** *22° 37'S 28° 37'E* (2 May 1973), *Van Graan HAR 443, (PRE);* **Lobombo flats** (Aug 1926), *Keet JDM 1495, (PRE);* **Louis Trichardt** *22° 52'S 29° 52'E* (30 Jul 1974), *Van Wyk AE 471, (PRE);* **Louis Trichardt dist** (Dec 1945), *Gerstner JJ 5781, (PRE);* **Magalakwin bridge** (2 Oct 1922), *Galpin EE 9137, (FHO, PRE);* **Majuleka** (30 Oct 1932), *Lang H TM 32262, (PRE);* **Messina** *22° 22'S 30° 07'E* (Aug 1937), *Chalmers PRE 55045, (PRE);* **Messina** *22° 22'S 30° 07'E* (24 Nov 1916), *Pole Evans IB PRE 13118, (PRE);* **Mpefu** (Jun 1938), *Smuts (Genl) J 2060, (PRE);* **Mutalerivier** *22° 22'S 30° 52'E* (May 1977), *Pienaar JN 1129, (PRE);* **Ngomondwane** (24 Apr 1954), *Van Der Schijf 3653, (PRE);* **Northern Transvaal** *22° 52'S 29° 07'E* (25 Sep 1972), *Mogg AOD 37032, (PRE);* **Northern Transvaal** (24 Aug 1936), *Pole Evans IB 3968, (PRE);* **Nuanetezi river** (26 Jul 1921), *Pole Evans IB 191, (PRE);* **Olifants river** *24° 07'S 30° 52'E* (14 Aug 1987), *Retief IM 618, (PRE);* **Pafuri** *22° 22'S 31° 22'E* (11 Aug 1952), *Van Der Schijf 1425, (PRE);* **Piet Potgieters Rust** (5 Jun 1948), *Codd LEW 4185, (PRE, SRGH);* **Pietersburg** *23° 52'S 29° 22'E* (4 Dec 1946), *Story R 1557, (PRE);* **Pietersburg district** (3 Aug 1934), *Galpin EE 13533, (P, PRE);* **Punda maria** (15 Oct 1952), *Van Der Schijf 928, (PRE);* **Saamboubrug** (1 May 1961), *Strey & Schlieben 8655, (PRE, SRGH);* **San river** *22° 22'S 30° 07'E* (2 Apr 1971), *Stephen JJF 254, (PRE);* **Sand river** (Jun 1923), *Keet JDM 1101, (PRE);* **Sibasa** *22° 52'S 30° 22'E* (26 Oct 1945), *Lamont W PRE 29391, (PRE);* **Vanetzi river** (2 Mar 1946), *Gerstner JJ 6077, (PRE);* **Wyliespoort** *23° 07'S 29° 52'E* (30 Jul 1974), *Botha DJ 854, (PRE);* **Chipese Hot Spring** (20 Dec 1938), *Smuts & Gillett 4000, (PRE, SRGH);* **Zontpansberg Upefu** (6 Aug 1937), *Smuts & Gillett 3608, (PRE, SRGH);* **Unknown,** (4 Jan 1950), *Lhote H 275, (P);* **Tit** (13 Apr 1950), *Lhote H 534, (P);*

**SUDAN. Blue Nile, Talbab forests** (27 Mar 1966), *Sahni KC 5, (K);* **Darfur, Kebali plateau** (12 Mar 1965), *Wickens GE 2882, (K);* **Wadi Kubbum** (30 Oct 1947), *Harrison ER 149, (K);* **Zalingei** (1 Mar 1965), *Wickens GE 2842, (K);* **Zalingei** (14 Apr 1964), *Wickens GE 1496, (K);* **Beldong** (21 Apr 1965), *Wickens GE 2920, (K);* **Dariba crater** (4 May 1964), *Robertson VC 135, (K);* **Saur** (4 May 1964), *Wickens GE 1573, (K);* **Gandatour** (13 Feb 1964), *Wickens GE 1284, (K);* **Khartoum,** (12 Dec 1930), *Aylmer G 87, (FHO, K);* **Gereif** (29 Nov 1928), *Aylmer G SN, (FHO);* **Kalakla** (11 Dec 1868), *Schweinfurth 890, (K);* **Kalakla** *15° 30'N 32° 29'E* (11 Dec 1868), *Schweinfurth G 890, (K, P);* **Khartoum** (28 Nov 1930), *Aylmer G 88, (K);* **Kordofan, El Obeid** (Sep 1875), *Pfund J 87, (K);* **Kordofan** *13° 05'N 30° 21'E* (18 Dec 1878), *Expedition Colston 4, (P);* **Kordofan** (18 Dec 1878), *Expedition Prout 400, (P);* **Kordofan** (18 Dec 1878), *Expedition Prout 112, (P);* **Kordofan** (18 Dec 1878), *Expedition Prout 455, (P);* **Unknown,** (1948), *Jackson JK 276, (FHO);* (Mar 1863), *Speke & Grant 771, (K);* **El Shellab** (9 Jul 1931), *Ahmed Ali Baggari 25, (K);* **El Shellab** (9 Jul 1931), *Ahmed Ali Baggari 2583, (K);* **Garsila** (6 Dec 1957), *Francis D 52, (K);* **K. Adarashia** (18 Feb 1933), *Cooke 115, (K);* **Kitgu** (12 Dec 1929), *Aylmer G 16, (FHO);* **Sedab** (19 Oct 1868), *Schweinfurth G 554, (K, P);* **Shendi** (Mar 1862), *Petherick SN, (K);* **Jebul Korkos** (24 Oct 1868), *Schweinfurth G 747, (K, P);*

**SYRIA. Saida** (26 Nov 1852), *Blanche I 16, (K);*

**TANZANIA. Central, Dodoma** (23 Jul 1956), *Semsei SR 2439, (EA);* **Mpwapwa** *6° 21'S 36° 29'E* (19 Nov 1988), *Fagg CW 425, (FHO);* **Mpwapwa** *6° 21'S 36° 29'E* (28 Aug 1930), *Greenway PJ 2477, (EA, K);* **Mvumi** *6° 21'S 35° 51'E* (17 Aug 1928), *Greenway PJ 787, (EA, FHO, K);* **Bubu river** (9 Nov 1927), *Burtt BD 697, (EA, FHO);* **Mpwapwa** *6° 21'S 36° 29'E* (30 Apr 1929), *Hornby Mrs 118, (EA, K);* **Coast, Dar es Salaam** *6° 48'S 39° 15'E* (Sep 1953), *Semsei SR 1368, (EA);*

**Dar es Salaam,** *6° 50'S 39° 16'E* (14 Nov 1988), *Fagg CW 402, (FHO);* **Amana** (10 Jan 1978), *Mwasumbi LB 11488, (DSM);* **Eastern,** *6° 07'S 37° 39'E* (Aug 1952), *Semsei SR 5914, (K);* **Mbuyuni** *7° 28'S 36° 31'E* (19 May 1970), *Furuya K 104, (EA);* **Morogoro** *6° 49'S 37° 40'E* (14 Nov 1971), *Pocs T 6485/B, (DSM, EA);* **Morogoro** *6° 49'S 37° 40'E* (1953), *Wigg LJ 1559, (EA, FHO);* **Morogoro University** (24 Nov 1971), *Pocs T SN, (DSM);* **Morogoro University** (17 Dec 1985), *Mhoro B & Mhinzi B 4480, (DSM);* **Mtibwa forest reserve** *6° 07'S 37° 39'E* (Aug 1952), *Semsei SR 914, (EA);* **Kigoma,** **Kibwesa point** (10 Jul 1958), *Jefford Juniper & Newbould 78a, (P);* **Kilimanjaro,** *3° 31'S 37° 33'E* (17 Nov 1988), *Fagg CW 418, (FHO);* **Lake,** *2° 20'S 31° 52'E* (17 Oct 1985), *Fitzgibbon & Barcock 83/A35, (K);* **Kyaka** *1° 16'S 31° 25'E* (Jan 1958), *Procter J 795, (EA, K);* **Masasi,** **Ndanda** *10° 30'S 39° 01'E* (20 Aug 1949), *Gerstner JJ 7206, (EA);* **Mbeya,** **Chimala** *8° 51'S 34° 01'E* (12 Sep 1949), *Carmichael sn, (K);* **Monduli District,** **Mto wa Mbu** (7 Apr 1978), *Magogo FC 1850, (EA);* **Mpanda,** **Mahali mountains** *6° 12'S 29° 50'E* (1969), *Nishida T 13, (EA);* **Northern,** *3° 21'S 37° 20'E* (2 Jul 1926), *Peter 42210, (K);* **Serengeti,** **Gol Kopjies** (8 Oct 1971), *Lamprey & Pennywick SRI 501, (EA);* **Gol Kopjies** (18 Oct 1971), *Pennycuick CJ & Lamprey HF SRI 501, (DSM);* **Songwe,** (16 Apr 1974), *Leedal GP 1802, (EA);* **Songwe valley** (3 Oct 1974), *Leedal GP 2121, (EA);* **Southern,** **Mahiwa** *10° 21'S 39° 16'E* (12 Dec 1962), *Ross JH 14, (EA);* **Southern Highlands,** *8° 00'S 35° 35'E* (1 May 1935), *Emson HE 374, (K); 7° 39'S 36° 10'E* (22 Nov 1988), *Fagg CW 433, (FHO); 8° 30'S 33° 30'E* (May 1959), *Procter J 1216, (EA, K);* **Ilula** (27 Oct 1955), *Benedicto 73, (EA);* **Itamba plains** (25 Sep 1968), *Shishira E ES28, (DSM);* **Mbagi** *7° 39'S 34° 55'E* (14 Jun 1967), *Gaetan 193, (EA);* **Msembe** *7° 39'S 34° 55'E* (14 Mar 1967), *Kololo A 44, (EA);* **Msembe** *7° 39'S 34° 55'E* (19 Apr 1970), *Greenway PJ & Kanuri 14389, (EA);* **Rujewa** *8° 41'S 34° 19'E* (24 Oct 1955), *Anderson B 1100, (EA);* **Utengule** *8° 41'S 33° 52'E* (Jun 1933), *Davies RM 915, (EA);* **Wagingombe** *8° 52'S 34° 38'E* (30 Oct 1991), *Fagg CW 571, (FHO);* **Himba** (Jun 1933), *Davies RM 913, (EA);* **Himba** (Jun 1933), *Davies RM 914, (EA);* **Tanga,** *4° 05'S 38° 00'E* (21 Mar 1914), *Peter A K441, (K);* **Kiruru** *3° 42'S 37° 34'E* (May 1928), *Haarer AE 1359, (EA, K);* **Kisuani** *4° 08'S 37° 57'E* (5 Feb 1930), *Greenway PJ 2164, (EA, FHO);* **Pangani river** *3° 32'S 37° 34'E* (13 Aug 1974), *Mhoro B & Backeus I 2166, (DSM, EA, K);* **Gonja Maore** *4° 16'S 38° 02'E* (Jul 1955), *Semsei SR 2080, (EA, FHO, K);* **Same** *4° 04'S 37° 44'E* (19 Feb 1957), *Wilson 25, (EA);* **Unknown,** *6° 30'S 29° 57'E* (10 Jul 1958), *Juniper & Jefford 78A, (K); 2° 42'S 35° 26'E* (18 Oct 1971), *Lamprey & Pennywick SRI/501, (K); 7° 46'S 35° 42'E* (), *Rea 35, (FHO, K);* **Chikundi** (20 Oct 1967), *Jahl 82, (EA);* **Lake Manyara National Park** (20 May 1962), *Dingle H Mrs HD264, (DSM);* **Mbulu** (17 May 1954), *Matalu L 3131, (EA);* **Mporogoro** *7° 46'S 35° 42'E* (29 Sep 1951), *Hughes JF 116, (EA, K);* **Ndanda** (1900), *Scheven J 18, (DSM);* **Nguru** (25 Jul 1933), *Schlieben HJ 4202, (P);* **Nzega town** (17 Nov 1986), *Mhoro B & Mhinzi B 4791, (DSM);* **Ruchioa** (1898), *Goetze W 1107, (P);* **Msasa river** *3° 28'S 35° 45'E* (21 Feb 1964), *Greenway PJ & Kanuri 11225, (K);* **Mpwapwa** (18 Dec 1969), *Mapunda WJ & Raya MD 1121, (DSM);* **Lake Magadi** (3 Mar 1967), *Braun HMH 181, (DSM);* **Western,** *6° 00'S 30° 00'E* (23 Sep 1952), *Jefford Juniper & Newbould 2570, (K); 8° 28'S 31° 08'E* (16 Jul 1957), *Richards HM Mrs 10137, (K);* **Kungwe bay** (Jun 1956), *Procter J 492, (EA);*

**TOGO.** **Unknown,** **Mango** (7 Feb 1978), *Ern H 3060, (K);*

**UGANDA.** **Acholi,** **Agoro** (Dec 1932), *Eggeling WJ 829, (FHO);* **Buganda,** **Lake Kachira** (Nov 1950), *Philip MS 411, (EA);* **Karamoja,** **Koputh** (Feb 1937), *Brasnett NV B 172, (FHO);* **Northern,** **Kangole** *2° 28'N 34° 28'E* (22 Feb 1940), *Thomas AS 3476, (EA);* **Moroto** *2° 32'N 34° 39'E* (19 Jan 1959), *Heady HF 1494, (EA);* **Western,** **Gayaza** *0° 47'S 30° 48'E* (Oct 1932), *Eggeling WJ 1008, (EA);* **Ibanda** *0° 08'S 30° 29'E* (29 Nov 1951), *Trapnell CG 2189, (EA);*

**YEMEN.** **Baljurshi** (14 Mar 1985), *Acres 345, (K);* **El Kod R/S** (22 Nov 1980), *Costin E & Bazara MAR SN, (K);*

**ZAIRE.** **Kibali Ituri,** **Kasenyi** *1° 24'N 30° 26'E* (1926), *Robyns 1867, (FHO, P);* **Shaba,** **Mabwe** *8° 41'S 26° 33'E* (Mar 1949), *de Witte GF 5759, (K);*

**ZAMBIA.** **Eastern,** *13° 08'S 31° 45'E* (26 Oct 1988), *Fagg CW 393, (FHO);* **Lusaka,** **Mt. Makulu** (1900), *Cole MM 16, (K);* **Kafue river** (Jan 1909), *Allen CEF 709, (K, SRGH);* **Northern,** (7 Jun 1957), *Savory CR 190, (K, SRGH);* **Luangwa river** (30 May 1958), *Fanshawe DB 4470, (K, NDO);* **Mfuwe** (5 May 1965), *Mitchell BR 2840, (K, SRGH);* **Mfuwe** (9 Oct 1967), *Astle WL 5111, (K);* **Sumbu** (6 Jul 1957), *Savory CR 200, (K, SRGH);* **Southern,** **Chirundu** *16° 02'S 28° 51'E* (12 Aug 1957), *Angus A 1653, (K);* **Kasengula** (21 Jul 1927), *Bourne R 12, (NDO);* **King George VI island** (2 Oct 1964), *Bainbridge WR 10105, (SRGH);* **Magoye** *16° 03'S 27° 37'E* (15 Apr 1963), *Van Rensburg HJ 1923, (K, SRGH);* **Mapanza N.E.** *16° 15'S 26° 57'E* (25 May 1953), *Robinson EA 269, (K);* **Monze** (9 May 1975), *Chisumpa S 222, (NDO);* **Namwala** *15° 45'S 26° 26'E* (24 Apr 1954), *Robinson EA 732, (K);* **Sinazeze** *17° 08'S 27° 25'E* (17 Jun 1961), *Angus A 2903, (K, SRGH);* **Choma** *16° 51'S 27° 03'E* (7 Sep 1963), *Bainbridge WR 857, (NDO); 17° 15'S 27° 25'E* (2 Dec 1989), *Fagg CW 484, (FHO);* **Gwembe** (Sep 1955), *Bainbridge WR 104/55, (NDO);* **Vwa's village** (1 Apr 1952), *White F 2388, (FHO, K, NDO);* **Katambore river** (Dec 1947), *Morze J 78, (NDO);* **Livingstone** *17° 51'S 25° 52'E* (Mar 1932), *Trapnell CG 1019, (K);* **Nakambala** (18 Apr 1932), *Duff CE 384/32, (NDO);* **Sikasondasima** (22 Apr 1929), *Stevenson D 42, (K);*

*15° 31'S 26° 40'E* (17 Oct 1988), *Fagg CW 370, (FHO, SRGH);* **Banga river** (4 Aug 1963), *Van Rensburg HJ 2440, (K, SRGH);* **Namwala** (12 Jun 1949), *Hornby RM 3006, (SRGH);* **Namwala** (12 Jun 1949), *Hornby RM 3007, (SRGH);* **Namwala** (24 Jun 1952), *White F 2978, (K);* **Unknown,** *9° 01'S 29° 25'E* (9 Oct 1949), *Bullock AA 1191, (K);* **King Edward Mine** *15° 30'S 27° 55'E* (1900), *Cole MM 71, (K);* **Western, Sesheke** *17° 29'S 24° 18'E* (Aug 1911), *Gairdner N75, (K);* **Sesheke** *17° 29'S 24° 18'E* (17 Sep 1969), *Mutimushi JM 3742, (K, NDO);*

**ZIMBABWE. Beitbridge,** *22° 05'S 29° 58'E* (11 Jul 1988), *Barnes RD 524,* **Bikita,** *20° 12'S 32° 15'E* (8 Jul 1988), *Barnes RD 519,* **Devuli ranch** *20° 15'S 31° 50'E* (24 Jul 1958), *Chase NC 6963, (K, LISC, SRGH);* **Binga, Lubu river** (18 Jul 1950), *Whellan JA 444, (K, SRGH);* **Lubu river** *17° 25'S 28° 55'E* (26 Jun 1951), *Lovemore DF 68, (K, LISC, SRGH);* **Buhera,** *19° 50'S 32° 40'E* (21 Apr 1990), *Barnes RD 2281, (FHO);* **Chipinge, Sabi experimental station** *20° 15'S 32° 15'E* (1 Jun 1972), *Gibbs Russell GE 2089, (SRGH);* **Sabi experimental station** *20° 15'S 32° 15'E* (1 Jun 1972), *Gibbs Russell GE 2090, (SRGH);* **Chiredzi, Sabi Lundi junction** (6 Jun 1950), *Wild H 3369, (K, LISC, SRGH);* **Sabi river** (13 Aug 1958), *Phelps RJ 245, (K, SRGH);* **Sabi-Lundi junction** (Jun 1950), *Plowes DC 1173, (MRSH, SRGH);* **Chivi,** (1955), *Armitage FB 115/55, (FHO);* **Gokwe,** (7 Nov 1942), *Arnold SRGH 9340, (SRGH); 18° 10'S 28° 15'E* (5 Jun 1989), *Barnes RD 1925, (FHO, SRGH); 18° 00'S 28° 13'E* (11 Apr 1990), *Barnes RD 2251, (FHO);* **Sengwa research station** (1 Jan 1983), *Mahlangu Z 647, (SRGH);* **Sessami river** (12 Sep 1949), *West O 3029, (MRSH);* **Gwanda,** (May 1959), *Thompson BR 19/59, (SRGH);* **Bubye ranch** *21° 33'S 30° 32'E* (3 May 1958), *Drummond RB 5543, (K, LISC, SRGH);* **Doddieburn ranch** (7 May 1972), *Pope G 656, (K, SRGH);* **Hurungwe, Kariba** *16° 30'S 29° 30'E* (23 Jul 1956), *McGregor GM 35/56, (K, LISC, SRGH);* **Mana Pools** (Sep 1969), *Gordon TAD 45, (SRGH);* **Sanyati river** (7 Jun 1956), *Phelps RJ 152, (K, SRGH);* **Rekomechi/Zambezi confluence** *15° 50'S 29° 07'E* (9 Oct 1991), *Barnes RD 3304, (FHO, SRGH);* **Chirundu** *16° 02'S 28° 50'E* (Oct 1988), *Fagg CW 361, (FHO);* **Chirundu** (29 Sep 1952), *Thompson 12/52, (SRGH);* **Hwange,** *18° 40'S 26° 17'E* (19 Sep 1990), *Barnes RD 2600, (FHO);* **Chimwara ranch** *18° 40'S 27° 15'E* (12 Nov 1992), *Barnes RD 4015, (SRGH);* **Kennedy siding, Wanki** (15 May 1953), *Hodgson LM 2/53, (FHO, SRGH);* **Lupane, Gwaai** (1900), *Eyles F 6444, (SRGH);* **Mwenezi,** *21° 42'S 30° 30'E* (11 Jul 1988), *Barnes RD 1518, (FHO);* **Bubi Limpopo confluence** (May 1961), *Boughey AS 164, (SRGH);* **Lion and Elephant Motel** *21° 42'S 30° 29'E* (2 Dec 1992), *Barnes RD 4051, (FHO, SRGH);* **Ndanga, Chiredzi river** (Nov 1951), *Seward 87/51, (SRGH);* **Nyamandhlovu, Gwaai nature reserve** (Oct 1959), *Armitage FB 110/59, (SRGH);* **Mangwe Creek** (19 Sep 1952), *Kennan TCD 1476, (MRSH);* **Maintengwe Dam** *19° 49'S 26° 53'E* (18 Nov 1992), *Barnes RD 4029, (FHO, SRGH);* **Unknown, Inyaka** (21 Sep 1960), *Hobbs DR & Sim J 947, (SRGH);* **Lower Sabi** (2 Feb 1948), *Wild H 2488, (K, SRGH);* **Mangwe creek** (19 Sep 1952), *Plowes DC 1476, (FHO, SRGH);* **Sabi** (20 Dec 1931), *Eyles F 6814, (K).*

**APPENDIX 3.** Seed collections of *Faidherbia albida* distributed for international provenance and progeny trials and molecular studies. FRC - Forest Research centre, Highlands, Harare, Zimbabwe; FRCE - Forest Research Centre, Sholla, Addis Ababa. Ethiopia; KEW - Royal Botanic Gardens, Kew, London; CIRAD - CIRAD-Forêt, Montpellier, France. In June, 2001, all seed held in the OFI seed store was transferred to the ICRAF seed store in Nairobi.

| Provenance | Country | Lat./Long. | Alt (m) | MAP (mm) | MAT (°C) | No. of trees | Seed bank | Seed I.D. | 1/2-sib lots |
|---|---|---|---|---|---|---|---|---|---|
| Bignonia | Senegal | 12.45N 16.25W | 10 | 1408 | 26.5 | 20 | OFI | 8/92 | 20 |
| **Bignona-2** | **Senegal** | **12.45N 16.25W** | **10** | **1408** | **26.5** | **20** | **OFI** | **8/93** | |
| Bolero | Malawi | 10.58S 33.43E | 1100 | 701 | 21.0 | 25 | OFI | 78/90 | 25 |
| **Bolgatanga** | **Ghana** | **10.46N 1.00W** | **201** | **1057** | **28.2** | **26** | **OFI** | **74/90** | **26** |
| Bubye river | Zimbabwe | 21.42S 30.29E | 500 | | | | OFI | 27/93 | 43 |
| **Bubye river** | **Zimbabwe** | **21.42S 30.29E** | **500** | | | **+10** | **OFI** | **28/93** | |
| Chawanje | Malawi | 14.39S 34.48E | 600 | 824 | 24.2 | 9 | OFI | 80/90 | 9 |
| **Chawanje** | **Malawi** | **14.39S 34.48E** | **600** | **824** | **24.2** | **71** | **OFI** | **7/92** | **80** |
| Chinzombo | Zambia | 13.08S 32.45E | 550 | 958 | 24.0 | 23 | OFI | 75/90 | 23 |
| **Chipinda Pools** | **Zimbabwe** | **21.18S 32.21E** | **170** | **627** | **24.5** | | **FRC/OFI** | **58/90** | **7** |
| Debre Zeit | Ethiopia | 8.48N 38.59E | 1850 | | | | OFI | 118/94 | |
| **Devure** | **Zimbabwe** | **20.10S 32.10E** | **550** | **516** | **21.6** | **25** | **OFI** | **47/90** | |
| Dumisa | Zimbabwe | 22.13S 31.24E | 280 | 438 | 24.7 | 30 | OFI | 22/92 | 30 |
| **Dumisa** | **Zimbabwe** | **22.13S 31.24E** | **280** | **438** | **24.7** | **30** | **OFI** | **76/92** | |
| Gelemso | Ethiopia | 8.45N 40.27E | 1800 | | | | OFI | 117/94 | 22 |
| **Gelemso** | **Ethiopia** | **8.45N 40.27E** | **1800** | | | **20** | **FRCE/OFI** | **115/94** | |
| Gona-re-zhou | Zimbabwe | 21.18S 32.22E | 130 | 548 | 20.5 | 25 | OFI | 30/92 | |
| **Guetale** | **Cameroun** | **10.57N 13.55E** | **450** | **850** | | **22** | **CIRAD** | **8505456** | |
| Guija (Limpopo) | Mozambique | 24.30S 33.02E | 60 | | | | OFI | 140/94 | |
| **Gwai river** | **Zimbabwe** | **18.40S 29.15E** | **950** | | | | **OFI** | **24/93** | **34** |
| Gwai river | Zimbabwe | 18.40S 29.15E | 950 | | | 20 | OFI | 21/93 | |
| **Hoanib River** | **Namibia** | **19.10S 13.45E** | **570** | **98** | **24.0** | **6** | **OFI** | **6/92** | **40** |
| Hoanib River | Namibia | 19.14S 13.23E | 350 | 98 | 24.0 | 40 | OFI | 14/94 | 40 |
| **Hundene** | **Ethiopia** | **9.00N 42.00E** | **1800** | | | **20** | **FRCE/OFI** | **139/94** | |
| Hwange N.P. | Zimbabwe | 18.44S 26.16E | 950 | 630 | 22.3 | | FRC/OFI | 57/90 | 7 |
| **Kafue Flats** | **Zambia** | **15.31S 26.40E** | **1000** | **871** | **21.0** | **15** | **OFI** | **76/90** | |
| Kapula | Zimbabwe | 18.42S 26.17E | 975 | | | 25 | OFI | 23/93 | |
| **Kapula** | **Zimbabwe** | **18.42S 26.17E** | **975** | | | | **OFI** | **22/93** | **20** |
| Khartoum | Sudan | 15.28N 33.38E | 100 | | | | FRCS/OFI | 21/94 | |

(continued)

**APPENDIX 3.** (continued)

| Provenance | Country | Lat./Long. | Alt (m) | MAP (mm) | MAT (°C) | No. of trees | Seed bank | Seed I.D. | 1/2-sib lots |
|---|---|---|---|---|---|---|---|---|---|
| Khor | Sudan | 13.04N 23.17E | 900 | 460 | | | FRCS/OFI | 146/94 | 32 |
| Kombo | Gambia | 13.15N 16.40W | 10 | | | | KEW/OFI | 27/88 | |
| Kuiseb | Namibia | 23.34S 15.02E | 400 | 20 | 16.8 | 25 | OFI | 60/90 | 25 |
| Kuiseb | Namibia | 23.34S 15.02E | 400 | 20 | 16.8 | 25 | OFI | 84/90 | |
| Kunene River | Namibia | 17.15S 12.26E | 250 | | | 28 | OFI | 15/94 | 28 |
| Lake Awassa | Ethiopia | 7.03N 38.28E | 1650 | 961 | | | OFI | 24/94 | 14 |
| Lake Koka | Ethiopia | 8.20N 38.59E | 1600 | | | | OFI | 119/94 | |
| Lake Awassa | Ethiopia | 7.03N 38.28E | 1650 | 961 | | 25 | OFI | 138/94 | |
| Lupaso | Malawi | 9.55S 33.53E | 500 | 1165 | 24.8 | 25 | OFI | 77/90 | 25 |
| Mana Pools | Zimbabwe | 15.45S 29.20E | 360 | 628 | 25.1 | 25 | FRC/OFI | 56/90 | 7 |
| Mana Pools | Zimbabwe | 15.45S 29.20E | 360 | 628 | 25.1 | 25 | OFI | 24/90 | 25 |
| Mana Pools | Zimbabwe | 15.45S 29.20E | 360 | 628 | 25.1 | 25 | OFI | 23/90 | |
| Mana Pools | Zimbabwe | 15.45S 29.20E | 360 | 628 | 25.1 | 25 | OFI | 19/92 | 35 |
| Mana Pools | Zimbabwe | 15.45S 29.20E | 360 | 628 | 25.1 | 25 | OFI | 28/92 | |
| Manyoni River | Zimbabwe | 18.04S 28.15E | 750 | 660 | 22.2 | 24 | OFI | 89/90 | 24 |
| Matameye | Niger | 13.25N 8.28E | 450 | 560 | | 20 | CIRAD | 8005035 | |
| Mfumbi | Tanzania | 8.50S 34.00E | 900 | 830 | 21.6 | 17 | OFI | 9/92 | 17 |
| Mojo | Ethiopia | 8.24N 39.10E | 1800 | | | | OFI | 81/94 | 20 |
| Msaizi | Zimbabwe | 20.12S 32.15E | 500 | 470 | 22.3 | 15 | OFI | 37/90 | 15 |
| Mwanza River | Malawi | 16.10S 34.46E | 100 | 811 | 26.3 | 8 | OFI | 33/92 | 8 |
| Mwanza River | Malawi | 16.10S 34.46E | 100 | 811 | 26.3 | 15 | OFI | 79/90 | 15 |
| Mwembe | Tanzania | 4.08S 37.51E | 860 | 569 | 23.5 | 20 | OFI | 10/92 | |
| Nyamepi | Zimbabwe | 15.45S 29.20E | 350 | 628 | 25.1 | 46 | OFI | 21/92 | 46 |
| Nyanyadzi | Zimbabwe | 19.45S 32.26E | 550 | 489 | 22.5 | 25 | OFI | 25/92 | |
| Obeid (Kordofan) | Sudan | 12.48N 30.00E | 200 | | | 19 | FRCS/OFI | 23/94 | |
| Okangwati | Namibia | 17.25S 13.17E | 1100 | 306 | 21.5 | 30 | OFI | 16/94 | 30 |
| Pongola River | S. Africa | 27.02S 32.16E | 40 | | | 25 | OFI | 88/93 | |
| Rama | Ethiopia | 14.24N 38.47E | 1400 | 742 | | | OFI | 17/94 | 27 |
| Rekomechi River | Zimbabwe | 15.50S 29.07E | 365 | 628 | 25.1 | 75 | OFI | 20/92 | 75 |

(continued)

**APPENDIX 3.** (continued)

| Provenance | Country | Lat./Long. | Alt (m) | MAP (mm) | MAT (°C) | No. of trees | Seed bank | Seed I.D. | 1/2-sib lots |
|---|---|---|---|---|---|---|---|---|---|
| Sabce (Kongoussi) | Burkina Faso | 13.13N 1.35W | 338 | 400 | | 10 | CIRAD | 8005038 | |
| Sesame River | Zimbabwe | 17.57S 28.46E | 1100 | 787 | 20.5 | 25 | OFI | 15/90 | |
| Shashi River | Zimbabwe | 21.56S 29.11E | 550 | 300 | | 22 | OFI | 147/94 | 22 |
| South Harar | Ethiopia | 9.17N 42.06E | 1860 | | | | OFI | 120/94 | |
| Tambarhata Vlei | Zimbabwe | 21.18S 32.22E | 130 | 548 | 20.5 | 25 | OFI | 75/92 | |
| Tambarhata Vlei | Zimbabwe | 21.18S 32.22E | 130 | 548 | 20.5 | 99 | OFI | 23/92 | 99 |
| Taupye | Botswana | 23.29S 27.14E | 850 | 471 | 20.8 | | OFI | 40/90 | 4 |
| Taveta | Kenya | 3.24S 37.42E | 760 | 545 | 23.5 | 34 | OFI | 179/92 | 34 |
| Tegwani/Masiti | Zimbabwe | 19.55S 27.07E | 1005 | | | | OFI | 26/93 | 30 |
| Tegwani/Masiti | Zimbabwe | 19.55S 27.07E | 1005 | | | 30 | OFI | 25/93 | |
| Tot | Kenya | 1.12N 35.39E | 1200 | | | | OFI | 145/94 | 21 |
| Voortrekker | Botswana | 22.34S 28.24E | 823 | 392 | 20.5 | 4 | OFI | 44/90 | |
| Voortrekker | Botswana | 22.34S 28.24E | 823 | 392 | 20.5 | 4 | OFI | 49/90 | |
| W. of El Obeid | Sudan | 13.10N 30.14E | 570 | 386 | | | KEW/OFI | 25/88 | |
| Wad Medani | Sudan | 14.16N 33.38E | 200 | 300 | | 15 | FRCS/OFI | 22/94 | 15 |
| Wagingombe | Tanzania | 8.51S 34.38E | 1450 | 819 | 20.6 | 74 | OFI | 5/92 | 74 |

# ANNOTATED BIBLIOGRAPHY

This bibliography is arranged in alphabetical order of authorship. Subject groupings can be accessed by reference to the publication numbers at the end of each section in the main text of the monograph. There is also an author index at the end of the bibliography in which the publication numbers are given for each author.

Both the published and the grey literature on *Faidherbia albida* have been searched for this bibliography. In some abstracts, information is given on other species where this serves to place *F. albida* in context in the subject being discussed.

Not all the publications cited were available to the authors. Where a publication was judged to be of significance from its title but neither the paper nor an abstract was available, it has, nevertheless, been included without annotation. Incomplete references have also been included, for example documents that have been seen but have not been dated or fully attributed, and incomplete references that have been picked up but have not been seen; the reader may have a better opportunity to follow up the latter.

All the references given in the CTFT monograph on *Faidherbia albida* (CTFT 1989) have been included whether or not the publication or document was available to the authors for abstracting.

In the monographic section, reference has been made to a number of works that do not specifically mention *Faidherbia albida* but which are pertinent to the discussion of the particular topic. For ease of reference, these are included, without annotation, in this bibliography rather than in a separate section.

Many of the abstracts have been specifically written for this monograph but, where necessary, the author's or the CABI abstract has been used, sometimes with modification. There has been no attempt to attain a consistency of style in the abstracts; each abstract rather follows the style of the paper itself or of the individual abstracter. Uniformity of style is on the other hand the aim in the monographic section of this publication.

The length of the abstract does not necessarily reflect the length or the importance of the document. If the publication is widely available in English, the abstract is generally briefer than one that is in the grey literature or one that has been translated from another language, mainly French.

Authorities for scientific names are not assumed in the abstracts if they were not given in the original publication or document.

1 ABDELGUERFI, A.; ABDELGUERFI BERREKIA, R. **[Reflections on the value of some forage species adapted to the arid and semi-arid zones]** Réflexions sur la valorisation de quelques espèces fourragères adaptées aux zones arides et semi-arides. *Annales de l'Institut National Agronomique El Harrach, Algeria* (1987) **11** (2) 1-10 [Fr, ar, 18 ref.]

The potential value of *Medicago polymorpha, M. truncatula, M. minima, M. orbicularis, M. laciniata, Scorpiurus muricatus* subsp. *sulcatus, Hedysarum glomeratum, H. pallidum, H. carnosum, H. spinosissimum, Atriplex halimus, A. glauca, A. canescens, A. polycarpa, A. semibaccata, A. nummularia, Acacia albida* and *Acacia raddiana* as forage species in Algeria is discussed.

2 ACOCKS, J.P.H. **Veld types of South Africa.** *Memoirs of the Botanical Survey of South Africa.* Pretoria, South Africa; Botanical Research Institute (1988) No. 57, 145 pp. [En, 21 ref.]

Detailed survey of the vegetation types in South Africa. *A. albida* occurs in forest patches in the Zululand palm veld associated with sandy soils on a badly drained coastal plain, in Zululand low altitude thornveld along streams with other Acacia species, and in lowveld bush within a narrow belt of riverine vegetation of acacias and palms between altitudes 150 and 600 m.

3 ADELODUN, M. **Firewood supply from Kano farms.** *Farm and Forest* (1944) No. 5, 80 [En]

A large percentage of the firewood used in Kano city is obtained from farm woodlands. Most of the farmers practise a kind of rotation, selecting old, infected or over matured trees for cutting and sowing Dorowa (*Parkia oliveri*) seeds in their place. Some naturally established species such as Gawo (*Acacia albida*) and Kurna (*Zizyphus spina-christi*) are also used as fuelwood. Regulations have recently been introduced to check unrestricted exploitation of farm woodlands.

4 ADEOLA, A.O.; DADA, A.O. **Potential agroforestry plants in Nigeria: Effects of some pretreatments on seed germination of *Acacia albida* and *Acacia senegal*.** *Research Paper, Forest Research Institute of Nigeria* (1985) No. 53, 8 pp. [En, 3 ref.]

Studies of the effect of five pre-treatments on the germination of 3- to 5-month-old seeds of *Acacia albida* and *A. senegal* at the Forest Research Institute, Ibadan, Nigeria. Treatments include (a) manual scarification and soaking for 24 hours (b) covering with boiling water which was then cooled for 24 hours (c) placing in 96% sulphuric acid for 10 minutes and then soaking in water for 24 hours (d) placing in 96% sulphuric acid for 20 minutes and then soaking in water for 24 hours and (e) soaking for 24 hours in water (control). For *Acacia albida*, treatments (a) and (c) were the most successful (99% germination after 4 days), but with *A. senegal* no pre-treatment was satisfactory though treatment (d) did have a significantly higher germination rate (57%) than the other treatments.

5 AGENCE DE COOPÉRATION CULTURELLE ET TECHNIQUE. **[Plant anti-transpirants that regulate stomatal water relations.]** *Anti-transpirants végétaux de type hydrorégulators stomatiques.* France; Muséum National d'Histoire Naturelle (1985) 32 pp. [Fr, 10 ref.]

Climate, drought and transpiration in the Sudano-Sahelian zone of N. Africa and the use of anti-transpirants are discussed with reference to research on wheat, maize, tomatoes, mungbeans (*Vigna radiata*), sorghum (*Medicago*), and woody spp. (*Acacia albida, A. nilotica, A. senegal, A. radiana, Balanites aegyptiaca, Gmelina arborea, Prosopis juliflora*) in Sudan, Niger, Mauritania and Mali. The physiology of hydroregulatory transpirants and stomatal action and K-bonding chemicals are described.

6 AHMED, I. **The role of forestry in correct land use with emphasis on shelterbelts in Kano State, (Nigeria).** *Samaru Agricultural Newsletter* (1972) **14** (1) 5-7 [En]

Briefly discusses the importance of forestry in the savanna region of Nigeria, the choice of species and establishment of shelterbelts in Kano State. Trial plantings of *Acacia nilotica, A. albida* and *Azadirachta indica* to protect soils and crops against winds, particularly the dry 'harmattan' wind, were first established in 1964. *A. indica* has been the most successful and is now the main species used in the belts. Further research using *A. senegal* revealed uniform growth rates and high survival, but maintenance proved a difficult problem. *A. albida*, an indigenous species, suffered extremely slow and irregular growth rates, and was therefore thought more suitable for replacements, rather than hedgerows or block planting.

7 AHMED, P. **Vegetative propagation of *Acacia albida*: A promising species for farm forestry in arid areas.** *The Indian Forester* (1987) **113** (7) 459-465 [En]

*Acacia albida* has been found very successful in the arid areas of Haryana, and is suggested as a replacement farm forestry species for *A. tortilis* which suffers from severe damage to logs by wood borers. The plantation was started in August 1982 with a few seeds provided by the Forest Research Institute, Dehra Dun. The propagation of this species is a problem because 10-year-old trees did not set sufficient seed, although it produces root suckers on the sand dunes. It was successfully raised from the shoot cuttings using 20 cm branch cuttings (diam. 0.5-1.5 cm) without any root hormone. Cuttings

were placed into four medium mixtures, and sandy loam and 30% farmyard manure producing the best growth. The sprouted plants not only developed a healthy root system but also showed vigour and continuous growth after plantation.

8 AHMED, P. **Performance of *Acacia albida* plants raised from shoot cuttings**. *Indian Forester* (1989) **115** (4) 270-271 [En, hindi, 2 ref.]

Comparative data are briefly reported on the performance of *Aacaia albida* raised from seed and from shoot cuttings in Haryana. Planting was done in July 1986 in medium textured loam of pH 8.4, and irrigation was carried out monthly. Maximum height at two years old was 580 cm for plants raised from seed, and 750 cm from shoot cuttings; maximum root collar diameter was similar for the two types of stock, 10.5 and 11.5 cm, respectively. Height growth of the cuttings was similar to that of 4-year-old plants raised from seed (max. height 750 cm and diameter 20.6 cm).

9 AKHTAR, S.; SALEEM, M.; AHMAD, M.; AHMAD, A.; BHATTY, M.K. **Chemical evaluation of the genus *Acacia* of Pakistan Part I. Fatty acid composition of the total lipids and lipid classes of *Acacia albida* Del. and *Acacia modesta* Wall**. *Pakistan Journal of Scientific and Industrial Research* (1988) **31** (10) 725-728 [En]

Seed oils were extracted from *Acacia albida* Del. (3.64% of total lipids) and *Acacia modesta* (6.5% of total lipids) and examined for their fatty acids composition. The oils were fractionated by TLC into lipid classes; which were neutral lipids (39.0, 55.3%) and polar lipids (60.9%, 44.7%) respectively. Further fractionation of the neutral lipids resulted in hydrocarbons, wax-esters, triglycerides free fatty acids, 1:3-diglycerides, 1:2-diglycerides and monoglycerides. Fatty acids composition of the whole oil and its fractions were determined by GC. This is the first report of the detection of margaric acid in *Acacia albida* seed oil.

10 AKUNDA, E.M.W.; HUXLEY, P.A. **The application of phenology to agroforestry research**. *ICRAF Working Paper* (1990) No. 63, 50 pp. [En]

In this paper plant phenology refers to the study of the seasonal timing of the life events of plants. The life cycle of any flowering plant consists of five phenophases: germination, vegetative growth, flowering, fruiting and senescence. This paper concentrates on data collected and analyzed at ICRAF's Field Station in Machakos from August 1985 to June 1988. The species selected for the study were *Acacia albida*, *Acacia stulmanii*, *Grevillea robusta*, *Leucaena leucocephala*, *Parkinsonia aculeata* and *Psidium guajava*. Shows the importance of phenological data in agroforestry practices.

11 ALEXANDER, M.J. **Soil development on mine spoil and reclaimed areas of the Jos Plateau. Soil profile descriptions**. *Report, Jos Plateau Environmental Resources Development Programme* (1984) No. 1, 78 pp. [En, 7 ref.]

Soil profiles from the Jos Plateau, Northern Nigeria are described. They include five mining dragline sites, six reclaimed mine areas, a forest site, a site to investigate the effect of *Acacia albida* on soil nutrient status and a market garden site where water from a flooded mine is used.

12 ALEXANDER, M.J. **Soil characteristics and the factors influencing their development on mine spoil of the Jos Plateau**. *Report, Jos Plateau Environmental Resources Development Programme* (1986) No. 11, 167 pp. [En, 72 ref.]

Soils were investigated in areas of unreclaimed mine spoil planted with *Eucalyptus* or with natural vegetation and reclaimed spoil planted with *Eucalyptus*. The three soil types showed differences in the degree of profile differentiation. In unreclaimed spoil chemical and biological differentiation of the 0-20 cm layer increased with increasing surface age. Vegetation cover also increased the morphological, chemical and biological differentiation of soils. The effect of *Pinus caribaea* on soil properties was similar to that found with *E. torrileana* (*E. torelliana*) but preliminary results suggested that *Acacia albida* was more effective in improving soils.

13 ALEXANDER, M.J. **The effect of *Acacia albida* on tin-mine spoil and their possible use in reclamation**. *Landscape and Urban Planning* (1989) **17** (1) 61-71 [En, 14 ref.]

On the Jos Plateau of Nigeria, *Acacia albida* is a natural colonizer of spoil mounds from opencast tin mining. Observation of the ground vegetation growing in the vicinity of a number of isolated *Acacia albida* indicated that the ground vegetation growing below the canopy was taller, more lush and a darker green than that growing outside the influence of the canopy, thus suggesting that the *Acacia albida* had a beneficial effect on the spoil soils. Organic carbon, total nitrogen, pH, percentage base saturation and exchangeable Ca, Mg, Na and K were all significantly higher in soils from beneath the canopy than in those from outside. The soil beneath the tree also had a better-developed and stronger structure and a more active population of soil fauna. The study was extended to compare the effect of *Acacia albida* on the spoil soil with that of the eucalypt plantations established on areas of reclaimed mine land. The sites under *Acacia albida* were found to have significantly higher levels of exchangeable Ca, pH and base saturation than those under the eucalypts. Having established that *Acacia albida* has a more beneficial effect on the spoil soils than the eucalypts, consideration is given to the possibility of using the native *Acacia albida* as an

alternative to the exotic eucalypts. It is concluded, however, that a more detailed study is required into the effect that *Acacia albida* has on the spoil soils before any firm recommendation can be made, particularly as the eucalypts have much greater economic value than *Acacia*.

14 ALEXANDRE, D.Y.; OUÉDRAOGO, S.J. **Variations in root morphology of *Faidherbia albida* in relation to soil and agronomic effects**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.]*. ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 107-110 [En, 4 ref.]

A preliminary study where several root systems of *Faidherbia albida* trees of different ages were excavated from five village sites in Burkina Faso. The roots developed differently on different soils. On sandy soils, the taproot penetrated deeply into the soil while root systems in compacted clay soils remained in the upper horizons. A number of the trees had been heavily lopped and were short and bushy. Suggests that those trees with shallow root systems on compacted clay soils may not have much agronomic value.

15 ALONI, R. **New site of *Acacia albida* Del. in the Sharon coastal plain of Israel**. *Israel Journal of Botany* (1972) **21** (1) 39-41 [12 ref.]

A stand of about 100 *Acacia albida*, arranged in five groups, was found near Dor, close to the northern limit of the species. The significance of this stand for reconstructing the original path of penetration of *A. albida* is briefly discussed.

16 ALONI, R. **Studies of *Acacia albida* Del. in Israel**. *Israel Journal of Botany* (1973) **22** (3) 202 [En, OBD]

Reproduction of *Acacia albida* by seed is at present somewhat prevented by ecological factors. Although more than 75% of the trees have numerous inflorescences, the number of fruits per year developing on each tree is only 0-1000, and the fruits generally contain only one seed. Germination, which is delayed for a year or more by the thick testa, occurs in the autumn with the first rains, but the seedlings die during the early weeks after germination because of increasingly lower temperatures. There are many morphological differences between the various clones of *A. albida* growing in Israel, the most pronounced differences being in the fruits. Chromosome counts of trees from five locations showed that 2n = 26, which is the same number as that reported for the species in Africa.

17 ALVORD, G.I.; BIDI, S.; GUTSA R. **A study of the vegetation types at the confluence of the Sapi/Zambezi rivers**. *The Zimbabwe Science News* (1982) **16** (4) 76-78 [En, 1 ref.]

Describes five vegetation types on the flood plain of the Sapi/Zambezi confluence, Zimbabwe, showing a succession from pioneer grasses, to *Acacia albida* woodland with grassland, *A. albida* woodland with some shrub layer, to mixed woodland and finally mopane woodland. The *A. albida* trees seem to be of similar age, with average heights from four areas of 11.5 - 16.2 m., girths of 2.3 - 3.4 m., and canopy covers ranging from 14.8 - 18.7m$^2$.

18 ANDERSON, J. **Some notes on the ecology of *Acacia albida* with special reference to its "reverse deciduous cycle"**. *Givinish Tropical Ecology, Spring* (1985) 45 pp. [En]

19 ANDREWS, F.W. **The flowering plants of the Anglo-Egyptian Sudan**. Scotland, UK; T. Buncle & Co. Ltd. (1952) Vol. 2, 132-133 [En]

*Acacia albida* Del.; Tree up to 60 ft high, probably the largest of the Sudan *Acacias*. Bark dull grey, fissured and scaly; slash pale brown, fibrous. Pinnae in 3-10 pairs. Leaflets grey-green, 6-20. Flower spikes 3-4 in long. Pod orange-yellow, twisting into strange shapes as it ripens, frequently forming hoops and spirals. Widespread.

20 ANIL, KUMAR; HOODA, M.S.; RAJ, BAHADUR; KUMAR, A.; BAHADUR, R. **Impact of multipurpose trees on productivity of barley in arid ecosystem**. *Annals of Arid Zone* (1998) **37** (2) 153-157 [En, 12 ref.]

The effect of scattered trees of *Prosopis cineraria* (10/ha), *Tecomella undulata* (6/ha), *Acacia albida* [*Faidherbia albida*] (3/ha) and *Azadirachta indica* (3/ha) in a farmer's field in the arid region of Haryana, India, was assessed on the productivity of *Hordeum vulgare* (barley). Five trees of each species (average ages 16, 10, 5 and 8 years, respectively) were selected in November 1993 and barley var. C-138 sown under them in the first week of November 1993 and 1994. The yield and yield-attributing parameters of barley increased under the tree species compared with those in areas devoid of trees. *P. cineraria* enhanced the grain yield by 86.0%, *T. undulata* by 48.8%, *F. albida* by 57.9% and *A. indica* by 16.8% over the control. The soils under the tree canopies were rich in organic carbon content, moisture availability and nutrient status (N, P and K).

21 ANON. **Report on two consignments of haraz *(Acacia albida)* from the Republic of the Sudan.** Ministry of Technology, Forest Products Research Laboratory (1968) 8 pp. [En]

22 ANON. **A note on *Acacia albida*.** Murdoch University, Western Australia (1974) 11 pp. [En, 50 ref.]

The significance of *Acacia albida* derives from what may be termed its paradoxical, 'seasonally-inverted' foliage cycle. In a literature review, various theories are put forward - including that of 'root drowning' whereby a rising water table at the onset of the wet season triggers the tree's defoliation. *A. albida* is also an important cultural tree to the Serer tribe of Senegal, and for the Bambara in Mali and the Zaghawa and Yedina in Chad it plays a major role in mythology and religion. Despite the demonstrated benefits and efficiency of the *A. albida*-based ecosystem and its flexibility in striding the frontiers between forestry and agriculture, it remains for the most part too unorthodox a method to have received the approval of mainstream tropical agriculture. The confusions of taxonomy and an 'ecologically-inappropriate' prejudice may well equate thorniness with uselessness, and a hindrance to the progress of farm machinery.

23 ANON. *Acacia albida.* The miracle tree of the Sahel zone. Canadian International Development Agency (1979) 7 pp.

24 ANON. [**Short monograph on *Acacia albida* Del.**] Fiche monographique - bilan: *Acacia albida* Del. *Troisième Comite Recherche Forestière, Institut de Recherche en Biologie et Ecologie Tropicale, Ouagadougou, République de Haute Volta, 30-31 Novembre* (1982a) 9 pp. In App. [Fr]

Gives the following vernacular names for *Acacia albida*:- Moré, Zaanga, Peul, Teski, Thiaiki, Tchaski, Bambara, Balanzan, Haoussa, Gao, Wolof, Kad. *A. albida* can attain 20-25 m in height, 1 m in diameter. It provides shade in the dry season, and allows cultivation under the bare crown in the rainy season. It improves soil fertility, provides cattle fodder and wood and is useful in the prevention of erosion as roots are 10-15 m deep. It is a very plastic species, found in all dry tropical zones in Africa, from desert to the 1800 mm isohyets. It can tolerate nocturnal frost (Israel) and altitudes up to 2700 m (Sudan). Propagation is limited by high permanent humidity and bad soil permeability. Grows on a range of soil types, best on sandy or sandy-clay. It does not grow on laterite. It is water-demanding, the greatest densities are found where the water table is high. There are 10,000-12,000 seeds $kg^{-1}$ which can be collected in January-April. High levels of parasitism by insects are common and therefore the seed should be collected early before it is attacked and sorted by floatation. Viable seeds are dried and coated in insecticide powder and Thioral if storing for a long time. The seed will keep for many years if dry. The cuticle needs treating prior to germination; digestion by cattle aids germination. Seeds collected from unripe fruit can be sown straight away. Mature seeds soaked for 24 hours in boiled water or boiled for 10-15 minutes before planting (then takes 1-2 months to germinate). Generally get 80% germination from sorted seeds. The spread of *A. albida* is dependent on human migration and the passage through cattle guts. Without digestion natural regeneration is very difficult due to poor germination and competition from wild grasses which out-compete young trees in the dry season. Soil cultivation and weeding increases the success rate of natural regeneration, as does protection from herbivores and cutting. Seeds sown in polythene bags, planted March-May, using green seed or that treated correctly can raise seedling in three weeks. Planted out when 3-4 months old (15-30 cm tall). Planted on mounds with base cut off plastic container (if planting delayed, reduce the watering in the nursery to prevent further root growth). Planted at 10 m spacing, or at 4-5 m (for rapid site capture on dunes) and thin to 8-10 in year 6-7. Need soil preparation on clayey soils (none on sandy soils). Roots grow first to reach the water table. This can take 3-4 years in which time the plants are very small and require protection from grazing. Growth of neighbouring plants can be highly unequal. If the seedlings survive the first dry season they are established (as long as they are protected) - and can attain 1.5 m height and 10 cm diameter in 10 years. Direct sowing is risky and needs soil scarification and seeds should be boiled to induce germination. *A. albida* improves the chemical properties of the soil, especially the organic matter content and P in the surface horizons in the dry season. It decreases the maximum and increases the minimum temperature under its crown, increases humidity, decreases evapotranspiration, increases water fall and sunlight reaching the crops in the rainy season. It increases the yield of crops grown under the crown. The wood is light yellow, easy to work, used for artisan, garden and kitchen objects in Sudan-Sahel. The branches are used for huts, granaries and sheds. It is prone to insect attack but made more resistant by soaking in water for several months prior to use to remove sap. Generally, *A. albida* has a lower quality wood, makes a small quantity of paper pulp and porous paper of low mechanical strength and makes average quality charcoal. *A. albida* is often the only vegetation available in the dry season. Leaves compare to an excellent hay with respect to protein content. Pods play an important role in the rural economy. Fruits February-March, which is a critical period for feeding cattle. Pods are either grazed as they fall or gathered by people and sold to sheep farmers as forage with greatest nutritional and monetary value. An adult tree produces 100-150 kg pods. With 20 trees $ha^{-1}$, the yield is 2500 kg of pods which is equivalent to 1930 fodder units. Fields cleared for cultivation in summer and a pasture with *Acacia albida* can support 1.3 beef cattle $ha^{-1}$. *Acacia albida* is known across Africa by rural populations, though some ethnic groups exploit it while neighbouring groups do not use it at all. Gets pruned to varying degrees for animal fodder, others rely entirely on pods for fodder. Medicinally, *F. albida* is used for broncho-emollient and anti-febrile properties of bark and root preparations. It is also used as an anti-malarial and as treatment for mental illnesses, rheumatism and ear-ache. Some report the use of macerated roots in curing deafness. *F. albida* is host to a number of insect pests. Cochineals cause benign deformations of the foliage.

Crickets and grasshoppers cause serious defoliation of young plants. Caterpillars bore small branches. *Cryptothelea junodi* causees severe defoliation and *Crypsotidia coniferi* causes greatest damage to *A. albida* crowns (>50% defoliation in adults and complete defoliation in young trees).

25 ANON. **Trees for food production**. *Daily Times* (Malawi) 13 October 1982 (1982b) 10 [En]

General article on the benefits of planting *Acacia albida* (indigenous) and *Leuceana* species to improve crop yields and soil quality on smallholdings and commercial estates in Malawi. *A. albida* grows best where the ground water is high, such as around dambos (e.g. in the Balaka area), at Salima, near Rumphi and in the Lower Shire.

26 ANON. **The apple ring**. *Agroforestry Today* (1989) **1** (2) 11-12 [En, 6 ref.]

This is a popular article that summarizes the value of *Faidherbia albida* as an agroforestry tree and draws on published information to promote its use to prevent soil degradation and counter the problems of drought and desertification. The species "contrariness" fits the farmer's needs well as it lets the sunlight to the crops in the summer and shades the soil, keeps temperatures down and prevents evaporation during the dry winters. It is highly prized in West Africa where severe penalties can follow if a tree is mutilated or felled. Its ability to survive in very dry conditions (down to 300 mm of rain per year) is attributed to a deep taproot that can grow 1 cm a day at the seedling stage, up to 5 m in a year and reach a depth of 20 m to tap in to the permanent ground water. It is reputed to have few surface roots and therefore does not compete with crops. It brings up nutrients from deep below ground making them available on the surface as a mulch when it sheds its leaves. Nitrogen levels can be almost double those outside the tree's influence. It is reported that production from an unfertilized millet crop was 152% higher under the trees. *F. albida* is considered to be the Sahel's most important forage crop and can yield 25 kg of leaves and 140 kg of pods annually. Twenty adult trees per hectare could yield 2500 kg of pods with a feed value of 1500 forage units (equal to 1500 kg of barley). The wood is used for boats and canoes, bowls, kitchen utensils, camel saddles and furniture and its ashes for soap. The flowers produce pollen that is collected by honeybees. The tree is expected to fail if the groundwater is below 5 m as it has insufficient lateral roots to utilize surface water and if it is not protected from browsing animals. Plantings are said to have been most successful in sandy soils.

27 ARNBORG, T. ?? *Agroforestry* (1984) 1-15 [En, 27 ref.]

The paper discusses natural resources in the tropics, with special reference to Nigeria and their quick depletion due to population growth. Agroforestry, which is defined as a management system that combines the production of crops and trees and/or animals in space and time on the same unit of land, is described as the system that can be used for the protection of land as well as for food and wood production in the savanna zone of Nigeria. Various agroforestry combinations to be tried in this region are mentioned including the planting of windbreaks using multipurpose trees, the planting of sand dune fixing plants, and the use of the wonder tree (*Acacia albida*) for protection, shade, food and wood production.

28 ASAKAWA, S.; HARAYAMA, S. **Root growth and leaf stomatal density of *Acacia* seedlings**. *Bulletin of the Faculty of Agriculture, Tamagawa University* (1990) **30**, 20-21 [En, sum, jap]

Leaf growth and stomatal density were studied in six species of *Acacia* indigenous to Kenya including *Acacia* (*Faidherba*) *albida* with the aim of providing knowledge on variation in genetic and physiological hardiness of planting stock to use in improving out-planting success. The *F. albida* seed for the study was collected at Mrumi Dodoma. Seedlings were grown in Wagner pots under three soil moisture regimes with maximum pF set at 1.9, 2.3 and 2.8. *F. albida* was the only species that optimized root growth at pF1.9; all the others had optimum root development at pF2.3. *F. albida* produced greatest root mass at all three regimes except for *A. tortilis* which just exceeded it at pF1.9; and pF2.3. *F. albida* had the lowest top/root (shoot/root) ratio under all regimes; only *A. polyacantha* equalled it at pF1.9. Taproot growth was measured after transplanting and *F. albida* seedlings grew over 50 cm in 14 days, within a few millimetres of *A. tortilis, A. nilotica* and *A. polyacantha* but nearly double that of *A. abyssinica* and *A. xanthophloea*. *F. albida* seedlings had the greatest total number of stomata on the combined adaxial and abaxial surfaces of the leaf with similar numbers on both surfaces unlike all the others, except *A. xanthophloea*, which had fewer on the adaxial surface.

29 ASAKAWA, S.; MAKINO, M. **Growth response of *Acacia* seedlings to soil moisture conditions**. *Bulletin of the Faculty of Agriculture, Tamagawa University* (1989) **29**, 1-10 [En]

The seedling growth of six acacias native in Kenya was examined with four kinds of soil moisture conditions. The results obtained are as follows: (1) Among six acacias used here, only *Acacia albida* seeds germinate well by the pre-treatment prescribed by the KEFRI Seed Centre, and seeds of the other five species required additional treatments to obtain a reasonable percent of germination, which indicates that hard-coatedness of these seeds varies greatly with seed lot. (2) With *A. albida*, which grew best in this experiment, the ratio of shoot length (H) to basal diameter (D)

was largest under moistest condition. (3) The H/D ratio was largest under moistest condition for three species, and smallest under driest condition for five species. (4) In *A. albida*, dry matter weight of root was larger than that of top under any soil moisture condition, whereas in the five other *Acacias* top weight was larger than root weight. (5) In *A. tortilis* and *A. xanthophloea*, the TR ratio of dry matter decreased with the decreased soil moisture, but did not change in *A. albida*. (6) The stomata density on the reverse side of leaf ranged from 39.4 (*A. xanthophloea*) to 70.9 (*A. nilotica*) per 2 mm. (average for four counts).

30 ASSEFA, F; KLEINER, D. **Nodulation pattern and acetylene reduction (nitrogen fixation) activity of some highland and lowland Acacia species of Ethiopia**. *Biology and Fertility of Soils* (1998) **27** (1) 60-64 [En, 25 ref.]

Endosymbionts from the Ethiopian highland species *Acacia abyssinica, A. negrii* and *A. etbaica*, and the lowland species *A. nilotica, A. prasinata, A. senegal, A. seyal, A. tortilis* and *Faidherbia albida* were isolated and characterized. Seven species were found to be nodulated by species of both *Rhizobium* and *Bradyrhizobium*. *F. albida* and *A. senegal* were nodulated by only *Bradyrhizobium* or *Rhizobium*, respectively. The nitrogen fixation (acetylene reduction) activities varied considerably and showed no correlation with the nitrogen content of the plant. Highland species were as effective as lowland plants, thus demonstrating good potential for soil reclamation. The endosymbionts isolated proved rather promiscuous, efficiently-nodulating other *Acacia* spp. and some tropical grain legumes, but did not nodulate temperate legumes.

31 ATCHINSON, E. **Studies in the Leguminosae II. Cytogeography of *Acacia***. *American Journal of Botany* (1948) **35** (10) 651-655 [En, 12 ref.]

Lists chromosome numbers of 38 species and varieties of *Acacia* in the world, 19 of which have been determined by the author. Tropical African species are listed as polyploids, having a chromosome number of 2n = 52. *Acacia albida* from North Africa has a chromosome count of 2n = 26. These are discussed in relation to evolution and distribution.

32 ATHAR, M.; MAHMOOD, A. **Qualitative study of the nodulating ability of legumes of Pakistan. List 3**. *Tropical Agriculture, UK* (1985) **62** (1) 49-51 [En, 25 ref.]

Data are presented for 45 species (4 Mimosaceae, 8 Caesalpiniaceae, 33 Papilionaceae). Nodules were not found and could not be indicated in the Caesalpiniaceae examined.

33 AUBREVILLE, A. [**The acacias of French West Africa**] Les Acacias de l'Afrique Occidentale Française. Comptes rendus de l'Association Colonies-sciences (1933) [Fr]

34 AUBREVILLE, A. [**Ecological comments on the distribution of some *Acacia* species in West Africa.**] Remarques écologiques sur la distribution géographiques de quelques espèces d'*Acacia* en Afrique Occidentale. *Revue de Botanique Appliquée* (1937) p. 796 [Fr]

35 AUBREVILLE, A. [**Contribution to the study of charcoals from French West Africa.**] Contribution à l'étude des charbons de bois de l'Afrique occidentale Française. *Actes et Comptes Rendus de l'Association Colonies - Sciences* (1941) No. 177, 1-31 [Fr]

Reports on experiments made by the government of French West Africa in 1983-89. The results are presented in a number of tables. Among the commoner species which were found to make good charcoal were *Acacia nilotica, A. raddiana, A. senegal, Balanites aegyptiace, Zizyphus jujuba, Dichrostachys glomerata, Combretum micranthum* and *C. glutinosum*.

36 AUBREVILLE, A. **Flore forestière soudano-gineene: A.O.F. - A.E.F.** *Soc. D'Editions géographiques, maritimes et coloniales, Paris* (1950) 280-283 [Fr]

37 AYOUB, S.M.H. **Flavanol molluscicides from the Sudan *Acacias***. *International Journal of Crude Drug Research* (1985) **23** (2) 87-90 [En, 16 ref.]

The isolation of (-)-epigallocatechin-7-gallate and (-)- epigallocatechin-5, 7-digallate from the ethyl acetate extracts of the fruits and stem bark of *Acacia nilotica* ssp. *nilotica, tomentosa* and *adstringens* (previously shown to have high molluscicidal activity against *Bulinus truncatus* and *Biomphalaria pfeifferi*, which transmit schistosomiasis in Sudan and Egypt) is reported. These two active compounds were also isolated from the bark and fruit extracts of 20 other *Acacia* taxa including *A. albida* Del., *A. senegal* var. *senegal* and *A. tortilis* ssp. *raddiana*, ssp. *spirocarpa* and spp. *tortilis*. Tannins in the plants are the source of the flavonal derivatives.

38 AYOUB, S.M.H.; YANKOV, L.K. **Algicidal properties of tannins**. *Fitoterapia* (1985) **56** (4) 227-229 [En, 5 ref.]

Methanolic extracts of *Acacia albida, A. seyal* var. *fistula, A. seyal* var. *seyal* and *A. catechu* (collected in Khartoum province) and *Uncaria gambir, Krameria triandra, Arctostaphylos uva-ursi, Terminalia chebula, Hamamelis virginiana* and *Caesalpinia coriaria* (commercially available), all of which contain hydrolysable and condensed tannins, showed algicidal activity when tested in ponds. The tannins acted by precipitating algal proteins.

39 AYOUB, S.M.H; YANKOV, L.K. **Molluscicidal properties of the Sudan *Acacias*.** *Fitoterapia* (1987) **58** (5) 363-366 [En, 13 ref.]

Ethyl extracts of 17 *Acacia* spp., applied at 100 to 200 p.p.m., gave complete control of the schistosomiasis-transmitting snails *Bulinus truncatus* and *Biomphalaria pfeifferi*. Spray-dried powders from *A. albida* and *A. seyal* were also active at 100 p.p.m. and could be used as cheap molluscicides.

40 BA, A.M.; GUISSOU, T. **Rock phosphate and vesicular-arbuscular mycorrhiza effects on growth and nutrient uptake of *Faidherbia albida* (Del.) seedlings in an alkaline sandy soil.** *Agroforestry Systems* (1996) **34** (2)129-137 [En, 23 ref.]

Response of *Faidherbia albida* to five levels of Kodjari rock phosphate (KRP, at 0, 310, 620, 1240 and 2480 ppm P, equivalent to 0, 775, 1550, 3100 and 6200 kg P/ha) and two species of vesicular-arbuscular mycorrhizal fungi (VAM, *Glomus manihotis* and *Glomus aggregatum*) was evaluated in an alkaline sandy soil collected from a stand of *Afzelia africana* in Burkina Faso. The *F. albida* seedlings grew poorly without mycorrhizal colonization and without KRP applications. For non-VAM *F. albida*, the maximum growth response and both P and N uptake in shoots was achieved with 620 ppm P. However, even without KRP application, VAM plants generally achieved better results in terms of biomass, and VAM plants with both *Glomus* spp. had improved growth and increased nutrient contents at any KRP application rate. Although mycorrhizal colonization was comparable at all levels of KRP application, the impact on nutrient content of the shoot varied. VAM plants did not accumulate more biomass than non-VAM plants at 620 ppm P and above, and growth response and mycorrhizal dependency decreased as KRP applied levels increased. These results suggest that VAM *F. albida* seedlings take up more P from soil and KRP than non-VAM seedlings.

41 BABU, R.C.; NATARAJARATHNAM, N.; PADMANABHAN, G.; DHARMARAJ, G. **An analysis of drought adaptive characters in certain species of *Acacia*.** *Indian Journal of Forestry* (1987) **10** (4) 276-278 [En, 19 ref.]

Measurements were made on healthy six-month-old seedlings of five species (*Acacia auriculiformis*, *A. albida*, *A. nilotica*, *A. tortilis* and *A. suma*) raised under normal nursery conditions; they were recorded during noon hours on a day before irrigation, when there would be peak evaporative demand. Parameters investigated were relative bark m.c. and, on fully expanded leaves from the top, leaf temp., stomatal resistance, transpiration rate, stem water potential and leaf proline content. Data are tabulated for each species and indicate that *A. auriculiformis* had the best drought resistant characteristics, i.e.: highest bark m.c., stem water potential, leaf temp., proline content and stomatal resistance; and lowest transpiration rate.

42 BAHRY, A.L. **Response of *Acacia albida* (Del.) to different rhizobial isolates in two soil types [Philippines].** *Thesis for M.Sc. in Forestry, College, Laguna* (1988) 65 pp. [En, 51 ref.]

The infectivity and effectivity of 12 rhizobial isolates on the growth of *Acacia albida* in two soils of varying fertility levels, were tested under screenhouse condition. Of the ten parameters chosen primarily for purpose of the study, nodule number, nodule dry weight, shoot biomass, total biomass, root/shoot ratio and diameter were found most effective in assessing treatment effects. All rhizobial isolates tested were infective but there were significant differences with respect to effectivity. Seedlings that were inoculated with isolate Am 2 appeared superior over those treated with other isolates and their performance was comparable to seedlings treated with nitrogen. This response was more pronounced in the less fertile (Caranglan) soil as compared with the more fertile (Calaca) soil. Seedlings treated with isolate Aal, and TAL 1458 have shown intermediate performance. Plants grown in Caranglan soil performed better with Am 2 and Aal 1 while those inoculated with TAL 1438 put up better growth in Calaca soil. The rest of the isolates had less effect on the seedlings growth. Uninoculated plants which were grown in Calaca soil exhibited vigorous growth comparable to those treated with nitrogen in the same soil. Generally, better growth was observed in the more fertile soil than in the less fertile soil. Results suggest that inoculation of *Acacia albida* with isolate Am 2 enhances better growth in Caranglan soil than in Calaca soil. The better growth performance of the uninoculated plants in Calaca soil might have been a result of the prevalence of native Rhizobia, as supported by the presence of large and effective nodules which must have supplied the amount of nitrogen to the plants. It is recommended that further tests on the performance of isolate Am 2 be conducted, so as to ascertain its suitability as an inoculant for the better growth of *A. albida*.

43 BAHUGUNA, V.K.; MAITHANI, G.P.; DHAUNDIYAL, U.D.; UNNIKRISHNAN, K.P. **Standardization of nursery techniques of *Acacia albida* Del. under north Indian moist climatic conditions.** *Indian Forester* (1987) **113** (2) 95-100 [En, hindi, 4 ref.]

*Acacia albida* is being extensively introduced into India for agroforestry purposes. Seeds were collected from the experimental garden of the State Forest Research Institute at Jabalpur, Madhya Pradesh, and nursery techniques tested at the Forest Research Institute, Dehra Dun. Soil media tested were: soil/ sand/farmyard manure (2:1:1); soil/sand (2:1); soil/sand/ farmyard manure (1:1:1); and soil/sand (1:1). Sowing methods were in polythene bags, in beds (line or broadcast sowing) and in

boxes (broadcast sowing). Records were made of sowing date, dates of commencement and completion of germination, daily germination, height and diameter of seedlings after completion of germination, and mortality. Survival was similar for all treatments. Germination was highest in the polythene bag treatments, and in the two soil/sand media. Days to completion of germination did not vary between treatments. Height and diameter growth were best in the sowing-in-boxes and polythene bag treatments and with the two farmyard manure media; these media stimulated growth after completion of germination. Recommended procedures are the use of polythene bags (or boxes) with soil/sand media until pricking out, when farmyard manure could be added to the growing media.

44 BAILLON, D.H. [**Revision of the medicinal acacias.**] Révision des *Acacia* médicinaux. *Adansonia* (1863) **4**, 85-127 [Fr]

Looks at the nomenclature of *Acacia* species with medicinal properties - both the genera *Mimosa* and *Acacia* have been split to form large numbers of other genera, leading to confusion in the study of medicinal plants. Lists the characteristics of the genus *Acacia*:- stamens either stand free or are joined to each other at the base usually by a disk around the base of the ovary; corolla valve-like before flowering, petals can be completely free or fused to varying degrees calyx consists of fused sepals and always shorter then the fully developed corolla; ovules in two vertical parallel descending rows with mycropile turned up and out; fruit polyspermous. *Acacia albida* (Delile) is described as follows:- not a true *Acacia*; flowers are polygamous and often hermaphrodite; calyx is fused, membranous, ciliate and borders may be complete or cut into five or more short irregular teeth. Five petals. Freestanding valve-like bud joined to stamen at base. Large number of stamens bunched together in the bud and separating once the anthers form - the filaments are inserted into the external surface of the small cupiform glandular disk, above which, still fused part way, they spread, each with a 4-sided anther with two parallel pollen sacs joined externally by a 4-sided thick, glandular, brownish tissue a bit narrower than the anther. Gynaecium consists of an ovary on a receptacle at the base of the disk. In the ovarian lodge there is a linear placenta formed by two salient bands each having 15-20 ovules arranged in descending order. Style is folded in the bud. Stigma is hollow, the tube is not wide, and the opening is entire. The fruit is leaf-like, very thin, flat, folded in on itself and shows a bit above the base a small bump that makes it appear detached from its base. Glabrous, sticky and bright green even when dry. Seeds held on long thin filaments. Flowers in long bunch, each on short peduncle, linked to cupiform base of receptacle. *Acacia albida* was first found in Egypt by Delile. It was also collected in Syria and Senegal. It is a tree, 30-40 feet tall, highly branched, white bark, bipinnate leaves, two straight stipulate spines. Not an *Acacia*, even though it provides gum for commerce. Looks more like *Albizia* to which it would be linked if stamens were not fused with the corolla, as they are in another group of the Mimosaceae, the Calliandra. Synonyms: *A. gyrocarpa* Hochst, *A. Senegal* W.

45 BAINBRIDGE, W.R. **Distribution of seed in elephant dung**. *Occasional Paper, Department of Game and Fisheries, Zambia Puku* (1965) No. 3, 173-175 [En]

Provides photographs of *Acacia* seedlings growing out of elephant dung. Characteristic glaucous green colour of *A. albida*. It is a well known riverine species, common along the banks of the Zambezi, where it is adapted to periodic flooding and can withstand more than 2 months of partial submersion. States that in the Sudan, two thirds of *A. albida* Del. seeds eaten by cattle pass through the digestive tract unharmed, and that the digestive juices of the cattle greatly improve the readiness to germinate. Elephant dung consists of a great deal of fibrous vegetative material which forms an ideal germination medium.

46 BANKS, C.H.; SCHOEMAN, J.P.; OTTO, K.P. **The mechanical properties of timbers with particular reference to South Africa**. *Dept. Forestry, South African Forestry Research Institute Bulletin* (1977) No. 48, 88 pp. [En, 24 ref.]

Information is given on the mechanical properties of a number of South African hardwood timbers, including *Acacia albida*, in the air-dry condition (12% moisture content). Mass - 562 kg $m^{3-1}$; static bending - modulus of rupture - 64 MPa, fibre stress at P.L. - 35 MPa, modulus of elasticity - 7652 MPa; compression parallel to Grain - max. crushing strength - 37.6 MPa; compression perpendicular to Grain - stress at 2.54 mm deflection - 11.9 MPa, stress at P.L. - 6.1 Mpa; shear parallel to grain - max. shearing strength 10.3 MPa.

47 BANKS, P.F. **The potential for agroforestry on forest land in the Sebungwe region**. *Zimbabwe Agricultural Journal* (1982) **79** (5) 161-163 [En, 1 ref.]

Describes the need for management of the forest lands of Sebungwe, Zimbabwe, amounting to a quarter of a million hectares, nearly all located on Kalahari sands. Briefly details an agroforestry pilot scheme for the Lutope valley area of Mafungabusi Forest, an area exploited by squatters but of low agricultural potential when the trees are removed. The objectives are to stop shifting cultivation, improve and maintain soil fertility, plant multipurpose trees for windbreaks, establish fodder banks and conserve indigenous vegetation by local families. In the arable area, establishing *Acacia albida* (for fodder) and other species in lines demarking the blocks of 10 hectares in a family unit area.

48 BARBIER, C. **[Proposals for the Maradi U.E.E.]** Propositions forestieres pour l'U.E.E. de Maradi. D.G.R.S.T.-G.E.R.D.A.T.-C.T.F.T. janvier (1978) [Fr]

49 BARNES, R.D. **The African acacias: a thorny subject**. Keynote paper in *Forest Genetics for the next Millennium. Proceedings IUFRO Working Party 2.08.01, Durban, South Africa, 8-13 October 2000.* ICFR, P.O. Box 200281, Scottsville 3209, South Africa. (2000) 9-15. [En]

There are 129 *Acacia* species in Africa. They are intermediate in plant succession, and colonize degraded land. They restore fertility and can be maintained indefinitely in agricultural systems. They provide many benefits but are disliked for their thorns and invasiveness. Seed was collected across the ranges of *Acacia erioloba, A. karroo, A nilotica, A.senegal, A. tortilis* and *Faidherbia albida*. Screening trials indicated that, with selection, all had potential inside and outside their natural ranges. A total of 21 provenances of *F. albida* were included in the screening trials in Zimbabwe. The southern African provenances did best overall but the West African provenances were taking the lead on sandy savannas by the fourth year. The high altitude provenances from Ethiopia did better on the heavier soils and on the frostier sites. Subsidiary studies showed that some acacias get their nitrogen from groundwater rather than from the atmosphere, that they can produce more crude protein per hectare than a grain crop and that there are annual rings in the wood. Farmers will resist planting acacias until the benefits can be translated into cash. The challenge for breeders in the new millennium is to produce trees that are inherently so good that they sell themselves to the farmer.

50 BARNES, R,D.; MARUNDA, C.T.; MAKONI, O.; MARUZANE, D.; CHIMBALANGA, J. **African acacias: genetic evaluation: phase I**. *Final Report of ODA Forestry Research Scheme R.5653.* Oxford Forestry Institute and Zimbabwe Forestry Commission. (1996) 209 pp. [En, 5 refs, 34 tab, 11 fig]

The Oxford Forestry Institute conducted a series of Research Schemes from 1987 to 1996 to develop the genetic potential of the African acacias to increase productivity in the semi-arid parts of the continent. The work was funded by the Forest Research Programme of the Overseas Development Agency of the British Government. Five of these projects have been concerned with taxonomic studies, exploration of the range, seed collection and dissemination of the information and seed. This Research Scheme was the first to have conducted field trials to test the comparative performance of taxa and provenances in the field in Zimbabwe, the first trial centre of a number intended over an appropriate range of environmental conditions in Africa. Screening trials incorporating a selected 70 provenances of six acacias, *Acacia erioloba, A. karroo, A. nilotica, A. senegal, A. tortilis* and *Faidherbia albida,* and their sub-specific taxa were established over eight sites in the Matabeleland Province. The sites selected provided good coverage of the main soil and climatic conditions under which the acacias are likely to make an impact on productivity. Single tree plot designs were used with many replications. The results of these trials are to be used to design and site larger main trials of each species incorporating more provenances. Assessments of survival, frost resistance and growth are reported with further studies in morphology, phenology, taxonomy, nitrogen fixation, rooting architecture, nutrition, salt tolerance and other disciplines planned. Socio-economic research into the current and potential value of the acacias to the farmer, on-farm research into techniques for their establishment and management and the study of the interface between grass and crops and the trees would be synergistic. Seeds for the trial were nicked at the micropylar end and pre-germinated in a controlled temperature cabinet at 25°C (night) and 30°C (day). After soaking for 7-8 hours, seeds of *F. albida* produced a radicle in 48-72 hours after which they were sown in pots and the hypocotyl emerged in 3 days. Seedlings of *F. albida* were tallest of the six species from one month after emergence to 7 months when they averaged 25.9 cm. across provenances. The Mana Pools (Zimbabwe) (53.0 cm) and Obeid (Sudan) provenances were tallest when planted out; the West African provenance, Sabce (Burkina Faso) (10.7 cm) were shortest. Field survival after the first year was about 90% on the 4 sites on which *F. albida* was likely to succeed and on these sites the species performed best after *A, karroo* in terms of height growth with provenance ranking remaining about the same as in the nursery. No riverine sites were planted but the species did best on young granite-derived soils on which average provenance height at one year after planting was 0.849 m with a range of 0.556 m for Matameyi, Niger, and 1.133 for Hoanib, Namibia. Crown diameter was closely correlated with height. *F. albida* was more frost susceptible than *A. erioloba* and *A. karroo*, about equal to *A. senegal* and *A. tortilis* and more resistant than *A. nilotica*. At the most frosty site, only 18% of individuals escaped damage. The Ethiopian provenances were most resistant and the Malawian least.

51 BARNES, R.D.; MARUNDA, C.T.; MARUZANE, D.; ZIROBWA, M. **African acacias: genetic evaluation: Phase II**. *Final Report of DFID Forestry Research Scheme R.6550.* Oxford Forestry Institute and Zimbabwe Forestry Commission. (1999) 49 pp. [En, 31 ref., 6 tab., 41 fig.]

This is the Final Report of the second DFID/OFI genetic evaluation project of the African acacias in Zimbabwe. For a brief summary of the background to the work, see abstract under Barnes *et al.* (1996). This report gives the latest results of the screening trials and the first results of the main trials which were planted as one of the objectives of the project. Wide spacings and single tree

plots were used in the main trial designs as the best compromise to avoid early competition and to provide enough replications to impose selection and management studies on the experiments, established with 30 wide-ranging provenances on four sites, in the future. The southern African provenances of *Faidherbia albida* grew faster than those from North and West Africa with the exception of those from higher altitudes in Ethiopia which did better than all other provenances on the heavier soils and the frostier sites. The West African provenances were the poorest performers of all although by the fourth year there was some indication that they might be coming into their own on the frost-free, wind-blown Kalahari sands site. The conclusion of the community studies on six *Acacia* species including *F. albida* was that research should focus on exploring the markets for locally produced gum arabic and pods and stimulating the demand for these products to provide the incentive for enhanced management and planting. An objective of this project has been to create a resource of information on and materials of the African acacias that can be used for future research with funding attracted from international agencies for projects from a wide variety of disciplines. This had started to happen before the end of the project by which time funds were assured for research into using acacias to restore fertility to degraded land, on-farm evaluation of *Acacia* species and livestock feeding trials with acacia pods. Although *F. albida* is exclusively a riverine species in east and southern Africa and regenerates only on newly-formed sand and silt banks after flooding along rivers where there is little or no frost, the species can grow and perform well away from the rivers in the right climate and on the right soils where man has removed the competition from grass and woody regrowth during the establishment phase. In Malawi, *F. albida* now grows in cultivated fields away from the rivers round the lake where the artificial weed-free environment and the tree's usefulness to farmers has resulted in a symbiosis that has helped the species to extend out of its natural environment. It is possible, therefore, that the species could be used far more widely than it is.

52 BARNES, R.F.W. **Effects of elephant (*Loxodonta africana*) browsing on woodlands in a Tanzanian National Park; measurements, models and management**. *Journal of Applied Ecology* (1983) **20** (2) 521-540 [En, 30 ref.]

A study of two woodland populations, (*Acacia albida* and *Commiphora ugogensis*), in the Ruaha National Park, and their distribution pattern as affected by elephants. *A. albida* is restricted to alluvial soils along the major rivers, and is particularly important in providing shade, fruits and food close to the water when other sources are in short supply. Its fruits are eaten by baboons (*Papio cynocephalus* L.), vervet monkeys (*Cercopithecus aethiops* L.), impala (*Aepeyros melampus* Lichtenstein), and kudus (*Tragelaphus strepsiceros* and *T. imberbis*) as well as elephants. There was a lack of regeneration and 40% of the *A. albida* woodland had been killed by the elephants, and it was concluded that large numbers of elephants needed to be culled to reverse the decline.

53 BARNES, R.F.W. **Woodland changes in Ruaha National Park, Tanzania, between 1976 and 1982**. *African Journal of Ecology* (1985) **23** (4) 215-222 [En]

Tree surveys made in 1976 and 1977 were repeated in 1982. Three species were measured: *Commiphora urogensis*, *Acacia albida*, and *Adansonia digitata*. All three showed significant decreases due to elephant browsing. These results confirm the predictions of the earlier surveys: elephants are causing a rapid and severe change in the rift valley woodlands of the Park.

54 BARROW, E.G.C. **Trees and pastoralists: the case of the Pokot and Turkana**. *ODI Social Forestry Network Paper* 6b (1988) 24 pp. [En]

The paper highlights traditional values that the Pokot and Turkana have which could be of value in soil and water conservation. It attempts to identify methods of incorporating such traditional values into soil and water conservation practices for arid/semi-arid lands. Pastoral people in arid/semi-arid lands have developed sustainable land use systems that make optimal use of the land both geographically and ecologically. Historically, such systems were self regulated but nowadays these mechanisms are no longer allowed full play resulting in environmental degradation, particularly in the areas around settlements. The woody vegetation such as the riverine forest, is the most valuable resource. Pastoralists such as the Pokot attach great value to trees and will rarely cut a valuable tree. Such trees include: *Acacia tortilis*, *Acacia albida*, *Balanites aegyptiaca*, *Cordia sinensis*, *Hyphaene coriacea*, *Dobera glabra*, and *Ziziphus mauritiana*.

55 BARROW, E.G.C. **Evaluating the effectiveness of participatory agroforestry extension programmes in a pastoral system, based on existing traditional values. A case study of the Turkana in Kenya**. *Agroforestry Systems* (1991) **14** (1) 1-21 [En, 35 ref.]

The Turkana silvopastoral system is a traditional natural resource management strategy for dry lands that forms a sensible basis for improvement. The system is based on transhumance wet and dry season grazing combined with specific dry season grazing reserves and based on groups of families who manage diverse livestock species (grazers and browsers) together to make the best use of the vegetation. The system is reinforced by social controls such as livestock sharing, flexibility of pastoral management strategies and mobility in grazing patterns. Trees are valued in the system, especially in the drier central parts of Turkana. Within the wet season grazing area the herd owner may have an area of riverine

forest to which the owner has usufruct rights. In the dry season it is often access to fruit and fodder trees that restricts movement. Some important species (*e.g. Acacia tortilis, Hyphaena* [*Hyphaene*] *compressa, Cordia sinensis, Zizyphus* [*Ziziphus*] *mauritiana, Dobera glabra* and *Faidherbia* [*Acacia*] *albida*) are protected by custom. There are several characteristics of the system that are directly related to drought resistance in pastoralism and inversely related to famine susceptibility; these are the availability of large diverse ranges, access to productive dry season ranges (including trees), high mobility and low to moderate stocking rates, and high to moderate stock units per person. Such complex broad systems have worked in the past but are now threatened. Involvement of the local people is vital in adapting and improving the system to bring out the potentials that exist in terms of broad land management strategies, and more specifically, in terms of the management of individual tree species. The participatory extension process being used by the Forestry Department in Turkana is described. It relates to the traditional natural management base as a means of trying to identify potentials, constraints, problems and solutions. Such extension programmes are difficult to evaluate. The data gathering methods for evaluating such extension work, involving over 6000 people, are discussed in the light of a mobile people, lack of a sampling frame and large distances in an arid and semiarid environment. The results of two surveys, together with other informal data gathering mechanisms, show that change is taking place, particularly in qualitative terms, and indicates the effectiveness of the participatory extension programme.

56 BASTIE, B; DIALLO, B. [**Comparison of provenances of *Faidherbia albida* planted in Burkina Faso. Survival and juvenile growth rate in the northern and southern sudanian zones.**] Comparaison de provenances de *Faidherbia albida* en plantation au Burkina Faso. Taux de survie et vitesse de croissance juvénile dans les zones nord et sud-soudanienne. In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Forêt, Montpellier, France (1996) 312 pp. 259-268 [Fr, en]

Eleven provenances of *Faidherbia albida* from six countries (Burkina Faso, Burundi, Cameroon, Ethiopia, Niger and Senegal), simultaneously introduced in 1985 and 1987 at the Dinderesso (south Sudanian zone) and Gonse (north Sudanian zone) stations, are compared 5.5 years after planting. Survival rates, overall, are higher at Dinderesso, while the trees are larger at Gonse, with a lower variability between provenances. Seeds coming from eastern and southern Africa have very high mortality rates at both stations. Seeds originating from Senegal (Merina and Bignona) were much better in the experiments in terms of height and basal diameter.

57 BAUMER, M. ***Faidherbia albida.*** In *Notes on trees and shrubs in arid and semi-arid regions.* Rome, Italy; EMASAR Phase II/FAO, Plant Production and Protection Division (1983) 165-181 [En]

The systematic position of *Faidherbia albida* is now more logically in a monospecific genus in the tribe of *Ingae* ensuring the transition between this tribe and *Acaciaeae*. The tree reaches 25 m high and 1 m in diameter; old trees have ascending branches and umbrella-shaped crown whereas young trees have a pyramidal shape; bark is grey, first smooth, becoming rough with age but trunk and shoots are almost white in young trees; the tap-root has been recorded to be 7 m long in young seedlings only nine months old and 5-6 cm high. The leaves are blue-green and about 10 cm long with 3-10 pairs of pinnulae and 6-23 pairs of slightly hairy foliolules; the strong white spines are thicker at the base than in other acacias; flowers are in axillary bunches, 7-10 cm long, fragrant, creamy white with 5-lobed calyx and 40-50 stamens; pods are thick, indehiscent, yellow-orange, 10-15 cm long curled and spiralled and they fall to the ground 3 months after flowering; there are 10-20 seeds per pod, shiny, ovoid, dark brown, 11500 to the kg; the wood is light yellow, soft and lasting. The species has an aberrant physiology shedding its foliage in the rainy season and keeping it in the dry season. The flowers appear at the same time as the leaves. Fruiting is said to start between two and four years of age under exceptionally good conditions in Niger but more usually starts at 15 years. The species is said to be anthropophilous because there are always human settlements at the sites of its occurrence. In the fields round Zinder where the sultans used to plant it 60 trees $ha^{-1}$ there is a yield of 400-600 pods per year. No fungal diseases have been reported, The mite [??] *Cryptoditia conifera* provokes defoliation, bruchids attack the seeds, in particular *Pachymerus longus, P. pallidus, Bruchidius silaceus* and *B, rufulus* and a wood boring beetle, *Sinoxylon senegalense*, has been reported. Annual growth rates have been recorded of up to 18.1 mm in diameter and up to 2 m in height (in the first three years). The oldest trees seem to reach an age of 80-100 years. The number of chromosomes is 2n = 36. Suckers grow from wounded roots. Natural occurrence of *F. albida* is throughout Africa between the 500 and 800 mm isohyets at altitudes from -270 in Israel to 2500 m in Sudan. Its presence is a good indicator of ground water at up to 15 m below the surface because it has a high water requirement in the dry season. Seedlings can reach water at this depth where annual rainfall is over 450 mm but this limit can be brought down to 300 mm if the years following planting are not deficient. The species does not grow naturally in clay soils (nor where there is some factor impeding root penetration) but, if it is given preliminary watering, it can be established on heavy soils provided there is a deep, non-standing, water table. In arid areas it is concentrated along drainage lines and in depressions and temperatures may range from 19 to 42°C. It is sensitive to cold and to fire. Successful germination and establishment requires fresh seed, or seed that has passed through animals, and cultivated soils. When these conditions are fulfilled, regeneration will come about.

Seed should be sown in 30 x 10 cm (flat) polythene tubes. Pre-treatment is not necessary if the seed is fresh but, if stored, it should be soaked in 66° Baume sulphuric acid for 4 minutes, then washed and dried, or soaked in water just come off the boil for five minutes then left to soak for 24 hours. Three to four months are required to produce a 10-12 cm seedling. Root pruning is important. Growth is slow to begin with but speeds up after 2-3 years and becomes very fast once the roots have reached he water table. Initial plant density should be no greater than 400 stems $ha^{-1}$; 40-60 trees $ha^{-1}$ is considered to be a high density in a mature stand. Seedlings are very sensitive to competition from grasses and other trees. The wood is soft and weak but easy to work and used to make handicraft items, mortars, pestles, calabash, kitchen tools and saddles and it is used in building, carpentry and to make canoes. Poles and pegs are soaked for several months to eliminate sap. The foliage is used as fodder for cattle goats and sheep but horses do not eat it. Trimming of small branches for fodder is better for the tree than cutting large branches. Feed value of pods is 0.774 FU $kg^{-1}$ with 10% crude protein. Up to 125 kg of pods can be expected from a mature tree but 10 kg of pods and 10 kg of leaves have bee taken as the average yield. The pods are a commodity of local trade and sold for fattening livestock to enhancing milk production. When food is short, seeds are boiled, peeled and eaten by humans. Feed value of leaves has been estimated as:- net energy 6.2-6.9 MJ $kg^{-1}$ DM; digestible protein 120-140 g $kg^{-1}$; DP/FU (Feed ratio) 130-160; Phosphorus 0.12-0.20 % DM. Feed value of pods has been estimated as:- net energy 5.5-6.2 MJ $kg^{-1}$ DM; DP/FU (Feed ratio) 90-120. Lean and weakened animals quickly recover when fed on the pods. It is estimated that stocking rates in a wooded savanna could be doubled after the introduction of *F. albida*. Stocking rates of 400 kg live weight $ha^{-1}$, yearlong were recorded in Senegal (equivalent to 3 000 000 Kcal $ha^{-1}$ $yr^{-1}$) with 50 trees $ha^{-1}$. Analysis of leaves and pods with digestible elements expressed in parts per 1000 of freshly harvested product were as follows:- green leaves - water 589.5; DM 410.5; Fat 12.1; crude protein (Hx6.25) 70.4; N-free extract 204.9; P 0.56; ash 35.3; insoluble HCl 16.8; green pods - water 719.7; DM 280.3; fat 2.8; crude protein (Hx6.25) 31.8; N-free extract 168.0; P 0.41; ash 10.0 insoluble HCl 1.3; and mature pods - water 395.4; DM 674.6; fat 10.1; crude protein (Hx6.25) 74.2; N-free extract 409.9; P 0.81; ash 26.0; insoluble HCl 3.1. Pods therefore have a mediocre content of fat but are fair in protein whereas leaves are fair in fat and comparable to excellent fodder in protein. *F. albida,* in the absence of green grass, constitutes the best possible stock feed. *F. albida* also improves the fertility of the soil; increases in nutrient content in land cultivated under the trees compared with land without trees have been estimated as follows:- clay 7%; assimilable P 134%; total carbon 60%; moisture equivalent 43%; total N 100%; exchangeable Ca100%; exchangeable Mg 70%. It has been estimated that 40-50 *F. albida* $ha^{-1}$ brings in to each ha as much nutrient as 300 kg of organic N, 50 kg of KCl, 80 kg of bicalcium sulphate, 125 kg of dolomite or 100 kg of agricultural lime. Millet yields can be 66% higher under the trees than away from them but groundnut yields are depressed because of an excess of N under the trees.

58 BAUMER, M. **The potential role of agroforestry in combating desertification and environmental degradation**. Technical Centre for Agricultural and Rural Cooperation (1990) 250 pp. [En, many ref.]

Short taxonomic review of the kadd, or *Faidherbia albida* (*Acacia albida*), and the evidence available which cites its more logical classification as a monospecific genus within the Ingae group. In addition, a literature analysis is given regarding research into the beneficial fertilizing role of kadd. Compared with a soil cultivated without kadd, a soil cultivated beneath *F. albida* shows an average increase of:- 7% clay; 100% total nitrogen; 40% water storage capacity; 100% exchangeable calcium; 43% equivalent himidity; 100% base exchange capacity; 60% total carbon; 134% assimilable phosphorus; 70% exchangeable magnesium; 160% organic matter. In Senegal it has been found that about fifty trees to the hectare give as much as 300 kg organic nitrogen or 50 kg of potassium chloride (24 kg K) or 80 kg of bicalcium phosphate (31 kg of soluble $P_2O_5$ and 25 kg Ca); or 125 kg of dolomite (15 kg Mg and 25 kg Ca) or 100 kg of agricultural lime. Studies also record an ear weight increase in sorghum of 85%, and a 32% increase in grain weight when crops are grown under kadd. Foliage is valued as a forage source, the leaves containing 7.4% crude proteins in the dry matter and 1.2% fats. It is estimated that a mature tree could produce 125 kg of pods with a forage value twice that of good hay or dried peanut or rice haulms. Hence with 20 mature trees/ha, it is theoretically possible to feed 1.3 head of cattle/ha, which will produce 9.1 litres of milk or 910 g of live weight each day.

59 BEBAWI, F.F.; MOHAMED, S.M. **Effects of irrigation frequency on germination and on root and shoot yields in *Acacia* species**. *Plant and Soil* (1982) **65** (2) 275-279 [En, 6 ref.]

A study was made of the effects of differing irrigation treatments (control, waterlogged, and every 1, 3 or 6 days) on the germination and initial growth of six *Acacia* species from Sudan. Mechanically scarified seed (6 months old) was sown in clay plots and the maximum germination and root and shoot yields were obtained with daily irrigation. *Acacia albida* had the greatest germination response (19.5%) over all treatments, and it was suggested that this may explain its wide ecological distribution in Sudan. It was concluded that variations in water supply may account for species adaptation and distribution in semi-arid zones.

60 BEBAWI, F.F.; MOHAMED, S.M. **The pre-treatment of seeds of six Sudanese *Acacias* to improve**

**their germination response**. *Seed Science and Technology* (1985) **13** (1) 111-119 [En, 12 ref.]

Four experiments were performed on *Acacia* seeds including *A. tortilis* spp. *spirocarpa*, *A. ehrenbergiana*, *A. nubica*, *A. nilotica* spp. *nilotica*, A. *seyal* var. *seyal* and *A. albida*, in investigating the effects of mechanical, chemical, and biological seed coat treatments on germination response. Pre-treatment was not necessary for a small percentage of seeds (though the lowest time for imbibing was only 192 hours). Mechanically scarified seed soaked in tap water for 8 minutes gave the best overall germination response. For *A. albida*, manual scarification and then soaking in tap water for 32 minutes gave the best overall germination (85%). Boiling water was particularly detrimental with only 3% average germination response (control 15%) over all boiling treatments.

61 BECKMAN, P. **Direct seeding experiments with *Faidherbia albida* in an arid environment**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 137-138 [En.]

Reports on direct seeding of *Faidherbia albida* into a field near Tanout, Niger, in 1990. Four seed scarification treatments were tried at 10 and 15 mm. sowing depths, and the total annual rainfall was 172 mm. After 10 months, the best result was 26% survival, achieved through nicking the seed with nail clippers and planting at the lower depth. Much poorer results were obtained at the 10 mm. depth.

62 BEGUE, P. **[Silvicultural aspects in tropical Africa]** Aspects de la sylviculture en Afrique tropicale. *Bois et Forêts des Tropiques* (1963) No. 89, 3-10 [Fr]

63 BEKELE, T. **Impact of *Acacia albida* on soil properties and undergrowth in Awasa, Southern Central Ethiopia**. *Thesis for B.Sc degree at Swedish University of Agricultural Sciences* (1982) 28 pp. [En, 5 ref.]

The study site was in Awasa public park is 7° 04' N and 38° 30' E, Southern Ethiopia. The altitude of the study site was 1 750 m, MAP 950 mm and average daily temp 19.2 °C. The soil texture varied from silt-loam to sand. Assessments were carried out on species composition, moisture content (MC) and biomass of the vegetation, and MC, texture and rate of infiltration (Rl) in the soil under *Acacia albida* and those in the open. Seventeen species were identified under *A. albida* and only eight in the open. The overall mean values for the assessments were 68% (MC) and 4.2 t $ha^{-1}$ of vegetation under the tree, and 7 (index value) (MC) and 5,8 l $hr^{-1}$ (Rl) in the soil. The mean values were 57% (MC) and 2.9 t $ha^{-1}$ biomass of the vegetation in the open , and 4 (index value) (MC) and 5,8 l $hr^{-1}$ (Rl) in the soil. Soil samples were prepared and sent to the laboratory for analysis on organic matter ( OM ), Nitrogen ( N ) and pH. The overall mean values under *A. albida* were: 4.3% (OM), 0.17% (N), 6 (pH) and 26.4 (C:N ratio). The corresponding values in the open are: 4.1%, 0.2, 7 and 13.2 respectively, Except for the N content, *A. albida* performed well in maintaining the growth of plants by enhancing soil fertility and optimizing MC beneath its canopy. The tree has proved that it never competes with shallow-rooted plants for moisture. Biomass is a good indicator of soil fertility and, since the biomass under *A. albida* is greater than the biomass in the open, logically the fertility is higher under the trees. With properly designed and appropriate land management technologies, the resources under this tree can be utilized in sustaining yields.

64 BELLEFONTAINE, R. **[Creation of a seed centre in Burkina Faso]** Creation d'un centre de graines au Burkina Faso. Programmes, difficultes et realisations. Ministere de l'Environnement et du Tourisme, Burkina Faso, C.T.F.T., Nogent-sur-Marne, juillet (1985) 117 pp [Fr]

65 BEN SALEM, B. **[Silviculture in arid zones]** Sylviculture en zones arides. *Unasylva* (1980) 32 (128) 16-18 [Fr]

66 BENTHAM, G. **Revision of the suborder *Mimoseae***. Trans. Linn. Soc. (1875) No. 30, 335-664 [En]

67 BERNARD, C.; OUALBADET, M.; NKLO, O.; PELTIER, R. **[Parklands in the Sudano-Guinean zone of West Africa. Example of the village of Dolekaha in northern Cote d'Ivoire.]** Parcs agroforestiers dans un terroir soudanien. Cas du village de Dolekaha au nord de la Côte-d'Ivoire. *Bois et Forêts des Tropiques* (1995) No. 244, 25-42 [Fr, en, 10 ref.]

An inventory of trees was made in a village in the south Sudanian phytogeographic zone. An analysis of the spatial distribution of trees within agricultural land indicated that there were two types of parkland - one dominated by *Faidherbia albida*, and one in which several tree species occurred, although shea trees (*Vitellaria paradoxa*) and locust bean trees (*Parkia biglobosa*) were dominant. It is shown that the two different types of parkland can be distinguished depending on their origin and evolution: the *F. albida* parkland (7 ha, 60 trees/ha), located around the village, was related to the production of cereal and legume crops without fallowing in each rainy season. Fertility transferred by livestock allowed

this permanent crop activity, but availability of manure limited its geographical extent. The study discusses the many different factors that influence landowners' decisions to maintain or promote trees at particular places within the village territory.

68 BERNARD, C.; OUATTARA, N.; PELTIER, R. [**The place of *Faidherbia albida* parkland in a sudanian zone. The case of the village Sénoufo in the north of Ivory Coast.**] Place du parc à *Faidherbia albida* dans un terroir soudanien. Le cas d'un village Sénoufo au nord de la Côte-d'Ivoire. In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.] Cahiers Scientifiques* No. 12, CIRAD-Forêt, Montpellier, France (1996) 312 pp. 55-84 [Fr, en]

The authors chose, in the Sudano-Guinean zone of Ivory Coast, very old village lands comprising, on the one hand, one of the most southern parklands of *Faidherbia albida* ever described in West Africa and on the other hand, a parkland composed of different species. The researchers surveyed the entire village lands, wooded areas, sacred forests, as well as all cultivated and fallow zones. They carried out a survey of the exact plot boundaries and the location of the big trees in the area that was cultivated in 1993. A number of maps were then made using G.I.S. The researchers were able to distinguish units with various combinations of morpho-pedological criteria, fertility management practices and tree species associated with crops. First, there is a 7 ha *F. albida* parkland around the village with an estimated density of 60 trees $ha^{-1}$. Information from aerial photos and historic surveys indicated that the limits and tree composition of the park had not changed within the last 30 years. It has been possible, due to fertility transfer by cattle, to practise mixed farming (cereals and legumes) under the *F. albida* trees during each rainy season, without ever leaving the land fallow. Second, there is a parkland of approximately 200 ha on the outskirts of the village dominated by *Parkia biglobosa* and *Vitellaria paradoxa*. Approximately 100 ha of this land were cultivated in 1993 and 100 ha were fallow. Cotton and cereals are grown in these fields with intermittent fallow periods. Aerial photos and historical surveys indicated that this parkland has been enriched since the introduction of cotton and it has also benefited from mechanized ploughing having been abandoned in favour of animal ploughing. Third, rice farming using rains or irrigation and commercial market gardening are carried out in the bottom lands without an agroforestry system. The landowner's decision to retain trees on a plot of land and the choice of tree species are therefore dictated by a number of criteria:- existence of seeds or of natural seedlings; possibility of introducing other species; morpho-pedology - the bottom lands have no trees; type of crop - for cold dry season crops which require light, it is necessary to reduce tree shade; possibility of protecting sensitive species like *F. albida* from bushfire by practising continuous cropping which is dependent upon animal-supplied fertility; the proprietor's interest in one of the various tree products provided by trees (*e.g.* forage for *F. albida* and *Ficus* sp. and seeds for *P. biglobosa* and *V. paradoxa*). The authors conclude that development agents must take the above requirements into consideration. They think particularly that it is no use attempting to extend *F. albida* widely beyond the limits of the existing small ring around the village where fertility transfer by cattle makes continuous cropping possible. They have, however, not ruled out the possibility of a progressive extension of this ring.

69 BERNHARD-REVERSAT, F.; HARMAND, J.M.; UGUEN, K. [**Forest litter and nitrogen cycling in various *acacia* biotopes in western and central Africa.**] Les litieres et la dynamique de l'azote dans divers biotopes à acacia d'Afrique occidentale et centrale. In *L'acacia au Senegal [edited by Campa, C.; Grignon, C.; Gueye, M.; Hamon, S.]. Actes de la reunion thematique sur l'acacia au Senegal, Dakar, Senegal, 3-5 decembre 1996. Editions de l'ORSTOM, Paris, France* (1998) 205-219, 457-458 [Fr, 28 ref.]

A summary is presented of research carried out at eight sites in Senegal, Cameroon, Congo and Côte-d'Ivoire into nitrogen cycling in various stands (natural or planted) which included nitrogen-fixing *Acacia* species (*A. senegal, A. albida* [*Faidherbia albida*], *A. seyal, A. holosericea, A. polyacantha, A. mangium* and *A. auriculiformis*). Other species included *Eucalyptus* spp., *Cassia siamea, Balanites aegyptiaca* and *Guiera senegalensis*. Rainfall at the sites varied from 300 to 1350 mm annually. Nitrogen (N) and carbon (C) contents of tree foliage, forest litter, soil organic matter and soil horizons were measured, and decomposition coefficients calculated. For all vegetation types studied, rainfall was significantly correlated with annual N cycling rates (although more so in the case of non-*Acacia* vegetation), with N mineralization, and with annual N mineralization rates. There was a significant correlation between N contents of litter and soil organic matter; however, there was no significant relation between total soil N and litter N content. The results are discussed in relation to the soil type (particularly clay content, which was a positive and significant factor in soil N content) and biogeochemical processes.

70 BERTRAND, A.; BERTHE, A.L. [***Faidherbia albida* and *Acacia seyal* pioneering trials. Regeneration in the Pondori Basin in Mali as a function of morphopedology and climatic and agrarian evolution.**] *Faidherbia albida* et *Acacia seyal* essences pionnières. Régénération dans le bassin du Pondori au Mali en fonction de la morphopédologie et des évolutions climatiques et agraires. In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Forêt, Montpellier, France. (1996) 312 pp. 45-53 [Fr, en]

The authors draw a parallel between the development of agrarian structures and the vegetation in the Pondori region in Mali. The droughts occurring in the 1970s and then in the 1980s have given rise to decreased floods in the Niger and Bani rivers. As a result of this, zones hitherto periodicallv used for cultivating rice have not been subjected to flooding over several years and have since been used only as pastureland. More clayey areas have seen the development of impenetrable thickets of *Acacia seyal.* In the lighter soil, on the contrary, *Faidherbia albida* has become established in scattered but quite dense clumps. These bushes have trapped wind-blown sand that has settled at their base in small piles, on which a whole series of plants have then developed. Because of this, moderate re-flooding should not give rise to the death of these trees, which will certainly be incorporated by farmers in a millet\F. *albida* agroforestry system. This would not be the case if flooding re-occurred and gave rise to a return to rice growing. This example illustrates the importance of climatic ups and downs and of modifications to farming practices stemming from them for the regeneration of F. *albida.*

71 BHEEMAIAH, G.; SUBRAMANYAM, M.V.R.; ISMAIL, S. **Performance of arable crops with *Acacia albida* under different alley widths in dry lands**. In *Proceedings of First National Symposium Allelopathy in agroecosystems (agriculture & forestry), February 12-14, 1992 [edited by Tauro, P.; Narwal, S.S.].* CCS Haryana Agricultural University, Hisar-125 004, India (1992) 120-122 [En, 4 ref.]

Data are briefly reported from the first two years of a dry land alley cropping experiment conducted in India [? in Andhra Pradesh] in 1989-90 using *Acacia albida* planted at three alley widths (of which the smallest was 3.0 m). For all three crops tested (castor [*Ricinus communis*]; sunflower [*Helianthus annuus*]; and redgram [*Cajanus cajan*]), crop growth and yield were increased in both years of the study, and at all three alley widths, in comparison with values for sole crops. Height and girth growth of the trees were not reduced by the intercrops but were better in association with castor and redgram than with sunflower, and better (but not pronouncedly so) at the smallest alley width.

72 BILLAND, A. **Variability of *Faidherbia albida* in progeny trials in Burkina Faso**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 71-75 [En, 9 ref.]

Gives details of three progeny field trials set up at Gonse, Burkina Faso, with seed of around 20 progenies from Kongoussi (Burkina Faso), Matameye (Niger) and Kagnobon (Senegal). The Kongoussi provenance was planted in 1987 and the other two in 1989, and height and collar diameters measured. Single tree balanced complete block designs were used. Yearly values for individual and provenance heritability for growth (height and collar diameter) and branching (length, number, and height to first branch) are presented. Heritability decreased regularly from 6 to 42 months for the Kongoussi provenance, but this provenance had the highest heritability values. Matameye had the lowest. Branching parameters had low heritability values (under 10%).

73 BILLAND, A.; FRAMMOND, H.DE. [**Genetic variation of *Acacia albida* (synonym *Faidherbia albida*) in comparative provenance trials in Burkina Faso.**] Variabilité génétique d'*Acacia albida* (synonyme *Faidherbia albida*) en essais comparatifs de provenance au Burkina Faso. In *Physiologie des arbres et arbustes en zones arides et semi-arides [edited by Riedacker, A, et al.].* Seminar Paris/Nancy, 20 Mars - 6 Avril 1990 (1990) 235-248. [Fr. En, 8 ref.]

Thirty-six provenances of *Acacia albida* (syn, *Faidherbia albida*) from nine countries (Burkina Faso, Burundi, Cameroon, Ethiopia, Kenya, Mali, Niger, Senegal and Zimbabwe) were compared. The trials were set up in 1985, 1986 and 1987 on IRBET/CTFT stations of Djibo (abandoned because of high mortality), Dinderesso (tropical ferrallitic soil, silty sand) and Gonse (Tropical ferruginous soil, silty sand with hardened lateritic pan), Burkina Faso. Eastern and southern African provenances had high initial growth and suddenly died at Gonse after 18 months although they stayed alive at Dinderesso. Central Sahelian provenances from Burkina Faso, Mali and Niger showed the best results as they overcame their initial poor performance and, at five years, these provenances appear to be the best choice for planting in Burkina Faso. Coefficients for total height and collar diameter were not correlated with rainfall and only poorly (and negatively) correlated with latitude of provenance origin. Coefficient of variation differences between Gonse and Dinderesso are highly correlated to deficit in heterozygosity measured by fixation indices F calculated from enzymatic electrophoresis by Zeh-Nlo in 1989 for eight provenances that are also tested in these trials. The conclusions drawn are:- 1) that juvenile growth is an important character to improve (so long as it is not associated later with adult characters such as poor forage quality) because it enables plants to escape the teeth of the ever-present cattle thereby limiting the problems of protection; 2) a good knowledge of juvenile traits that one can correlate with important adult characteristics will allow early selection and acceleration of gain; 3) several hypotheses can be formulated to explain the ill-adaptation of the East Africa to the ecological conditions at Gonse it is suggested that the prime cause is the more equitable rainfall distribution, and therefore soil moisture deficits, in the collections sites in east and southern African when compared to that at Burkina Faso; and 4) these mortalities give some ideas about the direction research might take to

explain the inverted phenology of *A. albida*. The correlations with latitude suggest that diurnal amplitude has an influence on growth and perhaps also on its physiology.

74 BILLE, J.C. **Measuring the primary palatable production of browse plants**. In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le]*. ILCA, Ethiopia (1980) 185-195 [En, Fr, 24 ref.]

Various proposals are made in order to establish the most appropriate method of calculating total biomass, or else net total palatable productivity, of a browse plant. Selected elements of browse relevance include bark, branches, flowers and fruit, and leaves. In the latter case, measurements of leaf production is on of the most frequently carried out studies, though leaf biomass in arid and semi-arid zones is fairly low. Research in Mali (rainfall 600 mm) recorded foliage mass per individual *Acacia albida*, according to tree diameter as: 1.6 cm (40 g/DM), 4.8 cm (340 g/DM), 9.5cm (1400 g/DM), 14.3 cm (3100 g/DM) 20.7 (6450), 25.4 cm (9600 g/DM) and 30.2 cm (13,000 g/DM).

75 BLAIR RAINS, A.; McKAY, A.D. **The Northern State Lands, Botswana. Ministry of Overseas Development (UK)**. *Land Resource Study, Land Resources Division, Directorate Overseas Survey* (1968) No. 5, 125 [En, 5 pp. ref.]

Describes an investigation of the land resources of the Northern State Lands, Botswana, based on surveys of the environment, with special emphasis on the vegetation. 16 vegetation communities are described and shown on a vegetation map (1:500 000). *Acacia albida* is specifically mentioned in two: (1) Closed woodlands and (2) Tree Savanna.

76 BLONDEL, D. [**First results on the microbial dynamics of nitrogen in two soils in Senegal**] Premiers resultats sur la dynamique microbienne de l'azote dans deux sols du Senegal. I.R.A.T., Bambey (1967) [Fr]

77 BOGDAN, A.V.; PRATT, D.J. ***Acacia albida***. In *Common Acacias of Kenya*. Kenyan Ministry of Agriculture, Animal Husbandry and Water Resources (1974) [En]

Gives a key, mainly vegetative, to 24 common species of acacias occurring in Kenya, followed by a description of each. *Acacia albida* is described as meduim-sized tree with thorns that are short and straight, and leaves of medium size. The white flowers are in long spikes, and the pods contorted into characteristic hard-walled "apple rings". *A. albida* is common in alluvial valleys at medium to low altitudes, often occuring in association with *A. tortilis* and *A. elatoir*. Young trees occasionally form thickets, but they are generally found in scattered stands.

78 BOLZA, E.; KEATING, W.G. **African timbers - the properties, uses and characteristics of 700 species**. CSIRO, Melbourne (1972) [En] ????

79 BONKOUNGOU, E.G. ***Acacia albida* Del. - a multipurpose tree for arid and semi-arid zones**. *Forest Genetic Resources Information, FAO* (1985) No. 13, 30-36 [En, 32 ref.]

*Acacia albida* is one of 14 priority species for the improvement of agricultural environment and rural living in arid and semi-arid zones selected by an FAO Panel of Experts. Notes are given on its taxonomy and intraspecific variation, distribution, regeneration, beneficial effects on the environment, fodder value and research needs.

80 BONGKOUNGOU, E.G. [**A monograph on *Acacia albida* Del., an agroforestry species withh multiple uses**] Monographie de *Acacia albida* Del., espèce agroforestière à usages multiples. Projet UNSO/DES/BKF/80/X02, Institut de Recherche en Biologie et Ecologie Tropicale, Ouagadougou, Burkina Faso. (1987) 93 pp [Fr, 86 ref.]

*Acacia (Faidherbia) albida* is among the tallest Acacias (15 to 30 metres high). It has long been recognized as precious and useful in West African culture and it is inherent to its various mythologies. The creation of parklands was an ancestral practice which not only ensured quality crops, but provided excellent fodder. Conservation laws were developed to protect the *A. albida* parklands. In Niger, the ancient sultans of Zinder decreed that anyone who cut a tree would be beheaded; anyone who mutilated one would have his arm severed. Not only the land but the trees would be counted as inheritance. In Burkina Faso, the pods are used to reward oxen when trained to pull the plough. The fodder has now been traded on Sahelian markets for several years. Traditional medicinal preparations of its bark or roots are used against fevers and respiratory diseases. Research into the potential of *A. albida* is being undertaken in the face of pressure from increasing population and the high cost and adverse effects of modern farming methods. *A. albida* generally has a deep root system which enables it to reach water and nutrients inaccessible to other trees. However a few individuals have been observed to have lateral roots which may hinder farming machinery. Its inverted phenology makes *A. albida* a most unusual and useful tree. It has leaves in the dry season (thus providing necessary fodder for cattle) and loses them in the wet season. It has great variation in growth, flowering and fruiting. This variability has made it difficult to establish its taxonomy. It has been divided in two breeds (A and B) and *Faidherbia albida* is now suggested as a more correct name. *A. albida* grows in dry to semi-arid regions, at varied altitudes. In southern Africa it is situated close to rivers. In western Africa, it seem "anthropophile", growing in association with men and

agriculture. This ecological diversity indicates great genetic variability. Fossil pollens dating back 200,000 years have been found in Ethiopia,- 60,000 to 70,000 yeas in Israel and 5,600 to 3,800 years in Lybia. All are linked with water sources. Studies of the effect of *A. albida* on the soil have shown raised humidity, doubling of carbon and nitrogen levels, higher (1.3 units) pH level and 2 to 5 times greater organic activity. The increased soil fertility improves crops without the use of fertilizer. Raising the tree from seed is relatively easy. Grafting techniques have been developed in Burkina Faso. The parameters for the natural regeneration are a humid environment, the passing of seeds through faeces and protection of the young plants from cattle. Success is easier in cultivated lands than in the bush because of the absence of competition from various grasses. The *A. albida* parklands are usually very ancient and are maintained by the present population. However the Dogon and Samo treasure the trees as they ensure perennial crops of millet. In Bissa country, the parklands have deteriorated because of decisions by the colonial administration to double the surface of cultivated land and to increase taxes. In many areas the crops are, to say the least, vulnerable and the farmer does not think in terms of future generations. His time scale is the next crop. Encouraging the natural regeneration of *A. albida* entails material rewards as well as increasing the awareness of the species' values. *A. albida* is not a miracle tree. However, associated with other technologies it can contribute greatly to agriculture in Africa. Further research is needed into the mysteries of its extraordinary variability and inverted phenology and to seek genetic improvement.

81 BONKOUNGOU, E.G. **Sociocultural and Economic Functions of *Acacia albida* in West Africa**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 1-6 [En, 19 ref.]

Paper highlights the importance of socio-cultural and economic functions of *Acacia albida* to the communities in the Sudano-Sahelian zones of Africa. Populations have traditionally developed agrosilvipastoral systems where trees and shrubs play a vital role in animal and crop production. *A. albida* is shown to be one of the most favoured, and is revered by the local people and central to various popular myths and religious beliefs. Gives examples such as the mythology of the Bambara people, who associate *A. albida* with the creation of the world. In the Dallor Maouri region of Niger, the species is part of the inheritance that the rural people pass on to their children. While current research focuses on the biology of the species, he argues that future work should focus more on socio-economic issues.

82 BONGKOUNGOU, E.G.; OUEDRAOGO, S.; DIANDA, M.; BILLAND, A. [***Acacia albida* in agroforestry: strategies for the improvement of vegetative material**] *Acacia albida* Del. en agroforesterie: stratégie d'amélioration du matériel végétal. Unpublished. Communication présentée aux journées scientifiques université - C.N.R.S.T. and C.T.F.T. Ouagadougou 31 Mai - 4 Juin, 1988. I.R.B.E.T., Burkina Faso (1988) 24 pp. [Fr]

In Burkina Faso, where 90% of the population lives off agriculture, *Acacia albida* is proposed as a viable alternative to traditional farming methods, which are no longer feasible due to increased population density and lack of land. Intensive farming practices are beyond the means of the local populace as a method to increase soil fertility and crop yields. The paper focuses on the identification of the causes of the large intra-specific variation that exists within *A. albida*, evaluating the role of soil micro-organisms in the heterogeneity of the plant's growth, and looking to ways to improve propagation methods. Trees from 40 provenances were tested at three research stations that varied in soil type and annual rainfall. The growth (dbh, height, and the combination of both) and survival rates of the trees were recorded in 1985, 1986 and 1987. The variable nature of the species is confirmed, both between and within provenances. Growth of different provenances was best at stations with conditions most similar to those of the provenance. Provenances of humid, coastal or altitudinous zones were found to perform best, although it is not known if these provenances maintain their advantage after 30 months. The chemical composition and biological aspects of the soil and the role of provenance and/or genetics were investigated as possible causes of the variation recorded. Sandy soils gave the poorest results due to inadequate water retention. *Rhizobium* made no difference to the dry weight except in PSA. Seed weight had a large influence on growth, with large seeded individuals gaining the greatest height. Seeds of one specimen were grown and showed distinct genetic determination of height and diameter. Vegetative propagation has been carried out *in vitro* using young and old *A. albida* material. One experiment looked at the time taken to root using adult branch and young shoot material and two growth hormones. Young shoots produced their maximum root growth within 5 weeks with indolbutyric acid (IBA) while the older material took > 10 weeks due to slower rooting and no effect of hormone additions. Indolacetic acid (IAA) produced longer roots while IBA produced denser rooting. The best time for root growth for young stock is outside Nov-Dec and for old stock outside Sept-Jan (flowering and fruiting season).

83 BONNEFILLE, R. [**The presence of fossil pollen of *Acacia albida* Delile and Cycadales in Pleistocene samples from Melka Konture (Ethiopia)**.] Présence de pollens d'*Acacia albida* Delile et de Cycdales dans échantillons pléistocènes de Melka Konture (Ethiopie). *Boissiera* (1975) **24**, 33-42 [Fr, en, 25 ref.]

Fossil pollen of *Encephalartos* from the lower Pleistocene and of *Acacia albida* from the middle Pleistocene have been found in the alluvial deposits in the Awash Valley, Ethiopia. The site is on the banks of the River Awash, 30 km south-east of Addis Ababa at 2000 m above see level. The polyad of *A. albida* is readily distinguished from other species because of its large size (92 μ) and it generally consists of 30 'monoades' (16 in other *Acacia* species); the size of fossil pollen is in the order of 40-50 μ. *A. albida* is widespread from Senegal to Ethiopia, in the north in the mountains of the Sahara and in the Nile valley as far as Lebanon, and in the east from Transvaal to Lesotho, and one site on the west coast of Angola. Its distribution corresponds to areas of wooded steppe, grass steppe, open forest and dry savanna. It is found from 270 m in Palestine to 2500 m in Jebel Marra (Sudan) where the greatest density of trees are found. As the species is pollinated by birds and insects, it produces relatively little pollen and the polyads are not transported very far from their point of origin. *Acacia* pollen in present day mud was much less abundant than *Acacia* was itself in the local vegetation. The genus is therefore held to be under-represented in the fossil pollen record by palynologists. Therefore, the discovery of three polyads of *A. albida* is of true significance regarding the presence of this species in the Awash Valley. It is shown that the presence of *A. albida* pollen coincided with a diminution of the number of grasses and an increase in the number of trees and it is indicative of a humid climate. Macro-botanical remains of *A. albida* found near Ghat in Libya in deposits dated 5600 to 3800 BC correspond to the Neolithic humid phase. Other pollen has been found in lake Hula in Israel, dated 60,000 to 70,000 years old (interglacial). It was not possible to date the *A. albida* pollen in the Awash Valley precisely but geological data allow it to be placed at 60,000-70,000 years old. Aubreville (1950) considers *A. albida* to be an ancient riverine species of east and southern Africa which expanded as a result of the activities of men and animals. For Chevalier (1928), the origin of *A. albida* was in north Africa whence the species spread to the east and to the south. Zohary (1962) considers this species in Israel to be a relic of the Sudanese flora. The present ecology of the species, described by Wickens, supports Aubreville's theory. This evidence of an extension of the geographic range of *A. albida* to Ethiopia in the Quarternary period supports the theories of Chevalier and Zohary.

84 BOOTH, F.E.M.; WICKENS, G.E. **Non-timber uses of selected arid zone trees and shrubs in Africa.** *FAO Conservation Guide* (1988) No. 19, vii + 176 pp. [En, many ref.]

Notes are given on names, distribution, description, main uses, other uses, economic importance, climate, site, life cycle, pests and diseases, seed supply, agronomy, yield, sociological factors, production potential, processing, development constraints, recommendations, related species, and references, for 27 species (*Acacia senegal, A. seyal, Adansonia digitata, Balanites aegyptiaca, Boscia senegalensis, Butyrospermum paradoxum, Conocarpus lancifolius, Cordeauxia edulis, Faidherbia (Acacia) albida, Flacourtia indica, Grewia bicolor, Leptadenia pyrotechnica, Maerua angolensis, Maytenus senegalensis, Mimusops angel, Moringa oleifera, Parkia biglobosa, Prosopis africana, Pterocarpus erinaceus, Ricinodendron rautanenii, Salvadora persica, Securidaca longipedunculata, Sterculia africana, Tamarix aphylla, T. nilotica, Ximenia americana*, and *Ziziphus mauritania*). Use categories include: agroforestry, browse/fodder, soil conservation, basketry/matting, food, fuel, gum/latex, bee food, oil, fibre, hedges, alcohol, medicinal, N-fixation, ornamentals, toxins/poisons, water purification, shade/shelter, and tannins.

85 BOUDET, G. [**Livestock production and possibilities of intensification in the Sahelian zone.**] Production animales et possibilités d'intensification en zone Sahélienne. *Bulletin, Recherches Agronom., Gembloux* (1972) 445-451 [Fr]

86 BOUDET, G. **Animal Production and Potential for Intensification in the Sahel.** ?? [Fr]

Animal rearing (cattle, goats, sheep) in Sahel is essentially itinerant on account of watering difficulties Flocks are moved north in rainy season and south in dry season. Nitrogen is available in shoots in the wet season but pasture is deficient in this in the dry and increasingly so as desertification advances. Some nitrogen-rich plants survive around permanent water holes. Fruits of some woody plants are eaten by animals but the seeds are not digested. Scarification of the seed coat in the digestive tract increases germination potential with result that there is regeneration of species such as *Acacia raddiana* and *A. senegal.* Traditional transhumant animal rearing is adapted to rough climatic conditions but is not helping in economic and social development objectives. These require improvement of habitat, hygiene and education of transhumant populations, the controlled and increased use of the pasture, improvement of animal stock, intensification of management of flocks and of marketing of related products. The possibility of developing pasturage around watering points is major preoccupation of national authorities but is dependent on geological and hydrographical possibilities and cost is often exorbitant. In spite of risks of parasitic infestation, management of surface waters could be interesting for pasture in rainy seasons. Wells would be needed for the dry season with improved techniques for raising water. Fire controls would need to be introduced for protection during dry season. Better management of flocks would transform traditional transhumant systems. Young male animals would be being marketed at the age 3-4 years to be sent

on either to reception and waiting ranches, set up in areas traditionally unused because of lack of access to water, or given to farmers in the Sudanese zone for local fattening. In the reception ranches abundance of pasture and of water would eliminate loss of weight in the dry season, which can reach 100 g per day in May and June. Weight gain can be maintained throughout the year due to the contribution of nitrogen at the critical period, either in the form of cotton seeds (1 to 3 kg per head and per day) or in the form of young leaves and fruits of woody tree species. The planting of *Acacia albida* (2 to 10 kg of pods per tree) would have to be systematic in these ranches.

87 BOUDET, G.; LEBRUN, J. P. ; DEMANGE, R. **[List of vascular plants in Mali]** Catalogue des plantes vasculaires du Mali..I.E.M.V.T., Maisons-Alfort (1986) 480 pp.[Fr]

88 BOUDET, G.; RIVIERE, R. **[Practical methods for the assessment of tropical pastures]** . Emploi pratique des analyses fourragères pour l'appréciation des pâturages tropicaux. I.E.M.V.T., Maisons-Alfort (1968) [Fr]

89 BOULHOL, P. **[The Gum-tree country of Southern Morocco.]** Le pays des gommiers du Sud-Marocain. *Bulletin, Société des sciences naturelles du Maroc* (1950) **4**, 18-23 [Fr]

Five thorny acacias occur in Morocco: *Acacia gummifera*, *A. farnesiana*, *A. albida*, *A. raddiana* [*A. tortilis* ssp. *raddiana*] and *A. seyal*. *A. raddiana* is found throughout the *Acacia* zone of Southern Morocco, while *A. seyal* is only found in the Dra Valley on less dry sites. The stands of these species are declining because of climatic changes, effects of humans and domestic animals, and the action of parasites. They are used as pasture and for timber, charcoal, tools, tannin and gum, and also in preventing soil erosion. *Acacia* stands can regenerate from seed, especially in wet years or years with few livestock. Conservation measures are outlined.

90 BOULOS, L.; HOBBS, J. **Three arboreal species new to the Eastern Desert of Egypt**. *Candollea* (1986) **41** (1) 183-191 [En, fr, 21 ref.]

Three arboreal species, *Olea indica* Burm. f., *Acacia albida* Del. and *Haloxylon persicum* Bunge are reported for the first time in the Eastern Desert of Egypt. Ecological notes are given, illustrated with photographs of a grove of *A. albida* trees situated on a terrace above a large wadi on Jebel Abul Hassau (1,500-2,000 ft. high). Most of the trees are only up to 3 m high, the rest are smaller.

91 BOURREIL, P. **[Index of Assessment of the preference of herbivores for certain plants in the province of Darfour (Sudan).]** Sur une indice d'appréciation de l'appétence des herbivores pour certaines plantes de la province du Darfour (Soudan). *Journal D'Agri. Trop. et de Botanique Appliquée* (1968) **15** (4) 200-201 [Fr, 3 ref.]

A study of the preferences of different herbivores to a range of fodder species in the pastoral areas of Darfur province. The areas selected were dominated by the highly palatable grass genus *Aristida*. Inspection of plants was accompanied by questioning of nomadic and sedentary pastoral people. The data is listed in a table for five phanerotypes, four grasses and one herbaceous plant. Goats and particularly camels fed on *Faidherbia albida* foliage but sheep, cows, donkeys and horses did not. Cows, camels, goats and sheep consumed pods with preferences in that order. Donkeys ate the occasional pod and horses none at all.

92 BRAIN, P. **Immunology and Phylogeny: a preliminary study of *Acacia***. *South African Journal of Science* (1987) Vol. 83, 422-427 [En, af, 16 ref.]

The seed proteins of 37 species of the genus *Acacia* were investigated serologically by double diffusion and immuno-eletrophoresis using rabbit antisera to *A. karroo*, *A. ataxacantha* and *A. mearnsii*. Identity and absorption tests revealed remarkable homogeneity in the series Gummiferae; all African species react identically except *A. albida* (which reacts atypically with all the antisera). Findings support the view that *A. albida*, despite having spinescent stipules is not a Gummiferae and probably not an *Acacia* at all.

93 BRENAN, J.P.M. **Flora of Tropical East Africa: Leguminosae - Mimosoideae**. London, UK; Crown Agents for Overseas Governments (1959) 173 pp. [En]

The first part of a floral treatment of the subfamily Mimosoideae in Tropical East Africa (Uganda, Tanzania and Kenya). Botanical description of the Acacias with a key based on floral and vegetative and pod and vegetative characters. Gives a botanical description with notes on distribution and ecology of *Acacia albida*; it occurs in riverine and ground water forest and woodland between 600-1830 m. Describes the two well marked races in the region, race B from Dodoma (Tanzania) southwards with larger pubescent leaflets and race A northwards to Kenya and Uganda with smaller glabrous leaflets.

94 BRENAN, J.P.M. ***Acacia albida* Del.** In *Flora Zambesiaca* (1970) **3** (1) 54-55, 63-65 [En]

Tree 6-30 m high, greenish-grey bark, spreading branches. Stipules spinescent, up to 1.3 cm long, straight, never enlarged and inflated. Leaflets 6-23 pairs, 3-10 pairs of pinnae. Flowers cream, sessile or to 0.5 mm pedicellate. Pods bright orange, thick, indehiscent, 6-25 x 2-3.5 cm, glabrous or very rarely puberulous, falcate or curled into a circular coil. Seeds elliptic-lenticular, 9-11 x 6-8 mm.

95 BRENAN, J.P.M. **Manual on taxonomy of *Acacia* species: present taxonomy of four species of *Acacia* (*A. albida, A. senegal, A. nilotica, A. tortilis*).** Rome, Italy; FAO (1983) 47 pp. [En, 24 ref.]

The most up to date synopsis of the taxonomy of four widespread species of *Acacia* in Africa (*A. albida, A. senegal, A. tortilis* and *A .nilotica*). For each species a brief description is given with comments on its generic position, recognition, distribution and a summary of previous taxonomic work. The variation within the species is described, with the occurrence of two geographical races in East Africa. In general, the synonymy of *A. albida* is limited because it is an easily recognizable and taxonomically isolated species.

96 BREWBAKER, J.L. **Genetic improvement of multipurpose trees for agroforestry systems.** *Congress Report, Volume B, Proceedings of 19th IUFRO World Congress, Montreal, Canada, 5-11 August 1990* (1990) 304-315 [En, 17 ref.]

The genetic improvement of multipurpose trees (MPTs) is discussed with emphasis on fast-growing, N-fixing tropical species, where the need for breeding appears greatest. It is suggested that the breeder must have a major role in prioritizing species for improvement, with emphasis on species that are easily bred and that offer large, protected germplasm bases. Interspecific cross-fertility appears to characterize many MPTs, calling for broadly based studies of all species that might be part of the useful germplasm base for improvement. It is stressed that knowledge of the chromosome numbers and breeding systems of MPTs is very limited, but is essential to breeding progress. It is also noted that breeding methods for such trees (with the aim of using them in agroforestry systems) differ little from those used for crops where the primary focus is on yield. The current status of breeding progress is reviewed briefly for some high-priority species including *Faidherbia albida* on which it is stated that work is just starting.

97 BROUWER, J.; GEIGER, S.C.; VANDENBELDT, R.J. **Variability in the growth of *Faidherbia albida*: a termite connection?** In *Faidherbia albida in the West African semi-arid tropics: proceedings of a workshop 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 131-135 [En, 12 ref.]

An investigation to study whether areas of good growth in a *Faidherbia albida* plantation near Niamey might be associated with higher levels of previous termite activity, not evident from the surface but nevertheless increasing soil fertility and *F. albida* growth. Three soil profiles were dug and sampled for soil characteristics and termite activity, from an area of poor, good and very good growth sites (edge of a termite mound). The poor growth site had low subsoil termite activity as well as low physical and chemical fertility (low organic carbon, pH, P, and free Fe), the very good growth site high activity and fertility, and the good growth site intermediate between the two extremes. Data taken from a trench 30 m in length from a poor to a good growth area in the trial also showed a positive correlation between growth of *F. albida* and level of termite activity, pH, and bulk density at 0.5-1.0 m depth. Frequent broad acre soil tillage has shown to decrease termite activity and therefore may have a detrimental effect on soil fertility and sustainable yields of the agroforestry system in the sandy soils of the Sahelian belt.

98 BROWN, A.V. **Within and between provenance variation in salt tolerance at the germination stage of *Faidherbia albida*.** *Thesis for B.Sc. Forestry Honours, School of Agriculture and Forest Sciences, University of Wales, Bangor, U.K.* (1998) 69 pp. [En, 69 ref.]

Salt-affected soils are a serious limitation on crop growth. As human populations increase, the need for successful utilization of saline soils is becoming more urgent. *Faidherbia albida* is recognized as an important multipurpose tree species that is potentially salt tolerant. This study considered within and between provenance variation in salt tolerance at the germination stage of *F. albida. F. albida* seeds were germinated at three different salt concentrations (0 mM NaCl, 200 mM NaCl, 4000 mM NaCl) to ascertain the salt tolerance between and within two provenances. The seedlots tested comprised 30 half-sib families from a Mana Pools, Zimbabwe, provenance and 30 half-sib families from a Chawanje, Malawi, provenance. Analysis of the results showed there to be significant provenance-treatment interaction in final germination percentage. The Chawanje provenance proved to be more salt tolerant in these germination tests. However, there was no significant provenance-treatment interaction in rate of germination. There were no significant family-treatment interactions in final germination percentage or rate of germination. Overall the results of this study suggest that the Chawanje, Malawi and Mana Pools, Zimbabwe provenances are moderately salt tolerant at the germination stage.

99 BRUNCK, F. [**First study of the decline of gaos in the Magaria and Matameye regions.**] Première étude sur le dépérissement des gaos dans les arrondissements de Magaria et de Matameye. *Unpublished report, C.T.F.T., Entomologie et Pathologie Forestières* (1972) 10 pp. [Fr]

This is a report on the study of dieback in *Acacia albida* parklands around Magaria and Matameye in southern Niger. Dieback was first reported in 1969 at Kara in Magaria and Ban Nama in Matameye in southern Niger. By 1970-72 occurrence was still common, but in small patches. The effect of the disease was difficult to quantify because dead trees are cut or blown down.

Mortalities occur between the 600-650 isohyets in regions with high levels of cultivation and cattle rearing. The dieback was generally localized with unaffected stands of trees occurring within 1 km of affected areas. Deaths have only been observed in seedlings and young trees and not in older trees with large diameters. Dieback progresses through stands. Collar and roots are healthy and there are no signs of fungal or insect attack. Eggs of two species of *Acridiens* (grasshopper/cricket) were found in soil at base of trees with dieback, *Kraussaria angulifera* Krauss, with short stocky eggs, and *Tylotropidius gracilipes* Brancksik, with elongate thin eggs. Trunks look healthy but a small adult moth *Crypsotidia conifera* Hampson was found in fissures in the bark. Branches over a certain diameter have bark gnawed by Cossidae caterpillar (possibly *Salagena transvena* Walker). Lecaniid cochineals were frequent on branches, *Ceroplates* sp and *Diaspine* sp. Young growth was more or less defoliated by Psychid (*Cryptothela junodi* Heylaerts) and Pyralidae (*Phycitines* sp) caterpillars. Leaves on severely attacked trees were of a reduced size and formed small withered clumps. There was no fruit on the trees in dieback areas. Other parasites found on *A. albida* elsewhere, but not (to date) in Niger include:- Senegal - small defoliating caterpillar found at the start of the dry season causes slight stunting. Defoliating crickets *Anacridium melanorhodon melanorhodon* Walker attack seedlings, damage negligible; Nigeria - caterpillar *Pandesma anysa* Guenée with similar behaviour to *Crypsotidia conifera*, causes damage; curculionid *Ischnotrachelus spinicollis* Hustache follivore of young *A. albida*, damage negligible; cricket *Anacridium melanorhodon melanorhodon* Walker, damage negligible; biting insects (Coreids) *Anophocnemis curvipes* Fabricius found at the start of the dry season, rarely abundant. Rainfall in the area fluctuates annually and there has been a general decrease since 1965. The water table has dropped 2-7 m. There has been a concurrent change in traditional practice including loss of the fallow, due to increased population pressure and more sedentary life. Over cultivation on poor soil has increased erosion. Changes in soil structure and permeability reduce infiltration, thus further lowering the water table. Forest vegetation is in decline heralding the start of desertification. Greater numbers of livestock may also contribute to the shift in equilibrium as grazing and water requirements are intensified. Defoliation by Noctuid caterpillars has been largely responsible for the dieback. The same size trees have, however, recovered from such attacks in previous years; their inability to do so now is believed to be the result of the drop in the level of the water table resulting from decreased rainfall and also from increased erosion resulting from cultivation practices that degrade the soil quality. *A. albida* is unable to form roots deep enough to reach the new water table and so is unable to produce a new flush of leaves and thus suffers from dieback. More observations are required, especially during December-January, to see if other defoliating agents are involved. Larvae and adults of insects involved must be collected and raised in labs for identification and their damage documented. An environmentally friendly method of fighting the defoliators is required *e.g.* use their parasites *e.g. Bacillus thuringiensis* which is harmless to cattle and man. Failing this, chemical products should be employed *e.g.* trichlorphon, and baits e.g. 2 g endosulfan to 1 kg of bran. The more delicate issue is of finding a way to increase the water retaining capacity of the soil. A long-term broad solution would require dramatic changes to present customs/social practices.

100 BUKHARI, Y.M.; KOIVU, K.; TIGERSTEDT, P.M.A. **Phylogenetic analysis of *Acacia* (Mimosaceae) as revealed from chloroplast RFLP data**. *Theoretical and Applied Genetics* (1999) **98** (2) 291-298 [En, 46 ref.]

Chloroplast DNA of 22 species of *Acacia* was digested with ten restriction endonucleases, Southern-blotted and probed with cloned fragments covering the chloroplast genome of tobacco (*Nicotiana tabacum*). Phyletic and phenetic analyses of the resulting 176 polymorphic bands recorded among the 22 species were performed. The phylogram was reconstructed using heuristic search and Wagner parsimony. The resulting most parsimonious consensus phylogram displayed three major phyletic lineages, consistent with the previously established three subgenera of *Acacia*. The 10 species of subgenus *Acacia* and the 6 species of subgenus *Heterophyllum* formed two monophyletic sister clades. The five species of subgenus *Aculeiferum* studied and *Acacia albida* [*Faidherbia albida*] grouped together and were basal to the clades of subgenera *Acacia* and *Heterophyllum*. The phylogram indicated that subgenus *Heterophyllum* diverged earlier from subgenus *Aculeiferum* than did subgenus *Acacia*; however, the phenogram indicated the reverse.

101 BUNDERSON, W.T.; EL WAKEEL, A.; SAAD, Z.A.; HASHIM, I. **Agroforestry practices and potentials in western Sudan**. In *Planning for agroforestry. Selected contributions from an international symposium held at Washington State University, Pullman, Washington, on 24-27 April 1989 [edited by Budd, W.W.; Duchhart, I.; Hardesty, L.H.; Steiner, F.]*. Amsterdam, Netherlands; Elsevier Science Publishers (1990) 227-246 [En, 29 ref.]

Management issues associated with the design and implementation of the Western Sudan Agricultural Research Project (WSARP) were discussed in a separate paper from this conference (Noel et al., Chapter 9). The evolution of WSARP's approach to research was stressed in relation to traditional systems of production and the role of agroforestry. Building on that management base, this paper discusses WSARP's planning process for initiating and improving agroforestry practices among traditional production systems in the rainfed areas of western Sudan. Lack of an adequate database necessitated an early emphasis on characterizing major

production systems and constraints. During this work three distinct production systems were identified: (a) sedentary farming communities focusing on crop production with some livestock; (b) transhumant, cattle-oriented agropastoralists migrating between well-defined wet and dry season areas; and (c) nomadic camel-dominated pastoralists in more arid environments, where movements were more frequent, migration patterns less distinct, and cultivation mostly opportunistic. The first two systems are targeted here, but many of the production strategies and problems of transhumant groups are also common to camel nomads. The sedentary systems are mainly based on bush fallow, but also include gum arabic production (from *Acacia senegal*) and irrigated gardens. Mention is also made of the *Acacia albida* farming system on the Jebel Marra massif in Darfur, even though this falls outside the region discussed. Resource and production constraints are identified as land tenure, a deteriorating natural resource base (including disappearing tree species), problems of soil fertility and erosion, and livestock nutritional deficiencies. WSARP has implemented a comprehensive research programme aimed at increasing or maintaining production among smallholder farmers and pastoralists. This has included system improvement and development strategies compatible with the target producers, and research on crops, livestock and pest and disease control. Several promising agroforestry interventions have been identified: fallow improvement by the introduction of leguminous (and other) trees and shrubs; permanent tree intercropping; improved home and irrigated gardens; shelterbelts; gum arabic production; and supplementary livestock feeding with leguminous tree pods. A list of tree species with agroforestry potential is included, indicating suitable systems/products for each.

102 BUTZER, K.W. **Climatic changes in the arid zones of Africa during early to mid-Holocene times**. ?? 72-83 [En]

The arid zones of Africa have experienced a succession of moister or drier oscillations during the Pleistocene and Holocene. In the case of the Sahara, the available evidence suggests that a hyper-arid oscillation *c.* 2350-870 B.C. was preceded by a moister sub-pluvial period 5500-2350 B.C., possibly interrupted by one or more dry spells. There is some further evidence in favour of moister conditions during the 7th millennium while conditions may have been hyper-arid a millennium earlier. None of these changes in precipitation or effective moisture can be quantitatively defined, and there is no evidence concerning temperature conditions. A palaeoclimatic outline is not yet possible for the other arid zones of Africa. Radio-carbon dating of macrobotanical remains of *Acacia albida* in the Lower Hearth Complex in the Fezzan (Libya) have contributed to the thory that there was a moister period with livestock rearing between 5600 and 3800 B.C.

103 CABI. ***Faidherbia albida***. [Original text by Fagg, C.W.] In: Forestry Compendium, Wallingford, UK. CAB International (2002) [En]

This is a summary of information on *Faidherbia albida* under 10 major headings. In "taxonomy and nomenclature" a brief account is given of the species' taxonomic history with the major references. Some authors still refer to it as *Acacia albida* but most have accepted the new name proposed in the basis of morphological, phenological and biochemical evidence. It is treated as one variable species with no sub-specific divisions. Under "importance", the species' value as a fast-growing, nitrogen-fixing tree suitable for agroforestry systems under arid conditions is emphasized. Among the disadvantages listed are its intolerance of competition, and its thorniness. Under "botanical features", a brief standard description is given and an account of its reverse phenology. Its "distribution" is described as Africa, Middle East, Arabia and Iran; it occurs from 270 m below sea level in Palestine up to 2500 m in Sudan and over 61 degrees of latitude. The main areas of introduction as an exotic listed include India, Pakistan, Nepal, Peru, Cyprus, Cape Verde and the Ascension islands. The greatest interest has been in the dry zones of the Indian subcontinent. There are many provenance trials within the area of its natural range. The species' "environmental amplitude" is described as tropical and sub-tropical, particularly hot and dry but extending to humid and even Mediterranean conditions, optimal at a mean annual rainfall between 500 and 800 mm but ranging from 1800 mm down to 8 mm provided it taps underground water. Mean annual temperature for optimum growth is 20 to 30°C but it will withstand maxima well over 40°C. It is susceptible to frost. It is commonly found on deep sandy soils that tend to be hydromorphic and neutral to slightly acidic. *F. albida* is described as a light demander under "silviculture and management" that will not colonize woodland without disturbance. It will produce coppice shoots and sucker. Culture is described as well-documented and is summarized. Natural regeneration is assisted by suckering from damaged roots and protection of seedlings or vegetative shoots until they are tall enough to be above the reach of livestock. Clonal propagation is possible from shoot and root cuttings. Adaptation to arid sites, provision of soil improvement, fodder and beneficial impact on cereal crop yields have been the major factors that have prompted the interest in *F. albida*, rather than wood yield. Average pod production for an individual tree can be over 150 kg $yr^{-1}$ but can vary from 40 to over 300 kg with the year and average pod production can be 590 kg $ha^{-1}$ $yr^{-1}$ at 11 trees $ha^{-1}$. The yield from lopped trees is reduced to about 20% or less. Natural regeneration requires cultivated areas, abundant seed and animals in the dry season to succeed, as the seedlings are very prone to competition by grasses. The section on "protection" concerns mainly insect pests of the species and damage from foraging animals. The tree is less susceptible to fungal diseases because of its inverse phenology. The

species' breeding system is described as insect-pollinated, self-incompatible and outcrossing in the section on "variation and breeding". Morphological variation in *F. albida* is considerable, particularly in pod morphology. The larger seeded east and southern African populations grow faster than the west African populations and have a higher shoot/root ratio, but can collapse in the more arid west African sites where water tables are deep. Isozyme studies indicate a large genetic diversity within the species, distributed into three major areas, southern, north eastern and west Africa with the latter being a key area of diversity. "Uses" is subdivided into services and products. The tree is used for soil improvement and conservation and shade. It produces an inferior fuelwood, but has specialized uses such as for dugout canoes, doors and mortars. Its most important products are foliage and pods for feeding livestock at critical times of the year. Leaves, pods and seeds can contain on average 200, 150 and 260 g total protein per kg of dry matter, and total protein digestibility can reach 73%. Tannins limit digestibility, but incorporating pods into low quality fodder enhances ingestion without reducing digestibility. Milling the pods increases digestion of the seeds when fed to cattle, which would otherwise pass undigested and scarified for germination. Cooked seeds are eaten as a human famine food. It is a useful source of pollen and nectar for honey bees especially as it flowers later than most plants. Thorny branches are widely cut for fencing.

104 CADET P; DUPONNOIS R; SENGHOR K. [**Relations between nematodes and *Acacia* species. A synthesis of preliminary work in Senegal.**] Relations entre les nématodes et les Acacia. Synthèse des travaux préliminaires au Sénégal. In *L'acacia au Senegal [edited by Campa, C.; Grignon, C.; Gueye, M.; Hamon, S.]. Actes de la réunion thématique sur l'acacia au Sénégal, Dakar, Sénégal, 3-5 décembre 1996* (1998) 397-411, 467 [Fr, 10 ref.]

Like most plants, the Acacias are attacked by many species of nematodes. In Senegal nematodes of the genera *Maloidogyne, Pratylenchus, Helicotylenchus, Tylenchorhynchus* and *Scutellonema* were found in the rhizospheres of *Acacia tortilis, A. senegal* and *A. holosericea*. The authors summarize recent research, focusing on a means of identifying plants affected by gall nematodes (*Meloidogyne* sp.) through the presence of large cells within roots, and using the rate of increase in nematode populations to evaluate host plant susceptibility and resistance. Tree species particularly susceptible to nematodes include *Acacia holosericea, A. mangium, A. hilliana* and *A. nilotica*; species more resistant include *A. tumida, A. lysophila* [*A. lysiphloia*], *A. albida* [*Faidherbia albida*] and *A. senegal*. Resistance increases with tree age. In fact the effect of inoculation of nematodes was to stimulate nodulation in *F. albida, A.senegal* and *A. raddiana* [*A. tortilis* ssp. *raddiana*], and with *A. hilliana* and *A. tumida* nodules did not appear on trees which were not infested with nematodes. In *F. albida*, phenolic compounds in roots suggest a resistance mechanism. The ways in which nematode, nodulation (and nitrogen fixation) and plant vigour may be interrelated are discussed in the light of this and other tests.

105 CAMPA, C.; GRIGNON, C.; GUEYE, M.; HAMON, S. (eds.) [***Acacias* in Senegal.**] L'acacia au Sénégal. *Actes de la réunion thématique sur l'acacia au Sénégal, Dakar, Sénégal, 3-5 décembre 1996. Colloques et Séminaires. Editions de l'ORSTOM, Paris, France* (1998) 476 pp [Fr, ref. at end of each paper]

About 12 species of *Acacia* occur in Senegal, and they are important multipurpose and agroforestry trees in this dry tropical region, as is reflected in the research undertaken into many aspects of the botany, ecology, utilization and improvement of the genus. This book contains 25 papers presented at a conference for scientists working in partnership with several institutes or organizations such as ORSTOM, CIRAD, INRA (in France), ISRA [Institut Senegalais de Recherches Agricoles], IDEFOR [Institut des Forets en Cote d'Ivoire], IRAD [Institut de la Recherche Agricole pour le Developpement] - previously known as IRA - in Cameroon, INERA [Institut National de l'Environnement et des Recherches Agricoles] in Burkina Faso, and UCAD [Universite Cheikh Anta Diop] in Senegal. The papers summarize recent and current research into *Acacia* species and *Faidherbia albida*, mainly in Senegal. The papers are arranged under six topics: ecology (6 papers); agroforestry and acacias (2); acacia and nitrogen (3); biotechnology (3); genetic variation (4); symbioses, Rhizobium, and other organisms (6). An introductory paper outlines the *Acacia* resource in Senegal, and a concluding paper emphasizes future research needs.

106 CAMPBELL, B.M.; CLARKE, J.M.; GUMBO, D.J. **Traditional agroforestry practices in Zimbabwe.** *Agroforestry Systems* (1991) **14** (2) 99-111 [En, 47 ref.]

Traditional agroforestry systems in the communal areas of Zimbabwe are described. There are systems centred on main fields, on home gardens, on home sites and home fields (the areas surrounding homes) and on grazing areas. In the main fields, the major tree-related management practice is the conservation of preferred indigenous fruit trees. Fruit trees are also the focus of forestry activities around the gardens and the home site, but here it is the planting of exotic species. In a localized area of Zimbabwe *Acacia albida* is important in fields. There is almost no use of tree fallows. Trees in grazing areas have numerous roles, but at present there is little knowledge about traditional management practices in these areas. It is suggested that in the development of agroforestry systems in Zimbabwe, those systems designed to improve fodder production will make a significant contribution to farm productivity because of the importance of cattle in the farming system and the present fodder shortage. Interventions involving the planting of fruit trees are likely to be very successful as there is much interest in such

planting. Another area that needs to be developed is that of tree plantings to improve soil fertility.

107 CAMPBELL, P. **The tree that follows people.** *Farm Forestry News*, Forestry/Fuelwood Research and Development (F/FRED) Project 3 (1) 7 [En]

Follows the success of traditional agroforestry practices and the encouragement in growth of *Acacia albida* by the Dogon farmers on the Seno Plain fields of Mali. Planting strategies to increase crop yields should complement rather than substitute natural regeneration.

108 CANADIAN INTERNATIONAL DEVELOPMENT AGENCY. ***Acacia albida. The miracle tree of the Sahel zone.*** Ottawa, Canada; CIDA (1979?) 9 pp. [En, 46 ref. Mimeo]

A collection of extracts from reports on research in Senegal and Niger, including notes on the role of the species in soil improvement and agroforestry, its natural and artificial regeneration, and its uses.

109 CAPON, M. **[Observations on the phenology of species of the Yangambi forest]** Observations sur la phénologie des essences de la foret du Yangambi. C.R. semaine agricole, Bruxelles (1947) [Fr]

110 CARR, J.D. ***Acacia albida*: an unusual occurrence.** *Trees South Africa* (1975) **27** (2) 30-31.

General description, distribution, and ecology. Also found in non riverine sites, such as mountain sides in the Eastern Transvaal and on the inland fringe of the Namib desert where it is tall, erect, single stemmed and with a small crown. Planted trees are recorded in Sekhukhuniland (6.5 m in 4 years) and in the Witkoppen area, 27 km from Johannesburg (10.5 m in 7.5 years, with a d.b.h. 940 mm). Describes the occurrence of a small population of *Acacia albida* between Pretoria and Pienaarsrivier far from their main distribution in the Transvaal Lowveld, near the railway line. Possible origin introduced from the railway.

111 CARR, J.D. ***Acacia albida* Del.** In *The South African Acacias*. Johannesburg, South Africa; Conservation Press Ltd. (1976) 165-170 [En]

A detailed botanical description of *Acacia albida* Del. Distribution: South West Africa, Botswana, Transvaal Lowveld and bushveld, Swaziland and Northern Natal. In riverine conditions it is deciduous, though remaining green during the winter, with foliage shed in summer. Bark: older main stem bark medium grey with longitudinal, shallow fissures and transverse splitting; branches light grey and appreciable circumferential wrinkling; smaller younger stems fairly smooth, pale grey almost white (hence the name "albida"). Thorns: located in pairs at intervals 20-30 mm, straight to slightly forward curved; up to 15 mm in length in drier conditions, but only 2-3 mm in riverine areas. Foliage: somewhat glaucous leaves, 3-5 pinna pairs, up to 12 pinnule pairs, length of petiole plus rachis 60-70 mm. Fruit: coffee coloured, indehiscent, curled, contorted seed pods with up to 14-21 seeds; occur in bunches, falcate, up to 200 mm long and 35 mm wide. Inflorescence: flowering takes place throughout the winter months, when the tree is in leaf; inflorescences are spicate, length usually 120 mm; rachis green and pubescent, flowers; cream coloured to white, scented. Cultivation: fastest growing of all South African *Acacias*; young trees definitely frost tender; though drought-resistant they respond well to copious watering.

112 CASEY, J.H. **Selling Agroforestry: a case history from Malawi.** *Ceres* (FAO) (1983) **96** (6) 41-44 [En]

Details a case history of introducing planting *Acacia albida* and *Leuceana leucocephala* into farmers fields in three different sites in Malawi. Describes the ameliorating properties of *A. albida* on the microclimate, and that the tree was readily accepted and its benefits realized by the local populations, where high populations intensively cultivate the land with resulting declining fertility. Future management plans discussed.

113 CASEY, J.H. **Selling agro-forestry.** *ADAB News, Dhaka, Bangladesh, Association of Development Agencies in Bangladesh* (1987) **14** (4) 34-38 [En]

A case history from Malawi, where considerable extension effort was expended on the introduction of an agroforestry system. The proposed package was in two parts: the establishment of a village woodlot of *Eucalyptus*; and the planting of a known indigenous tree (*Acacia albida*) interplanted with the locally unknown species *Leucaena leucocephala* along the contours of farm fields, at wide enough spacings to allow cultivation by ox-drawn equipment. The establishment of the system is described in three trial areas, emphasizing the communication, explanation and interactions with participants required. Preliminary (successful) results are outlined, and future management practices discussed.

114 CATINOT, R. **[Preliminary thoughts on a possible physiological explanation of the annual growth rhythms of trees in the African tropical forest.]** ?? *Bois et Forêts des Tropiques* (1970) **131**, 3-36 [Fr, e, es, 7 ref.]

Gives a condensed report, supported by numerous graphs and tables, of research in a number of tropical African countries on the apparent correlations between the annual growth rhythms of trees and the factors:- day-length; duration of exposure to sunshine and the quantity of energy received; rainfall; temperature; and atmospheric moisture saturation deficit. In drawing tentative

conclusions, the author notes that in all recorded cases of regular growth rhythms in trees in both deciduous and evergreen tropical forest, flushing and the beginning of growth coincide with the onset of rains or a sufficiency of rain, a reduction in the saturation deficit, and a rise in the mean minimum temperature, while leaf-fall and termination of growth coincide with a cessation of or reduction in rainfall, an increase in the saturation deficit, and a fall in the mean minimum temperature; the behaviour of certain species suggests that mean minimum temperature may be the key factor. Variations in the phenology and growth of *Tectona grandis* and *Terminalia superba* in different countries and climatic zones are used to discount the theory that dormancy is automatically broken after subjection of the tree to a given 'dosage' of cold or drought during the unfavourable season. Attention is drawn to the contrast, in evergreen forest, between the regular growth rhythms of some species (eg *Aucoumea klaineana*) with a single annual flush of new leaves, and the irregular growth rhythms of other species (eg *Tarrietia utilis*) that have several flushes in a year. The complexity of the problem and the inadequacy of the explanation offered are underlined by the unexplained behaviour of species with irregular or indiscernible growth rhythms (eg *Khaya*, *Pycnanthus* and *Canarium*), and of species that are in leaf and growth during the dry season (*e.g. Acacia albida*).

115 CATINOT, R. [**The forester's contribution to combating desertification.**] Contribution du forestier à la lutte contre la désertification en zones sèches. *Bois et Forêts des Tropiques* (1974) No. 155, 3-13 [Fr, en, es, 4 ref.]

116 CAZET, M. [**Plant antitranspirants that regulate stomata. Experiments in Senegal in 1986.**] Anti-transpirants végétaux de type régulateur stomatique. Expérimentation aux Sénégal 1986. Compte rendu des résultats obtenus en Octobre 1986. Report of results obtained in October 1986. *Unpublished report, Centre National de recherché forestières, Dakar, Sénégal* (1986) 25 pp. [Fr]

Four treatments were tested: control (TO); 1.5 g usnic acid. at a depth of 0.3 m in the planting hole (Tl); 0.75 guanic acid at 0.30 m depth + 0.75 g applied on the surface (T2); 1.5 g usnic acid applied on the surface (T3). The usnic acid was incorporated into a light humus at a rate of 0.75 g acid to 2 litres of humus. Each planting hole was planted with three pre-germinated seeds, and two rows were planted of each treatment, intercropped with peanut. Average survival after 65 days was about 8% lower than that of the control for treatments with surface application of usnic acid. However, there was high variation in survival between the two rows of the same treatment (23%) showing the effect of the worker on the survival rate. Usnic acid had a detrimental effect on the yield of the peanut intercrop regardless of application method.

117 CAZET, M. [**Artificial regeneration of *Faidherbia albida* in the Sahelian zone. Planting or direct sowing?: First results of experiments conducted at Thienaba (Senegal) in 1986.**] La regeneration artificielle de *Faidherbia albida* en zone Sahélienne: Plantations ou semis direct?: Premiers résultants de l'expérimentation conduite à Thienaba (Sénégal) au 1986. *Unpublished report, Institut Sénégalais de Recherches Agricoles, Ministère du Développement Rural, Dakar, Sénégal* (1987a) [Fr]

Two techniques can be used to achieve artificial regeneration of *Faidherbia albida*. Regeneration from plants first raised in a nursery and transplanted in balls of earth is now widely used. Artificial regeneration by direct sowing is not recommended as it has not given satisfactory results. Direct sowing, however, when carried out with certain precautions, provides much better results than planting in balls of earth, as much in respect of the level of resistance of the plants to drought as to their vegetative development at least in the juvenile stage. The dry weight of the stem at six months is increased 17-fold over nursery-raised plants while that of the roots is 24 times as great. The first results of the trials undertaken in 1986 at Thienaba to compare sowing and planting *F. albida* reveal the differences which exist between these two methods of artifical regeneration as well as some relevant sylvicultural improvements particularly with the utilization of hydro-retentor and anti-transpirant.

118 CAZET, M. [**Linear planting and intercalary cultivation on degraded sandy soil in Central North Senegal. Initial results of experiments conducted at Thienaba since 1985.**] ?? *Unpublished document, Institut Sénégalais de Recherches Agricoles, Ministère du Développement Rural, Sénégal* (1987b) [Fr]

Regeneration and enrichment with *Faidherbia albida* is generally the solution recommended for improving the condition of degraded soils in the zone north of the Senegalese groundnut basin. This solution has proved effective but it has its limits. Other species capable of improving soils and of providing varied yields while having more rapid growth were tested in an agro-forestry system of cultivation in lanes compatible with the constraints of harnessed/yoked farming. The present experiment enabled comparison to be made of the behaviour at a young age of five species, *F. albida, Acacia tortilis* ssp. *raddiana, Acacia nilotica* ssp *adstringens, Acacia senegal* and *Prosopis juliflora* on the sandy degraded soils of Thienaba and their eventual influence on the yield of intercalary cultivation to be tested. In this respect, *Acacia senegal* seems to be a particularly interesting species, as much in terms of its remarkable behaviour as of the improving role which it seems to play on intercalary cultivation. This experiment was aimed also at testing the effect of the inoculation of nursery plants on the behaviour of the trees after transplantation and eventually on the yield of intercalary cultivation. What the experiment made clear was the beneficial effect of inoculation on the growth at a young age

of certain species only, namely *Prosopis juliflora* and *F. albida*, and, correlatively, an improvement in the yield of cultivation alongside these two species. Recognizing the interest shown in nematicide treatment of plots of cultivation, the third objective of this experiment was to look at the eventual effects of this treatment on the behaviour of trees, as well as possible interaction between the three factors studied. It appears that the nematicide treatment improves the growth of trees during the first year of growth, but it can also annul the effects of inoculation on the yield of intercalary cultivation with certain species such as *Prosopis juliflora*.

119 CAZET, M. [**Tree plantation in line and alley cropping on degraded sandy soils of central north Senegal. Influence of inoculation of trees with *Rhizobium* sp. and the treatment of soils with nematicides on the behaviour of trees and cultivation.**] *Plantation en lignes et cultures intercalaires sur les sols sableux dégrades de la zone centre nord du Sénégal. Influence de l'inoculation des arbres avec le Rhizobium sp. et du traitement nematicide des sols sur le comportement des arbres et des cultures.* Direction des Recherches sur les productions Forestières, ISRA (1987c) 1-15 [Fr]

A comparative study of five leguminous species planted on degraded sandy soils of Thianaba, Senegal. It aims to test the effect of rhizobium inoculation and nematocide treatment on development of the trees, and crop behaviour. The species are; *Acacia albida*, *A. tortilis*, *A. nilotica*, *A. senegal* and *Prosopis juliflora*.

120 CECCHINI, G. **Notes on the germinability of some tree species and results of reforestation activities in Wollo region, Ethiopia.** *Desertification Bulletin* (1991) No. 19, 53-55 [En, 5 ref.]

In a test of survival of a variety of species over 390 ha of reforestation sites, *Acacia albida* had the greatest success at 100% when planted at 10 m spacing.

121 CELLAI, G. C. [***Acacia albida* Del., *leguminosae***] *Acacia albida* Del., *leguminosae*. Atlante Micrografico dei legni dell'Africa orientale V, undated.

122 CHAMSHAMA, S.A.O.; MUGASHA, A.G.; KLOVSTAD, A.; HAVERAAEN, O.; MALIONDO, S.M.S. **Growth and yield of maize alley cropped with *Leucaena leucocephala* and *Faidherbia albida* in Morogoro, Tanzania.** *Agroforestry Systems* (1998) **40** (3) 215-225 [En, 30 ref.]

The effect was examined of alley cropping with *Leucaena leucocephala* and *Faidherbia albida* on wood biomass, maize grain yield and soil nitrogen status, in a trial at Gairo, 150 km from Morogoro, Tanzania. The treatments (established in January 1989) were: trees planted alone at 1x5 m spacing; trees intercropped with maize; and a sole maize crop. Maize was planted at 90x30 cm spacing in January 1989, 1991 and 1992, and in February 1990; maize rows were N.-S. at right angles to the slope and parallel to the tree rows. All plots were weeded with a hoe during each cropping season and once during the dry seasons. The trees were cut back to 1 m height once a year just before maize planting and the prunings left on site. Maize yields were recorded for each cropping, and tree root collar diameter and biomass production at 2.5 year-old - the soil and maize foliage were also sampled at this time. Mulch biomass averaged 6.18 and 0.97 t $ha^{-1}$ for *L. leucocephala* and *F. albida*, respectively. Corresponding wood production was 1.71 and 1.11 t $ha^{-1}$. Both soil total N and inorganic N (NO3—N plus NH4+-N) were higher under *F. albida* then under *L. leucocephala*. Similarly, foliar N concentration in maize was higher in plots intercropped with *F. albida* than with *L. leucocephala*. Maize grain yield was little affected by the tree intercrop as competition for resources was reduced through the pruning and weeding operations. There was no gain in maize grain yield due to the presence of *L. leucocephala* and *F. albida*. These results suggest that alley cropping in Gairo is justified for wood production but not for increasing maize grain yield.

123 CHARREAU, C. [**The role of trees in agriculture in the tropical semi-arid regions of West Africa.**] *Le rôle des arbres dans les systèms agraires des régions semi-arides tropicales d'Afrique de l'Ouest* (1982) Vol. 43 33-36 (28, rue El Hadj A.A. Ndoye, B.P. 3340, Dakar, Senegal.) [Fr]

It is argued that rotating trees with crops improves soil fertility more than fallow periods using herbaceous plants. However, similar benefits could be obtained by growing deep-rooted species such as *Acacia albida* or *Prosopis cineraria* in association with crops.

124 CHARREAU, C.; NICOU, R. **The improvement of the cultural profile of the sandy and sandy-clay soils in the West African tropical rainfed area and its effect on agriculture (from the work of IRAT research workers in West Africa).** (ICRAF No. 2059) (1971) [Fr, en]

In this publication, special attention is given to the rooting of the main tropical plants in the rain-fed crop production area in Senegal. The relationship between rooting, plant growth and production are then investigated. There is a close linear relationship between rooting and grain yields in Senegal for sorghum, groundnut and maize. It was shown that good rooting is important for the crops. Bulk density of the soil appears to have most effect on plant growth and production. An inverse relationship was found between the bulk-density and rooting as well as between the bulk density and grain yield on sorghum, groundnut and maize: small increases in the bulk density can result in substantial decrease of the root weight and grain weight. The mechanism of the effect of porosity on

rooting in terms permeability changes in air and oxygen supply and mechanical resistance to penetration is discussed. It seems that this last measure best reveals the response of rooting to the porosity changes of the environment. It is pointed out that, in the sandy soils, porosity is generally less than 40% which is considered to be the limiting value for a good rooting. On the other hand, vegetation has an effect on the physical proprieties of soils through the ground cover which prevents the soil from being degraded by climate. There is a marked decrease in water infiltration from forest to a herbaceous type of vegetation (both fallow and crops) as there is in bulk density, structure stability, erosion, chemical proprieties, mineral balance, biochemical properties and humus balance of the soils. Proper management of the fallows and crops is crucial for the maintenance of productivity in the least fertile areas. In the areas with more amenable climate and soil, the part played by the fallows is not proven. Although the part played by management of the tillage, crop selection and rotation of the herbaceous vegetation can play a part in the maintenance of the cultural profile, it cannot alone markedly improve the physical properties of the soil. It is suggested that trees, and particularly *Acacia albida*, maintained in the cropping area have a favourable effect on the microclimate and make the plough layer richer by exploiting the deep soil horizons. The reverse leaf cycle of *A. albida* has two advantages, crops can grow under the trees in the rainy season without being shaded out, and the deep roots (15-20 m deep with no side roots above 1-2 m depth) bring nutrients up from depths not accessible to herbaceous plants. It enriches the surface horizons with decomposing leaf litter at the start of the rains and returns more nutrients than other forestry trees. *A. albida* increases the soil nutrient status, especially of sandy soil, particularly N (from leaves, bark and fruit), but also C, Ca, Mg, $K_2O$, $P_2O_5$ and humus. N is fixed by *Rhizobium* in young plants. The biological activity of the soil also increases. Such improvements are also found on more clay rich soils. Foliar analysis showed increased mineral nutrition (especially N) in plants grown under *A. albida*; this could explain the increase in growth noted in these plants. A density of 20-25 trees $ha^{-1}$ improve the microclimate of the soil. Evaporation potential is decreased by *c.* 50% in the dry season compared to open fields (*c.*10% in wet season). The trees also catch driving rain, modifying the hydrology of the soil. Fruits are high in protein (70 g $kg^{-1}$ of digestible N) and used as a forage resource (0.77 units of forage per kg of dry product at 10% Moisture content). Fruiting occurs between February to May (end of the dry season), a critical time for fodder, and can be dried and stored. In Senegal Jung reported 125 kg pods per tree covering 230 $m^2$ ; 135 kg per tree have been reported in Sudan by Wickens. With 20 trees $ha^{-1}$ this gives 1,930 forage units (20x125x0.77), better than other available forages. It is possible to feed 1.3 beef cattle $ha^{-1}$ without affecting cereal production. It is estimated that 7 kg pods/day are needed for the maintenance of adult cattle and the production of 5 litres of milk or 700 g weight per day, so a medium sized *A. albida* (125 kg pods) can give rise to the production of 90 litres of milk or 12.5 kg of meat. Although *A. albida* is important in traditional agricultural practice, the system is breaking down with increased population pressure. The agrosylvopastoral system cannot work where there are more than 80 people per $km^2$; the trees and soil are overexploited and results are at best mediocre. Only intensive agriculture will work, with mechanical ground preparation and fertilizers; trees in fields hamper mechanisation. Possible solutions are the use of the trees as wind breaks or the maintenance of a separate pasture with a high density of *A. albida* (20-30 trees $ha^{-1}$) providing fodder all year and improving the soil.

125 CHARREAU, C.; VIDEL, P. [**Influence of *Acacia albida* on the soil, mineral nutrition and yields of pennisetum millets in Senegal.**] Influence de l'*Acacia albida* Del. sur le sol, nutrition minérale et rendements des mils *Pennisetum* au Sénégal. *L'Agronomie Tropicale* (1965) **20** (6-7) 600-625 [Fr, 9 ref.]

*Acacia* plants are highly valued in Serere county. They are protected and may reach planting density of 40-50/ha. Soils and leaves of millet plants were sampled. Remarkable fertility gradient from external area to the trunk of the tree. All soil properties improved and paralleled increase in vigour, mineral content and status of millet plants. Seed yields (millet) increased by 250% and protein yields by 300-400%. [Question as to residual effect of dung under the tree from distant past even though livestock were excluded for a number of years.]

126 CHEVALIER, A. [**A revision of the acacias of north, east and central Africa**] Révision des *Acacia* du Nord, de l'Ouest et du Centre Africain. *Revue de Botanique Appliquée* (1928) No. 8 646-650 [Fr]

127 CHEVALIER, A. [**New observations on some acacias of west Africa**] Nouvelles observations sur quelques Acacias de l'Afrique occidentale. *Revue de Botanique Appliquée* (1934) No. 14 875-884 [Fr]

128 CHEVALIER, A. [**New observations on some West African acacias.**] Nouvelles observations sur quelques Acacias de l' Afrique Occidentale. Revue de Botanique Appliques. *Journal d' Agric. Tropicale* (1939) **14**, 875-884 [Fr]

This article was written after a journey made through the Sahara in the Sahelian and Sudanese regions of Sudan and Senegal in 1931-1932. It includes a description of *Acacia albida* (Delile). Further to an earlier publication on *A. albida*, the author feels this species is not an *Acacia* but a new genus previously recognized by Baillon (1863) but not named. It is re-named *Faidherbia* gen. nov. here in recognition of the the French general Faidherbe who was the first "organizer" of Senegal and had an interest in the vegetation of the

country. A latin description of *Faidherbia* is given – *F. albida* comb. nov. = *A. albida* Delile. The new genus establishes a link between *Acacia* and *Inga*. It is distinguished from *Acacia* because the stamens are connected to one another to a large extent and the free petals fused at the base to the filaments of the stamen. The fruit closely resembles *Enterolobium* (Mart.) of America, in shape, with its thick fleshy mesocarp when fresh, and with septas between the ovoid, rather than flattened, seeds. The species naturally occurs in the meridinal Sahara and the Sahelian region where it is common in mimosaceous scrub. It may previously have stretched to the Mediterranean when scrub covered the area. In the Sudanian zone it is under domestic cultivation round villages, as hedges, and in crops. It has been spread by man who has prized it highly as a forage; the pods and foliage are eaten by cattle. It binds the soil, fixes N and is leafless in the rainy season allowing crops to grow beneath it.

129 CHEVALIER, A. [**Wood of the acacias**] Le bois des acacias. In Révision des acacias du nord, de l' ouest et du centre Africain). *Rev. Int. Bot. Appl. Agric. Trop.* (19??) **8**, 646-650 [Fr]

130 CHEVALIER, A. [**A tree with a great future in the warm semi-arid country especially on the north and south borders of the Sahara**] Un arbre de grand avenir dans les pays subdésertiques chauds spécialement sur les confins Nord et Sud du Sahara. *Revue de Botanique Appliquée* (1953) [Fr]

131 CHEVALIER, M.H.; SOGNA, M.; SARR, A.S.; DANTHU, P. **Morphological variability of pods of four *Faidherbia albida* provenances in Senegal**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 67-70 [En, 3 ref.]

Morphological study of the pods of *F. albida* from four Senegalese provenances, each with 20-30 progenies. Pod traits were extremely variable between trees, outside pod length (112-270 mm), inside length (44-112 mm), pod width (12-71 mm) and pod mass (292-989 mg). Pods contained 7-23 seeds. Spiralling and surface area index, and the ratio of width to average length was also calculated. The traits were interpreted using analysis of variance, principal components and correspondence analysis, and discriminant factor analysis. Pod size and mass proved the most variable, intra provenance diversity was generally significant. However three of the populations were significantly different in morphological traits.

132 CISSÉ, M.I. [**The browse production of some trees of the Sahel: relationships between maximum foliage biomass and various physical parameters.**] Production fourragère de quelques arbres sahéliens: relations entre la biomasse foliaire maximale et divers paramètres physiques. In *Browse in Africa, the current state of knowledge [edited by Houérou, H.N. le].* ILCA, Ethiopia (1980) 205-210 [En, 7 ref.]

Foliage yield of *Acacia albida, A. seyal, Balanites aegyptiaca, Commiphora africana, Pterocarpus lucens* and *Ziziphus mauritiana* was strongly correlated with trunk circumference, tree height and crown area. The highest correlation was with trunk diameter for all species except *B. aegyptiaca*. Trunk circumference is easily measured in the field, and could be used to eliminate laborious scoring of foliage dry matter. For *A. albida*, the linear regression equations for biomass (B) were:- (1) circumference of the trunk at 40 cm above the ground in cm (C) was $\log B = 2.08 \log C$ ($r = 0.98$); (2) height in cm (H) was $\log B = 2.77 \log H - 4.01$ ($r = 0.95$); and (3) crown area in $dm^2$ (A) was $\log B = 1.26 \log A - 0.50$ ($r = 0.96$).

133 CISSÉ, M.I. [**Arid and semi-arid zones programme : a synthesis of practical lopping trials on some Sahelian forage trees from 1978 to 1983**] Programme des Zones Aride et Semi-Aride. Synthèse des essais d'ébranchages pratiqués sur quelques arbres fourragers sahéliens de 1978 à 1983. ILCA Mali, Programme Document (March 1984) No. AZ 103, 18 pp. [Fr, 10 ref.]

Various pruning techniques on *Acacia senegal* and *Pterocarpus lucens* in the southern Sahel, and on *Acacia albida* in the north Sudan from 1878 to 1983 were put into practice to determine whether method and timing had an influence on the foliage production of the species. According to the species, the treatments had a depressive effect on *A. seyal* and *P. lucens*, but stimulated the yield of *A. albida*. None of the species supported an exploitative regime.

134 CISSÉ, M.I.; KONÉ A.R. **The Fodder role of *Acacia albida* Del.: Extent of knowledge and prospects for future research**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 29-37 [En, 45 ref.]

*Faidherbia albida,* a species more Sudanian than Sahelilan, derives its importance in fodder production from the fact that it drops its leaves in the rainy season and re-foliates in the dry season. Hence, it benefits domestic animals with fodder in the form of leaves and pods. Although a method has been developed to evaluate foliar biomass and its seasonal changes as well as the impact of seasonal exploitation on foliar production, fruit production has not received the same attention. Feed value analyses have revealed that pods and leaves are rich in parietal content. Leaves, pods and seeds contain

respectively 200, 150 and 260 g total protein $kg^{-1}$ of dry matter. Anti-nutritional substances such as tannins limit the digestibility of the abundant protein; however, in spite of the presence of tannins, *F. albida* components, particularly pods, can be incorporated into low quality fodder to enhance ingestion without reducing digestibility. Future research on the role of *F. albida* as a fodder needs to be done as part of a multi disciplinary effort that evaluates the contribution of this species to agroforestry systems.

135 CLARKE, J. ***Faidherbia albida* in Zimbabwe**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 181-182 [En, 8 ref.]

Gives details of the natural distribution and ecology of *Faidherbia albida* in Zimbabwe, and summarizes its potential from provenance trials undertaken there. The species has a limited range in the country, occurring principally along the Zambezi and Limpopo river drainage systems. In its natural range in the communal areas and national parks, it serves an important role as a source of fodder for wild and domestic animals. Concludes its greatest potential in Zimbabwe is in these areas, where it is already well known and appreciated.

136 CLEMENT, J. [**Stakes and strategy of a new forestry politics : peasant silviculture**] Enjeux et strategie d'une nouvelle politique forestière: la sylviculture paysanne. *Aménagement et Nature*, Printemps (1986) No. 81 11-16 [Fr]

137 CLIVE-COLE, R.A.; FALOLA, J.A.; MAIN, H.A.C.; MORTIMORE, M.J.; NICHOL, J.E.; O'REILLY, F.D. **Wood Fuel in Kano**. United Nations University Press. ISBN 92-808-0726-9 (1990) 124 pp. [En, 4 pp. of ref.]

Detailed study of survey data collected by the Kano Rural Energy Research Project investigating wood fuel consumption in urban Kano, rural-urban trade in firewood, the ecology of wood fuel, and the management of wood resources in the hinterland around Kano in Northern Nigeria. Data was collected between 1982 and 1986 in and around Kano, the largest northern city with around a million inhabitants. Mean monthly consumption of firewood per household was 332 kg (n = 80), with firewood being brought from up to 400 km as well as from the land surrounding the city. The city is surrounded by a good deal of farmed parkland where *Acacia albida* (gawo) and *Parkia biglobosa* are dominant and are the most regularly lopped species. Both species are the most regularly cut, which occurs in the dry season, and are the species that have become less abundant in the last five years. Tree planting is common in this close settled zone, with *P. biglobosa* and mango the most popular species. Gawo is not planted as it regenerates naturally. In one surveyed farmed parkland, *A. albida* were the biggest of the dominant trees, with an average timber volume/tree of 0.8 $m^3$, and an average GBH of 89 cm (n = 214.) It had poor regeneration partly attributed to overgrazing. *A. albida* is recognized as the most valuable farm tree, with farmers not applying manure on land occupied by the species. Gawo is the eighth most preferred firewood species by householders out of the 50 species recorded; *Anogeissus leiocarpus* (marke) is the most preferred.

138 COE, M.; COE, C. **Large herbivores, *Acacia* trees and bruchid beetles**. *South African Journal of Science* (1987) Vol. 83, 624-635 [En, af, 85 ref.]

The African acacias may be divided into two very distinct dispersal groups, namely those with dehiscent pods and those with indehiscent pods. The latter are favoured by large browsing herbivores, and are also more likely to be attacked by bruchid beetles. Indehiscent seeds are thick and robust, and can resist the damage caused when passing through a herbivore's buccal cavity. In an examination of the structure of the seeds' testa, *Acacia albida* had a mass of testa which was 29% that of the total seed weight. A further study of *Acacia* seeds attacked by bruchid beetles and collected direct from trees or the ground revealed a 4.1% infestation in a total of 393 *A. albida* seeds from fresh pods.

139 COINEAU, Y.; SEELY, M.K. [**A population of microarthropods in the fine sands of the dunes of central Namibia.**] Mise en évidence d'un peuplement de microarthropodes dans les sables fins des dunes du Namib central. *New trends in soil biology [edited by Lebrun, Ph.; Andre, H.M.; Medts, A. de.].* Belgium; Université Catholique de Louvain (1983) 652-654 [Fr, 4 ref.]

A preliminary study to investigate which families of microarthropods occur in the dune sands of the central Namib desert near Gobabeb. Pits (30 to 40 cm deep) were dug in the bare sands and sand under a number of plants including *Acacia albida*, irrigated for a week and microarthropods extracted using the grease film technique. Eight families were found in the sand under *A. albida* beside the seasonally dry watercourse of the Kuiseb, in order of abundance: *Symphypleona* and *Acaridida* were abundant; *Arthropleona*, *Nematalycidae (Actinedida)*, *Oribatida*, *Gamasida* were common; *Pauropoda* and *Bdellidae (Actinedida)* were rare. The majority of the families were restricted to the vicinity of the plants.

140 COOK, C.C.; GRUT, M.; CHRISTOFFERSEN, L.E. **Agroforestry in Sub-Saharan Africa: a farmer's perspective**. *World Bank Technical Paper* (1989) No. 112 94 pp. [En, 32 pp. of ref.]

The first chapter of the report introduces the background to and methodology of the study. Phase I consisted of a literature review undertaken to identify information on factors affecting farmer adoption of 'agroforestry' techniques, and on reported cases of successful experiences which might be further studied in Phase II. 'Agroforestry' in this context is defined as including activities that involve the incorporation or retention of trees or shrubs in agricultural or pastoral systems. Chapter II of the report 'Agroforestry in Africa' gives a general description of the techniques identified: savanna grazing; farmed parklands; tree crops and shade trees; forested fallow; planted farm trees; home gardens; farm woodlots; forest plantation farming (taungya); fodder trees; alley cropping; and land and tree tenure. Chapter III presents seven case studies. These included both indigenous and innovative systems found in the highlands of East Africa, the semiarid zone, and the humid lowlands of West Africa. The case studies included *Acacia albida* in southeast Niger. The review and field studies identified a number of issues that need to be considered in the design and implementation of agroforestry projects for Africa for them to be successful. These are discussed in the last two chapters. One of the key findings was the importance of understanding the economics of agroforestry systems from the farmer's point of view as well as from the broader perspective of the benefits to society. Project evaluation should therefore take into account local markets and opportunities for off-farm employment offered by tree products, as well as the opportunity costs perceived by farmers in making adoption decisions. Farm households are not homogeneous, and project design should also be adapted to the socio-economic level, age and gender of the people who are expected to adopt the proposed technology. In Africa, trees are integral parts of agrosilvopastoral farming systems and should be considered in this socio-cultural context, with particular attention to the constraints imposed by customary and legal rules regarding land and tree tenure.

141 CORBASSON, M.; ROEDERER, Y.; FORNI, E. ***Acacia albida* Del.: Characteristics and ecology of the species, exploration of genetic resources and collection of provenances for international trials**. In *FAO Forest Genetic Resources Information* (1987) No. 15, 63-69 [En]

Describes the distribution, uses, and ecology of the species, and tabulates a list of provenance seed collections made from Mali, Niger and Cameroon, and now available at CTFT. The sampling technique and seed extraction is illustrated with photographs, and their proposed evaluation in intercropping trials is described. Measurements will be primarily on growth rate and later if possible the changes in fertility of the soil under the trees. Marked variability in size and shape of the pods were noted from individual trees.

142 CORBY, H.D.L. **Systematic implications of nodulation among Rhodesian legumes**. *Kirkia* (1974) **9**, 300-329 [En, 42 ref.]

Reports on nodulation in 489 Rhodesian species of legumes, including *Acacia albida*, from the 539 species surveyed. Most woody plants were grown from seed, and the seedlings examined for nodules. If they failed to nodulate, the seed was re-grown with either rhizosphere soil from flourishing plants of the same or related species or with rhizobial cultures from its near relatives, and the seedlings checked around 100 days later.

143 CORBY, H.D.L. **Types of Rhizobial nodules and their distribution among the Leguminosae**. *Kirkia* (1988) **13** (1) 53-123 [En, 92 ref.]

Describes a survey of 210 genera of the Leguminoseae, comprising 83% of all species, where five types of rhizobial nodules have been found on seedlings grown from inoculated seed. The vast majority of species, characteristic of woody tribes, belong to the Caesalpinioid type. The morphology and evolution of these nodule types within the family are discussed. Lists in the appendices the dimensions and morphology of the nodules for each species, and for *Faidherbia albida* records both Caesalpinioid and Crotalarioid nodule types.

144 C.R.D.I. [**The role of trees in the Sahel**] Le rôle des arbres au Sahel. Compte rendu du colloque Dakar, 5 au 10 novembre (1979) [Fr]

145 CRIDA (Central Research Institute for Dryland Agriculture). **Agroforestry research and demonstration at CRIDA** (1987) 1-25 [En.]

Mentions a demonstration plot (4x4m.) of *Acacia albida* planted in Sept. 1984 at CRIDA, Santoshnagar, Hyderabad. Partial leaf shedding occurred after 2.5 years.

146 CTFT (Centre Technique Forestier Tropical). **The *Faidherbia Albida* (*Acacia albida*)**. CTFT (1965) 1-35 [Fr]

The article consists of a series of soils analyses which demonstrate the beneficial effects of *Acacia albida* on soil fertility, the significant increases in millet yield and the improved grazing capacity in the dry season.

147 CTFT (Centre Technique Forestier Tropical). [***Acacia albida*: study of growth.**] *Acacia albida: étude de la croissance*. CTFT (1966) 14 pp. [Fr]

Paper dealing with the use of a dendrometer to semi-continuously measure increases in *Acacia albida* diameter over a two year period. Average circumference growth measurements for two trees at Bambey, Diourbel and Hann were 35, 11 and 1.9 cm/season respectively;

rapid growth from April until the end of July, no growth from August to November, and rapid growth from November onwards. In further experiments, for a ten month period, eight 32-month-old seedlings had an average height increase of 92 cm (with a 50 to 160 cm range) and a stem diameter increase ranging from 0.31 to 2.9 cm. Eight-year-old sprouted plants in the same period had diameter increased ranging from 0.63 to 2.54 cm (average increase 1.6 cm). In a separate study with two-year-old naturally-occurring plants, the diameter increase had a range of 0.15 to 1.27 cm (average increase 0.69 cm). These unexplained difference in growth rate could be attributed to heterozygosity of the seedlings.

148 CTFT (Centre Technique Forestier Tropical). **[Notes on Gao (*Acacia albida*).]** *Notes sur le gao.* CTFT, Niger Republic (1973) 17 pp. [Fr]

Describes the contribution of *Acacia albida* to the improvement and conservation of soil fertility in the arid zones of Africa, and through cost benefit analysis, the significant effects of this tree on crop yields. The practice of silviculture and propagation methods are also discussed.

149 CTFT (Centre Technique Forestier Tropical). ***Faidherbia albida* (Del.) A.Chev. (Synonym *Acacia albida* el.): A monograph**. Centre Technique Forestier Tropical (France) and Technical Centre for Agricultural and Rural Cooperation (Netherlands) (1989) 66 [En (original Fr), 189 ref., many photographs, tables, diagrams and drawings]

This monograph on *Faidherbia albida* was translated by P. J. Wood from the original in French prepared by the staff of the Centre Technique Forestier Tropical with assistance from the Institut d'Elevage et de Médicine Vétérinaire des Pays Tropicaux (IEMVT), Maisons-Alfort, France, the Institut des Recherches Agronomiques Tropicales et de Cultures Vivrières (IRAT) Nogent-sur-Marne, France and the International Council for Research in Agroforestry (ICRAF), Nairobi, Kenya. The monograph starts with an account of the nomenclature of the tree followed by a description including botanical drawings. A detailed map is given showing the natural distribution by race, A and B, with an account of what is known of genetic variation and the evolutionary history of the species and the climatic and edaphic conditions that determine its occurrence. Observations on the leafing pattern are given and there is an account of the theories on the origins of the species' reverse phenology. The rooting structure is described and tables of growth rates and a diagram of growth patterns included. There is a brief account of reproduction by seed, root suckers and cuttings. The place of *F. albida* in agriculture is dealt with in detail and a considerable amount of quantitative data are given on the influence of the tree on microclimate, its effects on soil fertility, and its influence on agricultural yields. There is a comprehensive chapter on *F. albida* and livestock which deals with its nutritional value and the management of the tree for animal production. Wood properties, use as food and medicine and its place in local mythology are described. Detailed instructions are given for raising and planting propagules and on managing natural regeneration. The species' pests and diseases are listed. The potential for genetic improvement is stressed. The monograph ends with a perception of the role of *F. albida* in rural development and it is concluded that it will contribute to solving the problem of reversing soil degradation in areas such as the Sahel where settled must perforce take the place of shifting agriculture.

150 CTFT (Centre Technique Forestier Tropical) BURKINA FASO. **[Annual report of activities 1985]** Rapport annuel d'activités 1985. I.R.B.E.T., C.T.F.T., Ouagadougou, octobre (1986) [Fr]

151 CTFT (Centre Technique Forestier Tropical) NIGER. **[Note on Gao]** Note sur le Gao - janvier (1973) [Fr]

152 CTFT (Centre Technique Forestier Tropical) SENEGAL . **[Research on *Acacia albida* – relation between growth and rainfall]** Recherches sur *Acacia albida* – Relation entre la croissance et la pluviométrie. Action de l'engrais sur la croissance. Dakar, undated [Fr]

153 CURASSON, M. G. **[Study of tropical and subtropical pasture]** Étude des pâturages tropicaux et subtropicaux. Revue d'Élevage et de Médecine Vétérinaire des pays Tropicaux, Paris (1958) [Fr]

154 CUTLER, D.F. **The vegetative anatomy of *Acacia albida* Del.** *Kew Bulletin* (1969) **23** (2) 203-208 [4 ref.]

A detailed description of the vegetative anatomy of twig wood, leaf and root, as well as a description of the mature wood of *Acacia albida*. It builds on information given previously in three non-English papers. (Chevalier, 1928; Seabra *et al.* 1957; Cellai, 1967). From his examination of a limited number of microscopic slides of the wood, the author suggests that *A. albida* belongs to the group of species in the genus with narrow rays and, among these, it is most similar *to A. farnesiana* (L.)

155 DALE, I.R.; GREENWAY, P.J. ***Acacia albida* Del.** In *Kenya trees and shrubs*. Nairobi, Kenya; Buchanan's Kenya Estates Ltd. (1961) 284-285 [En]

A short botanical description *Acacia albida* Del. which grows to 60 ft., and occurs in dry areas of the southern Rift Valley and coastal provinces of Kenya. Its heartwood is soft and easy to work, finishing smooth,

and it planes and seasons well, but is prone to attack by borers and termites. Its bark contains 29% tannins and pods are useful cattle feed. Lists vernacular names, Apple ring *Acacia*, Duyet (Sibei), Ol-erai (Masai)and Mukabubu (Taveta).

156 DANCETTE, C. [**Study of six microclimates in Bambey - influence of breeze**] Étude de six microclimats à Bambey - Influence des brise-vent. I.R.A.T., Bambey, C.N.R.A. (1966) No. 6 [Fr]

157 DANCETTE, C. [**Note on the advantages of the rational use of *Acacia albida* (*Faidherbia albida*, kad, sas) in Senegal**.] Note sur les avantages d'une utilisation rationnelle de l'*Acacia albida* (*Faidherbia albida*, kad, sas) au Senegal. *Unpublished paper, Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières, Bambey, Sénégal* (1968) 6 pp. [Fr, 11 refs]

In dry regions, *Acacia albida* is often referred to as the 'miracle tree' because it provides fodder, wood, soil fertility, shade *etc*. Many of the advantages stem from the fact that it leafs during the dry season. It is associated with traditional agricultural methods *e.g.* of the Serer in Senegal. While offering advantages in mixtures with crops *e.g.* improved microclimate, it is hard to manage and hinders agricultural tasks. The advantages of traditional use (in fields) are:- (1) It helps prevent desertification, transpiration in the dry season increases the humidity, reducing the drying power of the air and thus decreasing the potential evapotranspiration of crops and so their water requirements; more rain is collected on forested areas; trees decrease wind erosion. (2) It increases the yield of crops (millet, ground nut) grown beneath the crown; the increase is mainly due to improved physical and chemical properties of the soil (*e.g.* increase in N and organic matter); it increases the microbiological activity in the soil and modifies the microclimate; a similar effect may be achieved using fertilizers. (3) Wood is of good quality; insect resistance is increased by soaking in water; it burns well; leaves, roots and bark have medicinal properties; leaves and pods provide fodder; pods are highly nutritious and used in commerce. There are advantages in line planting. The trees form a break that limits wind erosion in the dry season and the force of rain in the wet season; the potential evapotranspiration decreases more behind the wind break, and this reduces the amount of water used by crop cultivation; in areas with limited rainfall it improves the success of seedlings and slows drying of the soil after the last rain (aiding harvest of groundnuts); it increases yield of protected crops. *A. albida* is favoured by rural populations throughout its range in Senegal. However, there has recently been massive destruction and no thoughts to future and there is a need to replant in lines. The density of windbreaks depends on the winds in the area. Senegal has severe winds and planting in two-tree lines intersecting in a square arrangement with sides of 100-250 m is recommended; 10 m height gives 200 m of protection. There is a need for further study to assess the effectiveness of different systems. The possibility of strip cultivation interspacing crops of varying height with rows of trees could be considered. The fallows between the trees would protect cattle and provide fodder. There is a need for planning of the rural landscape on large scale.

158 DANCETTE, C. [**Agroclimatology applied to water economy in the sudano-sahelian zone**] Agroclimatologie appliquée à l'économie de l'eau, en zone soudano- sahélienne. *L'Agronomie tropicale,* octobre-decembre (1979) XXXIV No. 4 331-355 [Fr]

159 DANCETTE, C.; SARR, P. L. [**Degradation and regeneration nof soils in the central-north regions of Senegal**] Dégradation et regeneration des sols dans les régions Centre-Nord du Sénégal (Cap-Vert, Thiès, Diourbel, Louga). I.S.R.A., Dep. Systèmes et Transfert, Dakar, janvier (1985), Travaux et Documents No. 2, 22 pp. [Fr]

160 DAVIES, C. **Multiplication végétative *in vitro* de *Faidherbia albida* (Del.) A. Chev. (*Acacia albida* Del.)**. D.E.A. Université de Dakar (1984) 69 pp [Fr]

161 DANCETTE, C.; NIANG, M. [**Roles of the tree and its integration into the agrarian systems of the north of Senegal**.] Roles de l'arbres et son intégration dans les systèmes agraires de nord du Sénégal. *CRDI Seminar on role of trees in the Sahel, Senegal 5-10 November 1979.* ISRA, Bambey (1979) 17 pp. [Fr, 34refs]

The north of Senegal is an arid zone where there is less than two months of the year when rainfall exceeds evapotranspiration (ETP). Annual plants and herbaceous cover take water from the first 2 m in the relatively deep sandy soil of the region while trees draw water from 2-20 m down and sometimes even from the phreatic level of pluvial origin. This water is transpired, cools the air and increases the relative humidity. The shade given by the trees and the reduction of wind speed contribute to tempering the climate significantly. Without trees, the climate of the region would be as unbearable as the open Sahara - wind erosion removes soil fertility and causes the loss of fine elements of the soil. *Acacia* (*Faidherbia*) *albida* has been shown to reduce ETP by 5-19% where it is traditionally used in fields. Beneath the trees it can compensate millet and groundnut crops for the absence of mineral fertilizers as it brings leached nitrates to the surface in the organic matter that it drops beneath its crown. *A. albida* also provides fodder to maintain herds of small ruminants in the form of lopped foliage and falling pods even through periods of very severe drought. In parts of Niger the usual range carrying capacity of

10 units to the square kilometre can be doubled with *A. albida*. More formality is being introduced into the spatial arrangement of the trees in fields. These include geometric arrangements, alternating strips of trees and cultivated land and strategically aligned windbreaks. Natural regeneration is encouraged to make windbreaks by banning grazing in narrow strips 50 m apart and small farmers are using trees to delimit the boundaries of their fields. In a drought year, the depression of crop yields does not occur under *F. albida* whereas it is severe under most other trees. The value of *F. albida* in the traditional agrarian systems of Senegal is tested and unanimously recognized by agronomists and it has no attributes that are undesirable enough to rule it out in cultivated fields.

162 DANCETTE, C.; POULAIN, J.F. [**Influence of *Acacia albida* on soil and climatic factors and crop yields**.] Influence de l'*Acacia albida* sur les facteurs pédoclimatiques et les rendements des cultures. *Sols Africains, Paris* (1968) **13** (3) 197-239 [Fr, 16 ref.]

A study was made in Senegal on the effect of individually spaced *Acacia albida* trees on evaporation, relative humidity, temperature, soil moisture and other properties, and rainfall, and on the yields of groundnuts and millet grown beneath and round the trees. It is concluded that in the traditional form of agriculture (*i.e.*, hand labour, and without using fertilizer) the *A. albida* trees are beneficial. In a more developed form of agriculture, with tractor or animal draught,a regular shelterbelt system should be preferred.

163 DANGASUK, O.G.; SEUREI, P.; GUDU, S. **Genetic variation in seed and seedling traits in 12 African provenances of *Faidherbia albida* (Del.) A. Chev. at Lodwar, Kenya**. *Agroforestry Systems* (1997) **37** (2) 133-141 [En, 10 ref.]

The extent of genetic variation in seed length, width, thickness, weight and germination percentage and seedling traits among and within 12 African provenances of *Faidherbia albida* was examined in a nursery study at the Kenya Forestry Research Institute. The regional provenances showed a consistent variation in seed length, seed width and seed weight: the southern African provenances had the largest seeds and west African provenances the smallest. Seedling height, stem collar diameter and true leaf number differed among the provenances 90 days after germination. The seedlings from west Africa were shorter, had smaller stem collar diameter and fewer leaves. In contrast, the southern and east African provenances had taller seedlings with bigger seedling diameter and more leaves per seedling. Seedling traits did not show clear-cut divisions between southern and east African provenances, but the west African provenances formed a distinct group. Positive correlations were found between some of the seed characteristics and seedling height among provenances, which could be an important criterion for early provenance selection. Greater variation was observed for seed and seedling traits among than within provenances suggesting that selection among provenances might result in rapid genetic gain for the traits studied.

164 DANTHU, P. **Study of the genetic variability of *Faidherbia albida* in natural range by isoenzyme electrophoresis**. In *Breeding Tropical Trees: Population Structure and Genetic Improvement Strategies in Clonal and Seedling Forestry [edited by Gibson, G.L.; Griffin A.R.; Matheson A.C.]*. IUFRO Proceedings, Thailand (1989) 388-389 [En, 4 ref.]

This preliminary isozyme study, using nine enzyme systems, was used to screen three provenances of *Faidherbia albida* (10 trees per provenance) from Burkina Faso. Describes the methodology, and concludes that this technique could be used to analyse the genetic diversity and structure of the populations, but that more plants per provenance were needed to be sampled.

165 DANTHU, P. **Vegetative propagation of adult *Faidherbia albida* by branch and root cuttings**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.]*. ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 87-90 [En, 6 ref.]

Describes a simple propagation technique using lignified branch and inverted root cuttings from 40 year old trees of *Faidherbia albida*. Propogation of branches was only effective for cuttings of 7-15 mm diameter and collected from trees in the bud breaking stage at the beginning of the dry season. Rooting percentage was low (20%), but since cuttings were easier to collect than root sections, and could tolerate 5-6 days storage in a moist cloth, branch cuttings were recommended for clonal production.

166 DANTHU, P.; SALL, P.N.; SECK, M. [**Grafting compatibility between some African acacias: first results**.] Compatibilite de greffage entre quelques acacias africains: premiers resultats. *Bois et Forets des Tropiques* (1998)No. 258, 49-57 [Fr, en, es 25 ref.]

Graft compatibility and grafting potential were investigated in Senegal for five *Acacia* species indigenous to Africa. Cleft grafts were carried out on eight-month-old container-grown plants (a total of 25 stock/scion combinations were made); grafted plants were grown under shelter for 2 months, then in nursery beds for 10 months. Some were transplanted to an experimental field station. Parameters measured were graft survival after 10 months and 5 years, and fruiting (evaluated during the fourth year). Nine species combinations had a survival rate greater than zero 10 months after grafting: these were both the homografts and the heterografts between *Acacia senegal* and *A. laeta* (both belonging to subgenus

*Aculeiferum*), and between *A. nilotica* and *A. raddiana* (belonging to subgenus *Acacia*). *Faidherbia albida* was only compatible with itself. Therefore, it seems that the graft compatibility pattern of African acacias follows the natural classification system proposed by Vassal (1972).

167 DAVIDSON, L.; JEPPE, B. **Acacias - A field guide to the Acacias of southern Africa**. Johannesburg, South Africa; Centaur Publishers (1981) 121 pp.

A field guide to 51 Southern African *Acacia* taxa which occur south of the Zambesi and Cunene rivers. *Acacia albida* is described and illustrated, with a list of simple characters, and a general distribution which is usually in frost free areas although it has been cultivated in areas subject to frost. In southern Africa it is the only *Acacia* with stright spines and spicate inflorescence although other Acacias have this combination further north.

168 DAVIES, C. **Multiplication vegetative *in vitro* de *Faidherbia albida* (Del.) A. Chev. (*Acacia albida*)**. D.E.A. Universite de Dakar (1984) 60 pp. [Fr]

169 DELAGE, J. [**Resaturation of soils by reforestation with *Faidherbia albida***] La restauration des sols par le reboisement en *Faidherbia albida* (Gao). Extrait du rapport annuel 1957 de l'lnspection Forestiere du Niger Est (1957) [Fr]

170 DELWAULLE, J.C. [**Desertification in the southern Sahara of Africa**.] Désertification de l'Afrique au sud du Sahara. *Bois et Forêts des Tropiques* (1973) No. 149, 3-20 [Fr, en, es, 8 ref.]

Discusses the decline in productivenes of the countries of the Sahelian zone (Mauretania, Senegal, Mali, Upper Volta, Niger, Chad and N. Cameroon) and attributes it largely to erosion caused by over-grazing and trampling by livestock, lopping of trees for cattle fodder, and bush fires. The remedy lies in appropriate agricultural, livestock and forestry measures; these include afforestation and planting of windbreaks, more effective forest protection, the prohibition of lopping, fire control and, in agricultural areas, the planting of *Acacia albida*.

171 DELWAULLE, J. C. [**The role of forestry in the struggle against desertification and its contribution to development**] Le rôle de la foresterie dans la lutte contre la désertification et sa contribution au développement. Consultation C.I.L.S.S./U.N.S.O./F.A.O. sur le rôle de la forêt dans un programme de réhabilitation du Sahel, Dakar, 26 avril - 1 mai (1976) [Fr]

172 DELWAULLE, J. C. [**Study of the practability of the integrated agricultural development project in Dosso**] Étude de pracitabilité du projet de développement agricole intègre de Dosso. Annexe 1. Note sur le Gao. Ministere des Forets et Faune, Niamey (1977a) [Fr]

173 DELWAULLE, J.C. **Species, techniques and problems of semi-arid zones (the Sahel)**. In *Savanna afforestation in Africa. FAO Forestry Paper 11, FAO, Rome* (1977b) 160-195 [En]

This paper deals with three subjects:- the establishment of village woodlots; *Acacia albida* and the farmer; and *A. senegal* and gum gathering. *A. albida* is a common tree in the Sudan-Sahel zone where its vernacular names are gao, cadde, balanza, zaanga or tchaski, depending on the area. It enriches the soil and does not interfere with crops and deserves its name of "miracle tree". Improvements in soil properties under *A. albida* (from research in Senegal) are listed as :- 7% clay content; 134% assimilable P; 60% total C; 43% equivalent moisture (and therefore water retention); 100% N; 100% exchangeable Ca; 70% exchangeable Mg. In Niger, it has been shown that the increases correspond to the following quantities of fertilizers:- synthetic fertilizer – 50-60 t $ha^{-1}$ ( = 300 kg organic N); potassium chloride – 50 kg $ha^{-1}$ ( = 24 kg P); bicalcium phosphate – 80 kg $ha^{-1}$ ( = 31 kg soluble $P_2O_5$ and 25 kg Ca); dolomite – 125 kg $ha^{-1}$ ( = 15 kg of Mg and 25 kg Ca); lime – 100 kg $ha^{-1}$ ( = 43 kg Ca). In Senegal it has been shown that yields of millet are 600 kg $ha^{-1}$ in the open, 1000 kg $ha^{-1}$ 5 m from an *A. albida* stem and 1700 kg $ha^{-1}$ at less than 5 m from the stem. The reasons for the beneficial effects of *A. albida* on the soil are given as:- active decomposition of leaves when crops are beginning to sprout; fertilization by livestock seeking shade under the trees; diminution of desiccation, evapotranspiration, leaching by rain, fluctuations in temperature; possibility of fixation of N; bringing nutrients to the surface from deep down in the soil. *A. albida* leaves provide an excellent fodder for livestock and 600 kg of pods can be produced annually from 60 trees $ha^{-1}$, equivalent to the fodder consumed between two over-wintering periods. *A. albida* should be planted at 10x10m spacing; a final stocking of 50 trees $ha^{-1}$ still covers the soil. The total cost $ha^{-1}$ of establishing the trees is estimated as CFA F30,000.

174 DELWAULLE, J.C. [**Forest plantations in dry tropical Africa**.] Plantations forestières en Afrique tropicale sèche. *Bois et Forêts des Tropiques* (1979) 188, 3-29 [Fr, 55 ref.]

The final instalment of a paper setting forth the results and conclusions obtained with a number of species on forestry plantations. From the taxonomic point of view, *Faidherbia albida* has a number of botanical characteristics which lie between *Acaciae* and *Ingeae*. Emphasis is placed on its ecology, natural regeneration and protection of the species, and nursery techniques and establishment success within plantations. Protection is most necessary in the first three years, when growth is slow and the root system is being established, and the plant is susceptible to browsing.

175 DELWAULLE, J.C. [**Species, techniques and problems of semi-arid zones (The Sahel).**] Essences, techniques et problèmes concernant les zones semi-arides (régions du Sahel). *Boisements des savanes en Afrique FAO, Rome* (1981), 177-185 [Fr]

Special emphasis on village woodlots, and the roles of *Acacia albida.*

176 DELWAULLE, J. C.; JACKSON, J. K.; FOX, A. V.; ORODE, M. 0.; ADEKA, B.; ALLAN, T. *G.* **Special techniques for problem areas.** In: Savanna afforestation in Africa. F.A.O. (1977) pp. 160-195 [En]

177 DELWAULLE, J.C.; MIALHE, P. [**Observations on the foliage of *Acacia albida*.**] Observations sur la foliation d'*Acacia albida.* Centre Technique Forestier Tropicale, Niger (1974) 7 pp. [Fr]

Observations are made the on the foliage of 15 *Acacia albida* trees near Niamey, Niger from May 1973 to February 1974. Variations in defoliation and re-sprouting patterns among trees make it extremely difficult to determine a relationship between flowering and rainfall.

178 DEMEL TEKETAY; ASSAFA TEGINEH **Shade trees of coffee in Harerge, eastern Ethiopia.** *International Tree Crops Journal* (1991) **7** (1-2) 17-27 [En, fr, sp, 24 ref.]

Seven coffee (*Coffea arabica*) producing provinces (awrajas) in the Harerge administrative region were surveyed to identify shade trees used by farmers in coffee plantations. Fourteen permanent shade trees (*Acacia albida, A. sieberiana* var. *woodii, Bersama abyssinica, Cordia africana, Croton macrostachyus* [*C. macrostachys*], *Entada abyssinica, Erythrina burana, Ficus sur, F. sycomorus, F. vasta*, an unidentified *Ficus* sp., *Leucaena leucocephala, Milletia ferru-ginea* and *Syzygium guineense*) and three temporary shade species (2 trees, *Ricinus communis* and *Sesbania sesban*; and 1 herb, *Lycopersicon esculentum*) were recorded. *A. sieberiana* is a new record for the region. They represented seven families of flowering plants, with 69% of the species belonging to two families: *Fabaceae* (Leguminosae) and *Moraceae.* Data are tabulated on the habitat/ecology, means of propagation, uses and geographical distribution of the species. Recommendations are made for future studies.

179 DEPOMMIER, D. [**Aspects of village forestry in east and north Cameroon**] Aspects de la foresterie villageoise dans l'Ouest et le Nord-Cameroun. – C.T.F.T., Nogent-sur-Marne, I.R.A., Yaounde, août (1983), rapport de stage. [Fr]

180 DEPOMMIER, D. [**Fruit and seed production of *Faidherbia albida*. The role of spermatophagous insects and livestock in the regeneration of the species.**] Production fruitière et devenir des semences de *Faidherbia albida.* La part des insectes spermatophages et du bétail dans la régénération de l'espèce. In [*Faidherbia parklands.*] *Les parcs a Faidherbia [edited by Peltier, R.].* Cahiers Scientifiques No. 12, CIRAD-Foret, Montpellier, France. (1996) 312 pp. 9-22 [Fr, en]

The fruit production of *Faidherbia albida,* measured over two consecutive years at Watinoma in ten seed trees, varies with climate, soil, genetics, and human intervention (tree trimming and pruning). Total fruit harvests thus vary from 23 kg to less than 300 g per year. Fruit production and seed viability can be greatly affected by attacks from spermatophagous insects, in particular the Bruchidae, and by other destructive agents such as granivorous birds. Field observations show that virtually no fruit that falls to the ground or is beaten from trees will escape the mouths of livestock roaming through parklands in the dry season. Feeding tests have been carried out with cattle, sheep and goats to assess the amounts of seeds contained in their faeces. The indications are that most healthy seeds are digested to close on 90% by cattle and goats, and to almost 99% by sheep. The sexual regeneration potential of the species seems to be very slight and perhaps even reduced to nothing. Cattle therefore have an adverse effect on this potential, by reducing the numbers of seeds, but they qualitatively promote the regeneration of the species by the dissemination of seeds, the germination of which seems to be widespread, thus responding well to the ecological conditions of the environment. Their future development is nevertheless still unpredictable as young seedlings are then liable to high mortality rates from the farmer's hoe and the mouths of cattle.

181 DEPOMMIER, D. [**Phenology of *Faidherbia albida*. The effect of pruning, site factors and size of tree on phenophases in Burkina Faso**] Étude phenologique de *Faidherbia albida.* Éffet de l'émondage, du site et de la dimension de l'arbre sur les phenophases de l'espèce au Burkina Faso. In *L'acacia au Senegal [edited by Campa, C.; Grignon, C.; Gueye, M.; Hamon, S.]. Actes de la réunion thématique sur l'acacia au Sénégal, Dakar, Sénégal, 3-5 décembre 1996. Editions de l'ORSTOM, Paris, France* (1998) 159-179, 455-456 [Fr, 12 ref.]

A study into the phenology of *Faidherbia albida* was carried out in two contrasting bioclimatic zones in Burkina Faso. This species has an unusual reverse phenology, with foliage remaining throughout the dry season, and leaf fall occurring at the onset of the wet season. Leaf opening, flowering period, fruiting, leaf yellowing and leaf fall were the features observed every 10 days over a 3-year period from 1992. In Watinoma park (600 mm annual rainfall), millet and sorghum are grown almost all year round in agroforestry systems beneath young uneven-aged *F. albida* trees, which are often heavily trimmed and pruned for fodder. In Dossi (>900 mm rainfall), cotton is the principal crop, but sorghum

and millet are grown in the *F. albida* agroforestry park, and the trees are pruned lightly if at all, as there are abundant fodder resources. At Dossi park, leaf burst and leaf fall cycle of unpruned trees occurred regularly, synchronized with the wet and dry climatic seasons. Site and size of tree were not significant factors. In contrast, trees which were experimentally pruned at Dossi exhibited disturbed phenophases: pruning at the end of the dry season extended the period of leaf retention, or stimulated an additional foliage development cycle. However, this pruning treatment had negative effects on the frequency and abundance of flowering and on fruiting.

182 DEPOMMIER, D.; DETIENNE, P. [**Growth of *Faidherbia albida* in the parks of Burkina Faso. Study of annual rings in the stem and in the root collar.**] Croissance de *Faidherbia albida* dans les parcs du Burkina Faso. Étude des cernes annuels dans la tige et le pivot racinaire. In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Foret, Montpellier, France (1996) 312 pp. 23-43 [Fr, en]

In the southern Sudanian area of Dossi and the south Sahelian area of Watinoma, a broad cross section of *Faidherbia albida* trees with circumferences between 50 and 250 cm were sampled with an increment borer to identify annual rings and to evaluate the age and growth of the trees. The probable age has been correlated with the circumference in a linear regression which emerged more clearly in the Watinoma area than at Dossi. This age depends on site effects and probably on trimming and pruning, a cause of major variations in tree growth. The plots seem to be relatively young, 10-30 years at Watinoma and twice that at Dossi, with an estimate by tree close to that made by farmers in the case of Watinoma. Because the best average annual growth rates in the sampling were, paradoxically, recorded at the driest station (10.9 mm as opposed to 7.2 mm), the authors put forward the hypothesis that foliation, which is more extensive because of the longer dry season at Watinoma, permits better tree growth. What is more, trimming at the end of the dry season, with consequent refoliation at the beginning of the rainy season, prolongs this growth. Based on a link established between the number of stem rings and the number of root rings, in *F. albida* specimens with a known age, it has been possible to estimate the age of clumps whose shoots are regularly felled at Watinoma. The collar ring samples showed that these systems have reached a certain age : at least 9 to 27 years for a circumference of 10-50 cm. They also showed that preserved shoots may have a high initial growth rate because of the root reserves formed despite the successive felling of shoots. The authors showed once and for all that the growth of *F. albida* in traditional agroforestry plots that are well managed under good soil and climatic conditions (in the south-Sahelian zone this means in well drained land with the ground water neither too deep nor too shallow) may be very high (more than 3 cm annual diameter growth) and thus guarantees of major timber production can be added to its other agronomic and pastoral advantages.

183 DEPOMMIER, D.; GUERIN H. [**Traditional pollarding of *Faidherbia albida*. Fodder production, nutritional value and wood collection at Dossi and Watinoma, Burkina Faso.**] Émondage traditionnel de *Faidherbia albida*. Production fourragère, valeur nutritive et récolte de bois à Dossi et Watinoma (Burkina Faso). In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Foret, Montpellier, France (1996) 312 pp. 55-84 [Fr, en]

The *Faidherbia albida* pollarding studies carried out over a three-year period in the Dossi and Watinoma village farmlands, together with the tree management survey made among farmers, reveal considerable know-how about pollarding techniques, especially among peul livestock farmers. Despite this, the species is overlogged at Watinoma, where adult specimens are pollarded twice per season, which affects more than 50% of their canopy. At Dossi, the abundance of fodder resources means that few trees are pollarded, and then only on a moderate scale. Total pollarding tests repeated over two years show that the trees produce vigorous shoots. The youngest trees remake their canopy in one year. The leaf biomass produced is well correlated with the ground-projected area of the canopy, but less so with the [stem?] circumference. It ranges from 10 to 15 kg of dry matter (DM) for small trees, and from 20 to 40 kg of DM for large trees. But pollarding is the main restriction for fruit production; it is more influential than climatic fluctuations and insect attacks. At Watinoma, it limits fruit production to just a few kilograms per tree, and sometimes no fruit at all. On the other hand, climate, site, tree size and genetics all seem to be determining factors at Dossi for trees that have not been pollarded, or only slightly so. Production ranges from a few kilograms to more than 150 kg, from one tree to the next, and from season to season. Pod average production figures are respectively 6, 12 and 22 kg for small, medium-sized, and large trees. Fire-wood, which is a valued by-product of pollarding at Watinoma, has been assessed at around 100 kg $yr^{-1}$ of DM from totally pollarded adult trees, and about a third or a quarter of this amount for smaller trees. As far as the nutritional values of *F. albida* leaves and pods are concerned, analyses confirmed the high level of crude protein. Their digestibility, however, is poor, though better for fruits than leaves. Variations in the chemical composition and enzymatic degradability of the leaves and pods analysed are not marked from one station and site to the next. Pollarding date makes a considerably clearer distinction in relation to the nutritional value of leaves removed at a fairly young age. Comparative analysis of the minerals and trace elements contained in *F. albida* leaves, fruit, and chlorophyllous branchlets showed significant differences based on organ

and site, with an often very marked variability between individual trees. But in most cases, levels of the most important elements for animals' dietary balance are such that they cannot be enough to mitigate deficiency thresholds, particularly of phosphorous, zinc and copper, on a sustainable basis. Finally, *F. albida* has relatively poor production levels for leaves and pods. At best, these levels vary a great deal on account of pollarding but this tree is still a fodder species of prime importance because of its reactions to heavy and repeated pollarding and because of the good quality of the dietary supplement it gives in the dry season.

184 DEPOMMIER, D.; JANODET, E.; OLIVER, R. ***Faidherbia albida* parks and their influence on soils and crops at Watinoma, Burkina Faso**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 111-115 [En, 6 ref.]

A study of four *Faidherbia albida* parks in the area of Watinoma, Burkina Faso, studying the trees and their influence on soil and crop yields. The parks varied from 0.6 to 4 hectares in size, two less fertile upland parks which were fertilized with manure and cropped with short duration sorghum, and two bottomland parks which were fertilized with manure and chemical fertilizers and cropped with long duration sorghum. Site and tree characteristics, pod variation and seed infestation, and chemical characteristics of soils and sorghum yields from both under and away from the canopies are tabulated.

185 DE SEABRA, L.; FERREIRINHA, P.; DE FREITAS, M.C.P.G. [**Contributions to the knowledge of the overseas flora**] Contribuições para o conhecimento tecnológico da flora do ultramar. *Garcia de Orta* (1957) Vol. 5 (4) 711-726 [Port]

186 DETREZ, C.; NDIAYE, S.; KERBELLEC, F.; DUPUY, N.; DANTHU, P.; DREYFUS, B. **Meristem micro-grafting of adult *Faidherbia albida*.** In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 91-95 [En, 8 ref.]

Details a chain micro-grafting technique, using meristems from vegetative buds (apical or axillary) collected from branches of a 50-year-old tree and 1-2-month-old seedlings of *Faidherbia albida*, which were grafted in vitro on 2-day-old seedlings. Grafts began elongating after 10 days in culture, and these shoots were used for second and third generation micro-grafting cycles. Optimal collection period of buds was from mature trees in Senegal follows Danthu (1992). Micro-grafted seedlings developed well after acclimatization, resulting in a rapid multiplication of selected individuals on root stock derived from seed.

187 DIAGAYETE, M.; SCHENKEL, H. [**Mineral contents in browse species consumed by ruminants in the Sahelian zone**.] Composition minérale des ligneux consommes par les ruminants de la zone Sahélienne. *Rev., Elev. Med. vet. Pays. Trop.* (1986) **39** (3-4) 421-424 [Fr, en. 11 ref.]

The major elements C, P, Mg, K, and Na as well as the trace elements Fe, Cu, Zn and Mn have been determined in 22 samples from different browse species collected in the Sahelian zone of Mali. Both leaves and dry pods of *Faidherbia albida* were included. and the results of the analyses were as follows:-

| | Dry material in mg $kg^{-1}$ | | | |
|---|---|---|---|---|
| | **Fe** | **Cu** | **Zn** | **Mn** |
| **Pods** | 183 | 7.5 | 47 | 36 |
| **Leaves** | 396 | 11.9 | 43 | 142 |

| | Dry material in g $kg^{-1}$ | | | | |
|---|---|---|---|---|---|
| | **Ca** | **P** | **Mg** | **K** | **Na** |
| **Pods** | 4.5 | 1.6 | 1.6 | 13.8 | .007 |
| **Leaves** | 29.1 | 0.9 | 1.7 | 6.8 | .007 |

Over species sampled, Ca contents were very high in the browse leaves whereas the P contents were very low, both resulting in a very wide range of Ca/P ratios. The Na contents of all the analyzed plant material were far below the values recommended for the normal Na allowance for ruminants. The Cu requirements of goats and sheep can be met with all studied plant material as well as generally for Zn. But should cattle depend on browse only, just 10 (including *F. albida* leaves but not pods) out of the analyzed samples had Cu contents which could have met their requirements. In the case of Zn, only three samples (just excluding *F. albida* leaves and pods) could satisfy cattle requirements.

188 DIALLO. I.; DANTHU, P.; SAMBOU, B.; DIONE. D; GOUDIABY. A.; POULSEN. K. **Effects of different pre-treatments on the germination of *Faidherbia albida* (Del.) A. Chev. seeds**. *International Tree Crops Journal* (1996) **9** (1) 31-36 [En, 17 ref.]

The difficulties of using sulphuric acid for removing the physical dormancy of *Faidherbia albida* seeds have resulted in a search for alternative methods of

pre-treatment of the seeds. This trial tested the efficiency of 10 alternative pre-treatments. The results show that sulphuric acid, manual scarification and scarification by hot wire, which achieved stable values of over 90% of germination of seeds after 8 days, were clearly superior to the use of a seed gun (80% germination after 16 days at the optimal setting of the gun) or of hot/boiling water methods (less than 20% germination after 16 days). However, due to the high capacity of the seed gun (around 1 kg of seed treated per minute), it appears that the gun method could be a useful way to treat large quantities of seeds despite the higher germination percentages obtained using methods that treat seeds individually. It is noted that the optimal speed of the rotation of the gun must be determined beforehand for each lot of seeds.

189 DIANDA, M. [**Isolation of symbiotic microorganisms (*Rhizobium* and endomycorhizal fungi). Tests of infectivity and effectiveness on *Acacia albida*.**] Isolement de souches de microorganismes symbiotiques (*Rhizobium* et champignons endomycorrhiziens): tests d'infectivité et d'effectivité sur *Acacia albida* Del. *Mémoire de fin études présente en vue de l'obtention du Diplôme d'Ingénieur du Développement Rural, Université de Ouagadougou, Burkina Faso* (1988) 82 pp. [Fr, 57 ref.]

A significant difference was found between the average height and the above ground dry weight of the *Acacia albida* under the different treatments – the effects of different *Rhizobium* stock on increase in height were not significant (except for $Di_3$ and $KO_5$) but 10 treatments increased above ground dry weight. The results correspond to other findings that height growth is not a good indicator of the effectiveness of different *Rhizobium* stock. The best *Rhizobium* stock came from recent *A. albida* plantations (none from old plantations). The collection of stock from many stations with diverse soil types and from areas where *A. albida* is rare is recommended. Some *Rhizobium* from Gonsé increased the N content of the plants as a result of N fixation (<13 mg N per g dry matter). The number and dry weight of nodules was positively correlated to the total N content of the plant, height and above ground dry weight. Fungal spores were separated from the soil samples of two stations (Gonsé and Kongoussi) and tested for their infectivity and effectiveness on *A. albida. Glomus mosseae* was also tested. The spores belonged to the genus *Acaulospora*, but could not be further identified and were split into colour groups. *G. mosseae* produced external hyphae on some roots. The lack of infection exhibited could be explained by the inoculum being >1 month old (reduced fungal hyphae vitality) and the infection potential being limited by the number of spores able to form in culture. The *Acaulospora* infected all roots, but did not influence growth. The filter paper used to inoculate the roots restricted root growth and the extent of the endomycorrhiza infection leading to stunting. A spore solution is recommended instead; this cannot, however be used in the field and an inoculated millet/ground nut compost is suggested instead. It was concluded that *A. albida* has a role in reforestation for soil improvement. Symbiotic root stock have the potential to increase growth in nurseries and plantations. Rhizobium infections are rare on soils poor in P and rich in N. 19 strains of *Rhizobium* were isolated from the test soil; these were used for trials in the laboratory and in the nursery. In the laboratory all plants were infected by the inoculum, but not in the nursery. This is probably due to higher temperatures in the nursery and indicates the need for shading when inoculating in nurseries. Three of the *Rhizobium* tested increased the growth, dry weight and N content of plants relative to the control.

190 DIANDA, M. [**Comparison of the effects of introduced and indigenous VA fungi associated or not associated with *Bradyrhizobium* on the fixation of nitrogen and the growth of *Acacia albida*.**] Comparaison des effets de champignons VA introduits et indigènes associes ou non a *Bradyrhizobium*, sur la fixation d'azote et la croissance d'*Acacia albida*. In *Physiologie des arbres et arbustes en zones arides et semi-arides [edited by Riedecker, A. et al.]*. Paris, France; Groupe d'Étude de l'Arbre (1991) 263-269 [Fr, en]

In the Sahelian zone, where leguminous trees are frequently used to regenerate the fertility of degraded soils, inoculation with rhizobial and mycorrhizal symbionts is often necessary to ensure good performance of the planted trees in agroforestry situations. However, their use is still not widespread because of competition from indigenous VA fungi that are nearly always present in the natural habitat. In this study, indigenous (Endo1 and Endo2) and introduced (*Glomus mossae* and *Gigaspora margarita*) VAM (endomycorrhizal) fungi associated or not with *Bradyrhizobium* (Br1 and Br2) were screened for their effects on nitrogen fixation and growth of *Acacia albida* seedlings grown on a sterilized soil in the nursery. No nutrient supplement was provided. At three months from inoculating, VAM fungi greatly stimulated plant growth. The effects of both indigenous and introduced types were found to be similar whereas dual inoculation was less effective; for example, plants inoculated with Endo1 saw their growth reduced by up to 50% when it was associated with Br1 or Br2. It is well known that the beneficial effect of mycorrhizae results from the improved mobilization of phosphorus that profits the plants. P is also indispensable for rhizobial activity and it has been shown that the presence of mycorrhizae on leguminous trees helps nodulation and the fixation of nitrogen. The total quantity of nitrogen contained in the aerial parts of the plants was practically the same for all non-mycorrhizal treatments and corresponded with that of the treatment with no inoculation where the only N available was from reserves in seed and the sterile sand. On the other hand, the levels of N in the plants with double inoculations were very variable; some were obviously

beneficial because of the symbiotic fixation but some combinations inhibited growth and had an almost parasitic effect. As indigenous fungi are often present in the soil, it will be important to know the species before selecting the strain of *Rhizobium* for inoculation.

191 DICKO-TOURE, M.; [**Measures of secondary production of pastures**] Les mesures de la production secondaire des pâturages. Colloque sur les fourrages ligneux en Afrique, Addis-Abeba, 8-12 avril (1980) pp. 245-251 [Fr]

192 DIOP, T.A.; SIMONEAU, P.; DALPE, Y.; PLENCHETTE, C.; STRUILU, D.G.; CAMPA, C.; GRIGNON, C.; GUEYE, M.; HAMON, S. [**Biodiversity and genetic variation of Glomales associated with *Acacia albida* in Senegal.**] Biodiversité et variabilité génétique des Glomales associes à *Acacia albida* Del. au Senegal. In *L'acacia au Sénégal [edited by Campa, C.; Grignon, C.; Gueye, M.; Hamon, S.]. Actes de la réunion thématique sur l'acacia au Sénégal, Dakar, Sénégal, 3-5 décembre 1996. Editions de l'ORSTROM, Paris, France* (1998) 423-442, 469 [Fr, 28 ref.]

Biodiversity of vesicular arbuscular mycorrhizas was studied in relation to *Acacia albida* [*Faidherbia albida*] tree age, season, and soil physical and chemical properties. Mycorrhizas of the order Glomales were collected in samples located at soil depths between 1.5 and 4.5 m deep (in the Sudano-Guinean biogeographic zone) and between depth 16 and 35 m (in the Sahel region). These two soil horizons represent the limits of the water table in the two biogeographic regions. *In vitro* culture of the mycorrhizas indicated a range of mycorrhizal morphological forms. The use of DNA and molecular markers in subsequent studies allowed the genetic diversity of the Glomales to be assessed more accurately.

193 DIOUF, D.; CAMPA, C.; NDOYE, I.; DREYFUS, B. [**Nitrogen assimilation in *Acacia albida*.**] Assimilation de l'azote chez *Acacia albida* Del. In *L'acacia au Sénégal [edited by Campa, C.; Grignon, C.; Gueye, M.; Hamon, S.]. Actes de la réunion thématique sur l'acacia au Sénégal, Dakar, Sénégal, 3-5 décembre 1996. Editions de l'ORSTOM, Paris, France* (1998) 221-233, 458-459 [Fr, 36 ref.]

Within a project to improve the nitrogen-fixing potential of *Acacia albida* [*Faidherbia albida*] in Senegal, a greenhouse study into the mechanisms by which nitrogen (N) is assimilated within the plant was undertaken, using seedlings inoculated with *Bradyrhizobium*. Root and stem contents of principal amino acids, amides, nitrate reductase and glutamine synthetase were recorded. The transport of N from roots to stem and foliage is discussed: it is argued that because *F. albida* contains N in the form of amides, it has N assimilation features more characteristic of temperate than tropical leguminous plants.

194 DJAVANSHIR, K.; EMTEHANI, M.H.; DJAZIREI, M.H. **Natural occurrence of apple-ring Acacia in Iran in the form of a new subspecies: *Acacia albida* Del subsp. *surculosa* Djavanshir, Emtehani and Djazirei.** *Iranian Journal of Natural Resources* (1998) **50** (50) 15-27 [En, Persian, 8 ref.]

A discussion is presented on the morphology and taxonomy of a new subspecies of *Acacia albida* [*Faidherbia albida*], *A. albida* subsp. *surculosa*. The new subspecies was observed only in the Razmabad plain between the villages of Sena and Razmabad, in the Boushehr province, Iran, in a limited area of about 50 ha. It is a small (8-9 m tall) evergreen tree which produces many suckers making it unsuitable for agroforestry.

195 DOAT, J. [**The calorific value of tropical woods**] **Le pouvoir calorifique des bois tropicaux.** ?? *Bois et Forêts de Tropiques* (1977) No. 172, 33.55 [Fr]

196 DOMMERGUES, Y. [**The biochemical cycles of elements in tropical formations**] Les cycles biochimiques des éléments minéraux dans les formations tropicales. *Bois et Forêts des Tropiques* (1963) No. 87 9-25 [Fr]

197 DORAN, J.C.; TURNBULL, J.W.; BOLAND, D.J.; GUNN, B.V. **Handbook on seeds of dry-zone *Acacias*. A guide for collecting, extracting, cleaning and storing the seed and for treatment to promote germination of dry-zone *Acacias*.** Rome, Italy; FAO (1983) 92 pp. [En, 8 pp. of ref.]

A useful guide to seed collection and storage of dry zone Acacias, with special reference to *Acacia albida*, *A. aneura*, *A. caven*, *A. nilotica*, *A. senegal* and *A. tortilis*. Chapters are included on habit, taxonomy, occurrence and ecology, and reproductive biology. Reviews literature, including unpublished data, on a number of seed pre-treatments that have been tried for the *Acacia* species. A 57-word glossary is included.

198 DOUGLAS, M.B. **Some land use considerations in the amelioration of soils by trees.** In *Amelioration of soil by trees [edited by Prinsley, R.T.; Swift, M.J.].* Commonwealth Science Council (1986), 166-172 [En, 8 ref.]

The integration of trees into the farming system has considerable potential for ameliorating adverse soil conditions for the smallholder. Consideration must be given particularly to traditional farming practices within the existing system. The incorporation of trees will necessitate additional management, and possible constraints including the loss of land from crop production. The soil improving qualities of the indigenous tree, *Acacia albida* are widely acknowledged, and farmers in Malawi are encouraged to plant it at 10-15 m intervals along contour

marker ridges that run through the fields, with *Leucaena leucocephala* established in between.

199 DREYFUS, B.L.; DOMMERGUES, Y.D. **Nodulation of *Acacia* species by fast and slow growing tropical strains of *Rhizobium*.** *Applied and Environmental Microbiology* (1981a) **41** (1) 97-99 [En, 11 ref.]

A cross-inoculation study of rhizobia, (isolated from native and introduced *Acacia* spp. and *Leucaena leucocephala* growing in Senegal Sahel) with seedlings of 13 *Acacia* spp. and *L. leucocephala*. The *Acacias* could be divided into three groups depending on the *Rhizobium* strain that nodulated with them. Group (1) such as *Acacia albida*, nodulated only with slow growing strains, Group (2) only nodulated with fast growing strains including *A. raddiana* [*A. tortilis* ssp. *raddiana*], *A. nilotica* var. *tomentosa* and *A. senegal*. Group (3) such as *A. seyal*, with both fast and slow growing strains. *L. leucocephala* also belonged to (2). Since slow growing strains of *Rhizobium* of the cowpea complex are common in many tropical soils, *Acacia* spp. nodulating with these strains would respond poorly to inoculation. Fast growing strains are assumed to be more specific and inoculation of *Acacia* spp. in group (2) in the nursery would show increased benefits in growth similar to those found in *L. leucocephala*.

200 DREYFUS, B.L.; DOMMERGUES, Y.D. **Relationships between rhizobia of *Leucaena leucocophala* and *Acacia* species.** *Leucaena Research Reports* (1981b) **2**, 43-44 [En, 2 ref.]

A table summarises the same results as in the previous paper; a cross inoculation experiment using *Acacia* species and *Leucaena leucocaphala* as host plants. *A. albida* nodulates effectively with slow growing cowpea type strains, but is ineffective with faster growing strains.

201 DUCOUSSO, M.; COLONNA, J.P. **Endomycorrhiza infection in young *Faidherbia albida*: influence on growth and development.** In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 151-156 [En, 10 ref.]

Study on the effects of inoculation by *Glomus mosseae* (versicular arbuscular endomycorriza) on the growth and development of *Faidherbia albida* seedlings. Seedlings were grown in bags, 1 litre capacity, or PVC tubes of 25, 50 and 75 litre capacities containing non-sterilized soil from Bambey, Senegal. Inoculation with *G. mosseae* enhanced heights (34% in bags, 68% in PVC tubes); shoot dry weight (82% and 112%); root dry weight (44% and 57%); and nodulation (30% and 263%) after 12 weeks growth. Apart from a slight depressive effect after one week, inoculation had a negligible effect on taproot elongation compared to the control. The majority of endomycorrhizal infections were found in the first 10 cm of soil, and none below 70-80 cm depth.

202 DUFFY, E.A.J. **A monograph of the immature stages of African timber beetles (*Cerambycidae*).** *Monograph, British Museum (Natural History), London.* (1957) 338 pp. [En, 18 pp. of ref.]

A monograph on the wood boring beetles (Cerambycidae) that attack a large range of African timbers, pods and seeds. Reference is made to 400 species, with keys to identify 286 species of larvae and pupae. A wide range of Acacia species is attacked, and specifically recorded for *Acacia albida* are *Sophronica calceata* Chevrolat (attack seeds); *Sophronica testacea* Gahan (attack pods) and *Enaretta castelnaudi* Thomson (attack seeds in Zambia).

203 DUGAIN, F. [**Report of the Niger Mission**] Rapport de mission au Niger. Centre de pédologie de Hann-Dakar, O.R.S.T.O.M. (1960) 22 pp. [Fr]

204 DUHOUX, E.; DAVIES, D. [**Shoot production from cotyledonary buds of *Acacia albida* and the influence of sucrose on rhizogenesis.**] Caulogenèse à partir des bourgeons cotylédonaires d'*Acacia albida* et l'influence du saccharose sur la Rhizogenèse. *Journal of Plant Physiology* (1985) **121** (2) 175-180 [Fr, en, 15 ref.]

Shoot formation of *Acacia albida* seedlings has been achieved by placing explants into nutrient medium (Murashige and Skoog) supplemented with NAA 0.5 mg $l^{-1}$, BAP 3 mg $l^{-1}$ and vitamins (Nitsch and Nitsch). Leafy shoot proliferation resulted from multiplication and development of cotyledonary buds. Axillary buds of young shoots thus formed could be excised and then rooted on Lin and Staba medium with sucrose 50 $g^{-1}$ and vitamins (Nitsch and Nitsch). The resulting plantlets were suitable for cultivation in pots.

205 DUNHAM, K.M. **Litterfall, nutrient-fall and production in an *Acacia albida* woodland in Zimbabwe.** *Journal of Tropical Ecology* (1989a) **5** (2) 227-238 [En, 15 ref.]

Litterfall was recorded for one year in *Acacia albida* woodland in Mana Pools National Park, Zimbabwe. Leaves fell throughout the year, but leaf-fall rate peaked in the wet season. Litterfall was 1.5 t/ha per annum, comprising 50% leaves, 20% fruits, 17% 'fine' material (mainly frass), 4% flowers and 9% wood and bark. Net annual above ground production by *A. albida* trees was 1.7 t/ha, including leaf production of 1.0 t/ha, twig production of 0.3 t/ha and fruit production of 0.3 t/ha. Insects consumed about 26% of leaf production.

Net annual above ground herbaceous production was estimated from rainfall data using regression equations: values were 6.8 t/ha for annual grasses and 2.8 t/ha for forbs. Net above ground primary production in *A. albida* woodland was 11.3 t/ha per annum. Seasonal variations in nitrogen, phosphorus, potassuim, magnesium and calcium concentrations of different *A. albida* litter components were recorded. Estimated falls of N, P, K, Ca, and Mg were 31.1, 2.1, 9.8, 15.0 and 3.4 kg/ha per annum respectively.

206 DUNHAM, K.M. **Long-term changes in Zambezi riparian woodlands, as revealed by photo-panoramas**. *African Journal of Ecology* (1989b) **27**, 263-275 [En]

Photo-panoramas were used to study changes in *Acacia albida* Del. woodlands in Mana Pools National Park, Zimbabwe, between 1961 and 1987. In 1958, the fire regime of the area altered when local people left and the flooding regime changed with the closure of the Kariba Dam. The tree population declined, due to low recruitment and the loss of canopy trees at a mean rate of 0.9% per year. Absolute mortality rate of trees was density-dependent. Mortality did not vary in relation to temporal changes in elephant density. At the end of the 1961 dry season, there was an almost continuous ground cover of dead grass but by the 1980s, dry season ground cover was much lower and often negligible. Before 1958 fire and large mammals were the principal consumers of the herbaceous layer, but after 1958, *Macrotermes* spp. mound density increased; termites and large mammals are now the main consumers.

207 DUNHAM, K.M. **Vegetation-environment relations of a middle Zambezi (Zimbabwe) floodplain**. *Vegetatio* (1989c) **82**, 13-24 [En]

Detrended correspondence analysis was used to study the relationships between environmental factors and the species composition of vegetation on Zambezi River alluvium downstream of the Kariba hydroelectric dam. Grass, sedge and woody species were recorded in 73 stands in Mana Pools National Park, Zimbabwe. Grass and sedge species composition was related to the soil moisture regime, as indexed by soil texture and flooding frequency. The first woody plant ordination axis was related to a stand development gradient; *Acacia albida* was a pioneer species on low-lying sandbanks and the woody species richness of stands increased with their height above the Zambezi River. Two-way indicator species analysis identified seven vegetation types which could be separated on the basis of their topsoil texture and flooding frequency. The types were: sandbanks; young *A. albida* woodland; *A. albida* woodland; *A. albida* dominated mixed woodland; mixed riverine woodland with understory; mixed riverine woodland; and grassland on clay soils.

208 DUNHAM, K.M. **Biomass dynamics of herbaceous vegetation in Zambezi riverine woodlands**. *African Journal of Ecology* (1990a) **28** (3) [En, 20 ref.]

In this study a comparison is made of the biomass dynamics, productivity and utlization of annual grasslands compared to perennial grasslands in the Middle Zambezi Valley. The annual grasslands occur on alluvium with an overstorey of *Faidherbia albida*-dominated woodland that has a herb layer dominated by the annual grasses *Panicum maximum* Jacq., *Urochloa trichopus* (Hochst.) Stapf. and *Echinochloa colona* (L.) Link. The associated forbs are *Cassia obtusifolia* L., *Diciptera verticilliata* (Forsk.) Chr., *Cassia occidentalis* L., *Indigofera practicola* Bak. F., *Cucumis anguria* (L.), *Ocinum urticifolium* Roth., *Corchoris olitoris* L., *Ipomoea aquatica* Forsk. And *Cassia quarrei* (Ghesq.) Steyaert. The area dominated by *P. maximum* had a larger grass standing crop than areas dominated *by U. trichopus* or *E. colona* which reflects the higher nutrient status of the soils under the tree canopies, the niche occupied by *P. maximum*. Production was generally higher in the adjacent perennial grasslands on lower-lying flooded areas and the river bank where the grasses grew throughout the year. In high rainfall years, forbs constituted much of the net above-ground primary production in annual grasslands, had higher nutrient concentrations than the grasses and were the only biomass in these grasslands during the dry season. Large mammal utilization of grasslands varied between 53 and 99% of annual production which is much higher than the 10% commonly recognized for terrestrial ecosystems.

209 DUNHAM, K.M. **Fruit production by *Acacia albida* trees in Zambezi riverine woodlands**. *Journal of Tropical Ecology* (1990b) **6**, 445-457 [En, 20 ref.]

Fruit production by *Acacia albida* (Leguminosae: Mimosoideae) trees in Mana Pools National Park, Zimbabwe, was monitored over eight years. Timing of ripe fruit-fall varied between years, as did fruit production: production of ripe fruits by the same tree varied from 5.4 kg in 1983 to 290.1 kg in 1988. Baboons reduced fruit production by feeding on unripe fruits and the mass eaten each year was negatively correlated with rainfall. Potential fruit production (i.e. production in the absence of baboons) was high when the late wet season was wet or cool and when fruit production in the previous year was low. Late wet season rainfall and temperature probably determined the degree of defoliation by caterpillars: in 1983 and 1987, when the late wet season was hot and dry, the trees were almost completely defoliated. During the late dry season, *A. albida* fruits were an important component of the diets of waterbuck, eland, elephant, buffalo and kudu; they were seldom eaten by hippopotamus and were ignored by zebra and warthog.

210 DUNHAM, K.M. ***Acacia albida* woodland in Mana Pools National Park**. *The Zimbabwe Science News* (1991a) **25** (1/3) 17 [En]

The Mana Pools National Park contains the largest stand of *Acacia* (*Faidherbia*) *albida* in Zimbabwe. This paper summarizes the results of studies in these stands reported in Dunham 1989; 1990; 1991a and 1991b) *q.v.*

211 DUNHAM, K.M. **Comparative effects of *Acacia albida* and *Kigelia africana* trees on soil characteristics in Zambezi riverine woodlands**. *Journal of Tropical Ecology* (1991b) **7** (2) 215-220 [En, 20 ref.]

Soil nutrient concentrations under *Faidherbia albida and Kigelia africana* (Lam.) Benth. trees growing in Zambezi riverine woodlands were compared with soils in the open, beyond tree canopies. Concentrations of N, C, P and K were higher under the tree canopies. Concentrations of Ca and Mg were unchanged. Such soils were slightly more acid under *F. albida* trees relative to open soil, but were less acid under *K. africana*. Soil P concentrations were higher under *K. africana* than under *F. albida*. Otherwise, the two species had similar effects on soil fertility. Despite previous claims, *F. albida* is probably no more efficient at increasing soil fertility than other savanna trees. Further, it is speculated that soil enrichment under *F. albida* might not be due to N-fixation as much as to transport of nutrients from deep in the soil profile or from topsoil outside the tree's canopy by lateral roots that may cover an area of up to six times that of the canopy. It is suggested that the main advantage of using *F. albida* in agroforestry schemes may be its habit of dropping its leaves in the cropping season rather than from an increase in fertility.

212 DUNHAM, K.M. **Phenology of *Acacia albida* in Zambezi riverine woodlands**. *African Journal of Ecology* (1991c) **29**, 118-129 [En, 17 ref.]

The phenology of 53 *A. albida* trees along a transect from the bank of Zambesi river was recorded from 1982 - 1988 in the Mana Pools National Park, Zimbabwe. Leaf flush occurred towards the end of the rains, and was soon followed by flowering. Ripe fruit fell in the late dry season. Most leaf fall occurred early in the following wet season, finishing early when the rainfall was high. Significant leaf fall also occurred throughout the dry season. After seasons of low rainfall, trees were defoliated by caterpillars of the moth *Crypsotidia conifera* soon after leaf flush, which prompted a second flush of leaves. In these years there were also two periods of flowering and fruit production, but when the second flowering was delayed by 5-6 months no fruits set. During dry years, the proportion of trees which failed to set fruits after flowering increased, fruit production by those trees which did bear fruit was reduced and fruit-fall started earlier in the year. Although the trees at Mana had year-round access to the water table and therefore were independent of local rainfall for their water requirements, fruit production and timing of fruit fall are indirectly, but strongly, influenced by local rainfall.

213 DUPRIEZ, H. **[Two examples of pre-intensive agriculture among the Serer and the Bashi.]** Deux examples d'agriculture preintensive chez les Sereres et chez les Bashi. ??

This example of pre-intensive Serer agriculture incorporates principles that are comparable to those observed among the Bashi and characterized by security devolved from maximizing organic manure, livestock management to enrich cultivated plots, association of crops with several tree species, in particular *Acacia albida*, and land regulations to ensure respect for fallow periods. Serer country (south of Dakar) is characterized by high population density, the 'pluvial' character of its agriculture closely linking farming and grazing activities, slower urbanisation than other Senegalese regions, traditional political institutions permitting balance between peasant forces and the military and the administrative nobility. Durability of rights is assured by work invested, not in underlying land. Clearing, working and planting provide an inalienable right to future produce. That is why a stranger can only practise annual cultivation; a planting of trees would automatically bring recognition of right of use of land for the lifetime of trees planted. Chiefs, priests, elders etc. decide each year which areas will be left fallow to reconstitute fertility of soil. These areas will be enclosed with material collected in areas returned to cultivation and will serve as compounds for flocks; they are called 'tos' of which the meaning is 'to manure'. *A albida* occupies a special place in tree cover. This species does not belong to the initial climax - it is introduced into the environment by man through the alimentary canal of cattle. The tree has some very special characteristics:- its vegetative cycle is inverted; the tree vegetates in the dry season and loses its leaves at beginning of rains when cultivation of crops begins. The tree therefore ensures protection from sun in the dry season, preventing big increases in ground temperature and of evaporation from surface. It draws water from deep down, bringing up nutrients which are restored to surface at the beginning of rainy season. It ensures abundant forage for cattle in the dry season, as much through quality of foliage as through the nutritive value of the pods. *A. albida* therefore fills an essential macro-ecological function. It also fills a micro-ecological function with positive influence on species growing under its canopy where the increase in mineral elements in the soil is equivalent to the effect of 50-60 tons of artificial fertiliser $ha^{-1}$,50 kg of potassium chloride, 80 kg of calcium chloride, 125 kg of dolomite or 150 kg of lime. The humus level is 50% greater under acacia and the nitrogen count 100% higher, improving the exchange capacity by +50% for calcium, +30-40% for potassium and +13% for phosphorous. (Charrreau and Vidal 1965). When the population density increases, occupation/use of land must be changed by acceleration of rhythms of cultivation. Serer communities react in two ways:- either they un-block the system by sending their flocks to more distant land during winter so as to cultivate fallow plots with a succession of millet-groundnut which

progressively reduces the quality of soil-vegetation complex; or they create a ring of permanent fields that must be regularly manured if degradation is to be avoided. The Serer have shown that their system of production is capable of absorbing innovations through, for example, improving the forage economy of *A. albida*, taking into account the biological, economic and ecological functions appropriate to each crop grown and systematizing the beneficial effect of livestock management. Unfortunately, rather than taking the agro-ecological balance to higher level of efficiency, surrounding societies have tended to provoke dislocation of the production system.

214 DUPUY, N.; DREYFUS, B. **Presence of *Bradyrhizobia* under *Acacia albida*.** In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 145-148 [En, 8 ref.]

Study of the presence of nodules in the root systems of adult *Acacia albida* trees in the Sahelian zone of Senegal. Two borings were taken near the trees at Louga and Diokoul, and soil samples taken at various depths, with the *Rhizobium* densities later estimated. Surprisingly, the highest density of *Bradyrhizobium* were found at the greatest depths, of 30 - 35 metres, at the water table level. Sixty-seven strains of *Bradyrhizobium* were isolated from both shallow and deep soils. These populations were less numerous at the Diokoul site which had a higher clay content in the soil. Several of the strains isolated from the deep soils could actively fix nitrogen in association with *A. albida*.

215 EDWARDS, I.D. ***Acacia albida*: a useful tree for agroforestry in Malawi**. Forestry Research Institute of Malawi (1982) 10 pp. [En, 16 ref.]

Reviews the literature on *Acacia albida* (nsangu, msangusangu, chitonya, or winter thorn) in order to assess its potential for use in agroforestry developments in Malawi. Natural distribution, natural and artificial regeneration and nursery techniques are discussed, and the beneficial value of the species on the soil, micro-climate and crop yields and as fodder.

216 EGGELING, W.J. **The Mimosaceae of Uganda. Provisional keys for their identification**. *Forest Department Bulletin, Entebbe, Uganda* (1934) No. 1, 20 pp. [En]

Keys to 14 species of *Acacia* including *Acacia senegal* and *A. albida*. *A. senegal* is confined to the more northerly parts of the country. Recorded in flower from Buruli (September to November), from Kitgum, Lango, and Bunyoro (December), from Bunyoro and East Madi (June), and again from Lango (August). *A. albida* recorded flowering within Uganda only from Kitgum (September to December) and Ankole (August to October)

217 EGGELING , W.J. **Indigenous trees of Uganda.** Entebbe, Uganda; Government Printer (1940) 110-111 [En]

The "Apple-ring " *Acacia* tree grows up to 60 ft, and is the largest of the Ugandan *Acacias*. Bark dull grey; fissured, scaly. Slash pale brown, fibrous. Branchlets white. Sapwood dirty white, heartwood yellow white, soft, easy to work, finishing smoothly under the plane, seasoning well in dry air but liable to discolouration if allowed to become damp. Prone to attack by borers and termites. Weight 35 lbs/ft$^3$ when air dry. Bark of trunk contains 29% tannin, and pods 5%.

218 EL AMIN, H.M. **Sudan *Acacias*.** *Forest Research Institute Bulletin No.1, Khartoum* (1973a) 64 pp. [En, 22 ref.]

Gives a key to 31 *Acacia* species native to Sudan followed by a descriptive taxonomic account and botanical review of each one. *Acacia albida* Del. occurs both singly and gregariously in a wide range of habitats, from the alluvial soils of perennial or seasonal watercourses (particularly Western Sudan in the Darfur province) to open savanna woodland and cultivated land. Distribution is also spread from Egypt, Senegal and Gambia, southwards to South Africa, northwards to Syria and Palestine, and throughout East and West Africa. A large tree up to 30 m high. Crown round or spreading. One main stem, buttressed or not. Inflorescence, spinescent stipules, petiole eglandular. Pods bright orange, falcate, curles of spiral, indehiscent, pulpy, glabrous or rarely pubescent. Flowering November to January, fruiting December to April.

219 EL AMIN, H.M. **Taxonomic studies on Sudan *Acacias*.** *M.Sc. Thesis, University of Edinburgh* (1973b) 282 pp. [En]

The anomolous position of *Acacia albida* is fully outlined in relation to 30 other examined Sudanese *Acacia* groups in the study. Though extremely distinct from them, it was retained as a separate monotypic group in *Acacia*, but with no definite affinities to other groups in the genus. A botanical description and distribution are given, as well as considerable explanatory taxonomic discussion based on evidence found regarding its morphology (*e.g.* leaves shed in the dry season, petiolos eglandular, cotyledons obovate and sessile), anatomy (*e.g.* transition from root to stem tissues delayed until just below the cotyledons), and palynology (*e.g.* polyad largest in size, 26-32 monads in the polyad, 4 pollen pores).

220 EL AMIN, H.M. **Germination and seedling development of the Sudan *Acacias*.** *Sudan Silva* (1975) **3** (20) 23-33 [En, 7 ref.]

Describes the germination and seedling development of 24 Sudanese *Acacia* species, subspecies and varieties. The results are discussed with a view to classification and evolutionary trends in the genus. *Acacia albida* differs from many *Acacias* in that its first seedling leaves (up to the 10th node) are bipinnate, alternate with one pair of pinnae, consistent up to the tenth node. Cotyledons are obovate and sessile and fall after two weeks. The shoot soon develops a white colour (unlike other *Acacias*) due to flaking pieces of bark. One paired pinnae leaves are the norm, although 2 pairs sometimes occur. The hypocotyl is striate. Though *A. albida* is related to climbing *Acacias* by having bipinnate leaves, it differs by only having 1 pair of pinnae, terete hypocotyl and spinescent stipules.

221 EL AMIN, H.M. **Study of *Acacia albida* in relation to other *Acacias*.** *Sudan Silva* (1977) **3** (22) 39-46 [En, 13 ref.]

Gives results of a taxonomic study of *Acacia albida*, where the micro-morphological characters are compared with other *Acacia* species in the Sudan. The habitat and distribution in the Sudan is described and lists its anomolies in gross morphology, anatomy and palynology when compared with other *Acacias*. *A. albida* is placed in a monotypic group in the Acacias because of its anomolies. (Chapter from his M.Sc. Thesis at Edinburgh.)

222 EL AMIN, H.M. **Trees and shrubs of the Sudan.** Exeter; Ithaca Press (1990) 484 pp. [En]

Concise botanical description of *Faidherbia albida*. Large trees up to 30 m high. One main stem, sometimes buttressed. Bark brown or dull grey, young branches ashen to whitish, zigzagging; stipules spinescent, straight, brown with white base, 0.9 - 2.3 cm long; pinnae 2 - 10 pairs, 2 - 3 cm long, glands present between leaflet pairs; leaflets 6 - 23 pairs, oblong-linear or slightly obovate, 2.5 - 12 x 0.7 mm. Inflorescence cylindrical spikes, white to cream, 3.5 - 15 cm long; peduncles 1.3 - 4 cm long, pubescent; flowers sessile to pedicellate 0.5 - 2 mm long, pubescent; sepals 1 - 2.5 mm long; corolla 3 - 4.5 mm long. Fruit calcate curled or spiral indehiscent pods 6 - 25 x 1.8 - 5 cm, bright orange with red glands; seeds 11 - 29, vertical in pod, obovate, 9 - 11 x 6 - 8 mm, brown; areoles U-shaped or O-shaped, marginal, 7 - 9 x 4 - 6 mm; funicles 4 mm long. Flowers November - January; fruits December - April. Found in various habitats, ranging from alluvial soils of perennial or seasonal water courses, to open savanna woodland and cultivated land. They occur singly or gregariously, widespread along rivers and water depressions, particularly gregarious in Darfur province, western Sudan.

223 EL DIN, A.E.S. **Agroforestry practices in the dry regions.** *At Tasahhur Received 1989. A paper presented at a Regional Seminar on Desertification at Darfur/ Kordofan, 1982* (1984) 2, 7-11 [En]

A brief account of the main land-use practices in the dry regions of Africa, with particular emphasis on the gum gardens of Sudan (*Acacia senegal*), the Bougage land rotation system in Niger (a sustainable variation of the traditional bush-fallow system in which there is an annual shift of a small portion of land from cultivation and livestock herding to fallow), and the use of multipurpose farm trees (particularly *Adansonia digitata*, *Borassus aethiopum*, *Acacia albida* and *Acacia tortilis* but also including small numbers of various other species).

224 EL HOURI AHMED, A. **Effects of land use on soil characteristics in the Sudan.** In *Soils Research in Agroforestry [edited by Mongi, H.O.; Huxley, P.A.].* ICRAF (1979) 1-13 [En, 30 ref.]

The traditional farming systems of Western and Eastern Sudan have resulted in a rapid deterioration of both soil fertility and productivity, and a build-up of pernicious weeds which eventually give way to desertification as rotations become shorter and cultivation continues. Both *Acacia albida* and *A. senegal* have been found beneficial for (1) the improvement of soil characteristics and arresting ecosystems degradation (2) the increasing of soil N fertility and a more favourable C/N ratio (3) supplying considerable amount of livestock fodder and (4) the production of fuelwood and gum arabic.

225 EL TINAY, A.H.; KARAMALLA, K.A.; EL AMIN, H.M.; SHIGIDI, M.T.A.; ISHAG, K.E.A. **Serotaxonomic studies on Sudan *Acacias*.** *Journal of Experimental Botany* (1979) **30** (116) 607-615 [En, 9 ref.]

Seed proteins from 22 *Acacia* species collected from Northern, Central and Western Sudan were compared by serological methods in an attempt to classify the Sudanese *Acacias*. The results of immuno-diffusion and immuno-electrophoresis studies showed that the studied *Acacias* could be broadly divided into two main established taxonomic groups and six subgroups. *Acacia albida* did not fit into either group. The three ssp. of *A. nilotica* (*nilotica*, *tomentosa* and *adstringens*) were found to be serologically identical and were grouped together in a subgroup within Group 1 (subgenus *Acacia*).

226 EMBERGER, L. [Trees of Morocco and how to identify them] Les arbres du Maroc et comment les reconnaître. Larose Editeurs, Paris (1938) pp. 185-186. [Fr]

227 E.N.D.A./C.C.E. **[Useful Plants and Trees: *Faidherbia albida* (*Acacia albida*).]** Plantes et arbres utiles: *Faidherbia albida*. Dakar, Senegal; C.C.E./E.N.D.A. (1987) 1-15 [Fr]

A review containing useful information on *Faidherbia albida* (*Acacia albida*) notably its vernacular names of West Africa, its geographical distribution, ecology, agroforestry characteristics, various uses, and the methods of species regeneration.

228 ETHIOPIA, FOREST RESEARCH CENTRE. **Growth of some forest trees in Ethiopia and suggestions for species selection in different climatic zones.** *Research Note* (1986) No. 2, 52 pp. [En, 11 ref.]

Planting trials were carried out concerning species selection (species elimination tests) in the Tigre, Wollo and Harerge regions of Ethiopia. Survival rates fluctuated according to the physical parameters of the site; annual rainfall, altitude and soil structure. *Acacia albida* fared best in areas with annual rainfall 300-700 mm. Survival rates varied between 72% (1650 m, shallow), 64% (1650 m, sandy alkaline), 44% (1650 m, moderately deep clayey), 38% (1600 m, sandy, alkaline) and 5% (1800 m).

229 EVANS, C. S. & BELL, E. A. **A preliminary survey of free amino-acids in seeds *of Acacia* species.** Groupe international pour l'étude des Mimosoideae, octobre (1975), No. 3 p. 39 [En]

230 EVANS, C.S.; QUERSHI, M.Y.; BELL, E.A. **Free amino acids in the seeds of *Acacia* species.** *Phytochemistry* (1977) Vol. 16, 565-570 [En, 9 ref.]

Results of a study to determine free amino acids in 80 species of *Acacia*. The possible taxonomic and phylogenetic significance of these results are discussed, with particular reference to five species, *A. albida*, *A. confusa*, *A. heterophylla*, *A. coulteri* and *A. kauaiensis*. Those identified in *A. albida* were: 4-OH and 5-OH pipecolic acid, djenkolic acid, diaminopropionic acid (weak); amino-acetylaminopropionic acid, amino-oxalyaminopropionic acid (medium); albizziine (strong).

231 EYOG MATIG, O. **[Root systems of *Faidherbia albida* in plantations. First observations in North Cameroon.]** Système racinaire de *Faidherbia albida* en plantation. Premières observations au Nord-Cameroun. In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD- For(t, Montpellier, France (1996) 312 pp. 227-236 [Fr, en]

In the agroforestry *Faidherbia albida* plantations of North Cameroon, the author made a series of observations on the root system and aerial part of the trees to get a first impression both about the diversity of their features and about the correlations that might subsequently be investigated. Three trees were selected in four sample plots, covering different seed provenances (north and south Sudanian), soil types (ferruginous with iron-crust, ferruginous on sandstone, vertisols), climate (north and south Sudanian) and age (4.5, 8.5 and 9.5 years). The heterogeneity of growth of the tree's aerial parts is well known but this study also showed up major variations in the biomass and distribution of the root system. Most of the trees observed had a considerable proportion of their roots growing horizontally close to the surface. They are thus likely to be in competition with crops for water and mineral elements. The small number of trees examined and the large range of variables do not make it possible to determine whether the form of the root system tends to be dependent on climate, soil type, age, genetic origin, or a combination of these factors. The author nevertheless emphasizes the importance of further studies so as to encourage the planting of *F. albida* only when the provenance-ecological environment is well selected so that the root system of the trees does not compete with the crop root system. Root architecture might be every bit as important as growth of the aerial part, which normally tends to be more closely examined by breeders.

232 FAGG, C.W. **Germplasm Collection of *Faidherbia albida* in Eastern and Southern Africa.** ?? (1992) 19-24 [En]

The Oxford Forestry Institute is making systematic range-wide collections of *Faidherbia albida* (Del.) A. Chev. in under-collected areas of eastern and southern Africa to assemble germplasm for international provenance trials. The wide and discontinuous distribution suggests there may be complex patterns of genetic variation. There is also variation in morphology. Highly significant differences in size and weight of pods were found between trees, within and between provenances, indicative of an out-crossing species. The large variation in phenology is also expected to be under genetic control. The wide use of the trees in farming systems in parts of its southern range and the influence of human disturbance on its distribution introduce complications that must he taken into account. A sampling strategy has been devised. In collaboration with other institutes a broad range-wide seed collection is becoming available for testing.

233 FAGG.,C.W. ***Faidherbia albida* - inverted phenology supports dry-zone agroforestry.** *NFT Highlights* NFTA 95-06. Arkansas, USA; Nitrogen Fixing Tree Association Network, Winrock International (1995) 2 pp. [En, 6 ref.]

The botanical features of the tree are briefly described. It is a diploid species (2n = 26)) over most of its range. A polyploid (2n = 52) has been recorded from Israel. Populations in Cameroon show 50-100% outcrossing. The inverted phenology does not occur in seedlings until their tap roots are well into the water table. The natural range extends throughout tropical Africa into the Middle East and Arabia. It has been introduced into India, Pakistan, Nepal, Peru, Cyprus,

Cape Verde and the Ascension Islands. It is usually a pioneer on alluvial flats but can form part of a fire climax vegetation in West African savannas. Increased crop yields are ascribed to *Faidherbia albida* in inter-cropping schemes but it has been argued that the fertility effect may in part be due to the tree developing on more fertile microsites than creating them. Small leaflets rapidly decompose and increase the fertility of the soil. Leaf fall has been estimated at 0.97 t $ha^{-1}$ $yr^{-1}$ from 10 trees $ha^{-1}$ in Senegal but 0,73 t $ha^{-1}$ $yr^{-1}$ from 11 trees $ha^{-1}$ in Zimbabwe. Total N and available P can nearly double beneath the canopy and this leads to an increase in yields from grain crops but a decrease in yields from groundnuts, which are not favoured by the high nitrogen status of the soil. Cereal cropping in Ethiopia showed an income gain of 82% under trees at 65 trees $ha^{-1}$ compared with open fields. The nutritional value of the leaves and pods are well documented as are the yields produced per tree. Leaves, pods and seeds contain 200, 150 and 260 g total protein $kg^{-1}$ of dry matter and total protein digestibility can reach 73%. Tannins can limit digestibility but incorporating pods into low quality fodder enhances ingestion without reducing digestibility. The wood is too light to make a good firewood but it is also used for dugout canoes, mortars, doors, and light carpentry although it is subject to damage by borers. Cooked seeds are eaten by humans in times of famine. The flowers produce good pollen and nectar and beehives are made from the bark. It is widely used for local medicines and the bark is used for toothbrushes and is reputed to contain fluorine. There are 7000-20000 seeds $kg^{-1}$, smaller from West African than from the east or south of the continent. Reference is made to the usual methods of pre-treating seed, raising seedlings and planting out. The seedlings are vulnerable to competition. Tractor ploughing between mature trees can promote suckering from damaged roots. Much genetic variation has been reported across its range - larger seeded east and southern African provenances grow faster than those from west Africa but can collapse after a couple of years if the water table is not reached. *F. albida* nodulates with *Brachyrhizobium* bacteria and has VA mycorrhizal associations. It develops both surface and deep tap roots and in sandy soils the greatest densities of *Brachyrhizobium* have been found at 30-35 m below the surface at the water table. Principal pests are insects and nematodes. Bruchids destroy up to 50% of the seeds, the nematodes *Meloidogyne javanica* and *M. incognita* are favoured by moist conditions on the nursery, sap-sucking insects and cochineal bugs attack the seedlings and caterpillars of the moth *Crysotidia conifera* can defoliate trees. Insect galls and parasitic plants occur sporadically in its native range. There are few fungal diseases but a leaf blight, *Rhizoctonia solani*, has been recorded in India.

234 FAGG, C.W.; BARNES, R.D. **African acacias: study and acquisition of genetic resources**. *Final Report of ODA Research Scheme R4348.* Oxford Forestry Institute (1990) 170 pp. [En, 9 tab, 9 fig, 85 ref]

This project was intitiated in response to a need for improved use of the genetic resources of four African acacias identified as having particular potential, *viz.*, *Acacia* (*Faidherbia*) *albida, A. nilotica, A. senegal and A. tortilis.* The main objective of the project was to undertake a systematic rangewide collection of seed in under-collected areas, notably east and southern Africa. Details of distribution, range and taxonomy of *F. albida* and the other three species are given with lists of provenances identified for collection and herbarium, nodule and wood specimens collected. Isozyme analyses were conducted on *F. albida* in collaboration with institutes in France, Burkina Faso and Senegal to elucidate the distribution of genetic variation and breeding systems. Seedlings were raised in the field for the collection of nodules for a joint study of with Dundee University of rhizobial variation with species and environment. Information was compiled from any sources often not found in the literature. (See Fagg and Barnes (1995) for an abstract of the final report of the final two projects in this series).

235 FAGG, C.W.; BARNES, R.D. **African acacias: study and assembly of the genetic resources**. *Final Report of ODA Forestry Research Schemes R.4583 and R.5655.* Oxford Forestry Institute (1995) 173 pp. [En, 89 ref, 57 photo,10 maps, 12 tab.]

The first of the ODA-funded projects (R.4348) on the study and assembly of the genetic resources of the African acacias at the OFI started in 1987 in response to an internationally identified need for improved use of the genetic variation in the genus. The objectives of these projects were, for *Faidherbia* (*Acacia*) *albida, A. tortilis, A. nilotica, A. senegal* and *A. erioloba*, to:- assemble rangewide material for evaluation, domestication and conservation; investigate selfing levels, breeding systems and genetic variation; distribute seed for evaluation; produce annotated bibliographies; describe phenology and morphology; collect rhizobia for taxonomic studies; establish the feasibility of dating the trees by dendrochronology; and to collect material to elucidate and resolve the taxonomic problems of the five species and their close relatives. It took a second three-year project plus a two-year extension to achieve these objectives. This report covers the work done in the second Research Scheme (R4583) and its extension (R5655). The products of these projects yielded information and materials that provided the basis for research on various aspects of the African acacias by many scientists in many other organizations. A summary of outputs from this research is included in this report. Rangewide seed collections were assembled with a total of 141 provenances of the 21 taxa that comprise the five species. The information gained from the concurrent investigations into selfing levels, breeding systems and genetic variation was used to improve the precision of sampling the natural range of each species. The initial sampling strategy for *Faidherbia albida* was modified

when it was found that the discontinuous southern African populations, originally thought to be most variable, were least variable with those of west and northeast Africa containing the highest levels of diversity. The studies showed a clear division between the southern African populations up to southern Tanzania and those north of this line. Selfing levels in *Faidherbia albida* were higher than expected and the conclusion was drawn that most taxa were mixed. *F. albida* was found to be diploid. Chloroplast DNA (cpDNA) used to study the genus *Acacia* as a whole showed that *A. albida* should be placed in the separate monotypic genus, *Faidherbia*. Collaboration was initiated between institutions involved in complementary *Acacia* research and germplasm collections in Africa. This led to the formation of the African *Acacia* trials network which includes the European institutions involved in acacia research *viz.* FAO, DFSC, CIRAD-Forêt and OFI. A large number of herbaria were visited and detailed information on *F. albida* specimens logged into the African *Acacia* database in the BRAHMS management system which contains detailed information on more than 11,500 specimens of *Acacia* species. The data can produce nomenclatural summaries, specimen citation lists and species distribution maps; it is also possible to assemble and synthesize altitudinal ranges, vernacular names, and phenological charts. Information on the variation in flowering and fruiting phenology of all five species throughout their ranges has been extracted and summarized. Variation in pod morphology is considerable in *F. albida* and significant variation has been documented between trees within and between populations. Seedlings of six African *Acacia* species including *F. albida* were raised in six nurseries in different environments throughout Zimbabwe and nodules collected for a study on rhizobia technology at Dundee University where the specific objectives of ODA Research Scheme *R.4714 African Acacia rhizobial technology and ecology*, were to isolate, identify and test the effectiveness and competitiveness of *Rhizobium* strains and produce inocula for these species. Known-age trees of 21 African *Acacia* species including *F. albida* were identified and radial and wood samples examined for anatomical features that could be matched to periods of annual growth. These were apparent in *F. albida* among others as narrow bands of marginal parenchyma filled with long crystal chains. The crystals were subsequently identified as calcium oxalate. The number of bands annually corresponded to the number of peaks in the annual rainfall distribution which provided further confirmation that the feature could be used for age determination. Growth rates were found to be faster than expected with an average annual diameter increment of 38.36 mm for *F. albida*.The vision of the role that the African acacias can play in increasing the productivity of non-arable land in the semi-arid zones of the continent has expanded since this work started eight years ago. The projects have begun to reveal the acacias' genetic prospects. There is also increasing evidence that the devastating droughts in Africa are likely to be long term; and the potential role of exotics in this situation has diminished with the growing concern about their invasive propensities. The most important areas for future research into the African acacias are in the fields of:- evaluation of the genetic potential of the acacias; socio-economic studies to quantify their current and potential value in farming systems; the relationship between seedling physiology and adaptation; selfing studies to determine genetic load; hybrid studies to assess heterosis, to resolve taxonomic inconsistencies and to produce sterile, fast-growing, productive cultivars; rhizobial studies; and investigations into the stand dynamics of invasion. These projects have now provided the information and materials on which much of this research can be based. The task in the future is to manage this resource efficiently to supply the needs of well-focussed research projects.

236 FAGG, C.W.; STEWART, J.L. **The value of *Acacia* and *Prosopis* in arid and semi-arid environments.** *Journal of Arid Environments* (1994) **27**, 3-25 [En, 171 ref.]

The great biological diversity in *Acacia* and *Prosopis* is reflected in their wide distribution and ecological amplitude, and particularly in the tolerance of some species to extremes of drought and salinity. Their value, however, lies not only in their ability to thrive under adverse conditions, but also in the range of useful products that they provide. Among these, animal fodder, both pods and browse, is of central importance. The wood of both genera is an essential source of fuel in arid and semi-arid areas, and the timber is also valued for a wide range of purposes. The greatest economic value of *Acacia,* however, lies in the production of gums and tannins for industrial uses. The promotion of more lesser-known species in planting programmes would help to conserve the valuable diversity in both genera. *Faidherbia albida* is mentioned specifically in a number of contexts. Pastoralists in Africa have developed techniques for harvesting browse by pollarding and collecting pods with long hooked poles. *F. albida* is said to produce about 300 kg $ha^{-1}$ $yr^{-1}$ of fodder and 200-600 kg $ha^{-1}$ $yr^{-1}$ of pods. The pods and seeds are collected and sold in markets both as animal and as human food. The tree can grow to over 2 m in diameter and has been used for doors and dugout canoes. The farmed parkalnds of *F. albida* in the Sudano-Sahelian belt are of great importance for many agrarian communities in West Africa. It is one of the few trees that can allow intensive farming beneath its canopy without the need for a fallow period in dry areas. These traditional practices have been perfected by the Hausa of Niger and Nigeria, the Seres of Senegal, the Bwaba of Burkina Faso, the Dogon of Mali and diverse agrarian civilizations of the Niger River delta. The benefits from this agroforestry tree are due in part to its inverted phenology. The widespread and disjunct distribution of *F. albida* in east and southern Africa shows adaptation to a wide diversity of ecological conditions and it is associated with traditional farming systems. Its expansion into large populations is nearly

always associated with man. Examples are the large populations on heavy vertisols in the Ethiopian Highlands, on the alluvial soils of the Kafue flats and on the Malawian lake shore and the large populations on sand around Wadi Azum in western Sudan. *F albida* can withstand periodic flooding for several months during the year.

237 FAHN, A.; WERKER, E.; BAAS, P. **Wood Anatomy and Identification of Trees and Shrubs from Israel and Adjacent Regions**. The Israel Academy of Sciences and Humanities, Jerusalem (1986) 221 pp. [En]

238 FAIRBAIRN, W.A. **Ecological succession due to Biotic factors in Northern Kano and Katsina provinces of Northern Nigeria**. *Institute Paper, Imperial Forestry Institute, University of Oxford* (1939) No. 22, 32 pp. + 1 map [En, 11 ref.]

An ecological study of Northern Nigeria, north of the 12°30' degree latitude, with a description of 13 vegetation formations. *Acacia albida* is noted to occur in 1) the Sudan woodland, where it is a dominant in this climax vegetation type; 2) dominant in the Sudan scrub-savanna; 3) in the thorn forest giving details of small stands in central Hadejia of over-mature trees which were prized and left on the farmland by farmers. Noted little regeneration; 4) in thorn savanna and a 5) in thorn - scrub.

239 FALL, S.T. [**Ulitization of *Acacia albida* and *Calotropis procera* for enriching the feed of small ruminants in Senegal**] Utilisation d'*Acacia albida* et de *Calotropis procera* pour améliorer les rations des petits ruminants au Sénégal. In *African small ruminant research and development, Proceedings of a conference held at Bamenda, Cameroon 18-25 January 1989.* Addis Ababa, Ethiopia; African Small Ruminant Research Network, ILCA (1989) 155-166 [Fr, en, 7 ref.]

Gives details of proximate analyses, *in vitro* and in vivo digestibilities and intra-ruminal degradability of dry matter and protein for leaves and pods of *Acacia albida* and leaves of *Calotropis procera* in order to establish their suitability as supplementary feeds for small ruminants. Feeding trials were also conducted on young sheep in order to study effects on growth rate. Organic matter digestibility was 48% and 62% for *A. albida* leaves and pods and 71% for *C. procera* leaves. Total protein was 11% for both leaves and pods of *A. albida* and intra-ruminal degradability was 55% and 63% respectively.

240 FANSHAWE, D.B. ***Acacia albida* Del.** In *Fifty common trees of Northern Rhodesia.* Natural Resources Board and Forest Dept. (1962) 4-5 [En]

*Acacia albida* Del. is a large, deciduous tree typical of river banks and alluvial flood banks throughout the Territory [Zambia], except in the north-west. Axillary spikes of creamy white, fragrant flowers are produced in May-July before the leaves appear, hence the name 'Winter thorn' to describe the winter flowering. The wood is course-grained, uneven-textured, medium-soft and whitish. It is used locally for building construction, canoes, paddles, tool handles and rough furniture. It is a weak timber and should by cut oversize if used for beams.

241 FANSHAWE, D.B. ***Acacia albida* Del.** In *Useful Trees of Zambia for the Agriculturalist.* Lusaka, Zambia; Ministry of Lands and Natural Resources (1972) 58-59 [En]

*Acacia albida* is described as one of 11 useful fodder trees, to be preserved on grazing lands for fodder and shade. A brief description of the tree, its common names, habitat and distribution, and uses in Zambia are given. It flowers in May to June before the leaves appear. It occurs along river banks and alluvial floodplains, being an indicator of good arable land. The wood is used locally for building and making canoes, but being weak it should be cut oversize if used for beams. A widespread fodder source (pods and leaves), but cautions the use of unripe green pods which can be poisonous (prussic acid). Bark and roots are used in traditional medicines, and occasionally to stupify fish.

242 FAO. [**Genetic resources of tree species of the arid and semi-arid zones**] Ressources génétiques d'essences arbores des zones arides et semi-arides. Projet FAO/IBPGR, (1980) [Fr]

243 FAROOQUI, J.A.; AHMAD, R.; AHMAD, M. ***Acacia albida* seed oil characterisation of coronaric acid**. *Fett Wissenschaft Technologie* (1987) **89** (1) 30-32 [En]

Coronaric acid makes up 7.8% of *Acacia albida* (leguminosae) oil triglycerides. Direct acetolysis of the oil followed by saponification gave cis-9,10-dihydroxy-octade-cis-12-enoic acid which was characterized by various spectroscopic studies and chemical transformations. Quantitation of the coronaric acid was done by gas-liquid chromatography. *Chrysanthemum coronarium* seed oil was used as the reference standard throughout the study.

244 FAVRE, J.M.; TRAORE, M. **Compared root morphogenesis in seedlings of *Acacia albida* Del. and two other leguminous trees *Prosopis juliflora* D.C. and *Robinia pseudoacacia* L.** *Phytomorphology* (1987) **37** (2/3) 131-137 [En, 11 ref.]

Root development of *Acacia albida* seedlings was compared after three months with that of *P. juliflora* and

*R. pseudoacacia*. Three substrata (peat, sand, pozzolana) and two temperature conditions (19C and 27C) were tested. The general growth pattern of each species resulted from the balance between the tap root and the lateral roots. The root system of *A. albida* in comparison with *P. juliflora* and *R. pseudoacacia* was characterized by a strong predominance of the tap root over the laterals and a lack of plasticity towards the modifications of the growth conditions.

245 FEAU, C. **[The experimental ecology unit of Maradi]** Unité écologique expérimentale de Maradi. Étude morphopedologique. République du Niger, INRAN, GERDAT, IRAT (1977) [Fr]

246 FEELY, J.M. **Observations of [the autecology of] *Acacia albida* in the Luangwa valley [Zambia]**. *Puku* (1965) **3**, 67-70 [En, 3 ref.]

*Acacia albida* (winter thorn) is a large tree characteristic of recent alluvia in the Luangwa valley, Zambia. It does not occur randomly distributed, but on seasonally flooded cut-offs or meanders of the river. It shows rapid early growth to avoid complete submergance in following floods, recording 9 feet in 2.5 years and 15 feet in 4.5 years. Juvenile trees are not deciduous. Preferential food plant for various ungulate mammals and mature trees were being damaged by elephants. Fallen pods eaten by rodents (*Tatera leucogaster*). Flowers eaten by hoards of Nyasa lovebirds (*Agaporins lilianae*).

247 FELKER, P. **State of the art: *Acacia albida* as a complementary permanent intercrop with annual crops**. University of California (1978) 143 pp. [En, 83 pp. ref.]

Comprehensive analysis of current literature regarding *Acacia albida*. Intercropping with *A. albida* has substantially increased the welfare of small farmers in West Africa and the Sahel by increasing soil fertility and crop yield and providing pods for animal feed. Approximately 45 large trees $ha^{-1}$ are required to complete soil cover. The trees flower at seven years old and first produce pods at eight years old.

248 FENTON, M.B.; CUMMING, D.H.M.; HUTTON, J.M.; SWANEPOEL, C.M. **Foraging and habitat use by *Nycteris-grandis chiroptera nycteridae* in Zimbabwe**. *Journal of Zoology, London* (1987) **211** (4) 709-716 [En]

This study describes the forging strategies, foraging areas, and roosts used by four female radio-tagged bats (*Nycteris grandis)* along the Zambezi River, in the Mana Pools National Park in Zimbabwe. The marked bats roosted in an old water tower or in a hollow *Acacia albida*. The bats exhibited two foraging strategies, sometimes hunting from perches, other times flying continuously close to the ground.

249 FERLIN, G. **[Impressions of the Cape Verde Islands.]** Impressions des Iles du Cap Vert. *Bois et Forêts des Tropiques* (1979) **183**, 19-32 [Fr,en, es, 5 ref.]

The history, geography, climate, vegetation and fauna of the islands are briefly described. Rainfall is sparse and erratic, very dependent on altitude and exposure to monsoon and trade winds; soils are rich and volcanic but only small areas are cultivable. Agricultural holdings average less than 2 ha with maize and beans as the main crops. Rains have been severely deficient since 1968, reducing livestock to goats and pigs only. Forest is restricted to mountain areas exposed to the trade winds; reforestation, chiefly with *Eucalyptus camaldulensis*, is for firewood. *Prosopis* spp. grow remarkably well and they are recommended on grazing land because of their edible pods. Other important indigenous and exotic species are listed including *Acacia albida*.

250 FOOD AND AGRICULTURE ORGANIZATION. ***Acacia albida***. In *Pulping and paper-making properties of fast-growing plantation wood species. FAO Forestry Paper* (1980) No. 19/1, 7-9 [En]

Gives details of the density, fibre, pulping and paper making characteristics for a sample of *Acacia albida* wood from Senegal. The wood is fairly soft and of intermediate density (0.54 $g/cm^3$). The extractives content seems somewhat high and also the lignin content (33%) which is apt to affect the quality of pulp produced therefrom. The fibres are of average length for hardwood (1080 μm), but with a somewhat high wall thickness (6 μm) which tends to make the fibres stiff and prevent proper bonding in paper. In spite of the fairly high alkali charge used for sulphate and chemical soda pulping - 17% and 20% $Na_2O$ as active alkali respectively - the Kappa number has remained far above the acceptable range for hardwood pulp. In addition, the yield of unbleached pulp is very low, and this species is therefore not recommended for plantations for pulping.

251 FOOD AND AGRICULTURE ORGANIZATION. **Botswana**. In *Tropical Forest Resources Assessment Project (in the framework of GEMS). Forest resources of tropical Africa. Part II. Country briefs. FAO Technical Report* (1981) No. 2, 37-43 [En, 10 ref.]

Describes the present situation in Botswana concerning the forest resource and its utilization, and outlines current trends in deforestation and degradation. *Acacia tortilis* is an occasional component of riverine forests in the northern region which grow to heights of 15-30 m and mostly comprise *Acacia albida*, *A. nigrescens*, *Combretum imberbe*, *Diospyros mespiliformis* and *Lonchocarpus capassa*. *A. tortilis* also occurs as scattered groups of shrub-like trees, together with *Terminalia prunioides*, in heavily grazed grasslands such as are found north of Kanyu and south of Gweta.

252 FOOD AND AGRICULTURE ORGANIZATION. ***Acacia albida* Del.; Case Studies.** *Forest Genetic Resources* (1985) No. 14, 22, 29 [En]

Gives a case study of the 20 most important forest species in Cameroon, including *Acacia albida* with a rough distribution map. *A. albida* is a spreading, thorny tree with bole up to 8 m tall and 1 m in diameter in Cameroon. It occurs in Sudan zone wooded savanna, in the area of the Mandara mountains and in Sahelian steppes in Cameroon on heavy but well-drained soils, where it may form continuous stands. The species loses its leaves at the beginning of the rainy season and is in leaf throughout the dry season. It is therefore beneficial in that it does not restrict light to agricultural crops during the growing season and provides dry season shade to stock, which enrich the soil around it through their droppings. As a result it is protected by farmers and pastoralists. The leaves and fruits are used for fodder and the wood is soft and easy to work. There are young plantations in the extreme north; growth is very slow.

253 FOOD AND AGRICULTURAL ORGANISATION. ***Acacia albida* Del.** In *Databook on endangered tree and shrub species and provenances. FAO Forestry Paper* (1986) No. 77, 21-28 [En, 9 ref.]

Based on a list of species considered by the FAO Panel of Experts on Forest Gene Resources to be threatened with extinction or subject to severe genetic depletion, 81 species monographs are presented including one on *Acacia albida*. Each monograph includes synonymy, common names, botanical description, wood properties and products, ecology, silviculture, recommended protective measures and a selected bibliography. *A. albida* is not in danger of extinction. Some stands in Israel are threatened because it is not regarded as economically important there. *A. albida* is a Sudano-Deccanian relic with fragmented habitats of a formerly continuous area of distribution in Palestine in the Oligocene and Miocene. The fragmentation is due to climate change although there is a decline in the populations duel to fuel and fodder shortages and changing land use patterns. Seed of some provenances is being collected in Israel and Senegal.

254 FOREST PRODUCTS RESEARCH LABORATORY. **Report on two consignments of Haraz (*Acacia albida*) from the Republic of Sudan.** Reports on overseas timbers No.10, FPRL consignments Nos. 1305 and 1373 (1968) 8 pp. [En]

Gives a general description of the timber and results of tests on 11 logs from different trees. The timber was somewhat unattractive in appearance and unpleasant-smelling when wet, easily damaged by insects and by stain and rot fungi, and poor in strength properties except hardness and shock resistance. It seasoned satisfactorily if straight-grained, sawed easily, finished well, and was easily treated with preservatives. Possible uses include building timber (wood from mature trees), fence posts (treated), general carpentry and shuttering.

255 FRAMMOND, H. DE. **[Preliminary results of trials of *Acacia albida* provenances in Burkina Faso.]** Premiers résultats d'essais d'évaluation de provenances *d'Acacia albida*, Burkina Faso. Burkina Faso; C.T.F.T./C.I.R.A.D., I.R.B.E.T., Note Technique No. 87/03, (1987) 12 pp. [Fr]

This is a study of the genetic variation in *Acacia albida* used in Burkina Faso to improve soil fertility and provide cattle fodder. Trials were carried out at three research stations (Djibo, Gonse and Dindereso) using seeds of 23 provenances from Senegal to East Africa. The classic nursery technique was employed (three seeds per pot, pre-treatment by soaking in 60% sulphuric acid for 15 minutes). No difference in the number of trees living was found between provenances at the end of six months. Strong inter-provenance variation was reported for *A. albida* with significant differences in the rate of growth detected at six months and maintained at 18 months. The most vigorous provenances were from humid regions, namely Senegal and altitudinal zones in Burundi. It is impossible to say at the end of the trial whether the different provenances are adapted to the Burkinian sahel in the long term.

256 FRANKE, R.W. **Power, class, and traditional knowledge in Sahel food production.** In *Studies in power and class in Africa [edited by Markovitz, I.L.].* New York, USA; Oxford University Press (1987) 257-285 [En]

The paper first outlines several important features of Sahelian farming and animal herding systems in order to establish that traditional farmer-herder interaction led to ecologically sound productive systems. Sahelian peoples have developed at least four apparently significant additional mechanisms for maintaining the environment: (1) a highly developed land use rotation among the Bouzou of Niger; (2) a complex system of fertilizer composting among the Dogon of Mali; (3) the intensive use of *Acacia albida* trees among the Serer of Senegal; and (4) an innovative set of land use regulations among the 19th century Fulani of the Niger River inland delta. In each of these cases, the agricultural resource base has benefited from association with the knowledge passed on from the herder-farmer interactions. The more egalitarian farming group has adopted and maintained the improved practice, rather than a more stratified neighbour with, presumably, similar opportunities.

257 FRANKLIN, J.; HIERNAUX, P.H.Y. **Estimating foliage and woody biomass in Sahelian and Sudanian woodlands using a remote sensing model.** *International Journal of Remote Sensing* **12** ( 6) 1387-1404 [En, 71 ref.]

Predictions of tree size and density from a remote sensing model were used together with allometric regression equations from the literature to estimate foliage and above-ground woody biomass in sparse woodlands. Study sites with woody cover ranging from 10-50% were located in the Sudanian (dominated by *Butyrospermum parkii [Vitellaria paradoxa], Acacia albida*) and Sahelian (dominated by *A. seyal, A. nilotica*) bioclimatic zones in Mali. Estimates compared favourably to independent measurements of foliage biomass made in the Sahelian sites, and to typical values of foliage and woody biomass from the literature for these regions and for similar woodland types. If combined with a vegetation stratification at the appropriate scale, this approach could provide estimates of woody biomass for fuelwood, and foliage biomass for browse over large areas (103-106 $km^2$). These estimates could be used in regional scale models of biogeochemical cycling. At three of the six Sudanian sites located near Segou Mali, *A. albida* was dominant, occurring at low density with crops under them. Field sampled data from the three sites were listed for *A. albida.* Its crown area varied from 57 - 110 $m^2$, and the density from 13 - 36 trees/ha giving a potential woody cover of 11-24%. The average stem diameters for *A. albida* trees was 45 cm.

258 FRANKLIN, J.; PRINCE, S.D.; STRAHLER, A.H.; HANAN N.P.; SIMONETT D.S. **Reflectance and transmission properties of West African savanna trees from ground radiometer measurements.** *International Journal of Remote Sensing* (1991) **12** (6) 1369-1385 [En, 40 ref.]

Reflectance and transmission properties of *savanna* trees were measured using a pole-mounted radiometer for four Sahelian (*Balanites aegyptiaca, Acacia seyal, A. senegal, Combretum glutinosum*) and two Sudanian (*A. albida, Butyrospermum parkii [Vitellaria paradoxa]*) species taken between November 1986 to October 1987 in Mali. Thirty-two trees in total were measured, including three trees of *A. albida.* The measurements showed that canopy spectral components (shadowed and sunlit tree crown and background) have distinct reflectance characteristics in red and infrared wavebands. Sunlit canopy was the greenest component (greatest infrared to red contrast), and sunlit background (consisting mostly of bare soil) the brightest (greatest summed red and infrared reflectance). Shadowed crown, the darkest component, was greener than shadowed background. The field radiometer measurements were used to calculate the normalized difference vegetation index (NDVI), and the spatial integral of the NDVI over the canopy was related to crown volume yielding per species $r^2$ of 0.75 to 0.81. Measurements of canopy transmission indicated that only 12-47% of incoming radiation was absorbed in these wavebands.

259 FRANKLIN, J. STRAHLER, A.H. **Invertible canopy reflectance modelling of vegetation structure in semiarid woodland.** *IEEE Transactions on Geoscience and Remote Sensing* (1988) **26** (6) 809-825 [En, 72 ref.]

A canopy reflectance model of Li and Strahler, which exploits tree geometry in an inversion technique, was used with Landsat Thematic Mapper multispectral data to give regional estimates of tree size and density in sparse woodland and wooded grassland in the Sahelian and Sudanian bioclimatic zones of Mali. Sites in the Sahelian zone were dominated by *Acacia seyal* or *A. nilotica* and those in the Sudanian zone by *Butyrospermum parkii* or *A. albida.* The model did not predict tree size well, but gave better predictions of density and cover. Regional differences in the structure of the woodland types were accurately detected and quantified by the inversion procedure.

260 GALABERT, J.: **[The most useful trees of Upper Volta]** Les arbres les plus utiles de Haute-Volta. Publication du Centre Culturel Franco-Voltaique (1972) [Fr]

261 GANRY, F.; DOMMERGUES, Y.R. **[Nitrogen fixing trees: a research area.]** Arbres fixateurs d'azote: champ ouvert pour la recherche. *Agriculture et Développement* (1995) No. 7, 38-55 [Fr, en,es, 72 ref.]

A synthesis is presented of recent research into nitrogen-fixing trees. The emphasis is on the use of such tree species in agroforestry systems in the tropics. An outline is given of nitrogen fixation, bacterial and mycorrhizal symbionts, methods for measuring nitrogen fixation, and field trials for investigating the effects of nitrogen fixing trees on associated crop growth (whether in alley cropping with hedges, bush fallows or long-term rotations). A list is included of high nitrogen-fixing species that includes *Leucaena leucocephala, Calliandra* spp., *Casuarina* spp., *Acacia mangium, A. mearnsii, A. seyal, Gliricidia sepium* and *Sesbania* spp., average nitrogen-fixing species such as *Prosopis juliflora*, and *A. saligna* and low nitrogen-fixing species which includes *A. raddiana, A. senegal, A. cyclops* and *Faidherbia albida.*

262 GARCIA, L.E.; GASMA, M.G.H. **Traditional beekeeping in Kubbum, Sudan.** *American Bee Journal* (1986) **126** (6) 417-419 [En, 10 ref.]

Details information on beekeeping in Southern Darfur, particularly around Kubbum which is a major production site of honey in Sudan. The vegetation in the area is dominated by *Acacia albida*, the tree being a major honey source. Average annual rainfall is 600 mm for the area, with average yearly temperatures ranging from 37 - 18°C. In 1979 estimated 2,000 beekeepers owning 11,000 hives in Southern Darfur. Describes construction of hives, honey harvesting and marketing, and the potential to increase production where a beekeeper

with six hives can produce 120 - 150 pounds of honey per year, around 100 US$ when sold in local markets. Most consumers buy honey for its medicinal properties.

263 GASSAMA, Y.K. [**In vitro culture and improvement of symbiosis using mature *Acacia albida*.**] Culture *in vitro* et amélioration symbiotique chez *Acacia albida* (Leguminosae) adulte. In *Trees for development in Sub-Saharan Africa. Proceedings of a regional seminar held by the International Foundation for Science (IFS), ICRAF House, Nairobi, Kenya, February 20-25, 1989.* (1989) 286-290 [Fr, en, 20 ref.]

This paper describes a technique for *in vitro* micropropagation of mature *Acacia albida* trees using nodes from root suckers. Regeneration starts to occur a few weeks after disinfection with $HgCl_2$ (1 ppm) and after the nodes have been cultured in a Murashige and Skoog medium enriched with BAP (0.5 mg/l), ANA (0.01 mg/l) and carbon (20 g/l). The final result is the formation of fully rooted plants. The multiplication coefficient can be increased by stimulating the formation of axillary shoots through cytokinin treatments (BAP: 20 mg/l). About four weeks after inoculating plants rooted in vitro, nodules start to appear.

264 GASSAMA, Y.K. [**In vitro nodulation and early rhizobial infection in *Acacia albida*.**] Nodulation *in vitro* et etapes precoces de l'infection rhizobienne chez *Acacia albida* (Del.) (syn. *Faidherbia albida*). *Annales des Sciences Forestieres* (1997) **54** (6)529-538 [Fr, en, 32 ref.]

Results are presented of investigations into the influence of the timing of inoculation on histological development and nitrogen-fixation of *Acacia albida* [*Faidherbia albida*] and *Bradyrhizobium*. Effective symbiosis developed between *F. albida* seedlings and *Bradyrhizobium* when inoculation occurred during the first 13 days following germination. During this period, after the appearance of young roots, the rate of infection (*i.e.*, the number of new nodules) was optimal. Seedling biomass and total nitrogen content were significantly higher than that of seedlings inoculated at 23 days. Observation of newly infected roots showed that, as with many other leguminous species, infection occurred through a characteristic short and curling root hair. Nodules of *F. albida* exhibited two morphological types: one was spherical and had this 3-4 weeks after inoculation; the other was a more indeterminate shape, even after 6 weeks.

265 GASSAMA, Y.K.; DUHOUX, E. [**Micropropagation of mature kad *Acacia albida* (Leguminosae).**] Micro propagation d'arbres adultes de Kad, *Acacia albida* (Leguminosae). *Les arbres fixateurs d'azote. L'amélioration biologique de la fertilité du sol. Actes des séminaires, 17-25 mars, Dakar, Sénégal. Editions d'ORSTOM, Paris, France* (1987) 216-224 [Fr, en, 10 ref.]

Nodes between two thorns bearing an axillary bud were taken from stool shoots and root suckers of mature trees. The root suckers had very little lignification. The nodes were cultured on three media: Lin and Staba, Murashige and Skoog, and Murashige and Skoog supplemented with K, Mg and $PO_4$. The media also contained 0-1 mg/litre NAA and 0-0.5 mg/litre benzyladenine and 0.01 mg/litre NAA. Best results were obtained with nodes from root suckers on modified Murashige and Skoog medium, and the best growth regulator treatment was 0.5 mg/litre benzyladenine and 0.01 mg/litre NAA.

266 GASTRELLU, J-M. [**You can see the wood for the trees, or: usus, fructus et abusus.**] L' arbre ne cache pas lafort, ou : usus, fructus et abusus. *Cah. O.R.S.T.O.M., sJr. Sci. Hum.* (1980) **17** (3-4): 279-282. [Fr]

It is essential to recognize that for the African villager nature is utilitarian - no sentimentality about plant kingdom, no ecological conscience, but a relationship between man and his surroundings which leaves no room for naturalist poetry, luxury of city dwellers. The tree is not an ornament; it is clothed in utilities all combined in one plant - economic, climatic, religious, fundamental uses. In the Sudano-Sahel, *Acacia albida* restores soil fertility, provides food for livestock and serves as barn for storing bean harvest. The tree's climatic influence is more difficult to show. The African villager has a sense of balance and respect but is affected by the call of the cash economy. In Senegal, pasture and charcoal making are speeding up degradation of parklands. Up to now, a woody cover has been kept without which cultivation of cocoa would be impossible; but there has been a recent introduction of a new variety of cocoa for which shade is no longer indispensable. Old have been abandoned to new cultivators who grow rice, maize and cotton on a short cycle of three years. Once three crops are grown, the fields are abandoned with catastrophic effects showing considerable modification of countryside. Banning of clearing of sacred woods contributes to the preservation of the natural environment. Trees also have a role in defining ownership of a plot or field. In Serer societies of Senegal and Agnl of Ivory Coast, the individual who planted a tree in a field is given the sole right to pick the fruit; he, or his descendants, and no one else can use this right which proves he is the owner of the field. A profound inequality is born in urban areas and grows in country areas where "planter-entrepreneurs" invest a small part of their urban income in the rural sector and introduce new links in opposition to the agricultural workforce.

267 GAUTREAU, P. [**Influence of Acacia albida on groundnut culture**] Influence de l'*Acacia albida* sur la culture de l'arachide. *Extrait du rapport 1966 de l'I.R.H.O, Sénégal* (1966) pp. 19-29. [Fr]

268 GEIGER, S.C.; VANDENBELDT, R.J.; MANU, A. **Pre-existing soil fertility and the variable growth of *Faidherbia albida*.** In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, J.R.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 121-125 [En, 17 ref.]

A study of *Faidherbia albida* trial planted in 1987 and measured three years later at the ICRISAT Sahelian Centre, investigating whether the variation in growth rates of the seedlings could be due to microsite variation in soil chemical and physical properties. 10 sites in the trial were investigated, five in areas of poor tree growth and five in areas of good growth. Good growth areas had higher clay contents and base saturations, and lower aluminium saturation percentages than poor growth areas within the site. Seedlings planted on sheet-eroded sites caused by runoff from micro-topographically high areas performed poorly. The proximity to abandoned termite mounds and other fertile micro-high areas determined the rate of tree growth. Old termite mounds were found to be visible, 3-4 cm above the soil surface. The outplanting of *F. albida* on these fertile microsites would improve its growth and survival, and partly contribute to the improved crop performance.

269 GELDENHUYS, C.J. **Raising indigenous trees.** *Department of Forestry Pamphlet, Pretoria, South Africa* (1975) No. 150, 32 pp. [En, 7 ref.]

*Acacia albida* (Ana tree) - very suitable for the drier parts of the Transvaal region. Medium sized tree with fast rate of growth (1 m or more per annum). Seed life more than two years. Treatment of seed by immersion in cold water for two days, and also in hot water, gave reasonable results. Germination period 2-3 weeks. Susceptible to frost, especially when young. Prefers sandy soil.

270 GETAHUN, A.; JAMA, B. **Alley cropping in the coastal area of Kenya.** *Paper presented at the International Workshop on Alley Farming for Humid and Sub-Humid Regions of Tropical Africa, Ibadan, Nigeria, 10-14th March 1986.* (1986) 163-169 [En, 2 ref.]

This paper reports results on crop yields, fodder, nitrogen contribution, weed control, soil fertility and economic wood yields of *Leucaena*, *Sesbania*, *Casuarina*, *Gliricidia* and *Acacia albida* of 1984 and 1985 under alley cropping, survival rates, heights and DBH of trees, maize yields and weed control percentages were quantified for eight densities of each species. Weed control was significantly higher under high densities of trees of all species. Maize yields varied with species and time as well as tree management.

271 GIFFARD, P.L. **[The possibilities of afforestation with *Acacia albida* in Senegal.]** Les possibilités de reboisement en *Acacia albida* au Sénégal. *Bois et Forêts des Tropiques* (1964) No. 95, 21-33 [Fr, en, es, 18 ref.]

The author examines the role that *Acacia albida* can play in afforestation in Senegal. The botanical, technological and ecological characteristics of the species are described as are its effects on the soil and its value as fodder. From the forestry point of view, artificial regeneration trials have ended in failure but a method now has been developed. Natural tree growth in Senegal is described and the possibilities of reafforestation discussed. The author shows how *A. albida* would be advantageous in the development of the Niayes region and in the ground-nut basin.

272 GIFFARD, P.L. **Ultilisation de l 5 *Acacia albida* dans la regeneration des sols en zones tropicales arides.** Third World Forestry Congress, Madrid, 1966 (1966) [Fr]

273 GIFFARD, P. L. **[Early research on *Acacia albida*]** Premières recherches effectuées sur *Acacia albida.* CTFT, Sénégal, décembre (1968) [Fr]

274 GIFFARD, P.L. **[Further research concerning *Acacia albida*.]** Recherches complémentaires sur *Acacia albida. Bois et Forêts des Tropiques* (1971) **135**, 3-20 [Fr, en, es, 13 ref.]

Studies in Senegal in 1966-69 emphasized the value of *Acacia albida* for agriculture in tropical regions; the marked superiority of crops in areas where *A. albida* is grown is attributable to enrichment of the soil with N and Ca through the biochemical cycle in the soil/*A. albida* system and the rapid decomposition of organic matter produced by the tree. Although the wood is of indifferent quality, it is usable locally. In fertile soil, *A. albida* grows rapidly. Artificial regeneration techniques have proved useful, but natural regeneration gives the best results. Marked reduction in maximum temps and slight increase in minimum temps under the tree. Details results from physical and mechanical props and its paper characteristics.

275 GIFFARD, P.L. **[The types of reforestation in Senegal: kad (*Acacia albida* (*Faidherbia albida* Chev.)).]** Les essences de reboisement au Sénégal: le kad (*Acacia albida* (*Faidherbia albida* Chev.). *Unpublished paper. Délégation générale a la recherche scientifique et technique, Centre Technique Forestier Tropicale, République du Sénégal. Dakar, June, 1974* (1974a) 32 pp. [Fr]

Information on the growth form, timber and paper making properties, and value of leaves and fruit as fodder and trading commodities *of Acacia albida* is given. The tree has creeping superficial roots to obtain water and has

two leaf seasons in areas of the tropics with two rainy seasons (also indicated in fossil records). The wood is a clear yellow, soft and easy to work. It is commonly used in the Soudan-Sahel for art objects and light use tools. The wood is not particularly good quality and is only used in regions where there is no alternative. Gives details on various paper-making techniques (mechanical and chemical) none of which are particularly successful. The foliage provides good forage for cattle in the dry season when other species are not in leaf, though problems have been encountered with nomads harvesting the leaves as they move through agricultural lands. Correct pruning is required or the tree will not re-fruit for several years. Fruit is produced in February-May, a critical time with respect to the feeding of cattle. The fruit used to get eaten as they fell by grazing animals, herds are now enclosed and the fruits must be gathered to be used as fodder or traded. *A. albida* has beneficial effects on the soil, including the level of activity of soil micro-organisms, though nitrogen is only fixed in areas lacking this mineral. Rapid decomposition leads to tight mineral cycling through the system, notably of potassium, magnesium and calcium, but not phosphorus. The greatest return of minerals to the soil occurs in Dec-Jan with leaf fall and then in March-April when pods fall. These effects have long been exploited in Senegal, Mali and neighbouring regions. Details of the culture of cereal (millet) and groundnut in association with *A. albida* are given. Millet growth increases with proximity to *A. albida,* and also with fertilization. The effect on groundnuts is less noted. The natural regeneration of *A. albida* is dependent on the ingestion of the seed by animals for the removal of the tough testa in the region under study as a humid/wet period required to break dormancy otherwise is not available (soaking the seeds in water is insufficient to break dormancy). Defecated seed will germinate in the next rain, provided it escapes insect attacks. Young regeneration suffers, however, from grazing, and protection is required for several years. In general, establishment by natural regeneration only works in areas where the tree occurs naturally. Artificial regeneration is similarly difficult. Seeds can be collected and stored for several years. The seed should be removed from the fruit after collection to prevent infestation by weevils, and stored in closed receptacles away from light and damp, and should be dusted with insecticide. They must be soaked prior to planting, and grown in full light with no weed competition. Ground preparation is not required. Sowing in pots in a nursery gave 40% survival by the end of the dry season, and planting in polythene bags has proved successful. Reforestation is still, however, in the experimental stage. In plantations, 50 trees/ha is recommended (10m spacing). In East Niger, *A. albida* has been attacked by scale insects (cochenilles), acridiens ?? (*Kraussaria angulifera* Krauss, *Tryloptropidia gracilis* Brancsik, *Anacridium melanorhodon* Walker and caterpillars (Lepidoptera) (*Salagena transvena* Walker, *Cryptothelea junodi* Heylaerts, *Crypsotidia conifera* Hampson, the last of which is the most serious defoliator).

276 GIFFARD, P.L. [**The tree In the Senegalese landscape.**] L'arbre dans les paysages Sénégalais. CTFT, Dakar (1974b) 431 pp. [Fr]

*Acacia albida* (kad) is included among 24 acacias whose place in the Senegalese countryside is described in this work. It is a most important species for growers in the Sahelian Sudan and the Sudanese Sahel. The crown often provides the only greenery during dry season. The tree permits both cultivation and cattle due to its ability to enrich soil without affecting development of associated plants. The foliage of *A. albida* (17% protein) is now collected in most villages in West Senegal and farming people increasingly oppose nomadic herdsmen removing branches when they cross their lands. Analyses have shown that leaves provide forage comparable to high quality hay in temperate regions in terms of protein. The top grows rapidly if correctly pruned; if not, it will take some years. The pods (11% protein [un-milled seed]) play a premier role in the rural economy. Fruits appear between February and May, a crucial period for cattle feeding, and are grazed gradually as they fall but, increasingly, farmers pick them at daybreak to feed them to animals kept in enclosures or to sell them to those who have sheep. The estimated foraging value is 0.77 UF per kg of product at 10% humidity, twice as much as good field hay or dry groundnut hulls. Yields of pods from individual trees have been estimated at 125 kg from a tree with a crown of 230 $m^2$ and 2500 kg $ha^{-1}$ with 20 adult trees $ha^{-1}$- which is the usual density In Senegal. The needs of a working ox have been estimated at 1500 U.F. a year. *A. albida* pasture can nourish 1.3 animals $ha^{-1}$ without affecting farm production. A daily ration 7 kg of pods to a cow of 250 kg is sufficient to obtain a daily gain of 0.7 kg of live weight or to supplement daily production of 5 l of milk. Leaves, young branches and green fruits not yet loaded with tannin are sought out by sheep and goats but only moderately by cattle. The bole wood of *A. albida* is used in Sudanese Sahel for the manufacture of artefacts, mortars and cooking utensils. Branches are used in the construction of huts, sheds and grain stores. The wood is attacked by borers but this is reduced if the branches are left submerged in ponds before using. The wood could be used for light carpentry, ordinary joinery and framing. The best treatment for obtaining pulp is the Kraft process but yield is poor, the mechanical characteristics of raw bleached pulp are mediocre and the paper obtained is porous.

277 GIFFARD, P.L. [**The role of *Acacia albida* in the improvement of soil in tropical arid zones.**] Role de *l'Acacia* dans la régénération des sols en zones tropicales arides. (1980) 41 1805-1810 [Fr, en, es, 8 ref.]

278 GILBERT, G.; BOUTIQUE, R. **Flore du Congo Belge et du Rwanda-Burundi**. Bruxelles (1952) pp. 145-169.

279 GILLESPIE, T. **Genetic variation in salt tolerance of four African *Acacia* species**. *Ph.D. Thesis, University of Wales* (1999) 209 pp. [En, 35 fig., 53 tab., 5 app., 371 ref.]

The objectives in this work were to develop a protocol for measuring tolerance of salinity for African acacias using *Acacia erioloba* and *A. nilotica*, to assess the likely levels of variation between populations using provenances of *A. karroo, A nilotica, A. tortilis* and *Faidherbia albida*, and, finally, to get an indication of the likely levels of within population variation using half-sib families of *A. tortilis*. Three provenances of *F. albida* were used, Gona-re-Zhou (Zimbabwe), Debre Zeit (Ethiopia) and Bignonia (Senegal). A growth room trial was set up with the three provenances with three replications of two salinity levels (0 and 200 mol $m^{-3}$) applied to 10 seedlings of each provenance. The traits measured were seedling height and diameter, number of leaves, number of abscission points, condition of terminal apex and survival. In the control treatment, the growth traits of Gona-re-Zhou and Debre Zeit were greater than Bignona. All provenances were affected adversely by the high salinity level but by the end of the experiment the reduction in growth and the loss of leaves was significantly less in the Bignona provenance. The slower growth and potential drought tolerance of this provenance may explain its greater tolerance of salinity.

280 GILLET, H. [**Observations on the causes of destruction of woody sahelian species and their resistance to depredations**] Observations sur les causes de destruction des ligneux sahéliens et sur leur résistance aux déprédations. Colloque sur les fourrages ligneux en Afrique, Addis-Abeba, 8-12 avril (1980) pp. 127-128 [Fr]

281 GIRI, J. [**The Sahel tomorrow : catasrophe or rebirth ?**] Le Sahel demain: catastrophe ou renaissance ? Editions Karthala, Paris (1983), pp. 270-271 [Fr]

282 GODA, S.E. **Pollen studies on *Faidherbia albida* in Sudan**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 25 [En, 2 ref.]

Confirms the pollen studies of many workers that show the distinctness of pollen of *Faidherbia albida* from other Acacia species.

283 GOLDSMITH, B.; CARTER, D.T. **Indigenous timbers of Zimbabwe**. *The Zimbabwe Bulletin of Forestry Research, Zimbabwe Forestry Commission* (1981) No. 9, 406 pp. [En]

Describes the wood anatomy, working properties and main uses of the 300 indigenous timbers from Zimbabwe. *Acacia albida* Del. is mostly found along the sandy alluvium of the large rivers (such as Zambezi) in Zimbabwe. The timber is described as light (560 kg $m^{-3}$) and with poor durability and is mainly used in light structural timber, crates, wood wool and for making canoe dugouts.

284 GOMES DE SOUSA, A. ***Acacia albida***. In *Dendrologia de Moçambique (Vol. 1) Instituto de Investigaçao Agronomia de Moçambique* (1996) 232-233 [Port]

285 GOSSEYE, P. **Introduction of browse plants in the Sahelo-Sudanian zone**. In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le.].* ILCA, Ethiopia (1980) 393-397 [En]

Germination of various browse spp. varied from 78% in *Combretum aculeatum* to 0% in some *Acacia* and *Atriplex* spp. Survival of seedlings was generally good. The use of root stocks and cuttings was disappointing. Root stocks had strike rates between 63% (*Acacia albida*) and 20% (*Ziziphus mauritiana*) and stem cuttings between 19% (*Grewia bicolor*) and 0% (most spp.). In general, local spp. responded better than introduced spp. When plants from these trials were planted out on a ranch, survival rates after 18 months ranged from 67% (*Bauhinia rufescens*) to 0% in several *Acacia* spp. and *Leucaena leucocephala*. Again, local spp. were better than exotics.

286 GOUDET, J.P. [**The balance of the natural environment in dry tropical Africa. Ligneous vegetation and desertification.**] *Bois et Forêts des Tropiques* (1985) No. 207, 3-15 [Fr]

Specifies the role of trees and of natural ligneous formations in dry tropical Africa - and the significance of their deterioration regarding forestry measures. Family plantations should be encouraged, as the intensification of fallow land planted with trees. There is a need for closer integration with other agricultural and pastural development projects. It appears that the struggle against wind erosion is based on the maintenance of a certain density of trees on the landscape, but scattered trees can create the problem of interfering with mechanised cultivation of the soil. *Acacia albida* is traditionally favoured, despite the essential problem of species regeneration and the protection of the young plants from browsing cattle.

287 GOUDET, J.P.; DEPOMMIER, D. [**Agroforestry: forestry and production systems, case studies.**] Agroforesterie: foresterie et systèmes de production, études de cas. Document de Travail, CTFT, (1983) 70 pp. [Fr, 73 ref.]

Review of the various uses of the tree and its products, and the risks posed by encroaching cultivation on the degradation of forest areas. Also presented are descriptive notes on agroforestry systems, including the Taungya system, and some examples of their application in certain African countries. The better woody species adapted to these systems are recommended, particularly *Acacia albida*, *Ziziphus mauritiana*, *Azadirachta indica* and *Eucalyptus*.

288 GOURLAY, I.D. **Age and Growth Rate Determination of some African *Acacia* species.** *M.Sc. Thesis, Department of Plant Sciences, Oxford University, United Kingdom* (1992) 130 pp. [En, 119 refs]

The age of most temperate tree species can be estimated accurately by counting the annual rings revealed by concentric circles in the wood anatomy. In the tropics and sub-tropics, this growth periodicity is seldom clearly defined. This research investigates whether any wood anatomical feature delimits annual periods in the African *Acacia* species. Most research on this topic has been based on sample trees from natural stands; the trees sampled for this study were taken from trees of known age. The radial cross-sections of wood samples from individual trees of known age of 21 African *Acacia* species, including *Faidherbia albida*, were examined for growth rings. These were apparent in most species, including *F. albida*, as narrow bands of marginal parenchyma filled with long crystal chains. The crystals were subsequently identified through the use of a scanning proton microprobe, as calcium oxalate ($CaC_2O_4$). Several other chemical elements were concentrated around this zone. The number of bands formed annually corresponded to the number of peaks in the annual rainfall distribution. Where the rainfall pattern was unimodal, one crystalliferous band was also laid down during the dry season; at lower latitudes where the rainfall pattern was bimodal, two crystalliferous bands were formed annually. Ring widths were highly correlated with the rainfall recorded in each wet season. These results suggest that the presence of marginal parenchyma bands and crystalliferous chains define growth phases in African *Acacia* species, and can be used for age determination. These findings applied generally to *F. albida*. The findings that were specific to *F. albida* follow. Acacias, including *F. albida*, show banded parenchyma of two types, apotracheal (independent of the vessels) and paratracheal (associated with the vessels). Both types can be broad and, in *F. albida* in particular, obscure the fine lines of terminal parenchyma that are independent of the vessels and relate to annual growth periods. In *Faidherbia albida*, however, the paratracheal bands produce patterns of decreasing and increasing frequencies at a growth ring boundary and, in this case, the feature is assists in identifying a growth ring zone. The correlation between the width of the annual growth rings in *F. albida* was much higher for the preceding than the current year which might be expected given the species deep rooting habit. Ring width was also well correlated with the annual minimum temperature for this species.

289 GOURLAY, I.D. **Growth ring characteristics of some African *Acacia* species.** *Journal of Tropical Ecology* (1995) **11** 121-140 [En, 64 ref.]

A study of the anatomical features of the wood of 19 species of *Acacia* and *Faidherbia* to determine their age. Trees of known age and management history were selected from east and southern Africa, and growth bands of marginal parenchyma determined. These were found to correspond to the number of peaks in annual rainfall distribution. Mean annual ring widths appeared to be similar for most of the Acacia species studied, between 6 to 7 mm of radial growth per year. Most of the specimens of *F. albida* were within this range, with an exceptional specimen from Malawi averaging 19.18 mm $yr^{-1}$.

290 GOURLAY, I.D.; KANOWSKI, P.J. **Marginal parenchyma bands and crystalliferous chains as indicators of age in African *Acacia* species.** *IAWA Bulletin* (1991) **12** (2) 187-194 [En, 27 ref.]

Sample discs were taken at approximately breast height from 11 trees of known age and management history representing six species of *Acacia* (*A. erioloba, A. fleckii, A. karroo, A. nilotica, A. tortilis* and *Faidherbia* [*Acacia*] *albida*). The trees came from Zimbabwe, Malawi, Kenya and Somalia. Radial cross sections of wood were examined for growth rings, which were apparent in most species, including *Faidherbia albida*, as narrow bands of marginal parenchyma filled with long crystal chains. The number of bands formed annually corresponded to the number of peaks in rainfall distribution. These results suggest that marginal parenchyma bands and crystalliferous chains define growth phases in African Acacia species, and may therefore be useful for age determination.

291 GRAINGER, A.; ESBENSHADE, H.W. **The development of tree crops for agroforestry systems.** Eighth World Forestry Congress, Jakarta, Indonesia, 16-28 October (1978) 11 pp. [En, 9 ref.]

*Acacia albida* is a species with great potential for dry areas, and is being planted in large areas in the Sahel where it is known to rejuvenate the soil. It is widespresd from southern Africa all the way to Cyprus, Israel and the Lebanon, growing in areas having an annual rainfall of between 250 and 1200 mm. Both leaves and pods are used for fodder, and it is particularly valuable for bearing its leaves in the dry season when other forage plants are leafless. An average of 135 kg of pods per tree has been reported from the Sudan, and the seeds can serve as human food. Its wood is used for both fuel and handicrafts. An appendix lists the comparative nutritional composition of selected tree crops and other foods,

including *Acacia albida*. An analysis of fresh leaves and pods from Niger and Tanzania are given below; all figures given as a % of dry matter.

| | Leaves (Niger) | Pods (Tanzania) | Pods (Niger) |
|---|---|---|---|
| Crude protein | 19.7 | 8.8 | 14.3 |
| Crude fibre | 19.6 | 24.6 | 24.7 |
| Carbohydrate | 51.9 | 61.7 | 53.2 |
| Crude fats | 1.6 | 1.4 | 1.5 |
| Ash | 7.2 | 3.7 | 6.3 |

292 GRINDLEY, D.N. **Investigation of the seed oils of some Sudan Mimosaceae**. *Journal of the Society of Chemical Industry, Transactions and Communications* (1945) **64** (5) [En, 5 ref.]

A brief description of the characteristics, principal constants and approximate compositions of the fixed fatty acids of *Acacia albida*, *A. sieberiana*, *A. verek*, *A. mellifera*, *A. seyal*, *A. arabica* and *Albizzia lebbek*. They contain a high percentage of unsaponifiable matter and no linoleic acid could be detected. The mixed unsaponifiable matter from these oils had an iodine value of 115 as determined by the Rosenmund and Kuhnenn method.

293 GUEYE, M. ***Acacia albida:* Nodulation by fast- and slow-growing rhizobia**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, J.R.]*. ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 149-150 [En, 4 ref.]

Reports for the first time on the isolation of three fast growing strains of *Rhizobium* in nodules of *Acacia albida*. Seedlings of *A. albida* were grown in soil from nine sites in central Senegal, and 25 *Rhizobium* strains isolated their nodules, most proving to be slow growing. It was assumed that they were all *Bradyrhizobium* strains. Seedlings of *A. raddiana [A. tortilis ssp. raddiana]* and *A. senegal* inoculated with the fast growing strains did not nodulate.

294 GUEYE, M.; NDOYE, I. [**Genetic diversity and nitrogen fixation of acacias.**] Diversité génétique et fixation biologique de l'azote chez les acacias. In *L'acacia au Senegal (edited by Campa, C.; Grignon, C.; Gueye, M.; Hamon, S.]. Actes de la reunion thematique sur l'acacia au Senegal, Dakar, Senegal, 3-5 decembre 1996.* (1998) 351-355, 464-465 [Fr, 8 ref.]

Intra- and interspecific variation in nitrogen-fixing capacity, nodulation, and type of N-fixing organism (*Rhizobium* or *Bradyrhizobium*) are briefly discussed for *Acacia* species. A fairly high N-fixing potential has been recorded for *Acacia mangium*, *A. seyal and A. raddiana*; and relatively low N-fixing potential has been noted for species such *as A. senegal, Faidherbia albida* and *A. pellita*. In Senegal, certain provenances of *F. albida* exhibited higher N-fixation rates.

295 GUEYE, M.; NDOYE, I.; DIANDA, M.; DANSO, S.K.A.; DREYFUS, B. **Active N2 fixation in several *Faidherbia albida* provenances**. *Arid Soil Research and Rehabilitation* (1997) **11** (1) 63-70 [En, 20 ref.]

For tree legumes, *Faidherbia albida* has a low symbiotic capability for a tree legume, and significant improvement is needed. An experiment was conducted in the greenhouse using the 15N isotope dilution technique to measure differences in the proportion of nitrogen derived from atmosphere (%Ndfa) and total N fixed (Ndfa) in seven *F. albida* provenances grown in an Arenosol soil in Senegal, and inoculated with *Bradyrhizobium*; *Parkia biglobosa* was used as the reference species. Total dry matter and N yield values were not significantly different among the provenances. In contrast, significant variability was measured in N2 fixation, with %Ndfa ranging from 0% in 2 provenances to 38% in the Kabrousse provenance. Total N fixed was also highest in Kabrousse (0.44 g N plant$^{-1}$) compared with the 0-0.26 g plant-1 fixed in the other provenances. Based on these results, Kabrousse was selected for further examination in the field (at the Mbao forestry station, east of Dakar, Senegal), where still higher % Ndfa values were obtained - 54, 58, and 54% at 3, 6, and 15 months after transplanting (MAT), respectively. These are higher than the commonly reported values of %Ndfa for *F. albida*, and indicate the potential of screening as a tool for obtaining higher N2 fixation in nitrogen fixing trees. Total N fixed, unlike %Ndfa, which remained fairly constant during the three harvest periods, increased from 0.54 at 3 MAT to 1.41 g N plant$^{-1}$ at 15 MAT.

296 GUILLARD, J. G. [**Assessment of the conditions of modernization of a village in north Cameroon**] Analyse des conditions de modernisation d'un village du Nord-Cameroun. Mouton & Co, Paris (1965) 502 pp. [Fr]

297 GUILLOTEAU, J. **Scheme for the improvement of the agricultural economy of Senegal**. *Sols Africains* (1954) **3** (2) 182-235 [Fr, En]

Based on the report of the Portères mission, Vol. III, carried out in Senegal at the end of 1952, gives an outline of a possible strategy for agricultural development in Senegal. Stresses the importance of *Faidherbia albida* in a mixed agricultural system in Senegal which can support up to 20 head of cattle per 100 hectares. Recommends the planting of *F. albida* in new areas at a density of 40 seedlings per hectare to be later thinned to

15 mature trees, within an overall farming system strategy to increase yields in many areas of North and Central Senegal.

298 GUINAUDEAU, C. [**The winds in Senegal**] Les brise-vent au Sénégal. Rapport F.A.O., Rome (1984) [Fr]

299 GUINET, P. [**New points on the role of pollen morphology in the classification of the genus *Acacia***] Données nouvelles sur le rôle de la morphologie du pollen dans la classification du genre *Acacia. C* C.R. Acad. Sc., Paris (1964) T 257 pp. 4823-4825.

300 GUINET, P.; LUGARDON, B. **Diversity of exine structures in the genus *Acacia* (Mimosaceae)**. *Pollen spores* (1976) (Recvd 1977) **18** (4) 483-511 [En]

The fine structure of the exine in the three pollen types found within the genus *Acacia* is described. When the pollen grains are without furrows or when they have pseudo-furrows (extra-porate pollen type), the exine structure is granular. When the pollen grains are colporate the exine structure is columellar. The granular structure of the exine is also found in the tribe *Ingeae* when the pollen grains are porate. A noteworthy exception is *A. albida*, whose natural relationships will remain difficult to determine. This species may be more appropriately placed in the tribe *Acacieae* than in the tribe *Ingeae*.

301 GUINKO, S. [**Traditiohnal treatment of some illnesses in the Bisa country (Haute-Volta)**] Traitment traditionelle de quelques maladies en Pays Bisa (République de Haute-Volta). In *Troisième colloque du CAMES. Médecine traditionnelle et pharmacopée africaines, Kigali, Rwanda 8-15 Octobre 1977.* Haute-Volta, Ouagadougou; Conseil Africain et Malagache pour l 5 Enseignement Supérieur (1977) 26-45 [Fr]

302 GUINKO, S. [**Contribution to the study of the vegetation and the flora of Burkina Faso**] Contribution a l'étude de la végétation et de la flore du Burkina Faso. Les reliques boisées ou bois sacres. Bois et Forêts des Tropiques, 2° trimestre (1985) No. 208 pp. 29-36 [Fr]

303 GUNN, C.R. **Fruits and seeds of genera in the subfamily *Mimosoideae* (Fabaceae)**. *U.S. Department of Agriculture, Technical Bulletin* (1984) No. 1681, 194 pp. [En]

Data is derived from extensive sampling of the species of all 64 genera of mimosoid legumes. Three keys provide for (1) the differentiation of mimosoid from other legume seeds, (2) the identification of mimosoid genera based on fruit and seed characters, and (3) the identification of mimosoid genera based on seeds alone. For *Faidherbia albida*, placed in the Acacieae tribe, a detailed illustrated description of fruit and seed characteristics is listed. Note is made of studies by Nongonierma (1977c, 1978a) whereby neither the fruit nor seed characteristics support separating the species from *Acacia*.

304 GUPTA, R.K.; SAXENA, S.K.; DUTTA, R.K. **Germination, seedling behaviour and phytomass of some *Acacias* in the nursery stage.** *Indian Forester* (1973) **99** (6) 352-358 [En, 4 ref.]

Seeds of *Acacia albida*, *A. senegal*, *A. tortilis* (ex Israel) and *A. verek* were sown in a loamy sand at the Central Arid Research Farm, Jodhpur. Subsequent observations made on germination percentage, seedling morphology and phytomass are tabulated. After 200 days the dry matter production in both the shoot and root of *A. tortilis* greatly exceeded that of the other species.

305 GWAZE, D.P.; STEWART, H.T.L.; SNIEZKO, R.A. **Variation in height growth and nodulation of *Acacia albida* and *A. erioloba* seedlings from Zimbabwe seed sources**. *Nitrogen Fixing Tree Research Reports* (1988) **6**, 34-36 [En, 5 ref.]

Seeds were collected from 16 open-pollinated parent trees of *Acacia erioloba* in Matabeleland North, and from 10 parent trees each of two provenances of *A. albida* (Mana Pools and Hwange). Seeds were scarified for 30 min with concentrated sulfuric acid before sowing two seeds per pot in August at the Matapos nursery, in a soil mixture made from soil collected from nearby termite mounds in an area with indigenous acacias (not *A. albida* or *A. erioloba*), mixed with coarse sand in the ratio 3:1; this in turn was mixed in the ratio 10:1 with soil from around the roots of a nearby *A. sieberiana* (to provide the *Rhizobium* inoculum). Germinants were thinned to one per pot when 4-5 cm tall. Height and nodule numbers were recorded 11 weeks after sowing. There were significant differences in height between families: the range for *A. albida* was 16.3-23.7 cm, and for *A. erioloba* 7.1-12.7 cm. The two *A. albida* provenances were not significantly different in height growth. Seedlings of *A. albida* were 64% nodulated while only 2 out of 240 seedlings of *A. erioloba* had nodules. For *A. albida*, mean nodules per seedling were 1.1-4.7, with mean nodule weight per seedling 5.7-38.0 mg; there were no significant differences among families; seedling height and nodulation characteristics were not related.

306 GWYNNE, M.D. **The nutritive values of *Acacia* pods in relation to *Acacia* seed distribution by ungulates**. *East African Wildlife Journal* (1969) **7**, 176-178 [En, 7 ref.]

An experiment to assess the selection of foodstuffs by cattle in dry areas of Kenya found that during the dry season the seeds and pods of *Acacia nilotica* ssp.

*subalata* constitued up to 65% of the dry weight food intake. It was estimated that 80-90% of the seeds would survive passage through the gut, suggesting that this is an important seed dispersal method for indehiscent pod species. From analyses of the ripe pods of three indehiscent species (*A. albida*, *A. nilotica* ssp. *subalata*, *A. sieberiana*) and one dehiscent species (*A. hockii*), it appeared that the attractiveness of indehiscent pods to animals was not due to high nutritive values relative to those of dehiscent types, although the carbohydrate-rich pods of *A. nilotica* were an exception. The accessibility, abundance and conspicuousness of indehiscent pods may be the explanation for their consumption in large quantities by cattle. Also, all indehiscent *Acacia* pods have, to a varying degree, a strong aroma which allows them to be detected from a distance. Gives chemical proximate analyses of *Acacia albida* pods and seeds collected at the Lake Manyara National Park, Tanzania, and at Kidepo National Park, Uganda.

307 HABISH, H.A. **Effect of certain soil conditions on nodulation of *Acacia* species**. *Plant and Soil* (1970) **33** (1) 1-6 [En, 14 ref.]

Reports on the effect of variation in soil moisture, temperature and pH on the growth nodulation and N fixation of *Acacia* species grown in sand. Five *Acacia* species (*A. albida*, *A. mellifera*, *A. orfota*, *A. senegal*, *A. sieberiana*) were initially tried and then only *A. mellifera* as they all showed similar responses. Growth and nodulation increased to an optimum of 15% soil moisture. With a soil temperature of 35°C nodulation was higher than 30°C (significantly more nodules produced). Nodulation only occurred between pH 6.5-9.0 and the optimal range was pH 6.5-7.0. Suggests that alkaline soils (pH 8.5-9.0) in Northern Sudan may tend to limit nodulation.

308 HABISH, H.A.; KHAIRI, S.M. **Nodulation of legumes in the Sudan. II. Rhizobium strains and cross-inoculations of *Acacia* spp**. *Experimental Agriculture* (1970) **6** (2) 171-176 [En, 9 ref.]

Describes and discusses the results of rhizobia cross-inoculation tests among 10 *Acacia* spp. (*A. albida*, *A. arabica*, [*A. nilotica*], *A. ehrenbergina*, *A. farnesiana*, *A. mellifera*, *A. orfota*, *A. polyacantha*, *A. senegal*, *A. seyal*, *A. sieberiana*) and cowpea (*Vigna sinensis*). The successful nodulation of cowpea with rhizobia from most of the *Acacia* spp., although non-reciprocal in some cases, confirmed *Acacia* as belonging to the cowpea cross-inoculation group. *A. arabica* and *A. sieberiana* nodulated with all the *Rhizobium* strains, but this may have been caused by contaminations. Every strain grew best at pH 6.5-7.0, less at pH 8.0, and little or not at all at pH 4.0-4.6. The growth of the rhizobia of cowpea, *A. mellifera* and *A. senegal* decreased at 35°C, but growth of the other strains reached a maximum at 30-35C. This suggested that the rhizobia of eight of the *Acacia* spp. are well-adapted to the warm dry conditions that prevail in the soils of the Sudan for 4-8 months every year.

309 HABISH, H.A.; KHAIRI, S.M. **Nodulations of legumes in the Sudan I. Cross inoculation groups and associated *Rhizobium* strains**. *Experimental Agriculture* (1986) **4** (3) 227-34 [En, 18 ref.]

Gives results of cross inoculation tests of 21 species of legumes in Sudan, including four species of *Acacia* (*A. senegal*, *A. seyal*, *A. albida* and *A. mellifera*). *Rhizobium* strains were isolated from active red nodules; which were later cross inoculated with the other species, and nodule formation, dry weight and nitrogen contents were recorded. *Acacia* species readily cross inoculated within themselves except *Acacia albida*, but not with other species. *A. albida* ineffectively produced nodules with *A. senegal* and *Vigna sineasis*. Dry weight and nitrogen contents of the plants increased in nodulating plants when compared with uninoculated plants.

310 HALEVY, G. **A study of *Acacia albida* in Israel**. *La-Yaaran* (1971) **21** (3/4) 97-89, 52-63 [En, He, 31 ref.]

Describes and illustrates the disjunct distribution and phenology of *Acacia albida* in Israel, comparing it with that in Africa. A phenological study of the species in 4 different climatic regions in Israel, revealed that in all sites the trees partially or fully defoliate in November, and in the winter (December to April) only in the colder sites did a second complete defoliation occur. Flowering was sparse with some flowers occurring throughout the year, but mostly in May to June and September to October. Few seed pods were found and most young trees grew from suckers. Gives the polyploid chromosome number of *A. albida* in Isreal as 2n = 52 (2n = 26 in Africa). Reproduction by suckers has allowed the tree to survive outside a tropical environment, on sites with widely differing ecological conditions. The probable migration routes from tropical Africa are discussed.

311 HALLIDAY, J.; NAKAO, P. **Technical note on the germination of leguminous tree seeds**. In *Simpósio sobre fixação de nitrogênio em árvores tropicais [coordinated by Dôbereiner, J.], 19-24 Sept. 1983, Rio de Janeiro, Brazil. Pesquisa Agropecuária Brasileira* (1984) **19** (Special issue) 231-234 [En, portugese]

Report is given on germination trials with mechanical or chemical seed pre-treatments on 33 leguminous species. *Acacia albida*, from Ethiopia (older than 10 months), gave 79% germination with mechanical scarification and 77% with immersion in concentrated sulphuric acid for 10 minutes. Scarification treatment of about three times the number of seeds required for an experiment is recommended as a rule of thumb when the germination percentage of seeds is in doubt.

312 HARMAND, J.M.; NJITI, C.F. ***Faidherbia albida* in northern Cameroon: provenance trials and crop associations.** In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, J.R.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 79-81 [En, 4 ref.]

Results of an agroforestry provenance trial established at Mouda Gazal, northern Cameroon where eight provenances (four local, four exotic) were established using a split block design with four replications. The intercropping treatments involved cropping rotations of groundnut, cotton and sorghum (improved varieties) on three-year rotations and local sorghum and cotton on two-year rotations. Crop yields and tree heights and mortality were measured. After five years the intra-provenance variability masked any differences between the six provenances from the Sudano-Sahelian zone, partly due to fractures in the lateritic horizon resulting in soil heterogeneity. Average height of 100 largest trees was 4 m indicating that the trees can develop well on fissured lateritic soil. Burundi provenance (east Africa) proved unadapted to the site. No positive effect was noted on crop yields, possibly masked by the fertilizer added. Planting the species at a fixed spacing of 10 x 10 m in a mechanically cultivated crop system would be feasible.

313 HARMAND, J.M.; NJITI, C.F.; BRUGIERE, D.; JACOTOT, N.; PELTIER, R. [**Plantings of *Faidherbia albida* in North Cameroon. Provenance trials and agroforestry associations.**] Plantations de *Faidherbia albida* au Nord-Cameroun. Essais comparatifs de provenances et associations agroforestières. In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Forêt, Montpellier, France (1996) 312 pp. 269-282 [Fr, en]

This article describes the results of tests on *Faidherbia albida* in northern Cameroon. The aspects examined were:- growth strategy in plantations; behaviour of various provenances; and association with a crop system. The growth strategy of *F. albida,* and in particular its slow early stages, constitutes an obstacle to the establishment of parklands in farming systems. During the first three years, the seedlings must be closely attended to, to avoid their destruction by farming activities. After this period, the parkland can be regarded as established. The species adapts well, with 850 mm of annual rainfall, to the ferruginous plateaus with fissured laterite slabs and very deep ground water. Ten years after planting on such sites, *F. albida* still does not influence the behaviour of associated crops. Seeds of Sudano-Sahelian origin, particularly those from Cameroon, represent the best choice for reforestation in the Sudano-Sahelian area of the country. Conversely, for the Sudano-Guinean zone, where the species is not yet present in the spontaneous state, the choice of provenances from the same ecological zone (southern Chad, southern Senegal) is broadly preferable to the use of seeds from northern Cameroon. Among the other recommendations for development, the authors propose the formation of *F. albida* parklands solely in lands that are continuously farmed in the form of line plantings. A spacing of 10m between lines is suggested so as not to get in the way of mechanized farming activities.

314 HARRINGTON, G. N.; WILSON, A. D. [**Methods of measuring the secondary production of woody forage**] Méthodes de mesure de la production secondaire de fourrages ligneux. Colloque sur les fourrages ligneux en Afrique, Addis-Abeba, 8-12 avril (1980) pp. 253-257 [Fr]

315 HARRIS, S.A.; FAGG, C.W.; BARNES, R.D. **Isozyme variation in *Faldherbia albida* (Leguminosae, Mimosoideae).** *Plant Systematics and Evolution* (1997) **207**, 119-132 [En]

Genetic variation was assessed in 30 populations (931 families) *of Faidherbia albida* (Leguminosae, Mimosoideae) from across its entire African range, using six isozyme loci identified by five enzyme systems. Among the populations studied a null allele was proposed to explain the absence of *Lap-1* activity in populations from southern and eastern Africa. The mean percentage of polymorphic loci per population, the mean number of alleles per locus and the mean genetic diversity within populations were 31.7%, 1.6 and 0.127 respectively. Genetic diversity was greatest in populations from West Africa and lowest in populations from eastern/southern Africa, with Ethiopian/Sudanese populations intermediate. The overall degree of genetic differentiation between populations ($Gg_{ST}$) indicated that approximately 56% of the enzyme variation resided within populations. Clustering of Nei's unbiased genetic distances calculated between all populations produced a dendrogram that generally followed the geographic distribution of the populations. Two major groups were identified that may be considered the eastern/southern African and the Ethiopian/West African clusters. Within the Ethiopian/West African cluster two sub-clusters could be recognised, one broadly corresponding to those populations from Ethiopia/Sudan and the other to those populations from West Africa. Patterns of genetic diversity have emerged that allow three hypothesis to be proposed regarding the present distribution of *F. albida:* (i) *F. albida* originated in the Ethiopian/Sudanian region, followed by extensive east-west movement (both by animals and man) along the nomad routes of sub-Saharan Africa and along the east coast of Africa; (ii) *F. albida* originated in West Africa and dispersed through the sub-Saharan region into Ethiopia and then into East Africa; (iii) *F. albida* originated in eastern and southern African and was later spread to West Africa by man and his. Evidence from the relative levels of genetic diversity in the three regions of the *F. albida* distribution identified, would indicate that a southern African origin of the

species is unlikely since genetic diversity is lowest in this area.

316 HARRISON, P. **The greening of Africa**. IIED - Earthscan, Paladin Grafton books (1989) 374 pp. [En, 13 pp. of ref.]

In drier areas the leguminous tree *Acacia albida* is an ideal companion for crops and livestock, tolerating rainfall as low as 300 mm $yr^{-1}$ where deep groundwater is available. Common in the plains around Debre Zeit in Shoa province, Ethiopia. Soil is enriched by the tree's nitrogen-fixing root nodules, by leaf fall and by the droppings of shade-seeking livestock.

317 HARSH, L.N.; MUTHANA, K.D. **Rooting media for vegetative propagation of *Acacia albida***. *Journal of Tropical Forestry* (1985) **1** (3) 275-276 [En, 2 ref.]

*Acacia albida* was introduced in 1979 from Kenya and has been observed to be fast growing with a mean annual increment in height of 90 cm. It has not flowered after six years of introduction. Branch cuttings 15 cm long, 0.75 to 1 cm in diameters were dipped in Seradix B growth hormones and placed in polythene bags filled with course river sand, sandy soil or a mixture of the two. After 20 days sprouting was observed in all three media but only 60% of cuttings rooted in the coarse river sand.

318 HASHIM, I.M. **Liveweight changes in sheep supplemented with seed pods of two leguminous trees in south Kordofan, Sudan, during the dry season**. In *Utilizations of research results on forage and agricultural by-product materials as animal feed resources in Africa [edited by Dzowela, B.H. et al.]. Proceedings of the first joint work-shop held in Lilongwe, Malawi, 5-9 Dec. 1988.* Addis Ababa, Ethiopia; PANESA/ARNAB ILCA (1990) 404-415 [En, 17 ref.]

Studied the nutritional value of the pods of *Acacia albida* (haraz) and *Dichrostachys cinera* (kadad), and their effects as supplementary feeds on intake and liveweight changes in sheep during the dry season. Crude protein and neutral detergent fibre constituents of haraz were 16.5% and 59.2%, and kadad were 10.9% and 53.1%. *In vitro* dry matter digestibility and *in vitro* organic matter digestibility were 43.9% and 45.8% for haraz and 50.5% and 48.1% for kadad respectively. Dry matter intake was 2.9 kg 100 $kg^{-1}$ of body weight and crude protein was 8.4 g 0.75 $kg^{-1}$ $day^{-1}$. Both supplements significantly increased liveweight over control, and sheep fed the haraz (*A. albida*) supplement gained significantly more liveweight than those fed with kadad.

319 HASHIM, I.M. **Assessment of haraz (*Acacia albida*) pods as a potential supplement for cattle**. *Tropical Grasslands* (1994) **28**, 127-128 [En]

320 HASSAN, A.S.; STYLES, B.T. ***Acacia albida* Del.** In *A Conspectus of Somali Acacias*. Oxford, United Kingdom; Oxford Forestry Institute (1990) 64-67 [En, 62 ref.]

Detailed botanical description of *Acacia albida*, found in Somalia only in the Dila valley (Woqooyi Galbeed and Togdheer), growing on alluvial valley soils with a high water table. It is, however, widespread in tropical and subtropical Africa from Senegal to Gambia in the west and to Egypt in the north east; southwards to Natal; also in Israel. *A. albida* is distinguishable by having falcate or coiled indehiscent pods, glands at the junction of every pair of pinnae and eglandular petioles, and is systematically isolated in the genus, lacking any close relatives. It differs from all the Somali (and indeed African) species in its large anthers that are eglandular and in its pollen morphology. Biological differences are also recorded. The species is therefore sometimes placed in its own genus, *Faidherbia*.

321 HEDBERG, I.; EDWARDS, S. **Flora of Ethiopia; *Pittosporaceae* to *Araliaceae***. National Herbarium, Addis Ababa Univ., Ethiopia and Dept. Systematic Botany, Uppsala Univ. Sweden (1989) p85 [En]

*Acacia albida* trees up to 30 m high, with rounded crown; bark rough, dark brown or greyish; branchlets straw coloured or whitish. Stipular spines up to 2 cm long, straight. Leaves with pinnae 3-10 pairs; rhachis with conspicuous gland at the junction of each pinna pair, but petiole eglandular; leaflets 6-23 pairs. Flowers yellowish-white, sessile or shortly pedicellate, in spikes 3.5-17 cm long. Calyx up to 2 mm long. Corolla up to 3.5 mm long. Filaments basally connate; anthers eglandular even in bud. Pods falcate or coiled, indehiscent, 6-25 x 2-3.5 cm, cream, bright orange or purplish-brown. A very important species in traditional agroforestry systems. In addition to the uses given for the genus, *A. albida* pods have been used as a soap substitute, bark extracts are used to treat toothache and the boiled seeds are edible. Previously in Ethiopia, planks for constructing large secure doors were made.

322 HELIN, W.H. **Irrigated agroforestry - the Luuq experience**. Mogadishu, Somalia; Church World Service (1989) 2 pp. [En, 2 ref.]

As part of a larger natural resources programme, multipurpose species such as *Leucaena leucocephala*, *Sesbania grandiflora* and *Acacia albida* were planted in 1982 in a small-scale species trial on a narrow band of alluvium (<500 m wide) along the River Jubba in SW Somalia. This is an area where irrigation is possible and many crops are grown. By 1984 several species, especially *L. leucocephala*, were growing well with irrigation. Local farmers were encouraged to participate at this stage, and seedlings of woody species (for windbreaks, woodlots, live fences, and fuelwood, fodder and fruit production) were raised in the nursery and distributed

free. An extension agent made contact with the farmers, encouraged the planting of trees with crops, and used a system of incentives (especially paying for labour to plant and protect young trees). The scheme progressed well. Beginning in 1988 the incentives were discontinued, apart from the provision of free seedlings to those who had raised trees successfully. Some 50-75 of the original farmers continued the scheme, and a survey of 33 of these was done in 1989; at the end of 1989 international assistance will cease. Some 55% of farmers sold poles and leaves, and 36% had raised trees for windbreaks. In 1984-85 *L. leucocephala* was the most commonly planted species (57%) with 14% *Eucalyptus camaldulensis*; in 1989 the respective figures were 38 and 23%. Most farmers planted trees in otherwise unused areas. Costs were low and returns good - mostly from the sale of construction materials (rather than fuelwood). Soil protection was also a factor in the decision to grow trees, 15% of farmers giving this as the main reason. Fodder production was also important. More farmers are now willing to pay for tree seedlings, and some grow their own.

323 HENTGEN, A. [**Forage trees in India: a chance for the rearing of ruminants.**] Les arbres fourragers en Inde: une chance pour l'élevage des ruminants. *Fourrages* (1985) No. 101, 105-119 [Fr, en]

The need for increased forage production in India, which it is estimated has 382 million ruminants, is considered. Forage crops represent only 4.4% of cultivated land. Two recent campaigns to establish and maintain forage trees in Rajasthan and Maharashtra are described. Under the arid conditions of Rajasthan only 11% of land is forested of which 66% is over-exploited and degraded. Planting fast-growing productive and palatable species such as *Leucaena leucocephala*, *Ailanthus excelsa*, *Azadirachta indica*, *Prosopis cineraria*, *Acacia albida*, *Tamarindus indica*, *Sesbania sesban* and *Zizyphus* spp. is recommended. Ensiling of foliage from *A. indica* and *Z. nummularia* was successful whereas other species were more suitable as browse, or for drying, cutting of branches or incorporation of leaves or buds into concentrate rations.

324 HERLOCKER, D.J.; BARROW, E.G.C.; PAETKAU, P. **A preliminary report on trial plantings of woody species in arid and semi arid Northern Kenya**. In *Proceedings of the Kenya National Seminar on Agroforestry [edited by Buck], 12-22 November 1980.* (1980) 511-580 [En]

Over 23 species were tested including *Acacia tortilis*, *Acacia albida*, *Casuarina equisetifolia*, *Conocarpus lancifolius*, *Tamarindus indica*. Germination rates especially for the *Acacia* spp. were low and often variable. Growth rates were also variable (ranging from nil to 0.94 m/yr). *A. albida* was not one of the best performers.

325 HERVOUET, J.P. ***Faidherbia albida:* a witness of agrarian transformation**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 165-169 [En, 9 ref.]

Describes the ancient use of *Faidherbia albida* parklands by Sudano Sahelian agrarian societies, drawing on interesting examples from Burkina Faso. The species is ubiquitous, yet now it is often not used or under-utilized in many agricultural systems. Its distribution is an indicator of past use and villages, as parklands are not found in recent settlements. Since the turn of the century the abandonment of intensive agriculture in *F. albida* parklands to a more extensive agriculture is traced to production norms defined by the colonizing countries rather than pre-existing agrarian structures. Only certain groups such as the Nioniossé in Mossi country retain the parklands. Establishment of the dense homogenous parklands requires a long term vision, as it is the descendants of those that tend them who will benefit. Examples of establishment are given such as the Bissa people who settled in Niaogho. Historically, after clearing, the land was dominated by *Parkia africana* but this has been succeeded by *F. albida* due to the presence of large herds and *P. africana* does not thrive on manured soil. But with colonization more land had to be cultivated and the tree was cut down to make mortars and pestles as cutting *Khaya senegalensis* was prohibited by the white man. Many people then left the area. Interestingly, a number of isolated groups have now started again re-establishing parks again throughout Burkina Faso without any outside intervention. This deserves more research.

326 HERVOUET, J.P. **From *Faidherbia* to bush cultivation changes and health degradation.** ??

Several Sudanese populations, notably in Upper Volta, adopted an intensive cultivation system with plantings of *Faidherbia albida*. Recent developments have lead to these techniques being abandoned. The dilution of people brings the risk of increases in endemic diseases like trypansomiasis (sleeping sickness) and oncherocercosis (river blindness). The aim of this article is not to establish a theory about cultivation of *F. albida* nor of the societies involved but to consider the abandonment of *F. albida* cultivation and alarming health implications for people in vicinity. It is important to look at the health factors, which have been ignored for a long time as result of a compartmentalisation of disciplines. Oncherocercosis is transmitted by fly called simulie (*Simulum damnosum*) which reproduces in river rapids in well oxygenated water laden with organic matter. The effect on the individual becomes more serious as the number of stings received increases and illness can lead to blindness. Where the density exceeds 50 inhabitants $km^{-2}$, the number of blind people remains lower than 5% and the population's survival is not threatened. Where there are less

than 35 inhabitants $km^{-2}$, the population is under sentence. Near rivers and streams, populations with agricultural systems with *F. albida* plantings which permit higher human densities put themselves beyond reach of strong endemicity, while communities practising extensive agriculture were sentenced on its disappearance. In abandoning plantings of *F. albida*, the bush multiplies and increases the contact between man and the tetse fly and man and the simulies fly. The space is not now fully cleared and controlled by man. Between fields, vegetation with trees and bushes survives along thalwegs. These bands of vegetation provide excellent shelter for tsetse and also very good dispersion routes for simulies which can cover 15 km between resting places and hunting grounds. The probability of individual being stung is therefore increased. In the last quarter of the 20th century there has been an abandonment of plantings and the development of extensive, often speculative, agriculture. The weakening of traditional political and religious authority, disappearance of physical insecurity, modification of demographic conditions, development of individualism and monetarism, adoption or new tools of production and priority increasingly accorded by these societies to consumption are among principal factors that have led to the change.

327 HETH, D.; BLUM, R.; WIRZBERG, B. **Tree introduction trials in the Negev**. In *Contributions on Eucalypts in Israel. National and University Institute of Agriculture, Ilanoth* (1967) Vol. 3, 55-65 [7 ref.]

Data is presented on elimination trials at 12 sites in the Negev desert, where of 86 species, varieties and ecotypes of the 37 *Eucalyptus* and *Acacia* spp. were planted in 1960-4, 12 are now listed as most promising (9 *Eucalyptus*, 4 *Acacia* and 3 *Casuarina* spp.). Although *A. albida* was noted as showing promising growth on Arad in Western Negev, it was too early to include it with the list of superior performers.

328 HIERNAUX, P. [**Inventory of potential tree and shrub forage in one region of the Sahel**] L'inventaire du potentiel fourrager des arbres et arbustes d'une région du Sahel malien. Méthodes et premiers résultats. Colloque sur les fourrages ligneux en Afrique, Addis-Abeba, 8-12 avril (1980) pp. 195-202 [Fr]

329 HIMSEL, H.H. **Traditional beekeeping in the Republic of Niger**. *Bee World* (1991) **72** (1) 22-28 [En, 5 ref.]

Describes beekeeping and the traditional methods of collecting and marketing of the products in the dry Sahelian country of Niger. Honey is harvested from wild colonies of *Apis mellifera jemenitica*, of the same species kept in grass hives and from wild colonies of stingless bees (*Meliponinae*). Amongst the most important bee forage species are *Acacia albida, A. nilotica, Bombax costatum, Ceiba pentandra, Guiera senegalensis,* and *Parkia biglobosa*. Honey can be harvested 2-3 times a year and production varies throughout the country and from year to year: an average of 1355 t/yr was estimated in 1986 but can be much less in a bad year. Beekeeping can increase the farmers annual income by 30-50% with little investment necessary. Honey and beeswax are much in demand and command good prices in the region.

330 HINES, D.A.; ECKMAN, K. **Indigenous multipurpose trees of Tanzania: uses and economic benefits for people**. FO:Misc/93/9 Working Paper, FAO, Rome (1993) [Fr]

331 HOCKING, D. ***Acacia albida* - the farmer's choice for semi-arid and arid zones**. Waimanalo, Hawaii, USA; Nitrogen Fixing Tree Association. *NFT Highlights* (1987) **87** (2) 2 pp. [En]

Notes are given on the botany, uses (principally as green manure, in intercropping, as fodder, and for various other products, including fuelwood, medicines etc.), ecology, seed treatment and establishment of this valuable nitrogen fixing tree.

332 HOEKSTRA, D.A. **Factors influencing the economic viability of three agroforestry systems in Eastern and Southern Africa**. In *Forest Ecology and Management Special Issue: Agroforestry research in the African miombo ecozone [edited by Maghembe, J. A.]. Proceedings of a regional conference on agroforestry research in the African miombo ecozone held in Lilongwe, Malawi, 16-22 June 1991.* (1994) **64** (2/3) 265-276 [En, 34 ref.]

Reviews three agroforestry systems in East and Southern Africa in terms of factors influencing their economic viability. They are the taungya (or shamba) system, the *Faidherbia albida* mixed intercropping system (carried out with scattered trees in fields, which may also be grazed), and hedgerow intercropping (alley cropping) system. Describes the benefits of the *F. albida* system and states that its productive roles (fodder, soil improver and fuelwood) can conflict with each other, since severe lopping of trees for fuelwood results in reduced canopy and pod production. Obviously the priority benefit depends on the farmer. While the costs of exploiting an existing system with large established trees is beneficial to most farmers, establishing a new system is more problematic given that trees take up to 10-15 years to become very productive. This period could be shortened considerably through use of earlier maturing trees by selection and breeding or by mixing alternative species which become productive sooner into the system. A critical factor for the long-term sustainability and potential expansion of the system is the time required to reap the benefits from newly established trees, thereby reducing the costs of establishment and protection.

333 HOEKSTRA, D.A.; TORRES, F.; RAINTREE, J.B.; DARNHOFER, T.O.; KARIUKI, E.M. **Agroforestry systems for the semiarid areas of Machakos District, Kenya**. *ICRAF Working Paper* No. 19 (1984) 28 pp. [En]

Report of one D&D case study based on the Kakuyuni catchment of the Yatta plateau in Machakos District. Kakuyuni is a densely populated area within agroclimatic zone 5 where farmers are more dependent on agriculture than on pastoralism. The soils of the catchment area have a low inherent fertility if the organic matter level is low, and the rainfall is typically bimodal with the October-December rains being more reliable. Overall farm productivity is low and appropriate technologies suggested include: 1. improving the productivity of the crop production system through conservation farming; 2. improving productivity of the livestock production system through improvement of feed and drinking water resources and veterinary services; 3. improving total cash income and its seasonal distribution. The specific agroforestry technologies recommenced are: 1. hedgerow intercropping using *Erythrina* spp., *Cassia siamea* and *Leucaena leucocephala*; 2. establishment of fodder browse shrubs/trees on grazing lands using *Prosopis* spp., *Acacia albida*, *Ziziphus* spp., and *Balanites aegyptiaca*, for pod production and other species for cut and carry system; and 3. windbreaks or live fences. The required on-station and on-farm agroforestry research designs are presented in detail.

334 HOROWITZ, A.; BAUM, B. **The arboreal pollen flora of Israel**. *Pollen et Spores* (1967) **9** (1), 71-76 [En, 5 ref.]

Description of the pollen grains and notes about 54 tree and shrub species which occur in Israel. *Acacia albida* is illustrated by a photograph of the polyad, dimensions about 50 x 100 μm composed of variable numbers of grains from 30 - 50. It is easily distinguished from other acacias in Isreal by greater number of grains in the polyad. The trees occur in wadi beds in Palestine, around the Lower Galilee, Esdraelon plain, Philestean plain, Judean mountains and the Jordon valley. It is insect pollinated.

335 HOSKINS, M.W. **Observations on indigenous and modern agroforestry activities in West Africa.** ?? (1982) 1-16 [En]

Describes traditional agroforestry systems in West Africa, castigating the modern approach aimed at improving the situation of the farmer, which tends to concentrate on those farmers with easy access to resources at the expense of smallholders with low capital input. Describes the new agroforestry approach that offers special advantages over traditional practices. The paper also gives some multipurpose trees (including *Adansonia digitata*, *Vitellaria paradoxa*, *Acacia albida* and *Parkia*) and describes shifting cultivation and the taungya system in West Africa.

336 HOUÉROU, H.N. Le. **The role of shrubs and trees in the management of natural grazing lands (with particular reference to protein production)**. Eighth World Forestry Congress, Jakarta, India, 16-28 October (1978) 24 pp. [En, 78 ref.]

Some species, including *Acacia albida*, play a determining role in dry tropical agro-pastoral ecosystems not only through their feed value but also in the maintenance of the agronomic fertility of these systems. Research shows that the shedding of its leaves equals in fertilization about 50 tons of manure per hectare/year for an average density of 50 trees/hectare, thus explaining the maintenance of the productivity of these agropastoral systems over centuries. Year long stocking rates of 400 kg of liveweight per hectare (or 3 million kcal/hectare) have been recorded in such systems with a high density of 50 trees/hectare, in addition to millet production of 1000 to 1500 kg of grain per hectare/year in Senegal under an average rainfall of 650 mm.

337 HOUÉROU, H.N. Le. **Chemical composition and nutritional value of browse in Tropical West Africa**. In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le.]*. Ethiopia; ILCA (1980a) 261-289 [En, 61 ref.]

A review of the literature for data on the chemical composition of different parts of 105 species of browse plants from Tropical West Africa. The basic analyses include crude protein and fibre, total minerals, total fat, silica, macro-elements and nitrogen free extracts (mainly carbohydrates). From these it was calculated that *Acacia albida* is a good forage which is high in Digestible Protein (mean DP = 10%), and energy (6.5 MJ) and a nutritional ratio of 108 (mean all browse species = 100). Stresses the need for browse to supplement the grasses in the dry season, dry grass not being able to meet livestock requirements. For an adequate maintenance diet, a minimum of 20% browse is required.

338 HOUÉROU, H.N. Le. **Planting and management methods for browse trees and shrubs**. In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le.]*. Ethiopia; ILCA (1980b) 351-359 [En, 56 ref.]

Examines the choice of ligneous species suitable for browse throughout the world, according to ecological and especially bioclimatic conditions of the areas to be planted. Propagation techniques are discussed, by direct drilling, planting out young plants, and propagation by cuttings. Planting out practices include soil preparation, plant spacing and density, watering and irrigation, fertilization and general maintenance. Management and utilization, feed value, agricultural value and yields are also covered. Plantations of *Faidherbia albida* in millet and sorghum or groundnut fields are recommended a planting density of 50 trees/ha, wider spacing encouraging fruit production. Maintenance includes corrective

pruning and complete protection from browsing in order to become strong enough to survive independently and develop a trunk. It is estimated that the average foliage production for a non-trimmed colony of *F. albida* is likely to be 20-25 kg/tree/year. At a rate of 50 trees/ha, this would afford a carrying capacity of 2.5 sheep/ha/year.

339 HOUÉROU, H.N. Le. **[Agroforestry techniques for the conservation and improvement of soil fertility in arid and semi-arid zones.]** Techniques agroforestieres pour la conservation et l'amélioration de la fertilité des sols dans les zones arides et semi-arides. In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le.]* Ethiopia; ILCA (1980c) 433-435 [Fr, 18 ref.]

Major agroforestry systems are listed and the *Acacia albida* system in Africa, fodder shrub plantations in the Mediterranean basin (including *Acacia* and *Atriplex* spp.), the Dehesa (mostly *Quercus* spp.), the effects of growing trees and grass together and methods of establishment and utilization are discussed.

340 HOUÉROU, H.N. Le. **The role of browse in the Sahelian and Sudanian zones.** In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le.].* Ethiopia; ILCA (1980d) 83-100 [En, 108 ref.]

Introduces the essential and multiple role in the balance of the Sahelian and Sudanian ecosystems by forage trees and shrubs. The classification of *Acacia albida* has a number of morphological, ontological and cytological characters which clearly distinguish it from the *Acacia* and more logically relate it to a monospecific genus of the Ingae family. It is an essentially Sudanian species, with optimum ecological conditions occurring on deep sandy soils between the 600 and 800 mm isohyets. Its ecology is similar in western and southern Africa. It grows as high as 1800-2000 m in the Ethiopian Rift Valley, where it is abundant, in the Blue Nile Valley and also in northern Somalia. The agro-pastoral system of apple-ring exploitation and millet and sorghum crops in terms of preserving soil fertility have been the object of many detailed research studies. From a pastoral point of view, *Faidherbia albida* makes excellent browse. The fruit is marketed in Sahelian and Sudanian countries for feeding and fattening sheep and prestige animals, and for family milk production. Nutritive values are as follows:-

| | Leaves | Pods |
|---|---|---|
| Crude Protein (%DM) | 15-20 | 10-15 |
| Net energy (MJ) | 6-8 | 5-7 |
| Digestible protein/FU | 100-180 | 20-80 |

341 HOUÉROU, H.N. Le. **The role of browse in the management of natural grazing lands.** In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le.].* Ethiopia; ILCA (1980e) 329-338 [En, 75 ref.]

Examines the importance of fodder shrubs in various ecological zones and their nutritive values. In the savannas in the arid and semi-arid sub-humid zones, *Acacia albida* as a ligneous species is an important component of natural grazing - playing a determining role in agropastoral ecosystems, not only through their feed value but also in the maintenance of soil fertility. Both leaves and pods are used by various kinds of livestock and wild herbivores. Sound management of ligneous rangeland requires optimum balance between grazing and browsing. Success has been demonstrated in the setting up of traditional peasant civilizations in West Africa based on *Acacia albida* and millet. Research has demonstrated that the shedding of leaves of *Acacia albida* is equivalent to a fertilization of about 50 tonnes of manure/ha/yr for an average density of 50 trees/ha.

342 HUGHES, J.F. **A summary of information available of *Acacia albida*.** Moshi, Tanganyika; Utilisation Division (1957) No. 2, 6 pp. [En, 3 ref.]

Gives details of a general description of *Acacia albida* in Tanzania, as well as its distribution, vernacular names, sawlog qualities and wood properties. While not as strong as most hardwoods, its recommended use is in building construction (especially when cut oversize) and for cheap joinery. Logs are very susceptible to attack by pinehole borers and staining fungi when green. Other uses mentioned are its pods as cattle food, the yielding of a good gum, and infusion of bark for diarrhoea treatment.

343 HUSSAIN, R.W. **Modelling for determination of biomass of *Acacia nilotica*, *Acacia albida*, *Acacia tortilis* and *Prosopis cineraria* in arid areas.** Peshawar; Forestry Res. Div., Pakistan Forest Institute. *Pakistan Journal of Forestry* (1989) **39** (4) 183-198 [En]

Energy crisis demands determination of total biomass for estimation of fuelwood from trees of different sizes. Biomass in green form of four species grown in arid conditions was determined using five growth models. Out of these, allometric model gave better results which was used for estimation of stem, branch and total weight separately of trees with varying diameter at breast height.

344 HUTCHINSON, J.; DALZIEL, J. M. **Flora of West Tropical Africa.** Second Editions revised by KEAY, R. W. J. Vol. I, Part II, Crown Agents for Overseas Governments and Administrations, London (1958) p. 499 [En]

345 IBRAHIM, A.M. **Genetic variation in *Faidherbia albida*: implications for conservation of genetic**

**resources and tree improvement**. *Tropical Forestry Reports Department of Forest-Ecology, University-of-Helsinki* No. 11, (1996a) 86 pp. [En, many refs]

Material from 11 provenances representing the central, western and southern parts of the distribution range of *Faidherbia albida* in Africa was studied. Pod and seed characteristics were measured and seedling development investigated both under normal and controlled environmental conditions. Field performance was evaluated for two years in three experimental plantations established along the rainfall gradient in the Sudan and isozyme patterns at 11 loci were analyzed. The results are in accordance with the previous discovery of two distinguishable ecological races. One, which appears to be endemic to the southern distribution range of the species, has larger and heavier seeds and pods, greater quantitative and qualitative growth potential, is more sensitive to drought and has a low isozyme diversity. The second race, which exhibits exactly the opposite characteristics, appears to be endemic to the western and central parts of the species' range (the Sahel). Clines of some morphological characters investigated were, however, shown in the riparian habitats of the central distribution range (the Nile). Two isozyme loci encoding superoxide dismutase (SOD-1 and SOD-2), which showed two different phenotypic patterns over the geographical range of the species were identified. One phenotypic pattern is confined to the Sahelian range and the other to the southern distribution range. The two patterns, however, were found to overlap in the central distribution range (north-eastern Ethiopia). Similar patterns were also observed in quantitative characteristics that appear to have selective value. This diagnostic feature of the SOD loci is regarded as indicative of a corresponding distribution of genetic variability over the species' range. Based on the results, recommendations are made pertaining to conservation, improvement and utilization of the species gene resources. The evolutionary history of the species origin and migration, and the present centre of diversity were inferred.

346 IBRAHIM A.M. **Conservation and utilization *of Faidherbia albida* Del. A. Chev. (syn. *Acacia albida*) gene resources**. In *Tree Improvement for Sustainable Tropical Forestry. Proceedings QFRI-IUFRO Conference, Caloundra, Queensland, Australia, 27 October - 1. November 1996 [edited by Dieters M.J; Matheson, A.C.; Nikles, D.G.; Harwood, C.E.; Walker, S.M.)*. (1996b) 404-408. [En]

This paper outlines the outcome of a series of investigations that involved genetic material collected from central as well as the two opposite ends of the range of *Faidherbia albida* (Del.) A. Chev. The aim was to bridge the gap in previous genetic work on the species and to provide an overview of the extent and organization of the species' genetic diversity. The results suggest that *F. albida* has a bimodal pattern of genetic variation. One variant is confined to the Sahelian range and the other to the southern distribution range. Based on the results, two ecological races were identified and their geographic distributions were approximately delineated. They overlap only in the area of high genetic diversity in Ethiopia, possibly its centre of origin. It is theorized that seed dispersal by animals may have contributed towards its genetic diversity in the Sahelian region whereas dispersal by water along the rivers might explain the lower genetic diversity found in the south of its range.

347 IBRAHIM, A.M.: FAGG, C.W.; HARRIS, S.A. **Seed and seedling variation amongst provenances in *Faidherbia albida***. *Forest Ecology and Management* (1997) **97**, 197-205. [En]

Seed and seedling morphology of *Faidherbia albida* was investigated in conjunction with isozyme analysis. Seeds from 19 seedlots representing central, western and southern parts of the distribution range were studied. The results are in accordance with the earlier discovery of two distinguishable ecogeographical races. The isozyme locus Sod-2 shows two different phenotypic patterns over the geographical range of the species. One phenotypic pattern was confined to the central and western parts of the distribution range (the Sahelian range) and the other to the southern part of the range, although the two patterns were found to overlap in north-eastern Ethiopia. A similar bimodal pattern of variation was also shown in the seed and seedling morphology; one phenotype appears to be endemic to the southern part of the distribution range, whilst the other appears to be endemic to the Sahelian range. Clines of some morphological traits investigated were also evident in the riparian habitat of the central distribution range (the Nile (N)). In practical terms, large-sized seeds were associated with southern African provenances which are in turn associated with riparian habitats. It is argued that, in this situation, greater embryonic capital gives the plants an advantage by favouring rapid establishment of canopies. This is in contrast to the West African populations which evolved under harsher conditions. Small seeds may have been a response to Sahelian habitats where there are greater environmental stresses. Greater heterogeneity in microsite conditions were matched with increased seed and seedling polymorphisms and morphology, and higher root:shoot ratios, in the Sahelian provenances compared with the relatively homogeneous southern African populations. The outstanding early performances of the southern African provenances may reflect both potential and liability of these genotypes as a target for achieving maximum productivity at planting sites. Greater RSR exhibited by Sahelian provs may be adaptation to greater water deficits.

348 IDENSOHN, M. **Mammal populations of the Sapi floodplain**. *The Zimbabwe Science News* (1982) **16** (4) 90-93 [En, 1 ref.]

Tabulates the mammal population densities recorded in the Sapi floodplain of the Zambezi river,

Zimbabwe, and supported the findings of Jarman, that the *Acacia albida* woodlands provides a richer and more prolonged supply of food resources than the surrounding mopane (*Colophospermum mopane*) woodlands in the dry season where average temperatures reach 39 C. The tree bears fruit in October and November and is still in leaf. Species with the highest densities recorded were impala, waterbuck and baboon.

349 INGRAM, C.L. **The afforestation of Dambos and lateritic soils in Malawi**. *South African Forestry Journal* (1984), 41-53 [En, 5 ref.]

Describes the species and provenance selections for dambos and lateritic soils in Malawi. *Acacia albida* has been tried in dambos (seasonally waterlogged areas, in this case mainly due to laterite), in two of three trails around Lilongwe and Chitipa, and while indicating mediocre early growth overall, in one trial it had a one year mean increment of 3 m equalling the best *Eucalyptus* species.

350 INGRAM, J. **The role of trees in maintaining and improving soil productivity: a review of the literature**. *Commonwealth Science Council Technical Paper* (1990) No. 279, 39 pp.; 7 pp. of ref. Also published as a chapter in *Agroforestry for Sustainable production. Economic implications [edited by Prinsley, R.T.]*. London, UK; CSC (1990) pp. 243-303. [En]

Topics covered include: definition and measurement of benefits (soil fertility, soil productivity, soil conservation, degradation, sustainable agriculture); reviews to date; evidence for improvement of soils by trees; effects of individual trees and shrubs on soils and crops beneath them (*Acacia albida*, *Prosopis* spp., and other examples of microsite enrichment under tree/shrub canopies); agroforestry systems research; processes by which trees affect soils (protection, conservation and increase of soil organic matter (SOM), above ground litter, below ground litter, factors affecting SOM decomposition and mineralization, increase in nutrient status, nutrient cycling, improved moisture status); tree selection and management; crop response; time; and levels of impact.

351 INSTITUTE DE RECHERCHE EN BIOLOGIE ET ECOLOGIE TROPICALE / CENTRE TECNNIQUE FORESTIER TROPICAL. [**Breeding of the genera *Acacia* and *Prosopis***.] Amélioration génétique des genres *Acacias* et *Prosopis*. *Annual Report, IRBET/CTFT Burkino Faso* (1985) 31-42 [Fr]

Trials of African provenances of *Acacia albida* in three climatic zones of Burkina Faso showed that, six months after planting, survival rates were good in regions of high and medium rainfall, but poor in the low rainfall zone. The local Burundi provenance was the best performer overall and showed good genetic potential. Average height decreased from the high rainfall zone to the low rainfall zone.

352 INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY (ICRAF). **Question: Suckers or seedlings?** *ICRAF Newsletter* (1988) No. 22, p.12 [En]

The author identifies the need for ways of increasing sustainable production through agroforestry interventions. At ICRAF's Machakos Field Station, various trials have been set up using 'stool beds' to determine the best methods of overcoming the re-establishment difficulties of *Faidherbia albida* woodlands. In particular, work has been carried out on planting seedlings and excavating root systems.

353 IRVINE, F.R. ***Acacia albida***. In *Woody plants of Ghana with special reference to their uses*. London, UK; Oxford University Press (1961) 321-322 [En]

Describes the distribution and habitat of *Acacia albida*, and also the wide range of uses found for different parts of the tree. Its foliage is a valuable fodder, and the pods also are a useful foodstuff. Powdered pods (with seeds) are used as a fish poison in the Rhodesias. Sapwood is used for pestles, mortars, canoes, and as firewood. The old bark is rich in tannin (28%). Root-bark on the Ivory Coast is used for leprosy, and as a liniment for pneumonia, and a bark infusion is used as a febrifuge for coughs and to assist difficult childbirth.

354 IRHO. [**A report on trials under kad**] Compte rendu des essais sous Kad. IRHO Senegal, Annual report, mimeo. (1966) Bambey, pp. 19-29 [Fr]

355 ISMAIL, A.M.A. **The significance of crown architecture in *Acacia albida* in the Sudan**. *Journal of Tropical Ecology* (1986) **2**, 51-54 [En]

Studies *Acacia albida* in Gezira area south of Khartoum. Leaf shedding occurred during the rainy season (June) from the upper branches of the crown downwards over a period of as much as a month. New leaves flush at the end of the wet season (Sept-Oct) and flowers appear. Results show that isolated trees have an anomolous crown shape in a south/south-west orientation. Other *Acacias* (*A. tortilis* and *A. nilotica*) had regular or asymmetric (wind direction orientated) shape. This confirmed findings of Werger and Ellenbroeck (1982) in Zambia who concluded that the phenological behaviour together with the position of the sun during dry season determined the asymmetry of *A. albida* crown.

356 ISSA, A.; GALADIMA, I.; MONTAGNE, P. [**The Gao-Dosso Forstry Project**] Projet forestier Gao-Dosso (FAC-CCCE). Rapport d'activité du 01/04/1981 au 30/09/1982, République du Niger, Ministère des Forêts et Faune (1982).

357 JACKSON, J.K. **Fung working plan for the period 1959/1968. Vol. I. General.** *Forest Bulletin (New Series), Forest Dept., Sudan* (1959) No. 3, 114 pp. [En]

A working plan for the forest reserves adjoining the Blue Nile River between Sennar Dam in the north and Roseires in the south. The main forest species of economic importance is *Acacia nilotica* ssp. *tomentosa* which characteristically colonizes areas that are subjected to annual or periodic inundations from flood waters. The river is typically bounded by banks of deep silt deposits (gerf) which slope gently on their landward sides down to level basins of silt layers over clay (maya). Beyond the basins are the eroded clay slopes of the plains (kerrib). The gerf is above normal flood level, but water is available by infiltration. The natural vegetation comprises dense *Ziziphus spinachristi* and scattered trees of *Acacia albida*, *Ficus sycomorus* and *Celtis integrifolia*. In the north of the area there are dense stands of *Tamarix aphylla*. The grass *Beckeropsis pirottae* is common in open places. The kerrib slopes are above normal flood level and carry a vegetation similar to that of the surrounding clay plain, *e.g. A. senegal*, *A. seyal*, *A. nubica*, *A. mellifera* and *Balanites aegyptiaca*.

358 JACKSON, J.K.; PEAKE, F.G.G. **Forestry Research in the Sudan, 1950 to 1954.** *Memoirs of Forestry Division, Ministry of Agriculture, Sudan* (1955) No. 7, 63 pp. [En]

Peake notes in the Entomology section that the seed of *Acacia mellifera*, *A. seyal* and *A. albida* all had Bruchid infestation and associated parasites. Also gives the life history of the Talh wood borer, *Sinoxylon senegalense* which mainly attacks felled wood of *A. seyal* but was also found in *A. albida* and *A. nilotica*. Details the practical control methods of the Talh borer.

359 JAGIELLA, C.; KÜRSCHNER, H. [**Atlas of Saudi Arabian woods**] Atlas der hölzer Saudi Arabiens. Die Holzanatomie der wichtigsten Bäume und Sträucher Arabiens mit einem holzanatomischen Bestimmungsschlüssel. Reihe A (Naturwissenschaften) Nr.20. Dr. Ludwig Reichert Verlag, Wiesbaden (1987) pp. 32-39 [G]

360 JAIYEOBA, I.A. **Amelioration of soil fertility by woody perennials in cropping fields: evaluation of three tree species in the semi-arid zone of Nigeria.** *Journal of Arid Environments* (1996) **33** (4) 473-482 [En, 30 ref.]

The effect of trees - two indigenous species, *Acacia albida* [*Faidherbia albida*] and *Parkia biglobosa*, and an exotic species, *Eucalyptus camaldulensis* - on soil properties was studied by comparing soil texture and chemical properties beneath the tree canopy, canopy edge, and outside the canopy, and by comparing changes in soil properties beneath the tree species. Topsoil (0-15 cm) texture was coarser, and organic matter and cation exchange capacity decreased with increasing distance from the three tree species. Nitrogen and some exchangeable cations also decreased with increasing distance from the indigenous species, whilst soil pH decreased with increasing distance from *E. camaldulensis*. The results indicate that *A. albida* improves soil fertility marginally more than *P. biglobosa*, but both these species have much greater benefits for soil fertility than *E. camaldulensis*.

361 JAMA, B.; GETAHUN, A. **Intercropping *Acacia albida* with maize (Zea mays) and green gram (*Phaseolus aureus*) at Mtwapa, Coast Province, Kenya.** *Agroforestry Systems* (1991) **14** (3) 193-205 [En, 25 ref.]

Long-term agroforestry demonstrations/trials using *Acacia albida* and other nitrogen fixing multipurpose trees/shrubs were initiated in mid-1982 to assess soil and crop productivity at a coastal lowland site characterized by low soil fertility, weed problems and consequent poor crop yields. Growth performance (height and diameter at breast height (d.b.h.)) of *A. albida* at eight densities and rotationally intercropped with maize and green gram (*Phaseolus aureus* [*Vigna radiata*]), crop grain yields, soil fertility changes and weed control were assessed for a five-year period (May 1982 to March 1987). A parallel-row systematic spacing field layout was used. Mean height and dbh of intercropped *A. albida* were respectively 140% and 24% higher than tree-only controls by the fifth year. Growth rate was low during the first year but increased in subsequent years giving mean height and dbh of 9 m and 10 cm, respectively, by March 1987. While differences in dbh were significant between treatments, those between stand heights were not. Crop yields were reduced in the intercropping treatments, especially under higher tree densities. This was attributed to shade, which also caused significant reductions in weed biomass. Soil fertility levels remained unchanged during the experimental period relative to the initial status, and differences between the inter-cropped *A. albida* plots and the tree- or crop-only controls appeared not to be significant. It is concluded that an understanding of the mechanism regulating leaf fall/retention phenomena in *A. albida* is crucial for determination of the intercropping potential of the species.

362 JAMA, B.; NAIR, P.K.R.; KURIRA, P.W. **Comparative growth performance of some multipurpose trees and shrubs grown at Machakos, Kenya.** *Agroforestry Systems* (1989) **9** (1) 17-27 [En, 23 ref.]

Data are presented on the growth rates of 29 multipurpose species or varieties, including *Acacia albida*, grown at the ICRAF field research station at Machakos, Kenya (a sub-humid to semi-arid climatic zone) for six years. The study started in Oct. 1981 and used seedlings at least 6 months old. All were intercropped with maize

and beans (*Phaseolus vulgaris*) twice a year, and recommended fertilizer types and rates were applied to the crops. Exotic species such as *Grevillea robusta*, *Sesbania grandiflora*, *Leucaena leucocephala*, *Cassia siamea* and *Sesbania sesban*, some of which were outside their traditional climatic zones, had larger diameters, heights and stem volumes (sometimes up to 130% more) than some of the indigenous species. Several exotic and indigenous species gave such a poor performance (either because of low ecological adaptation and/or pest and browse damage) that they were deleted from the trial and growth data are not given. These included *Acacia mellifera*, *Atriplex nummularia*, *Calliandra calothyrsus*, *Cassia alata* and *Cordeuxia edulis*. General ecological characteristics of some of the species tested are summarized in a table.

363 JIRU, D. **Evaluation of crop yield under *Acacia albida* shade and alley-cropping in semi-arid farms.** In *Proceedings of IAR/ICRAF national agroforestry workshop, Awasa, Ethiopia, 14-18 November 1988.* Addis Ababa, Ethiopia; Institute of Agricultural Research (1988) 33-37 [En]

A traditional farming system that holds crops, animals, and forest in harmony has been widely practised by smallholder farmers near Debre Zeit in Ethiopia. The most commonly-used tree in this system is *Acacia albida*. The distribution of the *A. albida* varies from single trees to clumps of continuous canopy formation in the farm. All trees in a farm are lopped every one to three years depending on growth and development of the coppice. Although the role of *A. albida* in soil improvement is known to the user farmers and agriculturalists, there are other minor factors that help increase the fertility of the soils, for example animal dung and bird droppings but, in this case, because the trees are lopped, they are less attractive to animals or birds. This study was initiated to evaluate the yield of agronomic crops in the immediate vicinity of *A. albida*:- to determine the optimum spacing of *A. albida* from information on yield responses; to observe the effects of shade on yield. The isolated trees studied were on black clay soil flats that has been cropped with tef and wheat. The crops were sampled on four axes at right angles at each other and more or less corresponding to the cardinal points and at four distances from the bole, 1.7, 6, 10, and 14 m. Overall, an increase in crop yield of 63% was found for a crop mixture under the tree canopy compared to open areas. Yield decreased as the distance from *A. albida* increased (*e.g.* in ratio 100:88:77:71 for Enkoy wheat)

364 JIRU, D. **Traditional agroforestry in Ethiopia with special reference on the direct and indirect role of trees in soil and water conservation.** Addis Ababa, Ethiopia; Forestry Research Centre [En, 7 ref.] ??

The paper sketches the integrated use of *Acacia albida* as a tree intercrop in cereal-based farming systems of middle altitudes. Crop yield is increased in the vicinity of the trees; at 3 m it is 40% higher than 14 m away. *A. albida* also provides shade, fodder, windbreaks, and is an excellent source of charcoal and high calorific fuelwood, of which production from the trees amounts to 30% of the total fuel consumption, without any sacrifice to the cereal crop yield.

365 JOLY, H. **The genetics of *Acacia albida* (syn. *Faidherbia albida*).** In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, J.R.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 53-61 [En, 27 ref.]

Reviews the current studies on the genetic resources of *F. albida* which are focusing on the differences between west African provenances and those from east and southern Africa. Describes the ecology, phenotypic and genetic variability, reproductive biology and organization of genetic diversity, and interactions with microorganisms. From trials mainly in Burkina Faso large provenance differences were found in the early growth rate, drought tolerance, phenology and degree of heterozygosity. The principal differences were low seed weight (west) compared to a high seed weight (eastern provenances); slow juvenile growth rate (west) compared with a fast rate in eastern provenances, although in drier west African sites eastern provenances failed after two dry seasons; and the level of heterozygosity was weak in the eastern provenances, the mean F value being 0.40 compared 0.27 for the western provenances. The article highlights the fundamental gaps that exist in the basic knowledge of reproduction, phenology, and water utilization that is needed for effective management of the considerable variability of the species.

366 JOLY, H.I. [***Acacia albida* or *Faidherbia albida*? Taxonomy and the potential of isoenzyme electrophoresis.**] *Acacia albida* ou *Faidherbia albida*? Taxonomie: potentialities de 1 5 ectrophorese isoenzymatique. *Revue Bois et Forets des Tropiques* (1991a) No. 230, 33-36 [Fr, 16 refs]

The taxonomic position of *Acacia albida* Del. or *Faidherbia albida* (Del.) A. Chev. is still under discussion. This species possesses a special combination of characteristics differentiating it from other African acacias. To show how isoenzymatic electrophoresis can be used to specify the phylogenetic relations between species, some experiments have been conducted with *A. albida*, *A. senegal*, and *A. tortilis*. The eight enzymatic systems studied fall into three categories:- those for which the number of loci involved appear to differ from one species to another; those for which the number of loci involved appear to be identical from one species to another but the profiles of whose species differ; and those which seem to involve the same number of loci for different species without any differentiation of the profiles of the species. A study in greater depth will be

necessary to specify, by incorporating a genetic approach, the phylogenetic position of *Acacia albida.* It will be necessary to adopt an all-inclusive approach to include morphological characteristics and immunological triats as well as isoenzyme genetic markers.

367 JOLY, H.I. **Population Genetics of *Acacia albida*.** *Bulletin of the International Group for the Study of the Mimosoideae* (1991b) No. 19, 86-95 [En, 13 ref.]

Used isozymes as genetic markers to study genetic diversity and breeding system of *Acacia albida.* Nineteen populations were studied (18 from West African countries), showing high levels of gene diversity within populations and a large differentiation between them; the major difference occurred between the west African populations and the one from Zimbabwe. The outcrossing levels of four populations from Niger was very high (0.893 - 0.996) for an insect-pollinated species considering the morphology of the inflorescence and the dynamics of flowering which would favour selfing. But the variation in outcrossing rates for different trees suggests that a flexible breeding system is operating involving some degree of self-incompatibility.

368 JOLY, H.I.; ZEH-NLO M.; DANTHU, P.; AYGALENT C. **Population Genetics of an African Acacia, *Acacia albida*. 1. Genetic Diversity of Populations from West Africa**. *Australian Journal of Botany* (1992) **40**, 59-73 [En, 29 ref.]

Used 14 isozyme systems as genetic markers; and the eight more reliable ones, involving ten loci, were used to study genetic diversity in 22 populations of *Acacia albida*, 20 from west Africa and two from Zimbabwe. Populations had a high gene diversity (or expected heterozygosity), ranging from 0.26 - 0.49 (average 0.45), much larger than found in many tropical trees including the Australian Acacias. Most populations exhibited a deficit in heterozygotes. Large differences in gene diversity were shown between the west African and Zimbabwe populations.

369 JUNG, G. [**Study of the influence of *Acacia albida* (Del.) on microbiological processes in the soil and on their seasonal variations**] Étude de l'influence de l'*Acacia albida* Del. sur les processus microbiologiques dans le sol et sur leurs variations saisonnières. *ORSTOM, Dakar, Senegal, Mimeo* (1966) 49 pp. [Fr]

Document comparing soil microbiological characteristics under *Acacia albida* foliage cover. Measurements were also made on physical (52% increase in clay, 51% increase in water holding capacity), and chemical (120% increase in cation exchange capacity, 91% increase in total soil carbon, 110% increase in total soil nitrogen) changes. There was a clear increase in invertase, dehydrogenase, asparaginase and respiratory $CO_2$. Carbon dioxide released upon soil moistening was also increased by 54%. Increased levels of fungi and actinomycetes, major decomposers of lignin, cellulose and organic matter, implied faster rates of organic decomposition, nitrification, and nutrient availability. A *Bacillus circulans* was found to fix nitrogen and to have a 20-fold higher population under the *Acacia albida.*

370 JUNG, G. [**The influence of *Acacia albida* on soil biology**.] Influence de l'*Acacia albida* sur la biologie des sols.*(DIOR). ORSTOM, Dakar, Senegal, Mimeo* (1967) 66 pp. [Fr, 46 ref.]

This as the concluding half of Jung's earlier report (Jung 1966), studying the effect of *Acacia albida* on the microbiology and the effects of possible microbial changes on soil fertility in Senegalese soils. Analysis was also made of the weight of litterfall and chemical analyses necessary to asses the flow of plant nutrients through the tree's soil system. Studies were made on leaf litter of *A. albida*, the prodominant shrub, *Guiera senegalensis,* and the predominant grass, *Andropogon,* to show their respective C/N ratios. In particular, experiments were carried out to elucidate the mechanisms for *A. albida*'s ability to increase soil nitrogen content.

371 JUNG, G. [**Nutrient mineral cycle in an ecosystem of the tropical, dry region: *Acacia albida*, Gray, ferruginous slightly leached soil (Preliminary note)**.] ?? *Ecol. Plant, Paris* (1969) **4** (2) 195-210 [F, e, g, 30 ref.]

This paper concerns the biogeochemical cycles of mineral elements in an ecological system of a dry tropical region: *Acacia albida* -tropical ferruginous soil (DIOR) and more precisely the storage of mineral elements by the plant and the return of these elements to the soil. Among the mineral elements studied, stored by the tree, it seems that N, K, and Ca are the most abundant. The litter, rich in nitrogen and ash elements but poor in phosphorus, is composed of fruits (47%), leaves and flowers (36%), dead wood and bark (17%); its rate of decomposition exceeds 100%. The retention of mineral elements in the surface horizon 0.5cm under *Acacia* is the highest for P and the lowest for K.

372 JUNG, G. [**Seasonal variations in the microbiological characteristics of a weakly leached, tropical ferruginous soil (DIOR), with or without the influence of *Acacia albida*.**] ?? *Ecol. Plant, Paris* (1970) **5** (2) 113-135 [F, e, g, 36 ref.]

Gives the results of analyses of soil samples from the experimental areas of the Centre de Recherches Agronomiques de Bambey (Senegal). Soils under *Acacia albida* showed greater biological activity in all seasons of the year than soils without *A. albida* cover. In the vicinity of the trees, the soils were more fertile, but they also showed greater seasonal fluctuations in physiochemical and biological characters.

373 JUNG, G. [**The influence of anaerobic and aerobic incubation on the composition of water-soluble extracts of tropical litters.**] ?? *Ecol. Plant, Paris* (1971) **6** (4) 297-317 [Fr, en, 18 ref.]

Gives the results of experiments with litter of *Acacia albida*, *Guiera senegalensis* and *Tectona grandis*. The water-soluble extract of *A. albida* had high contents of water-soluble C and N, and (in particular) of amino acids and sugars; that of *T. grandis* had high amounts of aliphatic and phenolic acids. The decomposition of water-soluble organic compounds was greater in aerobic than in anaerobic conditions. During anaerobic incubation, acidification of the water-soluble extracts took place, with the production of considerable amounts of lactic and succinic acids, resulting from anaerobic fermentation. During aerobic incubation, the pH of water-soluble extracts rose rapidly, the easily-decomposing litters (*A. albida* and *T. grandis*) producing the most alkaline extracts.

374 JUNG, G.; BRUCKERT, S.; DOMMERGUES, Y. [**Comparison of various water-soluble substances extracted from some tropical and temperate-zone litters.**] ?? *Ecol. Plant., Paris* (1968) **3** (3) 237-253 [F, f, g, e, 21 ref.]

Aqueous extracts of litter of *Pinus sylvestris*, *Calluna vulgaris*, *Festuca sylvatica* and *Fagus sylvatica* from the Vosges, and of *Acacia albida*, *Guiera senegalensis*, *Khaya senegalensis* and *Gmelina arborea* litter from Senegal were analysed for C, N, C/C ratio, aliphatic, phenolic and amino acids, and reducing sugars. Extracts from an $A_1$ horizon or a weakly leached, tropical, ferruginous soil, with and without an *Acacia albida* cover, were also analysed and compared. The tropical litter extracts were generally much richer than those of the temperate zone in aliphatic, phenolic and amino acids and in reducing sugars. The difference between the litters of *Festuca sylvatica* and *Calluna vulgaris* resembled the difference between those of hardwoods and conifers. Extracts from the A1 horizon under *A. albida* were richer in water-soluble substances than those from a similar horizon under *Andropogon gayanus*.

375 KABRE, A.; OLORY, N.; WEDRAOGO, F.X.; DIANDA, A.; BONKOUNGOU, G.E. [**Preliminary studies on symbiotic microorganisms of *Acacia albida* in Burkina Faso.**] Études préliminaires sur les microorganismes symbiotiques chez *Acacia albida* Del. au Burkina Faso. In *Trees for development in Sub-Saharan Africa. Proceedings of a regional seminar held by the International Foundation for Science (IFS), ICRAF House, Nairobi, Kenya, February 20-25, 1989.* Stockholm, Sweden; International Foundation for Science (IFS) (1989) 330-337 [Fr, 9 ref.]

Preliminary results are reported from laboratory and nursery studies on the isolation and selection of rhizobial strains and ectomycorhizal fungi of *Acacia albida* from soils from four localities (two trial sites, two *A. albida* parklands) in Burkina Faso. Nodulation of the plants occurred in all soils, with % of inoculated plants varying from 63 to 23. Spores of endomycorrhizal genus *Acaulospora* were isolated from two of the soils sampled.

376 KAMARA, C.S; HAQUE, I. ***Faidherbia albida* and its effects on Ethiopian highland vertisols.** *Agroforestry Systems* (1992) **18**, 17-29 [En, 21 ref.]

On a Vertisol under 850 mm rainfall, at an altitude of 1850 m, *Faidherbia albida* trees that occurred at 6.52 trees $ha^{-1}$, with a canopy cover that ranged from 97 $m^2$ $ha^{-1}$ to 229 $m^2$ $ha^{-1}$ were recorded. Studies on the lateral and vertical influence of the tree canopy on some physical and chemical properties of the soil, show apparent higher organic matter on the West side of the tree than the East due to accumulated litter blown by prevalent wind, and organic matter. N, P and K levels were higher under the tree canopy than outside for all directions and depths studied. Soil pH, exchangeable Na, CA, and Mg under the canopy and outside were similar. Available water capacity was 1.5 to 2 times more under than outside the tree. Noticeable increases in the silt fraction under the tree was recorded and discussed in relation to soil condition improvement and plant growth. [From the author's summary.]

377 KAMARA, C.S.; MAGHEMBE, J.A. **Performance of multipurpose tree and shrub species 28 months after planting at Chalimbana, Zambia.** In *Forest Ecology and Management Special Issue: Agroforestry research in the African miombo ecozone [edited by Maghembe, J. A.]. Proceedings of a regional conference on agroforestry research in the African miombo ecozone held in Lilongwe, Malawi, 16-22 June 1991.* (1994) **64** (2/3) 145-151 [En, 25 ref.]

A screening trial of 16 multipurpose tree and shrub species with potential for agroforestry was planted at Chalimbana near Lusaka, Zambia, in December, 1987. The trial was at 1280 m altitude on a sandy loam belonging to the luvisol-pharzem soil group, under unimodal rainfall (mean 880 mm). *Acacia albida* (Zambian provenance) had a 100% survival after 12 months along with most of the other species, but after 28 months was significantly slower than the faster species. *Sesbania sesban, Eucalyptus camaldulensis, Eucalyptus grandis, Leucaena leucocephala, Cassia siamea, Flemingia congesta [Flemingia macrophylla]* and *Acacia polyacantha var. campylacantha* grew fast reaching 3.5-6.8 m in height, 8.0 -14.3 cm in basal diameter, 10-57 $m^3$ $ha^{-1}$ standing volume and 19.0-57.7 t $ha^{-1}$ above-ground biomass (dry weight basis). *A. albida* reached 1.5 m in height, 3.1 cm basal diameter, 0.7 m canopy width and 4.5 $m^3$ $ha^{-1}$ standing volume and 1.17 t $ha^{-1}$ above-ground biomass (dry weight basis).

378 KARSCHON, R. ***Acacia albida* Del. in Israel and the Near East**. *La Ya'aran II* (1961) 4-7 [En, 10 ref.]

*Acacia albida* has been recorded in Upper Jordan Valley, Lower Galilee, Coastal Plain, Judean Mountains. It possesses a wide range of ecological adaptability occurring from -270 m to 300 m above sea level, mean annual rainfall from 300 to 550 mm and grows on a wide range of soils (dune sand, basalt and heavy alluvial soils. Also found on steep slopes away from water courses. Fifty-year-old tree recorded on heavy alluvial soil - 6 m high, dbh 42 cm.

379 KARSCHON, R. **On the occurrence of *Acacia raddiana* Savi and *A. albida* Delile in Jericho**. *Boissiera* (1975) **24**, 311-312 [En, fr, 6 ref.]

Discusses the possibility that the Lower Jordan Valley is the only area in the Middle East where the ranges of *Acacia albida* and *A. raddiana* Savi overlap. The Jordan Rift Valley is the southernmost occurrence of *A. albida* in Israel.

380 KARSCHON, R. **Clonal growth patterns of *Acacia albida* Del.** *Bulletin, International Group for the Study of Mimosoideae* (1976) **4**, 28-30 [En, 6 ref.]

A clone formed by root suckers of a single planted tree of *Acacia albida* is described; after 50 to 60 years its suckers had spread over a radius of 22 m with a potential size of 0.15 ha. In Israel, reproduction from root suckers appears to be the rule rather than the exception, whereas in Africa reproduction by seeds and not suckers is usual.

381 KASSIMANI, M.A. **Observations on the trials of some exotic species in Somalia**. *Somali Range Bulletin* (1983) No. 14/15, 71-78 [En]

Urgent calls have been made in Somalia for the identification of multipurpose trees to be introduced on a large scale to satisfy and meet the needs of fuelwood adequately. Trials of some exotic species were carried out at the Afgoi and Balcad nurseries, including *Sesbania grandiflora, Swietenia spp. Gmeliana arborea, Acacia arabica, A. albida, Dalbergia sisso, Punica granatum, Mangifera indica, Anacardium occidentale, Ziziphus jujuba* and *Cordeauxia edulis. Acacia albida* seeds were sown on 5/3/1983. Those soaked for 24 hours with hot water germinated after 3 days. The untreated seeds germinated after 23 days. Once the roots reach underground water, it was found to be the fastest growing of the *Acacia* species.

382 KERHARO. J.; ADAM. J. G. [**Traditional Senegalese pharmacopoeia**] Pharmacopée sénégalaise traditionnelle. Plantes médicinales et toxiques. Ed. VIGOT FRERES, Paris (1974) pp. 557-560 [Fr]

383 KERHARO, J.; PACCIONI, J.P. [**An old Senegalese remedy fallen into oblivion. The remedy of Joal Garab Diafan.**] Considérations d'actualité sur un vieux remède sénégalais tombé dans l'oubli: le remède de Joal (Garab U Djoala ou Garab Diafan). *Journal d'Agriculture Tropicale et de Botanique Appliquée* (1974) **21** (10-12) 345-350 [Fr, 16 ref.]

Describes three different traditional preparations for Joal's remedy, an old Senegalese herbal medicine for all chest ailments. The parts and the plants are listed, some plants feature in all three preparations, some in two and some only in one; the bark of *Acacia albida* only features in Sebire's list. The preparations made from the bark and roots of *A. albida* are currently used as a broncho-emollient and febrifuge in folk medicine. Only known qualities are the richness of tannin in the bark (28%) and the pods (5%). The three preparations are similar despite some variation, and all the constituents are pharmacologically active, although some are not recognized for chest ailments by modern medicine.

384 KERR, G.R.C. **Gawo: the ideal farm tree**. *Farm and Forest* (1942) **3**, 72-75.

Gawo (*Acacia albida)* is found mainly on farmlands and on the sites of abandoned villages. Leaves and fruits provide excellent forage for stock in the dry season. It is leafless while crops are growing, and its leaffall provides a valuable top dressing to the soil at the time cereal crops are sown. The tree develops a very long tap root and draws its moisture from the subsoil. The wood is used for canoes and articles in local use, and is very susceptible to attack by borers and termites. The characteristics of the tree are described briefly.

385 KESSLER, J.J. **Agroforestry in the Sahel and Sudan Zones of West Africa**. *BOS Newsletter* No. 29, Vol. 9 (1) (1990) 27-33 [En]

Attention is drawn to some ecological issues that should be taken into account when integrating trees with agricultural land-use. Afforestation has been a major strategy to regenerate a degraded environment and supply fuelwood. This started with conventional regularly spaced plantations but agroforestry is now being propagated as the way to integrate forestry activities with agriculture as it is supposed to serve both to protect the environment and to enhance production. Contrary to many sayings, trees have most of their roots in the upper soil layer and they compete with crops for available water. *Acacia* (*Faidherbia*) *albida* is an exception and has a long taproot. Many expectations of agroforestry for improving soil fertility are based on studies of *A. albida* under which crop yields have been shown to be higher than they are in the open field. However, its occurrence is limited to areas where there is a groundwater table that can be reached by the roots. Further, the higher fertility under the trees may be due to a redistribution of nutrients from a wide area by the extensive root system that concentrates the nutrients in the tree litter. The crops can utilize this increased fertility because the tree is leafless in

the cropping period and does not compete. Soil fertility is additionally enhanced by livestock that feeds and rests in the shade of the trees and deposits dung in the dry season. Nitrogen fixation from the atmosphere cannot be expected to contribute much since root nodules are rarely found. Young *A. albida* trees establish themselves on fertile spots, rather than cause soil fertility, and often fail on degraded sites. It is emphasized that most of the protective and regulating functions of trees concern the forest ecosystem as a whole. Tree planting may actually increase soil erosion if they shade out the herb layer and have a shallow root system. Farmers will only plant trees if the economic benefits are clear. For successful development of agroforestry practices, farmers must be given full responsibility for their forest resources not only in their croplands but also in the silvopastoral zone.

386 KESSLER, J.J.; BONI, J. [**Agroforestry in Burkina Faso. Assessment and analysis of the situation.**] L'agroforesterie au Burkina Faso. Bilan et analyse de la situation actuelle. *Tropical Resource Management Papers* (1991) No. 1 144 pp. Joint publication with Ministere de l'Environnement et du Tourisme, Direction Forets et Reboisement, Ouagadougou, Burkina Faso. Netherlands; Agricultural University Wageningen. [Fr, 61 ref.]

The results are presented of a cooperative study programme set up between the Agricultural University Wageningen (UAW) and the Burkina Faso Ministry of Environment and Tourism (MET), to evaluate agroforestry in Burkina Faso. The aims of the programme were the exchange of information between institutions in Burkina Faso and members of CILSS, defining an effective agroforestry programme for Burkina Faso, and identifying necessary areas of research. After an introductory section describing the programme and summarizing the main characteristics of Burkina Faso (topography, geology, climate, soils, hydrology, vegetation, population, and assessment of the use of wood) there are five other parts. (1) Agroforestry systems in Burkina Faso - an account of the agrosilvicultural and silvopastoral systems in use (shifting cultivation, fallow systems, trees in farm fields, and the 'parc arbore' - a system of dispersed trees in farm fields). (2) Agroforestry techniques under study in Burkina Faso (the 'parc arbore'; improved fallow; live fences; shelterbelts; corridor systems; silvopastoral techniques; forestry as a means of soil and water conservation; and forest villages and the method of taungya). (3) Conclusions and recommendations. (4) References. (5) annexes. The annexes are (i) a list of the sites studied, (ii) details of the species planted and the systems in which they were used, (iii) a study of the influence of *Acacia albida, Butyrospermum parkii* [*Vitellaria paradoxa*] and *Parkia biglobosa* on the growth of sorghum, (iv) a study of root systems in live fences, and (v) a study of factors affecting natural regeneration.

387 KHAN, F.A. **Nematicidal potentials of some naturally-growing medicinal plants against Pratylenchus zeae**. *Revue de Nematologie* (1990) **13** (4) 463-465 [En, 16 ref.]

Of the six plant species tested in pot experiments, incorporation of leaves of *Abrus precatorius* allowed the highest multiplication of *Pratylenchus zeae* population on *Capsicum frutescens* cv. PL 2289, while *Azadirachta indica* allowed the lowest. *Acacia albida, Albizia adianthifolia, Cnestis ferruginea* and *Tamarindus indica*, exhibited nematode toxicity to varying extents in between these two values. There was a direct relationship between the dose of amendment (25, 50 and 100 g $kg^{-1}$ soil) and plant growth.

388 KHAN, M.A.W. **Single tree growth statistics for *Acacia albida* (along the Blue Nile in Gezira circle)**. *Volume tables. Pamphlet For. Res. Educ. Proj. For. Dept. Sudan* (1965) No. 14, 16 pp. [11 ref.]

Tables show stem and branch volumes against dbh and gbh based on data from 302 trees.

389 KHONJE, D.J. **The potential of *Leucaena leucocephala* in the agroforestry systems of Malawi**. In *Trees for development in Sub-Saharan Africa. Proceedings of a regional seminar held by the International Foundation for Science (IFS), ICRAF House, Nairobi, Kenya, February 20-25, 1989.* (1989) 143-149 [En, fr, 12 ref.]

*Leucaena leucocephala* and several other tree species [including *Faidherbia albida*] are being evaluated in Malawi in different cropping systems with food crops such as maize. An alley cropping experiment done in 1981-84 showed no significant reductions in maize yields after two seasons when it was grown in association with *L. leucocephala*, while significant reductions in yield were observed when the crop was grown with *Gmelina arborea* (yield 4898 kg/ha) and *Eucalyptus camaldulensis* (yield 6235 kg/ha); maize yield in monoculture was 8511 kg/ha, with *L. leucocephala* it was 8642 kg/ha, and with *Acacia albida* 9029 kg/ha.

390 KIBON, A; ORSKOV, E.R. **The use of degradation characteristics of browse plants to predict intake and digestibility by goats**. *Animal Production* (1993) **57** (2) 247-251 [En, 16 ref]

A study to determine whether the degradation characteristics of five browse species (*Acacia albida, Tamarindus indica, Entanda africana, Anogeissus leiocarpus* and *Sterculia setigera* ) measured by the nylon bag technique or the *in vitro* gas technique could be used to predict their nutritive values. Trial was conducted with 25 male Borno goats, weighing 16 kg at 15 months old, at the University of Maiduguri, NE Nigeria, with fresh cut foliage. Dry matter (DM) intake was measured over 16 weeks followed by a digestion trial with five goats in a 5 x 5 Latin square

with 10 days' adaptation and 5 days' measuring. The DM intakes, apparent digestible DM intakes and growth rates were 0.60 kg $day^{-1}$, 0.43 kg $day^{-1}$ & 55 g $day^{-1}$ for *A. albida*, among the highest for the five species tested. The results after multiple regression analysis suggest that it may be possible to predict DM and apparent DM intakes of browse by goats from the rumen degradation characteristics.

391 KIDD, A.D.; ALEXANDER, M.J.; PHILLIPS-HOWARD, K.D. ***Faidherbia albida* on mine spoils in the tin mining region of the Jos plateau, Nigeria**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, J.R.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 177-1980 [En, 5 ref.]

A pilot study on one tree of *Faidherbia albida,* indicated that it had potential for reclaiming tin mine spoil heaps on the Jos plateau for farming, as an alternative to using *Eucalyptus spp.* In the follow up study, soil was sampled from under two trees in four mining sites, but soil fertility was not significantly different under compared with outside the canopies. Farmer interviews indicated that while the tree "produces fertility" and "makes the soil soft" was known and that the tree was used for a range of uses they ranked it bottom with *Eucalyptus camaldulensis* of a table of preferred trees principally because the other trees all provided human food (fruit and oil).

392 KIREGER, E.K.; BLAKE, T.J. **Genetic variation in dry matter production, water use efficiency and survival under drought in four *Acacia* species studied in Baringo, Kenya**. *Advances in Geoecology* (1994) **27**, 195-204 [En]

Total dry matter productivity, transpiration rate and their ratio, called water use efficiency (WUE) of 6-month-old potted seedlings of four dryland *Acacia* species were compared under irrigation in Baringo. Genetic variation in water use was measured by lysimetry and compared with productivity and survival to determine the ecophysiological basis of variation. Survival was assessed by calculating the number of days for 50% of the seedlings to die ($LD_{50}$). Significant genetic variation among the species of *Acacia* in dry matter production, water use efficiency and survival under drought was observed. Although dry matter production was not correlated with WUE, species with a higher WUE (*A. tortilis* (Forsk.) Hayne and *A. albida* Del.) had higher survival rates under drought but varied from higher to lower productivity respectively. The more water efficient species (*A. tortilis* and *A. albida*) allocated relatively more biomass to the roots than the less water-efficient species (*A. xanthophloea* and *A. nilotica*). *A. xanthophloea* transpired 50% more water than *A. albida*; *A. albida* had the lowest average diurnal rate. It is suggested that a strong potential exists for matching higher yielding *Acacia* species (*A. tortilis* and *A. xanthophloea* Benth.) to sites of higher and lower water availability, respectively based on their WUE. With judicious selection of species, tree productivity could thus be enhanced. Selection of tree species such as *A. tortilis* will allow a high dry matter production to be combined with a high WUE thereby maximizing both biomass production and water use in a dryland environment. Evidence is presented correlating dry matter productivity with dehydration avoidance ability due to low conductance to water vapour, enhanced root growth and the ability to control leaf area development.

393 KIRIINYA, C.K. **A study of *Acacia albida* Del. with reference to community afforestation**. *M.Sc. Dissertation, Science in Forestry, University Dar es Salaam* (1983) 1-125 [En, 53 ref.]

This thesis reviews the potential of *Acacia albida* for agroforestry in semi-arid areas of the tropics. The study was conducted in Morogoro, Tanzania and has six main objectives: to develop seed pre-treatment procedures that will ensure even and high-percentage germination; to ascertain the most appropriate plant size and age for transfer to the field from the nursery; to assess survival and early growth performance; to monitor early biomass production; to check the development of nitrogen fixation during the early months of growth; and to evaluate the fields of food crops (maize and beans) grown among the young trees of this species. The results will assist in the promotion of *Acacia albida* for use in afforestation in areas where there are shortages of fuelwood and other tree products.

394 KIRIINYA, C.K. ***Acacia albida* Del.; A potential species for nitrogen fixation**. *East African Forestry Journal* (1988) **53** (4) 225-227 [En, 9 ref.]

Increased yields of farm crops in the vicinity of *Acacia albida* suggest an influx of nitrogen into agricultural systems caused by these trees, and hence a high potential for land reclamation through nitrogen fixation. Experiments using acetylene reduction and root nodule biomass determination methods on *Acacia albida* seedlings 25-30 cm in height showed that nitrogen can be fixed at the rate of approximately 0.03-0.20 g N per year per seedling. This suggests comparability with the rates of *Leuceana leucocephala.*

395 KIRMSE, R.D.; NORTON, B.E. **The potential of *Acacia albida* for desertification control and increased productivity in Chad**. *Biological Conservation* (1984) **29** (2) 121-141 [En, 43 ref.]

Reforestation using *Acacia albida* has been proposed as a mechanism for combating desertification trends in the Sahel. This tree is characterized by a deciduous habit in the wet season; it is valuable for fodder, as a hardwood in woodwork industries, and for enhancing soil fertility of cropland. A three-year project for the

establishment of *Acacia albida* plantations in cultivated fields in central Chad is described.

396 KIRMSE, R.D.; NORTON, B.E. **The Potential of *Faidherbia albida* for desertification control and increased productivity in Chad**. In *The Improvement of Tropical and Subtropical Rangelands [edited by the Board on Science and Technology for International Development]*. Washington, DC, USA; National Academy Press (1990) 350-365 [En, 32 ref.] [En]

397 KLEIN, R. [**Clearing of farmlands in the sahelo-sudanian region of Africa**.] Le défrichement et le débroussaillage des terrains de culture en zone sahélo-soudanienne d'Afrique. Observations faites au CRA Bambey sur les procédés chimiques. *Bull. Agron. Inst. Rech. Agron. Trop. et Cult. Vivières* (1962) **18**, 7-13 [Fr, en, es.]

Describes traditional shrub clearing methods compared with mechanical and chemical techniques. An experiment was undertaken to clear saplings and isolated trees of cadde (*Faidherbia albida*) with an organic weed-killer, a mixture of 2-4-D and 2-4-5-T. The only effective treatment was to cut the species at 20 cm from the base or lower and apply the herbicide to the wounds. The concentration applied was 0.5 l to 75 l of water. A single treatment was sufficient to kill the trees.

398 KOKWARO, J.O. **??** In *Medicinal plants of East Africa*. Nairobi, Kenya; East African Literature Bureau (1976) 123 [En]

A decoction of the bark of *Acacia albida* is drunk as a cure for coughs, and also as a cupful twice a day for diarrhoea.

399 KOLBERG, H. **Acacias of SWA/Namibia**. SWA-Herbarium P/sak 13184 P/bag, Windhoek, 9000 (1989) 30 pp. [En, Af, 4 ref.]

*Acacia albida*; probably the largest of the *Acacias* in South West Africa/Namibia, reaching up to 30 m and with good specimens found along the Kuiseb, Swakop, Okahandja and Omaruru Rivers. The combination of straight, paired thorns and cream flower-spikes is unique among the *Acacias*. The tree is a protected species in SWA/Namibia under the forestry Act.

400 KORDOFANI, M.; INGROUILLE, M.J. **Patterns of morphological variation in the *Acacia* species (Mimosaceae) of northern Sudan**. *Botanical Journal of the Linnean Society* (1991) **105**, 239-256 [En, 19 ref.]

A numerical taxonomic review was carried out on 51 morphological characters from 12 *Acacia* species (including *A. albida*) occurring in northern Sudan. Twelve sites were sampled, with up to nine species found in any site, and *A. albida* was sampled at six of the sites. Using cluster, discriminant and principal component analyses there was evidence of large scale population variation. Each species has a peculiar local variation at each sampled site, even when sites are separated by only a few kilometres. Although *A. albida* is treated as an Acacia, principal components analysis clearly separates it from the rest of the species.

401 KORDOFANI, M.; INGROUILLE, M.J. **Geographical variation in the pollen of *Acacia* (Mimosaceae) in Sudan**. *Grana* (1992) **31** (2) 113-118 [En, 16 ref.]

Describes the pollen grains of 14 *Acacia* species, sampled in nine sites from different regions of Sudan. The pollen diameter, and pore number and diameter, follow a geographical pattern of variation both between species and topoclines within species. For *A. albida* the pollen diameter varied from 90-103 x 79-94 μ, the pore number from 3-5 and pore diameter from 2.9-5.0 μ. Pollen grains are smaller with fewer and smaller pores in arid northern Sudan than the humid southern Sudan. The number of grains in each polyad is 16 in all species except in *A. albida* which has 32 grains. This was the only distinguishing pollen character for *A. albida*. The spicate flowered acacias were not linked by any common pollen characteristics, *A. asak* had a finely perforate tectum, *A. mellifera* was finely reticulate and *A. albida* was foveolate. Patterns of morphological variation in scupturing of the exine, which are constant for species, are reported.

402 KROMHOUT, C.P. [**A key for the microscopic identification of the best-known indigenous timbers in South Africa**.] Sleutel vir die mikroscopiese uitkenning van die vernaamste in heemse houtsoorte van S. Africa. *Bull. 50, Dept. Bosbou, Pretoria* (1975) 140 pp. [Af]

403 LAIKE, A. ***Faidherbia albida* in the traditional farming systems of central Ethiopia**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, J.R.]*. ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 39-41 [En, 8 ref.]

*Faidherbia albida* is a component of the traditional farming system of the south-eastern Shewa region of Ethiopia, a high potential cereal zone where black vertisols are common. In this highland region, the tree is found on seasonally waterlogged areas and along river-banks, and as pure stands only in farmland areas. In this region the trees are pollarded every 3-4 years for fencing and fuelwood. In the coffee growing region of Hararghe, trees are maintained and protected in the coffee plantations for shade. Pods are eaten by all livestock, although

leaves are only browsed by goats. Trees are revered and protected in some areas, and the beneficial effects on crops understood, whereas in other areas this does not occur, particularly where chemical fertilisers are regularly used. Appreciation and protection of the species is limited to mature trees but not seedlings and it is possible that with cutting the species could decline from the region.

404 LAJUDIE, P. DE,; NEYRA, M.; DUPUY, N.; ALAZARD, D.; GILLIS, M.; DREYFUS, B. [**Diversity of *Rhizobium*, specificity of nodulation and ability of the Sahelian acacias to fix nitrogen**.] Diversité des *Rhizobium*, spécificité de nodulation et aptitude à fixer l'azote chez les acacias sahéliens. In *Physiology des arbres et arbustes en zones arides et semi-arides (edited by Riedecker, A., et al.)*. Paris, France; Groupe d'Étude de l'Arbre (1991) 257-262 [Fr, en]

Acacias are nitrogen-fixing trees with great potential for arid and semi-arid zones. A review is presented of current results of studies into *Rhizobium* and *Bradyrhizobium* capable of nodulating Sahelian acacias. This is the first report of the presence of nitrogen-fixing nodules on mature trees in Senegal grown in natural conditions. Slow-growing rhizobia nodulating *Acacia albida* have been isolated at 34 m below the soil surface, at water table level. A library of tropical *Rhizobium* strains isolated from different ecological areas in Senegal has been characterized especially in respect to their growth characteristics and their symbiotic properties (host range and nitrogen-fixing potential). These strains were compared to other known *Rhizobium* species by numerical taxonomy. Results here have confirmed that the acacias can be classed into three categories, those that associate with *Rhizobium*, those that associate with *Bradyrhizobium* and those that associate with both. Some species are less specific than others, mainly those that are in the first group and this includes *A. albida*. Practically, this idea is crucial; the species belonging to this group hardly respond to inoculation if at all not only because of the plants' inherent ability to associate with many strains oif rhizobia in the soil but also because these rhizobiums are *Bradyrhizobia*; and tropical soils contain mainly *Bradyrhizobia*. It is apparent that there is important variation in the scope of the host range in different rhizobia strains; strains with greater scope are less effective than those with a narrow range. This research has enabled the selection of rhizobia that are highly effective in specific associations in increasing growth of the tree. However, the future may lie in using gene transfer techniques to develop effective but less specific strains so reducing the number of strains of inoculum that must be produced commercially.

405 LAMPRECHT, H. ***Acacia albida***. In *Silviculture in the Tropics*. Eschborn, Germany; Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) (1989) 216-217 [En]

A general description is given of *Acacia albida* (apple ring tree, cad, balasa, gao) with its distribution, physiognomy, ecological requirements, silviculture and uses. Within its native habitat, it is conspicuous due to its relatively large dimensions, yet is undemanding as to soil structure and nutrient availability. It grows best on fossil dunes and riparian plains in deep, loamy sands rich in minerals, and thriving in areas of between 400 and 900 mm annual precipitation. A light-demander, this species bears fruit for the first time at age 7-12, producing copious seed crops every year thereafter - with 11,500 to 19,000 seeds per kilogram. Direct seeding is not advisable because of the high failure rate, but *A. albida* coppices well and on suitable sites can be regenerated using this method. Because of their long roots, transplanting of wildings is difficult. The wood is relatively easy to work, but not very durable. It is mainly used locally for making bowls, mortars and cooling utensils, but is not very suitable for fuelwood. The bark has a tannin content of 20-28%, which is used for medicinal purposes. Ash obtained by burning the wood is used for making soap. The flowers provide excellent bee forage.

406 LASSAILLY, F. [***Acacia albida*, the tree which grows against the seasons**.] L'*Acacia albida*. L'arbre qui vit à contretemps. *Inter Tropiques Agricultures* (1984) No. 4, 8-11 [Fr, 5 ref.]

*Acacia albida*, a species of wide natural distribution in Africa, produces leaves at the beginning of the long dry season and loses them at the beginning of the rainy season. This has the advantages of providing fodder for livestock during the dry season, fertilizing the soil before cultivation by its leaf fall, and not shading agricultural crops during their growing season.

407 LEBOT, V. [**Genetic improvement of exotic broadleaved species in Madagascar**.] L'amelioration genetique des feuillus exotiques à Madagascar. *Bois et Forets des Tropiques* (1996) No. 247, 21-36 [Fr, en, es, 13 ref.]

An account is given of forest tree genetic improvements being undertaken in Madagascar, part of a programme aided by the European Union (through the FED, Fonds Européen de Développement) for the supply of improved forest tree seedlings for village afforestation. The multipurpose trees *Acacia* spp. and *Eucalyptus* spp. were the principal genera selected. *Faidherbia albida* is being tested in the southern zone. Genotype-environment interactions are regarded as important, and consideration was given to regional smallholder or farmer needs for reforestation which were good coppicing ability, a thick bark for fire resistance, juvenile growth vigour and performance, and volume production for fuelwood and charcoal production.

408 LEBRUN, J. **[The growth rhythm of *Acacia albida*.]** A propos du rythme végétif de l'*Acacia albida*. *Collectánea Botánica, Barcinone* (1968) **7** (2, No.33) 625-636 [Fr, 22 ref.] From *Bois et Forêts des Tropiques* (1975) No.160, 75 [Fr]

Describes the ecological characteristics of *Acacia albida*, and discusses possible reasons for the pattern of growth of this deciduous species from tropical Africa, which loses its leaves during the rains and comes into leaf during the dry season, when making its annual growth. The growth rhythm of *A. albida* seems to be at least partly attributable to the unfavourable soil conditions, caused by flooding, that persist during the rains and to the relatively favourable conditions for such a deep-rooting species that occur when the soil dries out.

409 LELY, H.V. **The useful trees of Northern Nigeria.** London, UK; Crown Agents (1925) 128 pp. [En]

Botanical description of *Acacia albida*, the largest of the *Acacias* in the north, and particularly common in Sokoto where it prefers dry, sandy soils. Young tree has straight upright habit with a flat topped crown which later develops into large rounded spreading form similar to *Parkia sp.* Bark; uniform dull grey, long wide fissures and prominent ridges. Thorns; pairs, under 1/2 in. long, slightly recurved. Leaves bipinnate, 4 in. long with 6-7 pinnae pairs bearing some 10-15 pairs of dusty, grey-green leaflets. Flowers; Oct-Dec, in dense spikes 3-4 in. long, scented. Pods; ripening to bright orange, contorted shapes, 4-6 in. in January and February. Uses; inferior canoes, pods as fodder, nesting for the common brown kite in March and April.

410 LEMAITRE, C. **[The problems of soil conservation in Niger and gao]** Les problèmes de la conservation des sols au Niger et le « Gao ». Comptes rendus de la 2$^{e}$ conférence interafricaine des sols, Léopoldville, 9-14 août (1954), document 42, section III Ac. [Fr]

411 LEMATIRE, C. **Le *Faidherbia albida*.** *Thèse présentée au concours de principalat de 1954 pour Ingénieur de 1ere classe des Services de l'Agriculture de la France de la d'Outre Mer* (1954) 62 pp. [Fr]

Observations on the economics and extent of *Acacia albida* utilization in Niger, its effect on human and livestock population density, and anthropological problems posed by the species. Tremendous social consequences stem from the permanent sedentary agricultural settlements made possible by *Acacia albida*'s ability to eliminate fallowing and clearing of new land. A comparison is made of scarification treatments and sowing dates on the seed germination rate.

412 LEPAPE, M.C. **Browse in the Cape Verde Islands. A preliminary study.** In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le].* Ethiopia; ILCA (1980) 123-125 [En]

Climate, geology, relief, soils and vegetation of the area are described. Plantations, mostly of *Parkinsonia aculeata* and *Prosopis juliflora*, but also including *Acacia nilotica*, *Atriplex halimus*, *A. nummularia*, *Cajanus cajan* and *Leucaena leucocephala* are used as forage and are of considerable economic importance. Production data are presented for *P. aculeata*, *P. juliflora* and *Faidherbia albida*. For the latter, pod measurements over six trees of the Ribeira de Trinidade recorded 75 kg of pods per tree in 1967 and 55 kg per tree in 1968. The subjects were mature and well developed. Thirty-nine species introduced into arid zones are listed.

413 LESLIE, A.A. **Agroforestry practices in Somalia.** *Special issue. Agroforestry: principles and practices. Proceedings of an international conference 23-28 July 1989 at the University of Edinburgh, Edinburgh, UK [edited by Jarvis, P.G.]. Forest Ecology and Management* (1991) **45** (1-4) 298-308 [En, 11 ref.]

On the basis of a survey undertaken as part of the work of the research section of the British Forestry Project Somalia, traditional agroforestry methods used in the country and attempts to introduce new practices are described. The introduction to the paper gives background information on topography, climate and land use in Somalia. The traditional systems described are: Live fencing and hedges; Shelterbelts; Boundary planting; Bush fallows and shifting cultivation; Intercropping - naturally regenerated trees used and planted (mostly fruit) trees in intercropping, and temporary and permanent systems found; Soil stabilization measures; and Plantation grazing - under fruit trees. Nomadic pastoralism with shifting cultivation is practised over most of the country. Settled communities in these areas plant live fencing. The last part of the paper briefly describes research being undertaken and recently introduced agroforestry systems and projects including the establishment of fodder banks of *Acacia albida.*

414 LESUEUR, D.; NJITI, C.F.; DIANDA, M.; GALIANA, A. **[The symbiosis of *Faidherbia albida* and rhizobium. A laboratory study of the symbiotic and ecophysiological characteristics.]** Symbiose *Faidherbia albida* - rhizobium. Étude en laboratoire des caractéristiques symbiotiques et écophysiologiques. In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-For(t, Montpellier, France. (1996) 312 pp. 245-258 [Fr, en]

Like most of *Leguminosae*, *Faidherbia albida* is associated with rhizobia, symbiotic soil bacteria that form nitrogen-fixing root nodules. This ability to fix atmospheric nitrogen enables this species to become established in soils that are poor in combined nitrogen. The host spectrum of 13 rhizobium strains of various origins

showed that *F. albida* is a non-specific host plant because it nodulates indiscriminately with *Rhizobium* and *Bradyrhizobium* strains. All the *Bradyrhizobium* and *Rhizobium* strains tested formed efficient nodules on *F. albida.* Inoculated plants had a shoot dry weight that was 45-72% higher, depending on the strains, than that of non-inoculated control plants after a two-month growing period under greenhouse conditions. As far as the ecophysiology of the *F. albida-Rhizobium* symbiosis is concerned, we have shown that it was naturally adapted to acid soils, and that it was not affected by the presence of high concentrations of aluminium in the nutrient solution. On the other hand, in an iron-free nutrient solution, we noted a marked reduction of the nodulation and growth of the host plant. This means that iron is an essential micronutrient for the establishment and/or functioning of this symbiosis. As a result, *F. albida* is still a fairly easy species to establish in acid soils. Conversely, it is certainly preferable to use more appropriate species in calcareous or alkaline, iron-deficient soils. Artificial inoculation in nurseries has to be carried out when the superiority of a strain has been proven in the ecological conditions of the planting area. In other cases, seedlings have to be left naturally nodulated with indigenous strains.

415 LIBERT, C.; EYOG MATIG O. [***Faidherbia albida* and cotton production. Modification of the hydrological regime and the parameters of cotton yield under tree parks in North Cameroon.**] *Faidherbia albida* et production cotonnière. Modification du régime hydrique et des paramètres de rendement du cotonnier sous couvert du parc arboré au Nord-Cameroun. In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Foret, Montpellier, France (1996) 312 pp. 103-121 [Fr, en]

The authors carried out a study of the *Faidherbia albida*/cotton association in the parklands in the Sudano-Sahelian zone of northern Cameroon. The geological substratum is made up of recent sandy alluvia. Average annual rainfall is 800 mm. A 38 hectare plot was studied. In it, *F. albida* density was 5.5 trees $ha^{-1}$, basal area at breast height 1.8 $m^2$ $ha^{-1}$, crown cover 8.7% of the area, average height 12 m and average diameter 0.56 m. An initial study focused on the effect of 15 isolated trees on the growth of cotton, comparing the part beneath *F. albida* crowns and the part up to 20 m from the outer edge of the crown. Beneath the crown, the density of cotton plants was 20% lower, but the plants were larger and more evenly sized. The average capsular weight for them was higher. The cotton yield was higher beneath the trees in less fertile soils, and lower in more fertile soils. A second study made a comparison between a dense parkland areawith young *F. albida* trees (37 trees $ha^{-1}$, average diameter 34 cm, 26% crown cover, average crown area 70 $m^2$) and a nearby zone where trees were very few and far between. Although yields were high (1.61 t $ha^{-1}$) in the part outside the parkland, they increased by 32% in the parkland. The effect of dense parkland on cotton plant yield would thus seem to be more favourable than the effect of an isolated tree. The characteristics of the top 40 cm of soil were compared beneath and beyond crowns, taking three young and three old trees. The soil parameters seemed to have been more markedly changed under the old trees. Here, the pH, level of organic C and total N and C/N were higher on the surface. A third study dealt with the availability of water for the cotton plants, comparing the zones beneath crowns of four trees (two large specimens with a V-shaped configuration, and two short round-shaped trees). The following findings emerged. Cotton plant roots reached a maximum depth of 80 cm. In this zone, no *F. albida* roots were found, so the available water reserve at this soil depth was calculated. It was greater beneath the crowns at the start and end of the crop cycle. The phenology of the individual trees differed greatly, the earliest being totally in leaf by mid-July and the latest not starting to form leaves until mid-August. Two out of four trees intercepted more than 50% of the light throughout the cotton plant's vegetative period. Beneath the canopy, cotton plants flowered later and the plants were larger. At the same time, weeds developed better beneath crowns, but were less diversified, and weeding was more laborious. In conclusion, the authors noted that the influence of *F. albida* on the cotton plant has to do with the station. The effect of a stand on cotton production seems to be greater than that of isolated trees. Water availability for the cotton is greater at the start and end of the crop cycle. *A priori*, there is no competition for water and mineral elements between tree and crop. Any depressive effect is due to shade.

416 LILLY, M.A. **An assessment of the dendrochronological potential of indigenous tree species in South Africa**. *Occ. Pap. No.18, Dept. Geography and Environmental Studies, University of the Witwatersrand, Johannesburg* (1977) 90 pp. [En]

417 LOUPPE, D. [**The integration of trees in agricultural development in Niger.**] L'intégration de l'arbre dans le développement agricole au Niger. *Note présentée à Réunion Annuelle Cadres de l'Agriculture, INRA, Département des recherches forestières* (1980) 13 pp. [Fr, 11 ref.]

The necessity for integration of trees in the agricultural production system in Niger is demonstrated by a series of numerical data on their nutritional value. Species include *Adansonia digitata*, *Acacia albida*, *Bombax costatum* and *Andropogon gayanus*. The roles of the tree on the betterment and maintenance of soil fertility, and as a source of fuelwood, construction, and works of art, are also discussed.

418 LOUPPE, D. [***Faidherbia albida*: for a new silviculture?**] *Faidherbia albida*: pour une sylviculture

nouvelle? *La lettre du Réseau Arbres Tropicaux* (1990) **15**, 11-13 [Fr]

*Faidherbia albida* is a tree known to all. Height growth is about 1.5 m per year and it reaches a diameter of 40 cm in less than 20 years. Loses leaves in wet season, allows productive cultivation beneath. Improves physico-chemical properties of soil, increases cereal production, forage and lengthens period of cultivation of *e.g.* tomatoes and aubergines. Enables livestock to survive where fallow and herbaceous pasture in dry season is insufficient. Foliage is given to cattle by pruning. Pruning is vital - provides forages at crucial time, firewood and spiny branches for dead hedging necessary for management of village land. It is a main source of wood in dry areas of West Africa. Wood is drained of sap in creeks or stagnant ponds, then worked into mortars, pestles, small furniture, joinery, carpentry and even dug-out canoes. Wood is combustible and easily carbonized. The species has been protected through legislation which has enabled densification but over-protection of old trees has led to general ageing of the population with no recruitment. It seems that pruning has significant negative effect on village economy through reduced beneficial effect on cultivation, reduced pod production and increased erosion. No young trees seen now in parklands but there are many along transhumance tracks because it is a dynamic species that colonizes agriculture land. There is a need to exploit adult trees to make room for young. Protection for two years against weeding out of young trees has been shown to increase density by *c.* 20 plants per hectare. Income will be realized by exploitation by the saw of adult trees 50-60 cm in diameter. 'Dense' enclosure has foliage covering 25% of the ground which corresponds to a density of 15 adult trees per hectare. If enclosure is managed like a garden plantation, 50-70 trees per hectare could be raised and exploitation of an adult tree every 5 to 10 years could be envisaged. Clearings would meet needs of villagers for wood for different purposes, would allow agricultural production underneath and would provide important income supplement from sale of seed pods or using them to feed village livestock.

419 LOUPPE, D.; N 5 DOUR, B.; SAMBA, S.A.N. **[Influence of *Faidherbia albida* on ground-nuts and millet in Senegal. Methodology for measuring and estimating the effects of trimmed trees with or without the penning of animals.]** Influence de *Faidherbia albida* sur l'arachide et le mil au Sénégal. Méthodologie de mesure et estimations des effets d'arbres émondés avec ou sans parcage d'animaux. In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Forêt, Montpellier, France (1996) 312 pp. 123-139 [Fr, en]

*Faidherbia albida* is the commonest tree in the farmlands of the Senegalese groundnut-growing basin. Its influence on crop yields is acknowledged. Despite the benefits, this tree is not as respected by farming people as one might tend to think, and it is in regression even in the Sereres areas. Furthermore, it is currently very heavily trimmed and pruned to supply out-of-season fodder, branches for building dead fences, and fuelwood. The authors present the hypothesis that this trimming might have considerably reduced the favourable influence of *F. albida* on the two main crops in this region, groundnuts and millet. The purpose is thus to compare the production of these two crops on the basis of their distance from the *F. albida* trunk. To do this, in the first instance, they have developed a data-gathering protocol. To test this methodology, the surveys involved 21 trees, 10 of which were in plots planted with groundnuts, and 11 in plots with millet; all the trees were trimmed. For millet, in the case of plots with good productivity (645 kg of grain per hectare), significant increases were observed for yields of ears (+ 49%) and grain (+48%) in a radius of 6.3 m around the trunk. In this same zone, the average weight of the ear increased by 34%. The rise in the density of the seedlings at harvest and of the number of ears per square metre is only significant within a radius of 4 m. In plots with poor productivity (213 kg of grain per hectare), the increase in yield in the first six metres was 60%, but not significant. In both cases, production decreased swiftly starting from the trunk outwards, and stabilized at the level of the control as from 8 metres. For groundnuts, a significant depressive effect was observed on the yield of pods in the first three metres around the trunk, then an increased yield which nevertheless remained slightly lower than the sample, and again a significant drop in production between 8 and 10 metres. This not very productive zone is situated outside the limits of the canopy. The production of haulms in relation to pods is greatly helped by the tree as well as by the manure of animals. In the light of previous studies, the authors attempt to explain the whys and wherefores of these yield variations.

420 LOUPPE, D.; N'KLO OUATTARA **Growth of *Faidherbia albida* in nurseries: standard production techniques or air pruning?** In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, J.R.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 141-143 [En, 1 ref.]

Reports on techniques tried in the Ivory Coast to prune roots in the nursery raised seedlings of *Faidherbia albida*. Tap roots can take as little as 18 days to emerge from the bottom of the pots. Root pruning is needed otherwise root coiling occurs, and pruning can be needed as frequently as every 15 days. Trial looked at comparing manual root pruning with air pruning, and air-pruned seedlings proved as successful in development after outplanting. They also developed 50% more secondary roots and 28% more nodules than manually pruned seedlings, with less transplant shock. All treatments developed effective taproots after planting in the field.

421 LULANDALA, L.; *et al.* **The Mafinga Forestry Experiments: main findings and recommendations.** ICRAF 13434 (1989) p. 2 [En]

*Acacia albida* trees grew well (spacing 4 x 4m, 5 x 5m, 6 x 6m) when clean weeded or when inter-cropped with maize or beans. For these spacing treatments, wood yields at six years were 22, 13 and 10 $m^3$ $ha^{-1}$ respectively. Tree size increased with increasing spacing. The trees also grew faster when inter-cropped with a tall maize crop than either with a short bean crop or when clean weeded, apparently because of the dry seasons more effective mulching effect of the higher biomass of the maize crop residues which contribute to the better water economy. Maize or bean yields (1980-1986) were not significantly reduced by the presence of *A. albida*. The contribution of foliage and branches to the total biomass of four-year-old *Leucaena leucocephala* was 49%. However these components together hold respectively 76%, 68%, 63%. 72% and 60% of the total N, P, K, Ca, Mg and Na in the aerial biomass. This pattern of variation was also been noted for *A. albida*. It is concluded that conventional harvesting of wood would therefore remove only negligible amounts of nutrients from the site; but nutrient removal; through intensive fodder harvests represents a heavy nutrient drain annually at 87 kg N, 42 kg K, 20 kg Ca, 8 kg Mg, and 5 kg P.

422 MACDICKEN, K.; BREWBAKER, J.L. ?? *Nitrogen Fixing Tree Research Reports* (1984) **2**, 46-54 [En]

Descriptive information from NFTA database for selected species. *Acacia albida* has a fair to poor tree form. Occurs in an arid climatic zone, with a minimum rainfall of 300 mm. Produces good quality timber and forage (pods & leaves).

423 MACKAY, J.H. **Perspective in land planning.** *Farm and Forest* (1944) No. 5, 60-66; 99-107 [En, 8 ref.]

The maintenance of soil fertility in land already under cultivation, and the rehabilitation of land that has gone out of cultivation, is a constant problem arising in West Africa. The two principal dangers are erosion and laterization of the soil, though much could probably be done to alleviate these through contour cultivation with strips of grass or *Acacia*, and through fire protection to recover forest vegetation, which is important in preventing desiccation. Trees have an important role to play on farmland itself, as shelterbelts, but also in intensifying local humidity, keeping the soil moist, cool and open, tapping deep-lying water supplies, and in providing shade and fodder for cattle. *Parkia biglobosa* and *Acacia albida* are both excellent farm trees, with Mango most suitable for field shelterbelts. Amongst the most dangerous practices are over-cultivation, destruction of trees and shrubs by over-lopping for fodder, and excessive grass-burning.

424 MADSEN, J. **[Complex problems in the Sahel.]** Komplekse problemer i Sahel. *Vaekst* (1986) **107** (2) 22-27 [Da, 9 ref.]

The article is based on work in Senegal 1984/85. The area studied used to be able to feed its population of nomads and farmers, who benefited from one another, but is now a barren desert because of intensive groundnut cultivation which has impoverished the soil, overgrazing, and young trees being gnawed by animals or cut down. Sweden has financed two planting projects which were developed through area chiefs. Container- grown *Acacia senegal* and *Prosopis juliflora* were planted, hedged round with *Acacia albida*. Single trees were also planted to provide a good microclimate. Now advice will be needed to preserve the trees.

425 MAGHEMBE, J. **Preliminary performance of some multipurpose trees in the unimodal ecozone of southern Africa.** In *Trees for development in Sub-Saharan Africa. Proceedings of a regional seminar held by the International Foundation for Science (IFS), ICRAF House, Nairobi, Kenya, February 20-25, 1989.* (1989) 95-97. [En, fr.]

Two multipurpose tree (MPT) screening trials were planted in December 1987/January 1988 under the SADCC (Southern Africa Development Coordination Conference)/ICRAF Agroforestry Project which operates in Malawi, Tanzania and Zambia. The experiments included 16 species planted at Chalimbana near Lusaka, Zambia, and 9 species planted at Tumbi, near Tabora, Tanzania. *Acacia albida* was included at both. At the end of the first season (6 month old) *A. albida* was reported as a slow starter.

426 MAGHEMBE, J.A. *et al.* **Agroforestry in Farming Systems; Role in marginal agricultural areas.** *Presented at the Farming Systems and Farming Systems Research Conference, Arusha, Tanzania* (198la) 14 pp. [En, 18 ref.]

Gives results of an agroforestry experiment conducted in Morogoro, Tanzania from 1978 to 1980. A stage-by-stage analysis is detailed of the intercropping systems involved in the experimint, with *Leucaena leucocephala*, *Acacia albida* and *Eucalyptus melliodora* being the main tree species under test. Presents results and discusses the importance of intercropping.

427 MAGHEMBE, J.A.; CHINGAIPE, T.M.; LULANDALA, L.L.L. **Agroforestry and farming systems: role in marginal agricultural areas.** Morogoro, Tanzania; Forestry Division, University of Dar es Salaam (1981b) 1-14 [En]

Reviews a few case studies that have demonstrated the potential of agroforestry systems in marginal lands, including an intercropping trial that involves *Leucaena leucocephala* with maize and beans. Gives results of crop

yield and establishes further trials to find suitable tree spacings that can allow continuous crop production and provide good fuelwood and/or fodder. Presents results of the second trials with emphasis on tree performance and gives future considerations.

428 MAGHEMBE, J.A.; REDHEAD, J.F. **Agroforestry: preliminary results of intercropping *Acacia*, *Eucalyptus* and *Leucaena* with maize and beans.** Morogoro, Tanzania; Forestry Division, University of Dar es Salaam (1980) 17 pp. [En, 20 ref.]

Planting trials in Morogoro were undertaken in order to research the possibilities of making afforestation more attractive to peasant farmers. Long term investigations have been established, including intercropping maize with *Eucalyptus camaldulensis*, *Acacia albida*, and *Leucaena leucocephala* at a range of wider espacements up to 6 m for the multipurpose production of food crops, fuel, fodder and poles. *Acacia* has a reputation for slow initial growth, as it develops a deep tap root before the stem grows more rapidly. It is expected that significant interactions between the tree and the intercropped maize and beans will be manifest by the second year. The effects of spacing were not significant.

429 MAGHEMBE, J.A.; REDHEAD, J.F. **Agroforestry: preliminary results of intercropping *Acacia*, *Eucalyptus*, and *Leucaena* with maize and beans. II. Intercropping.** *Proceedings of the second symposium on intercropping in semi-arid areas, held in Morogoro, Tanzania, 4-7 August 1980 [edited by Keswani, C.L.; Ndunguru, B.J.].* Ottawa, Canada; International Development Research Centre (1982) 43-49 [En]

A trial was established in 1978 to study the interaction of trees with food crops. *Eucalyptus melliodora* was planted with maize, beans, and sorghum separately on clean-weeded and unweeded plots. The results were so encouraging that further trials, intercropping trees with maize and beans, have been established: *Eucalyptus camaldulensis*, for fuel and poles; *Leucaena leucocephala*, for fuel and fodder; and *Acacia albida*, for fuel and fodder. The results of these trials are presented in this paper.

430 MAHMOUD, A.; OBEID, M. **Ecological studies in the vegetation of the Sudan. I. General features of the vegetation of Khartoum Province.** *Vegetatio* (1971) **23** (3/4) 153-176 [En, 26 ref.]

Describes 13 'community types' with plant-sociological data for representative stands of each type. The three types dominated by tree species (*Acacia albida*, *A. seyal* and *A. nilotica* respectively) are found in the flood plain; they are four-layered (tree, shrub, and upper and lower field layers). *A. nilotica* grows closer to water than the other species and has also been successfully planted in the flood-plain. An interesting feature of the vegetation in this arid region is its floristic poverty and the surprisingly small number of plant communities.

431 MARCHAL. J-Y. **Trees and Bushes in the Sudanese-Sahelian Landscape. Dynamics of the plant formations in north of Upper Volta.** *Cah. O.R.S.T.O.M., Sér. Sci. Hum.* (1980) **17** (3-4) 137-149 [Fr, en]

There are two fields of interest in this paper, the position held by tree in landscape and the use made of it by the population. The issue of the apparent stability of the tree stratum in the general context of degradation of plant cover is also discussed. The list of plants and trees includes *Acacia albida*. The parkland in the study comprised 679 trees in a homogeneous scattered distribution with about eight trees $ha^{-1}$ (87 hectares) of land totally cultivated with millet each rainy season. *A. albida* was the most important species with a total of 377 trees (55.5% of the parkland). Apart from neem, which is planted like mangos, trees only survive of spared from weeding and protected from sheep and goats. A. *albida* are pruned. There are few young trees and their roots are often damaged. A disappearance of fallows is likely to result in the disappearance of the parkland in the next few decades. The low density of *A. albida*, which is only four per hectare, could be index of the slow decline of park. It was possible to make a comparison of the status of the trees from studies made in 1975, 1971 and from large scale aerial photographs. The limits of the park do not seem have changed since 1961. There were various reasons for the decline in numbers of other principal tree species such as *Balanites aegyptiaca, Acacia scorpiodes* and *A. radiana* but *A. albida,* was less affected than all particularly where it was concentrated on deep sandy-clay soils where the ground water was present at less than 1.50 m. The presence of *A..albida* has been taken as an indicator of a good siting for a well. It is also recognized that the production of millet and sorghum in *A. albida* parkland is consistently 25-50% higher than it is in open land. These are likely reasons for its relatively slower decline.

432 MARIAUX, A. [**Growth of *Acacia albida*. A study of growth rings of some sections of trees from Senegal.**] Croissance du kad (*Acacia albida*). Étude des couches d'accroissement de quelques sections d'arbres provenant du Sénégal. Centre Technique Forestier Tropical (1966) 18 pp. [Fr, X, 4 photos, 1 fig., 8 tables]

This work seeks to evaluate the possibility of using growth ring analysis in *Faidherbia albida* as an aid in planning sustained yield in the species. Samples were collected from trees of known age with supporting data on rainfall, silvicultural treatment *etc.* and from naturally-grown trees with supporting observations on anything that might have influenced growth. A binocular microscope with 10x magnification was used to examine the rings on six radii on each of nine discs. The annual ring boundary was taken as the point where there was a

sudden change in the appearance of the parenchyma associated with the vessels and a ring of closely-spaced vessels showed what was taken to be the start of the next growing season. The width of a growth ring could vary greatly round the circumference of the stem and where it became very narrow it was difficult to distinguish the boundary between seasons; with care, it was nearly always possible to do so although it became a very laborious process. The conclusion was that it the number of rings counted using this method did correlate with tree age. The growth rate of trees on cultivated land was described as remarkable (15 rings = 35-45 cm) but it was much slower in the naturally-occurring trees that were growing on sandy soils (15 rings = 10-15 cm).

433 MARIAUX, A. [**Study report. Growth of kad (*Acacia albida*)**] Rapport d'étude. Croissance du Kad *(Acacia albida)*. Étude des couches d'accroissement de quelques sections d'arbres provenant du Sénégal. CTFT, Division d'Anatomie, Nogent-sur-Marne (1966) [Fr]

434 MARIAUX, A. [**Nature and periodicity of growth rings in trees in the tropical dry zone of West africa**] Nature et périodicité des cernes dans les arbres de zone tropicale sèche en Afrique de l'Ouest. CTFT Division d'Anatomie des Bois, Nogent-sur-Marne (1979) pp. 40-42 [Fr]

435 MARIAUX, A. [**A dendrochronological trial in the Sahelian climate on *Acacia raddiana*.**] Essai dendroclimatologie en climat Sahélien sur *Acacia raddiana*. *Bois et Forêts des Tropiques* (1975) **163**, 27-35 [Fr]

436 MARUNDA, C.T. **Use of seed of *Faidherbia albida* (syn. *Acacia albida*) for human consumption during famine periods in the Gokwe communal lands of Zimbabwe.** In *Australian dry-zone acacias for human food [edited by House, A.P.N.; Harwood, C.E.].* Canberra, Australia; CSIRO (1992) 93-98 [En, 26 ref]

Observations during seed collection in Gokwe indicated the importance of the pods of *Faidherbia albida* as livestock feed and that boiled seed can be used as survival food and, in some cases, a source of income, for rural poor people. The pods, foliage and young twigs are browsed by animals. Pods and seeds contain 10-13% and 26-27% crude protein respectively and pods can provide up to 65% of an animal's food consumption when grass availability is low. Ratio of seed to pod weight varies between 1:2.6 and 1:7.7. Pod production begins when the tree reaches about 20 cm in diameter and it has been reported that a single mature tree can yield up to 1000 kg of pods in a year in South Africa but the usual range is 105-5400 kg $ha^{-1}$. Seed size is very variable but tends to increase from north to south on the continent. It is likely that there are between-tree differences in palatability of the pods as well as the seeds because elephants and cattle browse selectively. This difference might be due to there being more or less prussic acid in the immature pods. Seed is extracted from the pods by pounding in a mortar. The seed is then separated from the chaff using winnowing baskets. The chaff is fed to cattle. Improperly cooked seeds may cause gastric disorders. Legumes are known to contain toxins such as trypsin inhibitors, hemag-glutins, goiterogenic factors, cyanogenic glucosides, lathyric factors and compounds that cause favism and flatulence, the latter possibly caused by a gram positive anaerobic bacterium, present in the intestinal tract, that is stimulated by unknown substances in the dry seed. The seed requires careful preparation before eating: boil in water; remove and discard seed coat; boil seed for several hours with wood ash; wash with fresh water and repeat process several times; boil seed without ash and add salt; if preferred pound seed and bake into cakes or mix with maize meal. There are also reports of people using the ground pods as food. There is potential to select for pod production and palatability.

437 MARUNDA, C.T. **Geographical Variation and Physiological studies in *Faidherbia albida (Del.)* A.Chev. (syn.*Acacia albida* Del.).** *M.Sc Thesis, Department of Forestry, Australian National University* (1993) 164 pp.?? [En, 179 ref.]

*Faidherbia albida* (Del.) A. Chev. (syn. *Acacia albida* Del.) is widely distributed in Africa and parts of the Middle East. Its use in traditional agroforestry systems is well known and its potential in reforesting degraded lands is being evaluated in arid regions of many countries. Geographic pattern of variation of the species in Africa was studied to provide a basis for initiating a genetic improvement strategy. The influence of different environments on phenology and growth, and root morphology and size were studied to understand the growth patterns of the species. Twenty provenances were grown in a glasshouse and twenty-four traits assessed to test for the extent of genetic variation. There was strong evidence of genetic variation between provenances and, to some extent, between families-within-provenances. Most of the traits showed a north to south trend, with south-east Africa provenances having high growth rates (in terms of height, root collar diameter and dry weight production) and north-east provenances having qualities of adaptive significance (in terms of late leaf senescence, large root to shoot and leaf to stem ratios). A few traits showed random variation. The patterns of variation were strongly related to the temperature of seed origin and the type of ecosystem in which the species grows naturally. There were strong negative relations between grown traits and those of adaptive significance. Canonical variate analysis showed that the provenances of *F. albida* from Africa could be grouped into three regions. The groups fall into upland ecosystem of north-west Africa, the riparian ecosystem of south-east Africa and the Sudan/Ethiopian highlands and adjacent Lodwar valley in

Kenya (proposed centre of origin). Most of the traits had high heritability values which indicated that most of the variation was genetic in origin. Based on the observed variation, a breeding strategy which involves delineating provenances, collecting seed, setting up provenance trials and seed production areas was proposed. The effects of day length and water stress on the phenology and growth habits of provenances from the three regions were examined. Long day-length and water stress caused defoliation to occur, with those from the Sudan/Ethiopian highlands defoliating the most, followed by those from the riparian ecosystem and lastly, by those from the upland ecosystem. Height and root collar diameter extension were significantly reduced in seedlings exposed to long day-length and water stress. The result showed that defoliation of *F.albida* trees is linked to day length and moisture and that defoliation affects growth rate. Provenances from the upland ecosystem had the largest root length to stem height ratio, showing that they invested more biomass in root extension than those from either the centre of origin or those from the riparian ecosystem. Upland sources also had high specific root length values which suggested high root activity. The observations showed that upland provenances were better adapted to survive in drought conditions than either those from the riparian ecosystems.

438 MASUKA, A.J. **Effect of *Rhizobium*, phosphate and nitrogen on nodulation and growth of *Faidherbia albida* seedlings**. *Journal of Applied Science in Southern Africa* (1995) **1** (2)137-141. [En, 15 ref.]

A nursery experiment using sterilized soil was conducted with *Faidherbia albida*, two *Rhizobium* strains, phosphate and ammonium nitrate fertilizer. Five months following inoculation all three factors, Rhizobium, phosphate and nitrogen, had effected mean nodule number per plant. There were significant interactions of *Rhizobium* by phosphate and *Rhizobium* by nitrogen on mean nodule number, and *Rhizobium* by nitrogen on mean nodule weight. Nitrogen consistently had a negative effect on both nodule number and weight. Increase in height was negatively affected by *Rhizobium*. Neither phosphate nor nitrogen affected plant height. Mean shoot weight per plant was greater in the presence of *Rhizobium* and phosphate, but root weight was reduced by nitrogen. One of the two strains of *Rhizobium* increased root weight. Dry mass was a better indicator of the performance of the species than plant height.

439 MAYDELL, H.J. Von. **Agroforestry to combat desertification - a case study of the Sahel**. Hamburg; Institute for World Forestry, Federal Research Centre for Forestry and Forestry Products (1974) 16 pp. [En, 8 ref.]

The forestry situation in the Sahel and its contribution to combat desertification is discussed. Desertification in the Sahel, the demands of the local rural people and the different ways to avoid the widening gap between demand and supply are reviewed. Selected agroforestry projects in the Sahel and its neighbouring region of Sudan savanna are described. Emphasis is given to the importance of *Acacia albida* and *A. senegal* in some agroforestry practices.

440 MAYDELL, H.J. Von. **The contribution of forestry to regional development in the Sahel**. *Applied Science and Development* (1977) 164-174 [En, 15 ref.]

An improved supply of goods for daily needs, protection of man and resources and build up of stocks for emergencies are the goals of forestry in arid lands. Afforestation projects indicate that further research into soils, stand establishment, forest production, training of plantations, optimising harvests and assessing demand is needed.

441 MAYDELL, H.J. Von. [**Agrisilviculture: a combination of agricultural and forestry land use.**] Agroforstwirtschaft: Kombination von land- und forstwirtschaftlicher Bodennutzung. *Forstarchiv* (1978a) **49** (5) 96-66 [De, 8 ref.]

A general account of agrisilvicultural systems with particular reference to tropical regions. Stable agrisivicultural systems should be introduced in areas where shifting cultivation is practised. Mention is made of West German work on the use of *Acacia albida* as a multi-purpose crop in the Sahel. An outline is given of research and development proposed by the International Council for Research in Agrisilviculture.

442 MAYDELL, H.J. Von. **Tree and shrub species for agroforestry systems in the Sahelian zone of Africa**. *Plant Research and Development* (1978b) **7**, 44-49 [En, 16 ref.]

An outline is given of the criteria that should be applied in selecting species for the area, emphasizing; the local demands of the community; the establishment of fuel, pasture or shelter; adaptability to site conditions; and ecological constraints. There is a need for genetic improvement of local species, and for more information on their site requirements. Brief accounts are given of the characteristics and potential of some promising local and exotic species, including *Acacia albida*, *A. senegal*, *A. seyal*, *A. nilotica*, *A. tortilis*, *Eucalyptus camaldulensis*, *Prosopis juliflora*, *Azadirachta indica* and *Pinus eldarica*.

443 MAYDELL, H.J. Von. **Tree and shrub species for agroforestry systems in the Sahelian zone of Africa**. In *Forests for people Mitteilungen der Bundesforschungsanstalt für Forst- und Holzwirtschaft* (1979) No. 124, 7-25 [En, de, 16 ref.]

Describes a number of local and exotic woody plant species that have proved suitable for forestry projects and for integration into agro-silvo-pastoral land use

systems in the Sahelian zone. They have to offer either multiple or specialised uses, be compatible with other crops and complementary to dry farming or pastoralism and thrive under dry conditions. No single species meets all requirements, but *Acacia albida* is detailed as one of the most promising local species and as a model species for the proper use of forest trees for agroforestry under semi-arid conditions. Its main advantages is an excellent adaptation to the Sahelian environment; drought resistant when its fast growing tap root reaches the water table so is generally found on alluvium, river valleys and depressions; and competes little with crops so does not result in a loss of cropping area. Its unusual phenology provides fodder and shade in the dry season with protein rich pods maturing at the end of the season. Regenerates by vigourous coppice regrowth from stumps of felled trees, by rootsuckering and by seed. It offers multiple uses, including fodder reserves, tannins and medicinal uses and is actively preserved by the people of the Sahel. Its limitations include restriction to sites with a high water table in areas of more than 300 mm and preferably 500 mm of annual precipitation, and that trees need to be protected in establishment years against livestock. Need for applied research to study the cheapest way of establishing plantations and protecting young trees, with a community based involvement and cooperation and a timely supply of good seeds or seedlings.

444 MAYDELL, H.J. Von. **Agroforestry to combat desertification (a case study of the Sahel)**. *Forestry for local development. Workshop in Garpenberg, Sweden, December 14-17, 1981 [edited by Fries, J.]. Arbetsrapport No.6, U-landsavdelningen, Sveriges Lantbruksuniversitet, Sweden* (1982) No. 6, 41-54 [En, 12 ref.]

Three case studies are referred to in examining the progress of agroforestry in combating desertification in semi-arid zones, and particularly the Sahel. These are a combination of both *Acacia albida* and *A. senegal* with dry farming, and *A. senegal* with semi-nomadic or transhuman pastoralism. *A. albida* is well recognized and traditionally regarded as extremely valuable by rural communities for its soil enriching capacity and fodder resources. Particularly disadvantageous, however, is the slow growth of the seedlings when transplanted from nurseries into fields, and the long production cycle which may suffer from prevailing land tenure systems.

445 MAYDELL, H.J. Von. **Trees and shrubs of the Sahel - their characteristics and uses**. Eschborn, Germany; G.T.Z. (1986) ??

446 MAYDELL, H.J. Von. **Agroforestry in the dry zones of Africa: past, present and future**. In *Agroforestry a decade of development [edited by Steppler, H.A.; Nair, P.K.R.]*. Nairobi, Kenya; International Council for Research in Agroforestry ( ICRAF) (1987) 89-116 [En, 24 ref.]

*Acacia albida* is a commonly protected and highly venerated non-forest tree of large areas in semi-arid Africa, with the Emirs of Zinder, Niger, at one time passing death sentences upon people who felled them. *A. albida* is a prominent agrosilvopastoral tree species - during the cropping period there is no competetion for light, while during the hot dry months there is shelter for livestock, which also improve the soil through their droppings. Moreover, the roots penetrate into deep soil layers and do not compete for water and nutrients with agricultural plants, but intercept minerals at otherwise inaccessible depths and deposit them on the soil through the leaves which are shed just in time to fertilize the topsoil at the start of the cultivation season. Optimizing agricultural crop and animal production is the main concern and can be achieved as indicated for traditional systems such as those involving *Acacia albida* with millet and sorghum.

447 MBURUEU, G.N. **Nitrogen fixation in *Faidherbia albida* (Clev.) Del**. *Ph.D. Thesis, University of Dundee* (1994), F7b, 43-11916 (1994) [En]

Nodulation and arbuscular mycorrhizal infection was assessed in soils obtained from two habitats of *Faidherbia albida* in different ecoclimatic zones. A third site in a semi arid area but without *F. albida* was also assessed. All three sites had *Brachyrhizobium* spp. *Rhizobium* spp. and arbuscular mycorrhizas. Soils from the two sites with *F. albida* differed in mineral content, nodulation and mycorrhizal infection of *F. albida* and *Acacia Senegal*. In laboratory experiments it was observed that *F. albida* took about 21 days to nodulate. Inoculated seedlings suffered an early period of nitrogen stress. Application of combined nitrogen alleviated early nitrogen stress but reduced nodulation and nitrogen fixation. Combined nitrogen in the form of $NH_{4+}$ had less severe effects on nodulation than $NO_{3-}$ at the three levels of N (0.5, 2.5 and 5.0 mol $m^{-3}$) tested. In an experiment using 5.0 mol $m^{-3}$ N provided as $^{15}N0_{3-}$ (5 atom%) or as $^{15}NH_{4+}$ (5 atom %) it was established that preference for nitrogen form was pH dependent. Nitrate was preferred at low pH (5.5) and ammonium at high pH (6.5). The N form/pH combination resulting in good plant growth had also less severe effects on nodulation and nitrogen fixation. Improvised glass-fronted gutter containers, made from open gutter pipes, were used for monitoring taproot elongation. The effect of $N_2$, $NC_{3-}$ and $NH_{4+}$ at 5.0 mol $m^{-3}$ was assessed. The taproots elongated very quickly but independently of nitrogen for at least the first 70 days. There were also no statistical differences between taproot elongations in three provenances of *F. albida* tested. In an experiment to find out the effects of phosphorus and nitrogen form on *F. albida*, phosphorus was found to increase nodulation and nitrogen fixation. High levels (above 3.0 mol $m^{-3}$) of phosphorus reduced plant growth, nodulation and nitrogen fixation.

448 McGAHUEY, M. **Impacts of forestry initiatives in the Sahel on production of food, fodder and wood.** *Chemonics International* (1985) 1-25 [En, 35 ref.]

Strategies to increase productivity in the Sahel are discussed. The approaches being taken to increase productivity are given starting with the bush fallow system where *Acacia albida* trees are intercropped with food crops, and impact on fragile soils as well as the climate. Agroforestry initiatives in Chad and Somalia aimed at increasing food, fodder and wood on a sustainable basis are highlighted and the need to quantify these initiatives is addressed.

449 McGAHUEY, M. **Extension of *Acacia albida*: recapitalization of the natural resource base.** In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 159-164 [En, 7 ref.]

The regeneration of *Acacia albida* parks is in decline in many areas of the Sahel just when their establishment has a important long-term role to play in maintaining soil and livestock productivity, with increasing pressures on the land. Reviews the traditional husbandry of the tree, and examines past and present experiences in its extension, and considers possible options for the future.

450 MEHROTA, M.D. ***Rhizoctonia solani*, a potentially dangerous pathogen of khasi pine and hardwoods in forest nurseries in India.** *European Journal of Forest Pathology* (1990) Vol. 20, 329-338 [En, fr, ge, 3 ref.]

An account is given of the foliage diseases caused by *Rhizoctonia solani* Kuhn anamorph of *Thanatephorus cucueris* in forest nurseries. Three biotypes were identified based on morphological characteristics. The second of these produced small light brown to brown sclerotia on the glass surface in agar culture tubes, and included isolates of *Acacia albida*. Leaf blight on *A. albida* was recorded in New Forest, Dehra Dun; causing 100% disease incidence, heavy defoliation, growth reduction, and delayed planting.

451 MERGEN, F. **Using multipurpose trees and shrubs to reclaim arid lands.** Arid Lands and Tomorrow (19??) 857-864 [En, 32 ref]

Every year productive arid and semi-arid land is desertified. Reclamation is crucial to the welfare of the 680 million indigenous people who live in these regions. The variety of functions that trees and shrubs provide can make a significant difference to the economic and social lives of these inhabitants. *Acacia* (*Faidherbia*) *albida* is cited as one of a few species that have been a noteworthy success in agroforestry schemes in the arid regions of Africa. It grows in areas with an annual rainfall of 300-500 mm on sandy or silty soils. It has a long taproot allowing it to raise nutrients from deep horizons in the soil. It retains its leaves in the dry season and loses them in the rainy season which enables it to provide valuable shade and fodder when little else is available. It provides up to 135 kg of nutritious pods per tree for livestock which in turn manure the fields. Rain leaches nutrients from the manure, fallen leaves and branches and enriches the soil for food crops. It is fast-growing. Peanut yields can be doubled and millet yields may be up to five times as high under the trees compared with the open. Soil organic matter can be increased up to 100% which leads to better water-holding capacity and structure. The wood is used for general construction, furniture and fuel. The species has been used in reclamation projects in Senegal, Chad, Upper Volta, Niger and Sudan.

452 MEROT, B. **[Some germination trials on *Terminalia superba* and *Acacia albida*]** Quelques essais germinatifs sur *Terminalia superba* et *Acacia albida.* Rapport de stage, CTFT, Nogent-sur-Marne, juillet (1983).

453 MICHON, P. **[Is the Sahara advancing southwards?]** Le Sahara avance-t-il vers le sud? *Bois et Forêts des Tropiques* (1973) No. 150, 3-14 [Fr, en, es, 3 ref.]

A discussion article on problems of desertification. African countries bordering on the Sahara are undergoing a prolonged period of dryness which is of truly catastrophic proportions, and the question of the extension of the sedser arises. It can be noted that:- (1) Economic development has entailed the development of industrial crops - peanuts and cotton along with subsistence crops - and this has accelerated deforestation. (2) The lopping of branches practised by herdsmen to feed their animals, especially sheep, is often a necessity in the Sahelian zone, but in some cases it is practised excessively. (3) Bush fires are now more extensive than formerly as is evidenced by the presence of palmyra and calcedrates. Remedies suggested include more general use of the practice of early burning outside irrigated area under cultivation, and to grow un irrigated crops under *Acacia albida*, which is a good protection for cultivated soils.

454 MIEHE, S. ***Acacia albida* and other multipurpose trees on the Fur farmlands in the Jebel Marra highlands, Western Darfur, Sudan.** *Agroforestry Systems* (1986) **4** (2) 89-119 [En, 36 ref.]

A report based on the traditional agroforestry systems as practised by the Fur tribe, sedentary hoe agriculturalists on the lower slopes and highlands of the Jebel Marra massif, Sudan. The basic agrosilvopastoral system consists of terraced village fields, where semi-permanent rain-fed cropping of staple millet and other subsistence

crops takes place under stands of multipurpose trees dominated by *Acacia albida*, *Cordia abyssinica* and *Ziziphus spina-christi*. A gradual change to shifting cultivation caused by exploitative management is reflected in a successive decrease in the tree cover. *A. albida* is the dominant tree component in the altitudinal range of 1400 to 1900 m, extending into the montane zone. It is primarily valued as a dry season fodder resource, with branches for thorn fences and fuel, regenerating abundantly as a fellow pioneer on ash soils in Koronga, as well as from seeds as from stumps or root suckers. Data is presented on chemical and nutritive values of the *A. albida* components.

455 MIEHE, S. **Vegetation ecology of the Jebel Marra Massif in the semiarid Sudan.** *Dissertations botanique Vol.113. Cramer, J. in der gebrueder Borntraeger verlagsbuchhandlung, Berlin, West Germany* (1988) XIII + 171 pp. [En]

This volume presents the materials, methods, and results of an ecologically oriented study of the vegetation of the Jebel Marra Massif using the Braun-Blanquet (Zurich-Montpellier) method. Following a description of the study area and a discussion of concepts and methods used in the present study, the work focuses on the description of plant formations and communities in the region, the classification and ordination of the montane savannas and related grasslands, and a causal ecological analysis. Two provisional alliances (the lower montane *Acacia albida-Cymbopogon caesius* savanna and the Upper montane *Festuca-Andropogon* grassland) with four 'associations', represented by 15 communities, have been worked out. Forty-six new kormophytes for the Jebel Marra are recorded.

456 MILLER, O.B. ***Acacia benthamii* Rochbr**. In *Bechuanaland Protectorate [Botswana] (Provisional list). Check-lists of the Forest Trees and Shrubs of the British Empire, Imperial Forestry Institute, Oxford* (1948) No.6, 16-17 [En]

Lists *Acacia benthamii* (*A. nilotica* subsp. *kraussiana*) with seven vernacular names. The species is described as a tree 9-12 ft (2.5-3.5 m) high which fruits in February. The pods are eaten by cattle and contain tannin. The wood is durable and the tree yields an edible gum. The pod of *A. albida* has been used for stupifying fish in order to catch them in Northern Rhodesia [Zambia].

457 MITCHELL, M.R. **Susceptibility to termite attack of various tree species planted in Zimbabwe**. In *Trees for the tropics. Growing Australian multipurpose trees and shrubs in Developing Countries [edited by Boland, D. J.]*. Canberra, Australia; Australian Centre for International Agricultural Research. *ACIAR Monograph* (1989) No. 10, 215-227 [En, ref. at end of book]

A trial containing 52 seedlots from 41 species of Australian, Central American and Zimbabwean trees at Kadoma, Zimbabwe, gave results showing major differences in overall survival and susceptibility to the fungus-growing termites *Ancistrotermes latinotus* and *Macrotermes michaelseni*. Species with more than 80% survival and less than 10% termite-caused deaths were *Acacia holosericea, A. albida, A. salicina, A. plectocarpa, A. leptocarpa, A. difficilis, Enterolobium cyclocarpum* and *Senna atomaria*. The survival of the standard species, *Eucalyptus camaldulensis*, was 34% with all deaths due to termite attack.

458 MONOD, T. [**On some galls of African *Acacias*.**] Sur quelques galles africaines d'*Acacias*. *Bulletin de l'Institut Française d'Afrique Noire, Série A* (1968) **30** (4) 1302-1333 [Fr]

Illustrates with drawings of herbarium specimens a number of galls collected from various African *Acacia* species. Describes some leaf galls for *Acacia albida* Del. from Kuiseb bridge, South West Africa (Namibia), and between Mojjio and Debré Zeit, near Addis Ababa, Ethiopia. Leaflets form small bladder-shaped cavities in which a Homoptera insect was found.

459 MONOD, T.H. [**Contribution towards a flora of Gilf Kebir (south-west Egypt).**] Contribution a l'establissement d 5 une florule du Gilf Kebir (S-O Egypte). *Bull. Mus. Natl. Hist. Nat., Paris*, (1995) 4$^{e}$ ser., 17, Section B, Adansonia, No. 3-4, 259-269 [Fr, en,]

Following some expeditions on the sandstone plateau of Gilf Kebir (Libyan Desert) it has been possible to establish a list of phanerogams still locally living, recently disappeared or locally known as sub-fossils. Charcoal of *Acacia albida* was dated at between 6150 and 180 BP. The presence of this species is taken as an indication of seasonally dry and wet climate.

460 MONTAGNE, P. [***Faidherbia albida* : one tree, one project**] *Faidherbia albida:* un arbre, un projet. Bois de feu informations, avril-mai-juin (1984) No. 9 pp. 15-20 [Fr]

461 MONTAGNE, P. [***Faidherbia albida*: its development in Niger. Summary of operation Gao-Dosso.**] *Faidherbia albida*: son développement au Niger. Resume de l 5 operation Gao - Dosso. *Unpublished report, Association Bois de Feu* (1984) 90 pp. [Fr, 6 refs]

This monographic work on *Faidherbia albida* starts with a discussion of the nomenclature and taxonomy, its origins and its distribution. The root system is said to penetrate to 40 m below the surface. It grows on a range of soils from deep sands to heavy clays and laterites. The availability of water seems to be more important than the soil type. It needs water for growth of foliage in the dry

season and this leads to the development of a root system of large volume that is capable of penetration to the water table up to 40 m below the surface. *F. albida* is most widely used at the bottom of the slopes where it can grow when the water table is 1-20 m below the surface. The usual hypotheses for its reversed phenology are summarized. It is suggested that where water is not available in the dry season, as has recently been the case in the Sahel, the tree remains defoliated. The tree's value for paper-making and solid wood products are described as unremarkable. Although there is no evidence to suggest that there is a decrease in evaporation beneath the trees, the relative humidity does increase under the canopy and reduces the evapotranspiration at the start and end of the rains and therefore the water requirements of the plants. The extremes of air temperatures are reduced. There is little variation in soil humidity compared to the open site throughout the year. Rainfall infiltration increases in heavy and oblique rain and decreases in light vertical rain. As far as soil fertility is concerned, there is no effect on the percentage of clay and silt but there is an increase in the percentage of organic matter to 2 m depth. Soil humidity is maintained all year due to lower evapotranspiration under the canopy. Relative humidity increases above a wilting point of 2.8, otherwise there is no difference compared to the open as when it is below 2.8, water is no longer limiting to plant growth. There is a rise in pH and exchange capacity as a result of the increase in organic matter. K and Na are little influenced; Ca and Mg, which provide 95% of the exchange cations, both increase. P increases in the dry season. The C and N content doubles. The greatest increase in C occurs in August-September when microbial activity is high and the leaf litter is rapidly broken down. Greatest concentration of ammonium occurs at the end of the dry season, while nitric compounds are most abundant after the first rains. The C/N ratio of cultivated soil is 10, of leaves of *F. albida* in fallow 17, of cereals 80. Biological activity in the soil increases by 2.5 times (with seasonal variation) though only specialized fungi increase in abundance (e.g. N fixing). Mineral elements increase 20-40% depending on the season *e.g.* $P_2O_5$ increases by 2-3 times. The benefits of *F. albida* are, therefore, that it:- improves the microclimate; brings nutrients up from depth; defoliates at the end of the dry season allowing nutrients and light to reach crops during the rains which is also the principal time of agricultural work so leaves are rapidly incorporated into the soil and broken down; symbiotic N fixation occurs in young plants on N deficient soil; cattle receive shade in the dry season, their dung also helps fertilize the soil though this is not essential as *F. albida* improves the soil independently; the trees do not hinder agriculture due to the loss of leaves in the rains and the absence of shallow roots; the trees' inclusion in agricultural systems does, however, require more maintenance; the trees reduce aeolian erosion, particularly in the dry season and they scrub nutrients from the atmosphere through dust deposited on the leaves and which are later dropped. The effects of *A. albida* on crop yields vary from negative to beneficial. One study reports that *F. albida* litter is a better nutrient provider than fertilizers. All studies reported grain head yields of millet under *F. albida* are increased and that fertilizers further increase yield, though to no greater extent than they would on control soil. The pods are low in fat and fair in protein and the foliage fair in fat and high in protein. Studies have shown that, *e.g.* 20 trees $ha^{-1}$ increases beef production $ha^{-1}$ by up to three times. In the dry season animals graze on the branches and leaves lopped from the tops of trees; they are also cut at the end of the dry season to feed sheep and goats. But pruning in some places has been forbidden because if done badly or to too great an extent it can kill the tree and it reduces the number of pods produced and these provide essential fodder at the height of the dry season (February-April in Sahelian zone). The system used to work 30 years ago but increase in demand for aerial fodder and firewood has lead to over-exploitation with little thought to the regeneration of the trees. Saplings die from over-grazing by cattle and this starts the process of desertification. Artificial regeneration by direct seeding gives 70% germination but low survival after five months due to due to competing vegetation and drought. Seed requires 24 hour soaking in boiling water before use. Fresh green seed gives a more uniform germination. Three to four seeds are sown in plastic grow bags in a mix of sand and clay, watered twice a day, weeded once a week, soil turned after germination to increase water and root penetration, shaded at midday for the first month. Defoliation by caterpillars is a risk, rodents destroy large numbers of seedlings by cutting at the root collar, roots grow fast, excess clay hinders development, seedlings are ready after three months in nursery and roots will reach the bottom of the grow bag within four months. If planting is delayed watering is reduced to check their growth. No ground preparation is necessary, Seedlings are planted at 10 m spacing for improved ground fertility. Those that survive the first dry season will have established; marking individuals and fencing can increase their survival. There is little insect damage though caterpillar attacks at the start of the dry season can slow growth; trampling by domestic animals is a problem, goats uproot and sheep sever at the collar. Lessons learned from the Gao-Dosso Project are discussed. It was found that *F. albida* requires a long rainy season or high humidity and the passing of the seed through the gut of cattle for natural regeneration to succeed. After this, seed germinates rapidly in the first rains but areas that are not under cultivation or used by cattle show little or no regeneration mainly due to competition from grasses. Dry season grazing to the collar and uprooting will kill young plants, but mild successive grazing stimulates root growth and plants are able to reshoot each year provided the roots have already reached the water table. Eventually one shoot gets away to form the tree. It is crucial to protect the young tree and then rapid growth after the bush stage is the only way for the tree to survive in cultivated fields due to the risks of grazing and cutting at harvest time or pulling up during weeding. rapid growth is important once past the bush stage.

Pruning is necessary for the formation of the crown and requires careful management. In the Gao-Dosso project, 29 young trees were monitored in fields of nine farmers and a 76% survival rate was found; the majority of deaths resulted from termites. Over two years the average height increase was 32 cm. There is no growth until the end of the second winter as growth is concentrated below ground but after 27 months the average height of the plants was 67-130 cm. Exceptional growth rates have been recorded for trees grown under cultivation. Pruning increases production compared to cutting back. There is rapid tap root growth after planting (>2 m on dunes). The volume of roots is of greater importance to young plants than the growth of aerial parts. It has been found that roots have a greater diameter than shoots at equivalent depth/height, reached a greater depth than shoots attained height and covered a greater area. No lateral roots were found within 125 cm of the soil surface. The main causes of death in young plants were found to be field preparation before winter, weeding, grazing and children playing. An unexpected benefit from the trees is the sale of droppings from cattle egrets that roost in them. Without cattle and man *F. albida* would not be able to survive; there is a need to increase populations of all three concurrently or face rapid change in society. It is hard to impart the importance of the programme for establishing the trees in the system when the returns will not be seen for 10 years, and farmers' children are seeking their fortune in towns. The cost of a plantation programme to establish trees in the system would be seven times that of establishing *F. albida* parkland.

462 MONTAGNE, P. [**Protection of the natural regeneration of *Faidherbia albida*. Empirical evaluation of the Gao Dosso Project in Niger**.] Protection de la régénération naturelle de *Faidherbia albida*. (valuation a posteriori du projet Gao Dosso au Niger. In *[Faidherbia parklands.]* Les parcs a *Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Foret, Montpellier, France (1996) 312 pp. 283-296 [Fr, en]

The Gao Dosso Forestry Project was operational from 1981 to 1985 and designed to mobilize farmers and inform them about the protection of young naturally regenerated *Faidherbia albida* trees during the various farming operations in the dry season (land clearance) and in the rainy season (weeding). Ninety-four villages were thus concerned over a three-year period representing about 16% of the total number of villages. All the villages were of roughly the same size (600-900 inhabitants). To encourage farmers to locate and protect the young trees, the project granted them a bonus of 50 F CFA per seedling spread over three years. Between 1981 and 1984, almost 3,500 farmers took part in the operation and recorded more than 500,000 *F. albida* seedlings. In 1992 an inventory was made in10 villages previously involved in the project, to assess its impact. The following findings emerged:- the density of *F. albida* trees of all heights was 29 stems $ha^{-1}$ which represents 40 % of the trees in the wooded parklands existing in these village territories; it was possible to locate the three adult stems/hectare identified in 1981 at the start of the project; the project operations contributed to the survival of 15 seedlings $ha^{-1}$ in the 1.5-10 m height category; the cost of the project (excluding overheads) was less than 100 F CPA per live seedling seven years after the end of the operation; and the concept of the tree as the cornerstone of production systems is being better understood by farmers. The payment of a bonus had a mobilizing effect.

463 MONTGOLFIER-KOUÉVI, C. De.; HOUÉROU, H.N. Le. [**Study on the economic viability of browse plantations in Africa**.] (tude de la viabilité économique des plantations de fourrages ligneux en Afrique. In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le.]*. Ethiopia; ILCA (1980) 449-464 [En, Fr, 16 ref.]

A study was made in order to assess the economic feasibility of planting browse trees and shrubs as feed resources, and further to evaluate the cost price of the animal feed which could be produced under relatively extensive conditions (using a minimum of inputs). The price of livestock feeds depend generally upon their energy values (measured in forage units) and their digestible protein content per kg of feed. *Acacia albida* is usually planted in areas with an annual rainfall of 400 to 800 mm, in millet, cowpea and groundnut fields, forming part of a traditional agricultural system used by several African peasant civilizations. *A. albida* live to about 80 years, becoming productive only after 15 years. Fruit production and the fertilizer effect increase only gradually and do not reach their full extent until about 25 years when the tree is mature. Millet yields can increase from 500-800 kg/ha to an estimated 1000-1500 kg/ha when planted with *Acacia* in the semi-arid zones of West Africa, and in addition, pod production reaches an average of 200-600 kg/ha/year, providing livestock with a protein-rich feed to supplement their roughage. Despite the length of the production cycle, the delay before it begins, and the relatively low production of wood, the impact on crop yields is thought to be substantial. Establishment costs are calculated, according to whether barbed wire fences or thorny hedges are used.

464 MORI, T. **Application of chlorophyll fluorescence kinetics to the study of stress physiology in trees**. *Journal of the Japanese Forestry Society* (1990) **72** (1) 67-72 [Jp, 20 ref.]

Data are presented for *Populus* 'OP 226' (*P. caudina* x *P. deltoides*), *Alnus firma, Acacia cowleana, Acacia melanoxylon* and *Acacia albida*.

465 MOUSSA, K.A.M.; WILLIAMS, J.H.; BATIONO, A. [**Chemical properties of Sahelian sandy soil in**

***Faidherbia albida* parkland.**] Propriétés chimiques des sols sableux sahéliens sous parcs a *Faidherbia albida*. *Cahiers Agricultures* (1999) **8** (1) 70-72 [Fr, en, 13 ref.]

In Niger, changes in soil chemical properties at high or sparse *Faidherbia albida* tree densities were monitored at the beginning and end of the rainy season. Two sites with different *F. albida* tree density (Guilleny, 32 trees $ha^{-1}$; and Tilly, 4 trees $ha^{-1}$) were assessed and 10 trees with a mean trunk diameter of 95 cm were selected on each site. Soil was sampled in the four transects around trees at three distances from the trunk (1, 5, and 11 m), at 0-25 cm depth, in July and November 1992, 1993 and 1994. Increases in pH, total N, K and Bray P1 [this procedure provides a relative measure of phosphorus availability that predicts where supplemental phosphorus is needed for optimum crop production] were noted at the beginning of the rainy season. Bray P1 content decreased with the distance from the trunk, contrary to pH which was higher 11 m from the trunk. There were no effects of distance on total N and K contents. Soil fertility improvement was more significant for Bray P1 at Tilly and for total N and K at Guilleny. Soil nutrient gradients around *F. albida* trees were similar at the beginning and end of the rainy season. The high soil fertility under the tree canopy could be explained by several factors, *e.g. F. albida* litter fall, animals, dust, etc. Dissociating the contribution of these inputs would provide a better understanding of tree/crop/livestock interactions, and improve *F. albida* tree management.

466 MOUSSA ELHADJI ISSAKA. [**Record of the period from 1 June to 15 September (1977). Dosso Department, District of Bobeye**] Mémoire de stage du 1 juin au 15 septembre (1977). Département de Dosso, arrondissement de Bobeye. 1. Reboisement en Gaos des terres agricoles, 2. (tude sur l'exploitation et la commercialisation des feuilles de doums. IPDR, Kolo, I[er] année, septembre (1977) [Fr]

467 MOUSSA, K.A.M.; WILLIAMS, J.H.; ODONGO, J.C.W.; RENARD, G. (ed.); NEEF, A. (ed.); BECKER, K. [**On-farm crop diversification under *Faidherbia albida* in the semi-arid zone of West Africa.**] Diversification des cultures sous *Faidherbia albida* en milieu paysan, dans la zone semi-aride de l'Afrique de l'Ouest. In *Soil fertility management in West African land use systems. Proceedings of the Regional Workshop, University of Hohenheim, ICRISAT Sahelian Centre and INRAN, Niamey, Niger, 4-8 March 1997.* (1998) 299-303. [Fr, en, 6 ref.]

Recent work in the semi-arid zone of West Africa showed that *Faidherbia albida*, a traditional agroforestry tree in the region, modifies its environment substantially. The objective of this study is to show how to diversify crop production using the agro-ecological changes which occur under *F. albida*. The study took place at two sites south of Niamey in Niger, in 1993 and 1994. The experimental design was a latin square with eight trees and four crops (local millet, mil ICMV IS89305, sorghum ICSV111, maize INRAN Kollo). Results showed that there were no effects of distance from the tree stem on millet stover yield. Millet grain yield was higher in the southern and eastern directions but reduced under the tree canopy for all directions. Unlike millet, maize stover yield and grain yield followed the same gradient around the tree. Maize yields were higher in the northern and western directions and 5-10 times higher under the tree canopy than in the open field. Sorghum yield was better under the tree canopy and there are no effects of direction on yield of this crop.

468 MUELLER-ECKHARDT, H. **Final report to the government of the Sudan on wood-based board materials.** FAO, Rome; United Nations Development Program. *FAO Report No.TA 2402* (1967) iii + 26 pp. [En]

Discusses chiefly particle board, and includes provisional test data on the manufacture and properties of boards from *Boswellia papyrifera*, *Acacia albida*, *A. seyal*, *Azadirachta indica*, *Eucalyptus tereticornis*, *Conocarpus lancifolius*, and *Tamarix aphylla* (of which the two last named were the most suitable and only *Acacia albida* unsuitable.)

469 MUGASHA, A.G.; SHOO, M.E. ***Acacia albida* Del. - a potential resource in Tanzania.** *Tanzania Silviculture Technical Note* (1980) No. 47, 12 pp. [En, 33 ref.]

The natural habitat, silviculture and uses of the indigenous *Acacia albida* are reviewed. The study indicated that the species is potentially of use in agroforestry in the dry parts of Tanzania.

470 MUHAMMAD, SALEEM; MUSHTAQ, AHMAD; ASHFAQ, AHMAD. **Chemistry of the medicinal plants of genus *Acacia*.** *Hamdard-Medicus* (1998) **41** (1) 63-67 [En, 55 ref.]

The medicinal uses and chemical composition of 11 Acacia species are described: *Acacia albida* [*Faidherbia albida*], *A. arabica* [*A. nilotica*], *A. catechu, A. farnesiana, A. leucophloea, A. mellifera, A. modesta, A. senegal, A. seyal, A. siberiana* and *A. tortilis*. The bark, gum and roots are the main parts used. Most of the extracts are used as astringents to treat gastrointestinal disorders, as a gum wash to stop bleeding, as a clarifying agent and flavouring in the production of spirits from sugar and palm juice, or as demulcents and emollients.

471 NAIR, P.K.R. **Tree integration on farmlands for sustained productivity of smallholdings.** In *Environmentally Sound Agriculture [edited by Lockeret, W.]* (1983) 333-350 [En, 31 ref.]

Defines agroforestry and shows the interface between agriculture and forestry. Discusses examples of some agroforestry systems, like the taungya, cropping systems involving tree crops and herbaceous crops and smallholder systems giving examples in West Africa and Rwanda. Gives information on multipurpose trees and silvopastoral systems and touches on plant arrangement patterns in agroforestry as well as soil productivity and management.

472 NAIR, P.K.R.; FERNANDES, E.C.M.; WAMBUGU, P.N. **Multipurpose leguminous trees and shrubs for agroforestry**. *Agroforestry Systems* **2**, 145-163 [En, 35 ref.]

Describes of the role of woody legumes in agroforestry, both as a protective and a productive one. Lists a number of leguminous species (including *Acacia albida*) summarizing their general growth characteristics, ecological adaptability, combining ability with other species and their uses/functions. Also gives early growth characteristics of 14 woody legumes planted at ICRAF's Machakos Field Station, Kenya, situated at 1500 m above m.s.l., with 700 mm per annum. Measurements are given 1.75 years after planting and out of 45 plants of *A. albida* the mean height was 1.77 m., mean crown diameter 1.24 m., and stem diameter 4.09 cm at base and 2.12 cm 1 m above ground.

473 NAO, T., Van. **Agrisilviculture; Integrated food and wood production**. *Eighth World Forestry Congress, Jakarta, Indonesia, 16-28 October* (1978) 18 pp. [Fr, 18 ref.]

*Acacia albida* is a tree of savanna and semi-arid zones, with rainfall varying between 300 mm and 900 mm. This tree has a penetrative root system which allows the drawing of water and nutrients through the shallower soil layers and is therefore not competitive with food crops whose roots are developed in the upper horizons. In the dry season, it retains its foliage and therefore can shade the soil and cattle from excessive heat. In the wet season, it loses its leaves, hence not interfering with the growing crops and remaining an indispensable species within African agro-silviculture.

474 NASROUN, T.A.H. **Sudan timbers: their properties, uses and potentialities**. *Sudan Silva* (1975) **3** (20) 40-47 [En, 1 ref.]

Tabulates the physical and mechanical properties of some Sudanese timbers, including density, static bending, impact bending, hardness and shear strength. Of the 19 species tested, *Acacia albida* is a light weak wood. The structural uses for 34 Sudanese timbers are also listed, and *A. albida* is a perishable timber which will readily accept preservatives, and suitable only for light construction, joinery, furniture, boat building, hardboard and particle board and poles.

475 NATIONAL ACADEMY OF SCIENCES. **Underexploited tropical plants with promising economic value** (1975) pp. 111-114.

476 NATIONAL ACADEMY OF SCIENCES. ***Acacia albida***. In *Tropical Legumes; Resources for the future* (1979) 142-145 [En, 12 ref.]

*Acacia albida* retains its foliage throughout the dry season, and sheds them just as the rainy season begins: this has a number of economic benefits. Dense foliage provides cool shade for livestock in hot months. Shade protects the soil when otherwise would succumb to drought. Equally, the tree's lack of leaves in the wet season enables sunlight to reach the crops planted around it. Favoured crops are groundnuts and millet. It is recognized as being the fastest growing *Acacia* in South Africa. Trees have reached 6.5 m after four years and 10.5 m (with a 9.4 cm diameter) after 7.5 years.

477 NATIONAL RESEARCH COUNCIL. **Tropical legumes : resources for the future.** Washington D.C., National Academy of Sciences (1979) pp. 142-145 [En]

478 NATIONAL RESEARCH COUNCIL. Agroforestry in the West African Sahel. National Academy Press, Washington D.C. (1983) 86 pp. [En]

479 NDOUR, P; DANTHU, P. [**Effects of water and salt stress on the germination of some African acacias**.] Effet des contraintes hydrique et saline sur la germination de quelques acacias africains. In *L 5 acacia au Senegal [edited by Campa, C.; Grignon, C.; Gueye, M.; Hamon, S.]. Actes de la réunion thématique sur l'acacia au Sénégal, Dakar, Sénégal, 3-5 décembre 1996. Editions de l'ORSTOM; Paris; France* (1998) 105-122, 453-454 [Fr, 39 ref.]

Seeds of nine species of *Acacia* from contrasting biogeographic zones in West Africa were scarified, and water stress or saline conditions were simulated using sodium chloride (0 to 40 g/litre - osmotic pressure from 0 to -2.4 MPa), polyethylene glycol (PEG, 0 to -2.1 MPa) or mannitol (0 to -1.7 MPa). The species (approximate rainfall range added in brackets) were: *Acacia ehrenbergiana* (<100-200 mm), *A. raddiana* (<100-400 mm), *A. nilotica* subsp. *adansonii* (200-600 mm), *A. senegal* (200-600 mm), *Faidherbia albida* (200-800 mm), *A. nilotica* subsp. *tomentosa* (200-800 mm), *A. seyal* (400-800 mm), *A. sieberiana* (600-1200 mm), and *A. dudgeoni* (800-1500 mm). Results are tabulated for the effects of both stress factors on seed germination. Generally, *A. nilotica* was the most susceptible to both water and salt stress, and *A. senegal and A. raddiana* were the most tolerant. The findings suggest that seed germination under stress conditions is not a good indicator of tree ecophysiology.

480 NDOYE, I.; GUEYE, M.; DANSO, S.K.A.; DREYFUS, B. **Nitrogen fixation in *Faidherbia albida*, *Acacia raddiana*, *Acacia senegal* and *Acacia seyal* estimated using the 15N isotope dilution technique**. *Plant and Soil* (1995) **172** (2) 175-180 [En, 19 ref.]

A pot experiment was conducted in a greenhouse using the 15N isotope dilution method and two reference plants, *Parkia biglobosa* and *Tamarindus indica*, to estimate nitrogen fixed in four *Acacia* species: *A. raddiana, A. senegal, A. seyal* and *Faidherbia albida* (formerly *A. albida*). For the reference plants, the 15N enrichments in leaves, stems and roots were similar. With the nitrogen fixing plants, leaves and stems had similar 15N enrichments; they were higher than the 15N enrichment of roots. The amounts of nitrogen fixed at five months after planting were similar using either reference plant. Estimates of the percentage of N derived from fixation (%Ndfa) for the above-ground parts, in contrast to %Ndfa in roots, were similar to those for the whole plant. However, none of the individual plant parts estimated accurately total N fixed in the whole plant, and excluding the roots resulted in at least 30% underestimation of the amounts of N fixed. Between species, differences in N2 fixation were observed, both for %Ndfa and total N fixed. For %Ndfa, the best values were for *A. seyal* (average, 63%) and *A. raddiana* (average, 62%), being at least twice the %Ndfa in *A. senegal* and *F albida*. Because of its very high N content, *A. seyal* was clearly the best in total N fixed, fixing 1.62 g N/plant compared with an average of 0.48 g N/plant for the other acacia species. The results show the wide variability existing between *Acacia* species in terms of both %Ndfa and total N fixed: *A. seyal* was classified as having a high N2 fixing potential (NFP) while the other species had a low NFP.

481 NEILAND, A.E.; VERINUMBE, I. **Fisheries development and resource-usage conflict: a case-study of deforestation associated with the Lake Chad fishery in Nigeria**. *Environmental Conservation* (1991) **18** (2) 111-117 [En, 23 ref.]

The anticipated recovery of the Lake Chad fishery (following the Sahel drought episodes of 1972-73 and 1979-83) is assessed in relation to the supply and demand for fuelwood, timber and fodder in the region. Fresh fish are traditionally cured in clay ovens. A trend to reprocess the fish before sale in the urban markets of Nigeria could significantly increase demand for fuelwood. The increasing demand for fish products in Nigeria and the commercialization of the fisheries in the Chad basin could lead to further depletion of the already meagre bioresources (fish and trees). It is concluded that planning and regional development strategies (reforestation, particularly of multipurpose indigenous species such as *Acacia albida*, and regulation of the fisheries) are required if severe resource depletion and environmental degradation are not to occur in the foreseeable future.

482 NEUMANN, K. **Middle holocene vegetation of the Gilf Kebir/SW Egypt - a reconstruction**. ?? 179-188 [En]

Excavations of prehistoric sites from two wadis in the Gilf Kebir (Libyan Desert) yielded a number of charred wood remains which were examined by means of SEM-photography. The species combination *(Tamarix* sp., *Ziziphus lotus, Acacia sp., Maerua crassifolia* and *Balanites aegyptiaca)* suggests an arid climate with annual precipitations not exceeding 100 mm between 8000 and 4000 BP. In a description of the wood anatomy of *A. albida*, it is stated that no growth rings were discernable, vessels were solitary or in small clusters with simple perforations, parenchyma was confluent-banded, rays homogenous, composed of long, procumbent cells, uni- and bi-seriate and storeyed. The wood was easily distinguished from that of other North African acacias by the banded parenchyma and the uni- and bi-seriate and storeyed rays. The isolated presence *of A. albida,* dated at 6150 to 180 BP, indicates a slightly moister period of unknown duration. In spite of the arid climate prevailing during the Middle and Late Holocene, the Gilf Kebir offered a favourable environment for prehistoric nomads because of the seasonal availability of surface water and the comparatively rich wadi vegetation.

483 NEW, T.R. **A biology of Acacias: a new source book and bibliography for biologists and naturalists**. Melbourne, Australia; Oxford University Press (1984) 153 pp. [En, 29 pp. ref.]

A useful reference book, reviewing the literature on the biology and ecology of the genus *Acacia* up until 1982. Includes a number of references on *Acacia albida* and its synonyms, a chapter on taxonomic classification, and a detailed entomological section. It is one of the preferred foods of elephant and other grazers, and in Zambia elephants can push over trees to gain access to fruits and foliage. They also have been recorded ringbarking trees. On standing mature trees, the browse line for elephants may be more than 6 m high above the ground. *Acacia* foliage and pods may be a valuable stock feed. A large proportion of seed may pass through the gut undamaged: stabled deer in the Sudan fed on *A. albida* passed 65% of the seeds in germinable condition.

484 NIANG, A.I. **[Preliminary notes on two multipurpose tree species. *Acacia albida* Del. and *Butyrospermum parkii* G. Don (Karite).]** Note préliminaire sur deux espèces a usage multiple. *Acacia albida* Del. and *Butyrospermum parkii* G. Don (Karite). Burkina Faso; SAFGRAD (1987) 1-28 [Fr]

Monograph presenting the morphology, physiology, phenology and geographic distribution of *Acacia albida* and *Butyrospermum parkii*. Presents the uses of these two species and the beneficial effects afforded on the microclimate, soil and cultivation found within their proximity. Also presents a chemical analysis indicating

the nutritive value of food products and fodder from these trees.

485 NIGERIAN FEDERAL DEPARTMENT OF FOREST RESEARCH ***Acacia albida***. In *The properties of some savanna timber trees. Forest Products Research Reports, Ibadan, Nigeria* (1967) No.FPRL/11, 36-40 [En]

Gives the vernacular names, and description of *Acacia albida* (Gawo) and its timber, structure of the wood and seasoning properties, preservation, durablity and strength, and also summarizes and tabulates the mechanical and physical properties. The following are the statistics given for wood that was green, air-dried at test conditions and air-dried to 12% respectively for each parameter:- moisture content (%) – 72.5, 12.5, -; specific gravity (oven dry weight) – 0.51, 0.55, -; weight (lb $ft^{-3}$) at 12% MC – -, -, 39; weight (lb $ft^{-3}$) at 50% MC – 48, -, -; static bending:- modulus of elasticity (1000 lb ft $in^2$) – 60, 85, 870; work to max. load (lb ft $in^3$) – 21.3, 15.6, 15.4; total work (lb ft $in^3$) – 34.3, 25.3, 24.9; impact bending:- max. drop (in) – 47, 31, 30; compression:- max compressive strength (lb ft) – 3170, 4570, 4650; hardness (side):- indenting load (lb ft) – 780, 1030, 1050; sheer stress (lb ft $in^{-2}$):- radial – 1130, 1630, 1660; tangential – 1200, 1760, 1780; cleavage (lb ft $in^2$ width):- radial – 68, 96, 98; tangential – 75, 105, 107.

486 NIGERIAN FORESTRY DEPARTMENT. **Termites and soil fertility**. *Niger. For.* 1 (1940) **2**, 8-11 [En]

The early stages of an investigation into the possible value of termite activity in the processes of soil recovery in Nigeria are outlined. Observations have been made on the rate of destruction of certain substances such as manure, fruits of *Acacia albida*, cornstalks and grass by termites, and on apparent relations between rate of destruction of these materials and climatic conditions, density of tree cover and species of termite. The effect of termite activity on soil aeration and fertility is shown by soil-analysis data obtained from an active heap, a deserted heap and a control soil.

487 NIKIEMA, A.; TOLKAMP, G.W. **Propagation of *Faidherbia albida* by cuttings: Experience of the National Forest Seed Centre**. In *Faidherbia albida in the West African semi-arid tropics. Poceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 91-95 [En, 5 ref.]

Summarizes studies on propagation of *Faidherbia albida* by shoot and root cuttings carried out at CNSF, Ouagadougou, Burkina Faso from 1988-91. Optimal period to collect cuttings was during rains (June - Sept.) when the trees are most likely to be leafless. Rooting of branch cuttings took 2-3 months and cuttings from young plants rooted more readily. Basal treatment of 1% indole butyric acid gave better rooting than other hormone treatments, although the percentage rooting of all hormone treatments was no better than the control. Overall rooting rates remained low (38%), due in part to unresolved problems with temperature and fungus attacks.

488 NIMBKAR, B.V.; NIMBKAR, N.; ZENDE, N. **Desertification of Western Maharashtra, India: Causes and possible solutions. I. Comparative growth of eight tree species**. *Forest Ecology and Management* (1986) Vol. 16, 243-251 [En, 14 ref.]

Discusses the results of a field trial of eight tree species assessing the effect of spacing and fertilizer applications on their growth and survival in order to determine their suitability to wastelands of Western Maharashtra, and to investigate methods of establishing them rapidly and economically. The eight species included *Acacia albida*, *A. nilotica* var. *cupressiformis* and *A. nilotica* var. *indica*. Seedlings were raised in polybags (10 x 20 cm) and transplanted three months later, at spacings of either 5 x 0.6 m or 3 x 1.0 m. All *Acacias* had a high survival rate. Fertilizer applications up to 100:100:100 kg of $N:P_2O_5:K_2$ per ha had little significant effect on mean basal stem diameter and mean stem heights except for *A. nilotica* var. *cupressiformis* which had a significant response in height. *Leucena leucocephala* gave the greatest response to fertilizers and *Cassia siamea* at 62% had the lowest survival rate.

489 NJITI, C.F.; GALIANA, A. **Symbiotic properties and *Rhizobium* requirements for effective nodulation of five tropical dry zone acacias**. *Agroforestry Systems* (1996) **34** (3) 265-275 [En, 15 ref.]

Four-day-old seedlings of five tropical dry zone acacias were inoculated with three fast-growing *Rhizobium* strains and four slow-growing *Bradyrhizobium* strains. After two months of growth in the greenhouse, the plants were harvested and their shoot height and dry weight, nodule number and dry weight, acetylene reduction activity, and total shoot nitrogen were determined. The results showed that: (1) *Acacia polyacantha* (being evaluated for the first time) was promiscuous, nodulating indiscriminately with *Rhizobium* and *Bradyrhizobium* strains; (2) *Faidherbia albida and Acacia holosericea* (that were previously known to nodulate with *Bradyrhizobium* strains only) nodulated with *Rhizobium* strains as well; and (3) *Acacia senegal* and *Acacia nilotica* that were previously known to be nodulated exclusively by *Rhizobium* strains only were nodulated with both genera.

490 NKAONJA, R.S.W. **Dryland afforestation problems in Malawi**. *La-Yaaran* (1980) **30** (3-4) 100-105 [En, 5 ref.]

*Acacia albida* is listed as one of nine species out of 30 tried, showing promise in the dry zones of Malawi

with relatively slow growth but good survival. The dry zones are characterized by having high livestock populations and active termites, and while *Eucalyptus* species require fertilizers and insecticides to establish well, they are not essential for *A. albida*.

491 NKAONJA, R.S.W. **Fuelwood and polewood research project for the rural population of Malawi.** *Forestry Research Record, Forestry Research Institute, Malawi* (1985) No. 62, iii + 83 pp. [En, 4 ref.]

Results are reported from 93 species trials (covering 200 ha) established in 1979-81 with 28 species at 73 sites in seven dry silvicultural zones; 48 sites were on communal lands, 20 on individual farms and five on government forest lands. The best adapted and more productive species on these sites were *Eucalyptus camaldulensis* and *E. tereticornis*, followed by *Cassia siamea*, *Melia azedarach*, *Gmelina arborea*, *Albizia lebbek* and *Acacia albida*. *Azadirachta indica* and *Leucaena leucocephala* grew well on sites with pH 6.5 or more, and *E. maidenii*, *E. pellita* and *E. grandis* grew best on hydromorphic soils. Describes the medicinal uses of 369 species of plants, indigenous, naturalized or cultivated in North Africa. A decoction of the bark of *A. albida* is taken orally against leprosy. It occurs in Egypt, Libya, and Algeria.

492 NOEL, J.C.; SAAD, Z.A.; BUNDERSON, W.T. **Planning for agroforestry research in western Sudan: approaches, issues and lessons learned - the evolution of a management approach.** In *Planning for agroforestry [edited by Budd, W.W.; Duchhart, I.; Hardesty, L.H.; Steiner, F.]. Selected contributions from an international symposium held at Washington State University, Pullman, Washington, on 24-27 April 1989.* Amsterdam, Netherlands; Elsevier Science Publishers (1990) 203-226 [En.]

The Western Sudan Agricultural Research Project (WSARP) has established an agricultural research network in the four western provinces of Sudan. The research programme functions in concert with its parent organization, the national Agricultural Research Corporation, to plan and implement research leading to sustainable improvements in agricultural production and productivity for the farmers and pastoralists of the regions. Three major types of production systems were identified in the area: sedentary farming systems dominated by crops but including some livestock/poultry and carried out in areas cleared of *Acacia seyal* (sometimes tapped for gum, and re-establishing after a 5-7 yr cycle) but with retained *Balanites aegytiaca* [*B. aegyptiaca*] and *A. albida*; transhumant pastoralist systems which utilize *Acacia senegal* (for gum arabic and fodder) and *Balanites* and *A. albida* (for fodder); and true nomadic pastoral systems which also gather gum arabic and use perennial species for fodder. Within the context of a systems-oriented research approach (*i.e.* production systems or farming systems approaches), the WSARP developed a strategy, policies and procedures, and carried out research and planning efforts in which agroforestry development of the existing production systems figured prominently.

493 NONGONIERMA, A. [**Contribution to a biosystematic study of the genus *Acacia* Miller in West Africa. II. Characters of the inflorescences and flowers.**] Contribution à l'étude du genre *Acacia* Miller en Afrique occidentale. I. Caractères des inflorescences et des fleurs. *Bulletin de l'Institut Française d'Afrique Noire, Série A* (1976) **38** (3) 487-657 [Fr, en, 19 ref.]

A detailed biosystematic study of the floral characters of the West African acacias, illustrated with detailed drawings, and correlates them with phenological, cytological and biogeographic information. Proposes the formation of the monotypic genus *Faidherbia* A. Chev., with two subspecies *F. albida* (Del.) A. Chev. ssp. *albida* and *F. albida* (Del.) A. Chev. ssp. *senegalensis* Benth., and with subspecies *senegalensis* having three varieties. Subspecies *albida* has a mean of 5 pinnae pairs and a smaller leaf size and occurs in north-east Africa and Isreal, whereas ssp. *senegalensis* has a mean of 6-8 pairs, larger leaves and occurs only in West Africa. Within ssp. *senegalensis*, var. *senegalensis* is pubescent or villous as a mature plant, with glabrous fruits, var. *glabra* is totally glabrous, and var. *pseudo-glabra* is glabrous except for the seedlings /young plants that are pubescent, and a small percentage of the seedlings also have 2 opposite leaves at the epicotyl node (in var. *glabra* as well). For *F. albida* ssp. *albida*, 2 chromosome determinations are given 2n = 26, 52. *F. albida* is anomalous in many of the characters studied including stamen glands absent, only species with filaments partly joined at the base, only species with a spicate inflorescense and having dehiscent pods, and these points are illustrated with detailed drawings. It also flowers much later than other *Acacias*, most flowering between 1-3 years whereas it first flowered in the seventh year after planting.

494 NONGONIERMA, A. [**Contribution to a biosystematic study of the genus *Acacia* Miller in West Africa. III. Edaphology.**] Contribution à l'étude du genre *Acacia* Miller en Afrique occidentale. III. Édaphologie. *Bulletin de l'Institut Française d'Afrique Noire, Série A* (1977a) **39** (1) 23-74 [Fr, en, 18 ref.]

A study of 54 sub groups of soils taken from 613 soil profiles from Upper Volta, Mali, Mauritania, Niger and Senegal and compares them with the distribution of 27 *Acacia* taxa studied. Most of the *Acacia* species grew on wide range of soil types and different climatic conditions, including *Faidherbia albida* ssp. *senegalensis* a mesophyte widespread in the Sahelian, Sudanian, Sudanian-Guinean zones. Most *Acacia* taxa were found to be calcifuges, growing in soils with a low mean exchangeable calcium content (0-5.2% in milli-equivalents), and *F. albida* ssp. *senegalensis* var. *glabra* and

var. *pseudoglabra* are grouped as preferential calcifuges (1.7-2.0 % in m.e.), and *F. albida* ssp. *senegalensis* var. *senegalensis* as a facultative calcifile (5.2% in m.e.).

495 NONGONIERMA, A. [**Contribution to a biosystematic study of the genus *Acacia* Miller in West Africa. IV. Bioclimatic distribution of different taxa.**] Contribution à l'étude du genre *Acacia* Miller en Afrique occidentale. IV. Distribution bioclimatique des différents taxa. *Bulletin de l'Institut Française d'Afrique Noire, Série A* (1977b) **39** (2) 318-339 [Fr, en, 70 ref.]

A field study of the distribution of *Acacias* in the Sahelian countries in West Africa (Upper Volta, Mali, Mauritania, W. Niger and Senegal), which are presented in four maps showing their distribution limits in West Africa, with rainfall isohyets. *Faidherbia* ssp. *senegalensis* var. *glabra* occurs in areas with a mean annual rainfall of 250-375 mm, and for var. *pseudoglabra* and var. *senegalensis* in areas with 250-1600 mm.

496 NONGONIERMA, A. [**Contribution to a biosystematic study of the genus *Acacia* Miller in West Africa. V. Biometric characters of the fruits.**] Contribution à l'étude du genre *Acacia* Miller en Afrique occidentale. V. Caractères biométriquesdes fruits. *Bulletin de l'Institut Française d'Afrique Noire, Série A* (1977c) **39** (4) 695-787 [Fr, en, 8 ref.]

A biometric study of 16 characters of the fruit of West African *Acacias* illustrated with drawings and a key to saperate the taxa. *Faidherbia albida* is separated from *Acacia* genus, by the dimensions and colour of the fruits, by the seed number, (a mean of 17 seeds [range 10-22], as opposed to 2 to 12 seeds [range 2-18] in *Acacia*), comparison of the mean length compared with the mean seed number, and that it was the only spicate flowered *Acacia* with indehiscent fruits.

497 NONGONIERMA, A. [**Contribution to a biosystematic study of the genus *Acacia* Miller in West Africa. VI. Biometric characters of the seeds.**] Contribution à l'étude du genre *Acacia* Miller en Afrique occidentale. VI. Caractères biométriques des graines. *Bulletin de l'Institut Française d'Afrique Noire, Série A* (1978a) **40** (2) 312-422 [Fr, en, 17 ref.]

A biometric study of 19 seed characters of West African *Acacias* illustrated with drawings and a key to separate the taxa. He notes that *Faidherbia albida* differs from all other taxa studied, especially with regard to the spicate group of *Acacias*. Also gives a mean seed weights of *F. albida* 7.5 g per 100 seeds (from sample of 44,900 seeds).

498 NONGONIERMA, A. [**Contibution to a biosystematic study of the genus *Acacia* Miller in West Africa. VII. Biological characters of the seeds: germination.**] Contribution a l'étude du genre *Acacia* Miller en Afrique occidentale. VII. Caractères biologiques des graines: la germination. *Bulletin de l'Institut Française d'Afrique Noire, Série A* (1978b) **40** (3) 480-511 [Fr, en, 10 ref.]

A comparative study of germination in both manually scarified and whole seed (6-12 months old) from 50 taxa of West African *Acacias*. Many figures and tables give the rates of germination over time. For *Faidherbia albida*, scarified seed reached maximum germination after seven days, whereas whole seeds took an average 39.9 days. Tests on viability indicate that *F. albida* seeds survive storage longer than most *Acacias*.

499 NONGONIERMA, A. [**Contribution to a biosystematic study of the genus *Acacia* Miller in West Africa. VIII. Morphological, biometric and biological characters of young plants.**] Contribution a l'étude du genre *Acacia* Miller en Afrique occidentale. VIII. Caractères morphologiques, biométriques et biologiques des jeunes plants. *Bulletin de l'Institut Française d'Afrique Noire, Série A* (1978c) **40** (4) 705-832 [Fr, en, 21 ref.]

A biometric study of the morphological development of 7547 seedlings of *Acacia* taxa mainly from West Africa, from germination to the 20th or 30th leaf stage, illustrated with drawings and a key dividing the taxa. *Faidherbia albida* differs from other *Acacia* taxa in the mean number of pinnae pairs per leaf from 1st to 20th node is very variable. Most species took 12 weeks to reach the 20th leaf stage, when sown in July, but over three times as long when sown in November.

500 NONGONIERMA, A. [**Contribution to a biosystematic study of the genus *Acacia* Miller in West Africa. IX. Biometric characters of the leaves of the floriferous stems.**] Contribution à l'étude du genre *Acacia* Miller en Afrique occidentale. IX. Caractères biométriques des feuilles des tiges florifères. *Bulletin de l'Institut Française d'Afrique Noire, Série A* (1979) **41** (2) 215-285 [Fr, en, 14 ref.]

A biometric study of 17 leaf characters from 7,976 leaf samples of 34 taxa of *Acacia* mainly from West Africa but also other areas of Africa & the Near East. A key is given separating the taxa, and *Faidherbia* is separated from *Acacia* by having a very reduced or no gland on the petiole, but having a gland at the base of every pinnae pair (in 99.5% of the cases). The number of pinnae pairs on the leaves of flowering shoots distinguishes ssp. *albida* (mean of 5) from ssp. *senegalensis* (mean 6.9), as well as the leaf sizes. Also illustrates a unusual occurrence of an imparipinnate leaf in *F. albida* ssp. *senegalensis* var. *glabra*.

501 NSAHLAI, I.V.; OSUJI, P.O.; UMUNNA, N.N. **The degradability by sheep of fruits of *Acacia* and leaves of *Sesbania sesban* and the effects of supplementation with mixtures of browses and oilseed cake**

**on the utilization of teff (*Eragrostis tef*) straw.** *Animal Science* (1995) **61**(3) 539-544 [En, 22 ref.]

Thirteen rumen-cannulated sheep were fed *ad libitum* on teff straw supplemented with oilseed cake (50:50 mixture of noug (*Guizotia abyssinica*) and groundnut cake) 155 g, or oilseed cake 92 g + *Sesbania sesban* 118 g or *Acacia* fruits 179 g in a randomized complete-block design experiment. Diets were formulated to supply 10.5 g supplementary nitrogen per day. The diet containing sesbania had a higher DM washing loss, potential degradability and faster DM degradation rate than the diets containing acacia fruits. The N washing loss was highest for *Acacia sieberiana* (500 g/kg) followed by *A. albida* (431 g/kg), *A. tortilis* (431 g/kg) and sesbania (241 g/kg). The potential N degradability was higher for sesbania (978 g/kg) than for *A. albida* (848 g/kg), *A. tortilis* (865 g/kg) or *A. sieberiana* (785 g/kg). The degradation rates of oilseed cake-N and teff straw-DM, particulate and liquid passage rates, basal intake and DM digestibilities were similar among diets, but organic matter intake was highest for the *A. albida* diet.

502 NSAHLAI, I.V.; UMUNNA, N.N.; OSUJI, P.O. **Influence of feeding sheep on oilseed cake following the consumption of tanniferous feeds.** *Livestock Production Science* (1999) **60** (1) 59-69 [En, 39 ref.]

The synergism between oilseed (50:50 noug (*Guizotia abyssinica*) and groundnut cake) (OSC) and tanniferous feeds (*Acacia albida* [*Faidherbia albida*] pods *and Sesbania sesban* leaves) was investigated in two experiments. *S. sesban* has a lower content of soluble phenolics than *F. albida* pods (196 vs. 270 g/kg). Dietary treatments during trial 1 comprised teff (*Eragrostis tef*) straw given *ad libitum* supplemented daily with the following: 168 g of OSC alone (T1), or 100 g of OSC plus 135 g of *Sesbania* leaves (T2) or 100 g of OSC plus *F. albida* pods 50 (T3), 100 (T4) or 200 g (T5); 30 male sheep, weighing 19.5-22.9 kg were used. During trial 2, dietary treatments comprised T1, T2, T5 and an additional treatment consisting of a mixture of *Sesbania* leaves 100 g and *F. albida* pods 200 g; 30 sheep weighing 14.6-18.1 kg were used. One strategy (sequence) was to give the OSC following complete consumption of *Sesbania* leaves or *F. albida* pods while the other strategy (mixture) was to mix OSC with either of these forages before feeding. The sequence strategy was used in trial 1 while both strategies were used in trial 2. Each experiment used 30 sheep in a RCB design. During trial 1, incremental intake of pods resulted in a linear increases ($P<0.05$) in liveweight gain (LWG), organic matter (OM) and N intake but had no effect on straw intake. T5 and T2 had similar LWG (60 vs. 56 g) and intake. During trial 2, total N intake was within the range 12.0 to 12.9 g daily for diets containing OSC. Dietary treatments had no effect on the intake of teff straw, but the diet supplemented with OSC alone had lower DM intake (595 g daily) than the *Sesbania* leaves (637 g daily; $P<0.08$) and *F. albida* (694 g daily; $P<0.001$) diets. The digestibility of DM, OM and NDF were similar among diets. Faecal N (g/day) was similar between the *Sesbania* (5.11) and *F. albida* (5.29) diets which were higher ($P<0.01$) than on OSC alone. Sheep fed on the *Sesbania* diets excreted similar urinary N as did those on *F. albida* (4.04 vs. 3.39 g daily) but more ($P<0.05$) than those on OSC alone (2.9 g daily). Sheep had similar rates of LWG (g daily) on *Sesbania* leaves (57) and OSC alone (62) which were inferior to the *F. albida* diets (74). The difference in LWG between *Sesbania* and *F. albida* groups was small using the mixture strategy (10 g daily) and substantial using the sequence strategy (23 g daily; $P<0.01$). Similarly, LWG differences between strategies were small (2 g daily) for the *Sesbania* and large (15 g daily; $P<0.05$) for the *F. albida* diets. A comparison between the OSC-*F. albida* mixture and *F. albida*-Sesbania mixture suggested that *Sesbania* leaves could replace OSC with rather marginal increases in LWG. The discussion is structured to explain why the sequence strategy could offer a greater chance of interaction between tannin and OSC-protein than the mixture strategy and why such an interaction is more probable with *F. albida* pods than with *S. sesban*. It is concluded that it is beneficial to feed sheep on OSC following the intake of tanniferous feeds as this could support superior LWG.

503 NWAIGBO, L.C. **Human and animal impacts on vegetation and forage plants in the southern Guinea savanna of Nigeria.** *Proceedings of the XVI International Grassland Congress, 4-11 October 1989, Nice, France.* Versailles, France; Association Française pour la Production Fourragère (1989) 1073-1074 [En, fr, 5 ref.]

The effects of annual early burning (mid-Dec.), annual late burning (mid-Feb.) and grazing on the seedlings and saplings of savanna forage plant species (*Afzelia africana, Pterocarpus erinaceus, Acacia albida* and *Daniellia oliveri*) were investigated at Mokwa, Nigeria. Four plots: A (protected), B (early burning), C (late burning) and D (uncontrolled grazing and burning) were used. Results indicated that only plot A recorded an increase in the initial population of seedlings and saplings. Annual late burning destroyed seedlings and saplings of these forage species at a rate twice that of their regeneration rate; the effect of annual early burning was only 1.5 times the regeneration rate. Plot D showed a more resilient and stable ecosystem, with rates of seedling and sapling destruction equal to the regeneration rate in plot A.

504 OBEID, M.; MAHMOUD, A. **Ecological studies in the vegetation of the Sudan. II. The ecological relationships of the vegetation of Khartoum Province.** *Vegetatio* (1971) **23** (3/4) 177-198 [En, 21 ref.]

Discusses the water relations and soil preferences of the different plant communities and the destructive effects of grazing and human interference. *Acacia seyal* is shown to occupy a zone of intermediate moisture content between the richer shrub-land and the riverain zone subject to flooding for longer periods and occupied by *A. albida* and *A. nilotica*. Other species, typical of shrub-land, would normally grow into trees but acquire a bush form as a result of extensive grazing.

505 OBOHO, E.G. **Using forestry to improve living conditions of the Sokoto State dwellers**. *Presented at the launching of the Biological Sciences Association Magazine (Bioscope)* (1984) 1-16 [En, 31 ref.]

Discussion article on forestry activities in the Sokoto State of Northern Nigeria (semi-arid). Notes that *Acacia albida* is one of a number of fire hardy tree species. In this area there is conflict between the nomadic Fulani (traditional grazing rights) and local settled farmers over the use of these trees. Mentions that *A. albida* is slow growing (1 $m^3$ $ha^{-1}$ $yr^{-1}$). Advocates planting *A. albida* on farms and around houses, and as street trees for shade, nicknamed 'poor man airconditioners'.

506 OBOHO, E.E.G.; ALI, J.Y. **Preliminary investigation of the effect of seed weight on early growth characters of some savanna species**. In *Proceedings of 15th Annual Conference of the Forestry Association of Nigeria, Yola, 25-29 November, 1985 [edited by Okojie, J.A.; Okoro, O.O.]*. (1985) 144-156 [En, 9 ref.]

A study was made in the nursery of the effect of seed weight on early growth characteristics of *Acacia nilotica*, *A. albida* and *Azadirachta indica*. Germination time did not vary with seed weight but seedling height at time of appearance of leaflets did, being tallest for the high weight and lowest for the low weight class. The number of leaflets, biomass production and growth rate varied with seed weight. Seedlings from the low weight class had the highest root/shoot ratios.

507 ODEE, D.W. **A cross-inoculation study on indigenous rhizobia and selected tree legumes**. *Kenya Forestry Research Institute, Research Note No.3* (1989) 21 pp. [En, 7 ref.]

A rhizobia cross-inoculation study testing seven host species (*Acacia albida*, *A. mearnsii*, *Calliandra callothyrsus*, *Leuceana leucocephala* (two provenances), *Prosopis juliflora*, *Sesbania grandiflora*, and *S. sesban*) with their rhizobial strains. Isolates from *A. albida* collected from trees at Mbita Point (Nyanza Province) were found to be fast growing and acid producers. After 10 weeks from inoculation, *A. albida* nodulated with all strains, but was most effective with strains from *A. mearnsii* and then its own strain (evidence taken from tabulated results of shoot dry weights and visual observation).

508 ODEE, D.W.; SUTHERLAND, J.M.; KIMITI, J.M.; SPRENT, J.I. **Natural rhizobial populations and nodu-lation status of woody legumes growing in diverse Kenyan conditions**. Plant and Soil (1995) **173** (2) 211-224 [En, 33 ref.]

The rhizobial populations and nodulation status of both indigenous (mainly *Acacia* species) and some introduced (*Sesbania sesban*, *Prosopis juliflora* and *Faidherbia albida*) woody legume species were assessed under glasshouse conditions in soils collected from 12 sites located in different ecological zones of Kenya. The populations among the sites, as estimated by the MPN technique, varied from <3.6 to >2.3 X 105 cells $g^{-1}$ of soil. There were some intra-site variations in population estimates depending on the trap host species, date of soil collection and the method used in sampling the soils. Nodulation in whole soil also varied across the sites with test species frequently showing higher nodulation ability in native soils. *Sesbania sesban* was the most prolific nodulating species while *Acacia tortilis* was very erratic in nodulation. Nodulation of most species showed inter-plant and intraspecific variability within a single soil source.

509 ODERA, J.A **Agroforestry research in Kenya for more productive land use**. *Paper presented at the Training Workshop on Agroforestry, 27-30 June 1983, Lilongwe, Malawi*. ICRAF (1983) 21pp. [En]

The paper focuses on the "shamba" system as used in Kenya as being cost effective in plantation establishment and food crop production. The shamba system as a method of tree establishment is compared with three other systems using *Cupressus lusitanica* and *Pinus patula*. The paper also presents experimental results of intercropping maize/bean with young *Acacia albida* planted at 4 x 4 m which showed that there were no ill effects on the crop.

510 OKORIO, J. **The effect of *Faidherbia albida* on soil properties in a semi-arid environment in Morogoro, Tanzania**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.]*. ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 91-95 [En, 13 ref.]

Results of a six-year-old agroforestry trial of *Faidherbia albida* at Mafiga, Morogoro, Tanzania, where the effects of trees on soil properties when intercropped with food crops are given.

511 OKORIO, J.; MAGHEMBE, J.A. **The growth and yield of *Acacia albida* inter-cropped with maize (*Zea mays*) and beans (*Phaseolus vulgaris*) at Morogoro, Tanzania**. *Forest Ecology and Management* (1994) **64**, 183-190 [En, 22 ref.]

This experiment was conducted to evaluate growth and production of *Acacia albida* growing in agroforestry systems without crops, with maize and with beans with and without trees at 4, 5, and 6 m square spacing. At six years the mean height and diameter at breast height were 8.4 m and 10.7 cm respectively. Height growth was not affected by inter-cropping or by tree spacing but diameter was reduced at the 4x4 m spacing. Tree volume production varied between 9.9 and 24.9 $m^3$ $ha^{-1}$ and total biomass from 12.4 to 28.3 t $ha^{-1}$. Inter-cropping did not significantly affect tree volume or biomass production but spacing did significantly affect productivity with higher values at close spacing. Food crop yields were low, 200 to 400 kg $ha^{-1}$ for beans and 300 to 950 kg $ha^{-1}$ for maize. The yields were not significantly affected by the presence of trees, even at the closest spacing, but this may have been due to the young age of the trees and/or to the fact that the crops were fertilized which might have obscured any effects.

512 OLEGHE, P.E.; ODO, P.E. **Effect of water stress on the performance of seedlings of Gawo (*Faidherbia albida*) and *Acacia auriculiformis*.** *Nitrogen Fixing Tree Research Reports* (1991) Vol. 9, 25-26 [En, 3 ref.]

A study evaluating the effect of water stress on the growth of 10-week-old potted seedlings of *Faidherbia albida* and *Acacia auriculiformis* at the University of Maiduguri, Northern Nigeria. Thirty-six seedlings of each species were put under moisture stress levels of -0.5 MPa (severe), -0.3 MPa (moderate), and -0.01 MPa (control). After 16 weeks no significant differences were noted in seedling heights between species, but in both species seedling heights and leaf numbers significantly decreased with increased soil water stress.

513 OLIVER, R.; DEPOMMIER, D.; JANODET, E. **[The influence of *Faidherbia albida* on the soil and sorghum. Observations in the parkland of Watinoma in Burkina Faso.]** Influence de *Faidherbia albida* sur le sol et le sorgho. Observations dans le parc de Watinoma au Burkina Faso. In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Foret, Montpellier, France (1996) 312 pp. 141-152 [Fr, en]

A survey was undertaken in the Sahelian zone of Watinoma to compare sorghum production beneath and outside (control) *Faidherbia albida* canopies in four parklands with markedly different soil conditions. This study was carried out in 1990, a year with slightly less than average rainfall (547 mm as opposed to 608 mm on average). The pedological measurements were carried out under 12 trees and in 12 control situations. The agronomic measurements were carried out in each of the four parklands on ten sample plots beneath the canopy and ten sample plots outside the canopy. Because of colluviation, the soil at the top of the slope was shown to be much poorer than that at the bottom of the slope, but in every instance most chemical characteristics were better under the canopy. Under *F. albida,* likewise, there was a general improvement of the agronomic characteristics of sorghum, particularly with regard to the number and weight of stems and ears per hectare. The enhancing effects of *F. albida* on sorghum production seemed to be so marked that it was significant even if there was low tree density (10% of cover by canopies), but this effect was more appreciable in poor soil.

514 ONG, C.K.; SINGH, R.P.; KHAN, A.A.H.; OSMAN, M.; BLACK, C.R. **Recent advances in measuring water loss through trees.** *Agroforestry Today* (1990) **2** (3) 7-9 [En, 3 ref.]

A review done in 1986 of the techniques available for measuring transpiration in agroforestry systems concluded that porometry and sap-flow techniques offered the best potential. This paper describes two new sap-flow techniques, which have been evaluated over two years. The first is the 'custom heat-pulse system' developed in New Zealand by R. Edwards and the second the 'heat-balance technique' developed at ICRISAT in conjunction with G. Campbell of Washington State University, USA. The two techniques are described and representative results given from studies at ICRISAT for perennial pigeon pea (*Cajanus cajan*), *Acacia albida* and *Albizia lebbeck*. There was good agreement between the methods.

515 OPENSHAW, K. **Animals and trees: food for thought.** *Tanzanian Veterinary Bulletin* (1979) **1** (3) 2-8 [En, 4 ref.]

Animals and trees are examined from a position of mutual benefit rather than exclusive land use forms. Mentions the soil improving abilities of *Acacia albida*, the advantages of shade for cattle in the dry season and the valuable protein rich harvest of pods at the end of the dry season. Trees pump up nutrients that have been lost from the top soil. The canopy also helps to cut down wind erosion.

516 OREV, Y. **By the bootstraps - a contribution to the problem of enhanced food production in the Sudano-Sahel.** *Desertification Bulletin* (1991) No. 19 [En]

In this paper suggestions are put forward for improving food production in the Sudano-Sahel based on Australian ley-farming methods. The recurrence of severe droughts and loss of fertility destroy the food base in the Sudano-Sahel. There is a need for an agricultural revolution to improve and maintain soil fertility. The system proposed for the region is 3-5 years of grass, *Andropogon gayanus*, perhaps strengthened by *Stylosanthes*, grazed by tethered cows, which will result in considerable inputs of manure, followed by 2-3 crops of millet and perhaps cowpeas. Rows of *Acacia albida*

along field boundaries would raise the soil nutrients from deep levels to the surface.

517 OSONUBI, O.; BAKARE, O.N.; MULONGOY, K. **Interactions between drought stress and vesicular-arbuscular mycorrhiza on the growth of *Faidherbia albida* (syn. *Acacia albida*) and *Acacia nilotica* in sterile and non-sterile soils.** *Biology and Fertility of Soils* (1992) **14** (3) 159-165 [En, 39 ref.]

A growth study over 18 weeks of seedlings of *Faidherbia albida* and *A. nilotica* grown in pots in Ibadan Nigeria, with sterile and non-sterile soil inoculated with the vesicular-arbuscular mycorrhiza (VAM) *Glomus clarum*. Drought stress was imposed for the last 10 (*F. albida*) or 12 weeks (*A. nilotica*) of the experiment by watering once every two-week intervals. The effect of the VAM fungi in sterile soil significantly increased plant biomass of both species at the end of the experiment compared to the uninoculated control. In the non sterile soil, no significant difference was found, due to the indigenous VAM fungi (mainly *Acaulospora dilatata*) in the soil. There were significant interactions between VAM inoculation and drought stress or between VAM inoculation and soil sterilization for plant biomass and P uptake in *F. albida*, indicating that mycorrhizal infection is beneficial to P uptake and plant growth under drought-stressed conditions.

518 OUEDRAOGO, A.S. [**Comparative study of *Acacia albida* provenances at Gonse, Burkina Faso.**] Essai comparatif de provenances d'*Acacia albida* à Gonse, Burkina Faso. *Semences Forêts et Développement* (1987) 1, 27-32 [Fr]

A trial of six provenances showed significant differences in height between provenances in the nursery, but there was no significant difference in collar diameter between provenances in the field at age 18 months. Survival of all provenances was high (99.5-100%).

519 OUEDRAOGO, A.S.; ALEXANDRE, D.Y. [**The dynamics of the *Faidherbia albida* parklands.**] Dynamique des parcs à *Faidherbia albida*. Contraintes écologiques et économiques sur le terroir de Watinoma au Burkina Faso. In *[Faidherbia parklands.] Les Parcs a Faidherbia [edited by peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Foret, Montpellier, France (1996) 312 pp. 191-202 [Fr, en]

The study of the vegetation of Watinoma, a village in northern Burkina Faso, has shown a very marked differentiation here based on the toposequence and soils. In the arid conditions of the zone, the species in the agroforestry parkland are good indicators of ecological limitations and pedo-climatic conditions. *Faidherbia albida* occurs from preference at the bottom of the toposequence in deep, sandy soils. It is also found around villages in gravelly soils. But, in these conditions, it does not develop well, except around micro-depressions like those used for the manufacture of banco bricks. The study of the demographic structure of the species shows a great abundance of bushy specimens forming stems with a circumference of less than 10 cm, which are regularly felled by farmers. For specimens of more than 10 cm, the parkland appears to be ageing. The survey carried out shows various causes for this state of affairs *viz.*, the management restriction imposed by forest regulations in force, which prohibit farmers from cutting trees as they wish, and reduced interest in the species. This loss of interest results from the advent of chemical fertilizers, the trees' role as a roost for granivorous birds and thorns scattered in fields by transhumant herdsmen. In conclusion, contrary to what may be observed for other tree species, the future of *F. albida* depends much more on human than on ecological factors.

520 PAGEARD, R. [**Note on *Acacia albida* (*Faidherbia albida*) in Upper Volta**] Note sur l'*Acacia albida* (*Faidherbia albida*) en Haute-Volta. *Notes et documents Voltaïques* (1971) **4** (4) 50-59 [Fr]

This paper reports original anthropological observations of *Acacia albida* in Upper Volta. A description is given of chickens and millet being made to *A. albida* trees, and 'divine rules' promulgated by priests to protect the species.

521 PALGRAVE, K.C. ***Acacia albida***. In *Trees of Southern Africa*. Cape Town and Johannesburg, South Africa; Struik, C. (1977) p. 229 [En]

This is a protected tree in South Africa, and one of the largest species of *Acacia* - growing up to 30 m in height. The fruits which are an unusual pod (bright orange to reddish-brown in colour, thick, indehiscent, and characteristically and conspicuously curled and twisted), are eaten by both stock and game, and are regarded as valuable fodder for horses and cattle. The seed germinates readily if soaked in hot water and growth thereafter has been found to be fast if given favourable conditions; the trees are probably tender to frost.

522 PALMER, E.; PITMAN, N. **Trees of Southern Africa**. *A.A. Balkema, Cape Town, South Africa* (1972) **2**, 741-743 [En]

Gives a general description, illustrated with photographs, of Anaboom (*Acacia albida*) in Southern Africa, and lists its vernacular names. The species with camelthorn (*A. erioloba*) plays a vital role in local economy of the Topnaar Hottentots, who live in the margins of the Kuiseb river in the Namib desert. Their bark is used for building huts, and their pods as a food supplement. Anaboom can grow relatively fast under good growing conditions, reaching 7 m in 3 years, but is slightly frost tender.

523 PARDY, A.A. **Notes on indigenous trees and shrubs of Southern Rhodesia: *Acacia albida* (Del.) Mimosaceae.** *Rhodesian Agricultural Journal* (1953) **50**, 324-326 [En]

*Acacia albida*. White thorn or Ana tree. (Musangu, umpumpu, umtungabayeni). Large tree in the vicinity of the rivers in the Low Veld, up to 90 ft. high, d.b.h. 5 ft. Creamy white flowers appear in the early part of dry season (May - June), and light brown pods towards the end of the year. Found in fertile alluvial soils, often in groups or solid belts along the lower reaches of rivers flowing into Zambezi. Pods relished by wild animals particularly elephant and buck, and eaten by baboons. Valuable cattle feed, but records of powdered pods and seeds used for poisoning fish in pools. Seeds eaten as human famine food after boiling them, removing skins, boiling again then discard water, than finally boiled before eating. Large boles used for dugout canoes along Zambezi, possibly why trees more scattered along Zambezi than its tributaries, which have little or no water in dry season.

524 PARKER, A.K. **Report to the Government of Nigeria on Diseases of Forest Nurseries and Plantations.** *Summary Report, FAO Expanded Technical Assistance Program* (1964) No.1883, 39 pp. [En]

Brief reference that mistletoe (*Loranthaceae*) was found on a 13-month-old *Acacia albida* plant growing at Maidugari, Northern Nigeria.

525 PARODA, R.S.; MAL, B. **New plant sources for food and industry in India.** In *New crops for food and industry [edited by Wickens, G. et al.]*. London, UK; Chapman and Hall Ltd (1989) 135-149 [En, 18 ref.]

Eighty-one little-known cultivated food plants grown in India are listed and classed as seed/nut crops, vegetable crops, root and tuber crops, fruit crops, and spice, condiment and beverage plants. Plants suited to extreme environments, and those whose products have industrial uses are noted. The work of the All-India Coordinated Research Project on under-utilized and under-exploited plants is discussed with particular reference to research on winged bean, *Vigna* spp., *Amaranthus* spp., buckwheat, *Chenopodium album*, *Leucaena leucocephala*, *Bambusa* spp., *Dioscorea* spp., *Casuarina* spp., sugarcane, *Parthenium argentatum*, *Simmondsia chinensis*, *Euphorbia* spp, *Citrullus colocynthis*, *Cuphea* spp., *Faidherbia albida* (*Acacia albida*) and *Jatropha curcas*.

526 PARVEZ, A. **Vegetative propagation of *Acacia albida*: a promising species for farm-forestry in arid areas.** Indian Forester (1987) **113** (7) 459-465 [En, hindi, 5 ref.]

*Acacia albida* has been suggested as a replacement farm forestry species for *A. tortilis* which has been planted in arid areas of Haryana, Rajasthan and Gujarat, but suffers from severe damage to logs by wood borers. Preliminary experiments established in August 1982 indicated that of five species (*A. albida, A. tortilis, Prosopis cineraria, Tamarix articulata* [*T. aphylla*] and *A. chundra*) planted on dune and inter-dune areas, growth of *A. albida* was the best. However, *A. albida* either seeds irregularly or not at all, although it has been shown to produce profuse root suckers on sand dunes. Accordingly, vegetative propagation tests were made using 20-cm branch cuttings (diam. 0.5-1.5 cm) taken in the last week of February [1986?] from fresh twigs of *A. albida* in a research plot established at Jhumpa, Haryana, in 1982[?]. In the last week of February, cuttings were planted in polybags in 4 media: (a) sand from dunes; (b) sand + 30% farmyard manure (FYM); (c) sandy loam; or (d) sandy loam + 30% FYM. A thin slice was removed from the thicker end of cuttings just before planting. Bags were kept in flow-irrigated sunken beds. Sprouting was observed in nearly all cuttings within four weeks but successful rooting occurred in only 65% of cuttings. Shoots from thinner cuttings (diameter <0.7 cm) died a month after sprouting. Data are given on % sprouting, maximum and average shoot length, root numbers and maximum root length in relation to medium and/or cutting diameter. The best medium was (d) and the best diameter (giving the max. number of secondary roots) 1.0-1.3 cm. Cuttings were planted out on 25 July and height growth measured after 50, 100 and 150 days. Growth of cuttings from the FYM media (b and d) was best with (d) again producing maximum growth. Only the lower new roots developed further.

527 PAWICK, T. **The Unexploited Bee.** *Agroforestry Today* (1989) **1** (2) 8-10 [En]

Refers to the importance of phenology for dryland beekeeping, and that *Faidherbia albida* flowers at the end of the rains, providing a source of nectar and pollen when other plants have finished flowering.

528 PAYNE, W.A.; WILLIAMS, J.H.; MOUSSA, K.A.M.; STERN, R.D. **Crop diversification in the Sahel through use of environmental changes near *Faidherbia albida* (Del.) A. Chev.** *Crop Science* (1998) **38** (6)1585-1591 [En, 19 ref.]

Pearl millet (*Pennisetum glaucum*) is well adapted to the harsh environment of the West African Sahel but has relatively low genetic yield potential and market value. This study tested the hypothesis that alternative crops could be grown near *Faidherbia albida*, a tree species of semi-arid Africa, because of its ameliorating effects on the surrounding environment. Octants around trees were sown to pearl millet, maize (*Zea mays*), sorghum (*Sorghum bicolor*) and cotton (*Gossypium hirsutum*). Crop, soil and climate measurements were made periodically during the growing season. Soi fertility and fine-particle content decreased with distance

from trees. Inside the canopy, irradiance was reduced by 0.5 to 1.0 kW $m^{-2}$ and daytime soil temperature at a depth of 0.05 m was reduced by as much as 6°C. Improved conditions within the tree canopy were reflected by increased crop yield. Sorghum and maize tended to use less soil water than millet. Sorghum and maize yielded more than 120 g $m^{-2}$ near the tree bole, whereas millet yielded 80 g $m^{-2}$. Near the edge of the tree canopy, where pearl millet maintained yields of 40 g $m^{-2}$, the other crops tended to fail. *Faidherbia albida* trees can be used to diversify cropping systems and increase yields in the Sahel, but adoption of this agroforestry system may be constrained by modern social factors which have disrupted traditional land husbandry practices.

529 PEAKE, F.G.G. **A Bruchid seed-borer in *Acacia arabica*.** *Memoirs of Research Division, Ministry of Agriculture, Sudan* (1952) No. 29, 317-324 [En, 3 ref.]

Names two Bruchid pests of *Acacia albida*; *Pachymerus pallidus* Pic. (also found occasionally on *A. arabica*) and *Pachymerus pallidus* Ol. (also found on *Medicago* sp., *Terminalia*, *A. verek*, and *A. arabica*).

530 PEDLEY, L. **Classification of acacias**. Groupe international pour l'étude des Mimosoideae (1981) No. 9 pp. 42-48 [ ??]

531 PELISSIER, P. [**The peasants of Senegal - the agrarian civilizations of Cayor in the Casamance**] Les paysans du Sénégal - Les civilisations agraires du Cayor a la Casamance. *Imp. Fabregues, Saint Yrieux* (1967) 265-274 [Fr]

Develops fundamental and seldom recognized relationships between farmers of Senegal and *Acacia albida* trees. The tree's poor capacity for natural regeneration is largely blamed upon an impermeable seed coat which germinates with great difficulty and a high mortality of the germinated seedlings which leaf out and grow in the dry season with perhaps only a very shallow root system.

532 PELISSIER, P. [**The tree in the agricultural countryside of black Africa**] L'arbre dans les paysages agraires de l'Afrique Noire. L'arbre en Afrique tropicale - la fonction et le signe. Cahiers O.R.S.T.O.M., *ser. Sci. Hum.* (1980) XVII, (3-4) 131-136 [Fr]

533 PELTIER, R. [**Results of Silvicultural Trials, 1983 Measurements.**] Resultats des essais sylvicoles mesures 1983. Centre de Recherches Forestières, Cameroon (1984) 5 pp. [Fr]

Presents, through statistical analysis, the results of a 1983 study of interactions between woody species and annual cultivation (crop yields), particularly *Eucalyptus camaldulensis*, *Acacia albida*, *Acacia nilotica*, *Dalbergia sissoo*, and *Azadirachta indica*.

534 PELTIER, R. [**Agroforestry trials in northern Cameroon.**] Les essais d'agroforesterie au Nord-Cameroun. Centre de Recherches Forestières / Centre Technique Forestier Tropical, Maroua, Cameroon (1989) 1-42 [Fr, en]

Same paper as PELTIER & EYOG-MATIG (1988) below.

535 PELTIER, R.; EYOG-MATIG, O. [**Agroforestry trials in northern Cameroon.**] Les essais d'agroforesterie au Nord-Cameroun. *Bois et Forêts des Tropiques* (1988) **217**, 3-31 [Fr, en, es]

In traditional farming systems in Cameroon, trees were interspersed with crops. Attempts to modernize agriculture have resulted in the removal of trees from fields to facilitate monocultures and mechanization (leading to reduced soil fertility and erosion problems), whilst tree plantations have generally been unsuccessful. Results are reported of agroforestry experiments established by the Cameroon Forest Research Centre, the purposes of which were to devise methods of establishing small profitable private woodlots, and to reintroduce trees into the mechanized cropping systems to improve fertility and reduce erosion. The farmers of Meskine developed a mango (*Mangifera indica*)/onion (*Allium cepa*) intercropping system. After 5-10 years, the onion crops are gradually phased out. Based on this system, a method was developed for growing crops with *Eucalyptus camaldulensis* coppice used for fuelwood and building poles. The recommended cropping rotation is thus: 1st year, groundnut (*Arachis hypogaea*); 2nd year, cotton (*Gossypium*); 3rd year, sorghum (*Sorghum*); and 4th year, grazing. The trees are cut down in the 4th year and the slash burnt, the cycle starting again the following year. Forest fallow trials, and trials of windbreaks around fields of dry season sorghum are still in progress. Vegetatively propagated living fences are common in N. Cameroon. A method is proposed using planted or sown *Acacia nilotica* which is pruned regularly. Alley cropping, especially with *Leucaena leucocephala*, reduced crop yield. Intercropping of annual crops with *A. albida* had not produced conclusive results after three years, while intercropping with *L. leucocephala* reduced crop yield. Plans for erosion control studies are outlined.

536 PERSSON, R. **Forest Resources of Africa. Pt 1. Country descriptions. *Acacia albida*; Chad, Mali, Mauratania, Senegal (planted) Sudan**. ??

Very general data, e.g. total area planted *etc.*

537 PETROFF, G.; DOAT, J.; TISSOT, M. [**Pulping characteristics of some tropical reforestation species.**]

Caractéristiques papetières de quelques essences tropicales de reboisement. Vol. II. *Centre Technique Forestier Tropical Publication* (1967) No. 29 (2) 176 pp. [Fr]

Presents results from pulping trials on woods from 8 different tree species. Logs of 22-60 cm diameter from 2 trees of *Acacia albida* from the Diourbel Region Senegal were used. The density, fibre and chemical characteristics are given as well as details of the pulping and papermaking characteristics of unbleached or bleached pulp. Although it was possible to obtain bleach alkaline chemical pulp, yield is relatively low and the mechanical properties of the pulp are poor. None of the processes tried (sulphate, chemical soda and neutral sulphite semi-chemical) gave pulps of acceptable quality, either as unbleached or bleached pulps. *A. albida* is not recommended for planting for pulpwood production.

538 PEYRE de FABREGUES; LEBRUN, J. P. [**List of woody plants of Niger**] Catalogue des plantes vasculaires du Niger. IEMVT, Maisons-Alfort, Étude Botanique, No. 3, avril (1976) pp. 160-161 [Fr]

539 PHILLIPS-HOWARD, K.D. **Indirect mineland reclamation on the Jos Plateua, Nigeria**. *Land Use Policy, January 1993* (1993) 2-15. [En, 31 Ref]

This is a review of the experience and policy of mineland reclamation on the Jos Plateau, Nigeria with suggestions for improved resource use in the region. It is suggested that mineland should be farmed by local communities using their own priorities, knowledge and experience. Various trials and pilot projects were established to check the viability of the approach and these included tree species. *Faidherbia albida* was among the most successful, especially when planted in catchment basins, and had the potential of providing fodder and fuelwood and improving soil fertility. Further trials are needed to demonstrate longer term viability. The conclusion was that, with appropriate government support, the local people could be encouraged to reclaim much of the waste land for agricultural production.

540 PIOT, J. [**Management and utilization methods for woody forages: natural stands and artificial plantations**] Les méthodes de gestion et d'exploitation des fourrages ligneux: peuplements naturels et plantations artificielles. In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le.]*. Ethiopia; ILCA (1980) 339-349 [En, Fr, 13 ref.]

Reviews the perennial nature and long-growth phase of ligneous forage species, and their relatively delicate character when young. *Faidherbia albida*, however, at one year old, may have a tap root entrenched up to 5 m depth. Traditional management and utilization of ligneous plants are covered, for both natural formations and artificial stands. With *F. albida*, trimming proved to be a far better method for obtaining higher forage yields, than cutting the larger branches.

541 PIOT, J.; MIALHE, P. **Fiche monographique. Bilan. *Acacia albida* Del.** CTFT, Huste Volta (1982) 8 pp. [Fr]

542 PIOT, J; NEBOUT, J.P.; NANOT, R.; TOUTAIN, B. [**Utilization of the Sahelian woody perennials by domestic herbivores. Quantitative study in the southern zone of the Mare d'Oursi (Upper Volta).**] *Utilisation des ligneux Sahéliens par les herbivores domestiques. (tude quantitative dans la zone sud de la mare d'Oursi (Haute Volta).* Centre Technique Forestier Tropical, Institut d'Élevage et de Médicine Vétérinaire des Pays Tropicaux CTFT/IEMVPT, Paris (1980) 304 pp. [Fr, 23 ref.]

Describes the phenology, ecology and uses of 22 common forage tree species, forage nutrient values for 30 species, the biomass production in a few species and the feeding habits of domesticated animals in the Sahelian zone of Burkina Faso. Leaf flushing occurs between the end of September and November (at the end of the rainy season) in adult *Acacia albida* trees, however young trees may retain their leaves during the rainy season. Flowering occurs 1-2 months after leaf flushing, with fruits occurring in January through until March (3 months after flower anthesis). *A. albida* is found in the zone bordering the Mare d'Oursi on sandy soils with an easily accessible water table. It is an attractive fodder tree (especially pods and leaves) for goats, sheep and camels.

543 PITOT, A. [**The effect of the trade wind on some wood species in the Cape Verde Peninsula.**] L'action de l'alizé sur quelques espèces ligneuses dans la Presqu'île du Cap Vert. In *Proceedings 2a, Conferéncia Internacional dos Africanistas Ocidentais 1947, Lisbon* (1950) Vol. 2, 285-300 [Fr]

Describes and illustrates some effects of the wind on the growth of *Acacia (Faidherbia) albida*, *Parinari macrophylla* and *Elaeis guineensis*.

544 PLAYFORD, J.; APPELS, R.; BAUM, B.R. **The 5S DNA units of *Acacia* species (*Mimosaceae*).** *Plant Systematics and Evolution* (1992) **183**, 3-4, 235-247 [En, 23 ref.]

The DNA sequence structure of 5S DNA units in *Acacia* species, including representatives from the three subgenera of *Acacia*, have been determined for the first time. The data were interpreted to suggest that at least three lineages of 5S DNA sequences exist in *Acacia* and the proposal was made that the lineages be named 5S Dna-1, 5S Dna-2, and 5S Dna-3. The 5S Dna-1 lineage was represented by units from *A. boliviana* (Aculeiferum) and *A. bidwillii*, (Acacia), the 5S Dna-2 lineage by units from *A. melanoxylon*, *A. pycnantha*, *A. ulicifolia*,(all Phyllodineae) *A. boliviana*, *A. bidwillii*, and *A. albida (Acacia)*, and the 5S Dna-3 lineage by

units from *A. bidwilli, A. boliviana,* and *A. senegal* (Aculeiferum). Based on this interpretation of the sequence data, the Australian species of subgenus Phyllodineae grouped together as a cluster, quite separate from the subgenera Aculeiferum and Acacia, which were very similar for this character. As expected from the analyses of morphological characters, the 5S DNA units from *A. albida* (syn. *Faidherbia albida*) were quite separate from the other *Acacia spp.*, further support to it belonging to *Faidherbia* [from authors summary.]

545 PORTERES, R.: [**Management of the agricultural and rural economy of Senegal**] Aménagement de l'économie agricole et rurale du Sénégal. Mimeo report, ?? (1952) [Fr]

546 PORTERES, R. **Un arbre vivant a contre-saison en Afrique soudano-zambezienne: *Faidherbia albida*.** *Science and Nature* (1957) **19** 569-579 [Fr]

In *Acacia albida*, a thorny species found in the Sahelian and Sudanese zones of Africa on marginal land, leaf flushing, flowering and seed maturation take place in the dry season. Some other tree and shrub species show an autumnal growth spurt, but *A. albida* is unique in having its only vegetative period during the dry season. However, it flowers at about the same time as other *Acacia* species. It is hypothesized that damp soil inhibits the growth of *A. albida*, and that its aeration by lowering the water table stimulates growth. As it has no foliage during the rainy season, it does not interfere with crops grown under it. It provides shelter for livestock; prunings and pods are used for fodder, and branches are used for fences and fuelwood. In the dry season it provides protection against erosion. As the leaflets fall at the start of the rainy season they decompose without destruction by termites and provide nitrogen, phosphoric acid and lime. The foliage of plants grown under *A. albida* is more luxuriant than normal. Its presence makes possible a type of agriculture which high population pressure and a high concentration of livestock would otherwise inhibit.

547 POSCHEN, P. **An evaluation of the *Acacia albida*-based agroforestry practices in the Hararghe highlands of eastern Ethiopia.** *Agroforestry Systems* (1986) **4** (2) 129-143 [En, 16 ref.]

The growing of *Acacia albida* as a permanent tree crop, on farmlands with cereals, vegetables and coffee underneath or in between, is an indigenous agroforestry system in the Haraghe highlands of Eastern Ethiopia. A survey of paired plots at 27 sites in a 40 km radius around the Alemaya College of Agriculture revealed that maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L. Moench) yields were significantly greater under the tree canopy than without tree cover; a statistically significant increase in crop yields of 56%. Additional benefits from the *Acacia albida* trees include the supply of fuelwood and fodder. Quantitive estimates of these outputs as well as their monetary values are presented in the paper. Factors affecting the incorporation of *A. albida* into cropping patterns are discussed, including its relatively slow and highly variable growth, attitudes of the farmers, and a conflict with the spreading cultivation of Ch'at (*Catha edulis*).

548 POSCHEN-EICHE, P. **The application of farming systems research to community forestry - A case study in the Hararge Highlands, Eastern Ethiopia.** *Tropical Agriculture, Triops Verlag* (1987) ISBN 3-8236-1111-9 [En]

In this publication it is contended that Newcombe's (1984) model for the utilization of trees, in which "mining" advances until all tree cover is removed and dung becomes the only source of fuel, is not universal in Ethiopia. It is held that, although arable cash or staple food crops are given priority, farmers do not eliminate trees altogether but impose a selection by species and allow for recovery of trees in and around agricultural land, but in altered species composition. However, competition for land between trees, crops and livestock has been the overriding cause of deforestation. This is compounded for farmers with small holdings with a resultant preference for tree conservation and planting along roads, around homesteads, along field boundaries, on eroded sites and on communal grazing land where competition with crops can be avoided. The population in the Hararge Highlands meets the bulk of its needs for tree products from only 6-8 species but the potential of some of these has not yet been fully realized. *Acacia* (*Faidherbia*) *albida* is among them but it only figures in parts where there is some active propagation of trees in the fields to supplement natural regeneration and then only in minor quantities compared with species such as *Cordia africana*. Where it does occur, it is mainly at 1500-2400 feet altitude in cultivated land in valley bottoms with some occurrence in grassland, round homesteads and in degraded natural vegetation. It is as much or equally used for fuel, shade and mulch as any other species, commonly used for fodder/browse, household utensils and bee-keeping and rarely also used for poles fencing and tool handles. Only *Cordia africana* and *A. albida* were named as having positive effects on crops. The farmers' esteem of *A. albida* was increased with the frequency if its occurrence. Most people who remove trees from their cultivated lands do so to harvest the wood products rather than to remove competition from their crops.

549 POSS, R.; ROUSSEL, B.; JALLAS, E. [**Relationships between environmental features and woody species in Northern Togo**] ?? *Revue d'Ecologie la Terre et la Vie* (1990) **45** (1) 7-24 [Fr]

The structure of the woody vegetation of 65 sample plots of Sudanian savannas in northern Togo is analyzed

using correspondence analysis (reciprocal averaging). Five groupings of species were identified, each with some characteristic species, and a number of environmental factors responsible for the presence or absence of the latter were singled out. The role of anthropic and edaphic factors is emphasized. Man drastically alters the floristic structure of the vegetation, either directly by selecting useful species, or indirectly by creating conditions (fallow fields) that favour ruderal species with quickly sprouting new shoots. The nature of the soil is equally important: in areas with similar rainfall, differences in soil type explains the presence of either Sahelian or Guinean species. The results are compared with those of previous vegetation surveys. Four of the species groupings correspond to vegetation categories already described. However, the fifth grouping, characteristic of eroded areas, had never been identified previously.

550 POULAIN, J.F. [**Influence of *Acacia albida* Del. on pedoclimatic factors and crop yields.**] Influence de l'*Acacia albida* Del. sur les facteurs pedoclimatiques et les rendements des cultures. Le pont de vue de l'agronome. *ORSTOM/IRAT, Upper Volta* (1970) 9 pp. [Fr, 21 ref.]

Analyzes the effects of *Acacia albida* on the pedoclimate, soil fertility, and crop yields. Also presents the advantages and disadvantages of integrating *Acacia albida* in both a traditional and mechanized cultivation system. Principle conclusions from Dancette and Poulain (1968)

551 POULAIN, J. F. [**Influence of *Acacia albida* on the pedoclimatic factors and crop yields. The agronomic point of view**] Influence de *l'Acacia albida* Del. sur les facteurs pedoclimatiques et les rendements des cultures. Le point de vue de l'agronome. IRAT, Haute-Volta (1984) [Fr]

552 POULSEN, G. **Trees on cropland; Preserving an African heritage**. *Ceres* (1985) **18** (2) [En]

Describes the traditional farming system practised by most African farmers of cultivating crops and grazing livestock under and among trees. Gives the main tree species grown with special reference to *Acacia albida*, *Vitellaria paradoxa*, *Parkia biglobosa* and *Cassia siamea*. Describes the functions of these trees and stresses the importance of shelterbelts and their influence on climate.

553 POULSON, G. **Making something out of nothing - and more than that**. *Sylva Africana* (1979) No. 6, 6-8 [En]

Since 1971, the Bamburi Portland Cement Company, 10 km north of Mombassa, Kenya, has been attempting to return about 100 ha of rocky open-cast mined land to a useful purpose. This has been done successfully by creating a natural forest ecosystem rather than by systematic species elimination trials. The $N^2$ fixing species *Prosopis pallida* and *Casuarina equisetifolia* have been successfully introduced, often in combination with other 'multipurpose' species (providing fodder and wood) such as *Leucaena leucocephala* and *Acacia albida*. Selected wildlife and fish species have also been introduced, so as to produce a balanced ecosystem capable of exploitation.

554 PRATT, G.H. **Timber Drying Manual**. 2nd Edition revised by C Turner. *Building Research Establishment Report, Princes Risborough Laboratory, Princes Risborough* (1986) 122 pp. [En]

Details the principles of good drying practice and provides comprehensive information on the drying properties of commercially available hardwoods and softwoods. "Haraz", *Acacia albida* has an approximately shrinkage of 3% in tangential and 2.0% in radial section for a decrease from green timber to 12% moisture. It dries at a moderate rate with little tendency for surface checking or splitting. Original shakes may extend and distortion may be severe in timber with irregular grain. The standard kiln drying schedules are listed for various timber thicknesses and schedule "A" is recommended for *A. albida*.

555 PROT, J.C. [**Susceptibility of seven leguminous trees to the root-knot nematodes *Meloidogyne javanica*, *M. incognita*, *Scutellonema cavenessi* and *Dolichorhynchus elegans*.**] Sensibilité de sept légumineuses arborescentes aux nématodes *Meloidogyne javanica*, *M. incognita*, *Scutellonema cavenessi* et *Dolichorhynchus elegans*. *Revue de Nématologie* (1986) **9** (4) 416-18 [Fr, 5 ref.]

Seven tree species (six *Acacia* spp. and *Prosopis juliflora*) proposed for reforestation of the Sahelian zone of Senegal were tested for susceptibility to infestation with four root-knot nematodes common in Senegal. All the tree species were more or less susceptible to *Meloidogyne javanica* and *M. incognita*, with *Prosopis juliflora* as the best host for both. *Acacia raddiana* (*A. tortilis* ssp. *raddiana*), *A. nilotica*, *A. senegal* and *A. tumida* were poor hosts, only maintaining the initial population innoculated, whereas *A. albida* and *A. holosericea* were good hosts. Weak reproduction of *Scutellonema cavenessi* took place only in *A. holosericea* and *P. juliflora*, and *Dolichorhynchus elegans* reproduced only in *A. holosericea*.

556 PULLAN, R.A. **Farmed parkland in Zambia**. *Zambia Geographical Association* (1974) **26**, 1-17 [En, 32 ref.]

Describes the trees that form part of a farmed parkland in West Africa, such as *Acacia albida* and *Parkia clappertonia*, and contrasts them with the situation in

Zambia. Two species, *A. albida* and *Adansonia digitata*, which are used and preserved in West Africa are also found in the drier woodlands of Zambia. Lists a number of sites where *A. albida* occurs, the most important being on the densely populated farms in the alluvial fringes of the Kafue Flats (distribution map included). There it grows with *Ficus sycamorus* and the area supports a high population with large herds of cattle. Describes the benefits of farmed parkland, the need to conserve and increase planting of *A. albida* especially along field boundaries and settlements as there is little tradition of protecting them as in West Africa. Notes that its pods and seeds are used as a famine food by the Gwembe Tonga.

557 RADWANSKI, S.A., WICKENS, G.E. **The ecology of *Acacia albida* on mantle soils in Zalingei, Jebel Marra, Sudan**. *Journal of Applied Ecology* (1967) **4** (2) 569-579 [En, 5 ref.]

Reports on the ecology of *Acacia albida* and the soils on which it grows in the Jebel Marra region of Western Sudan. It is dominant on the alluvial soils of the river (wadi) terraces and the deeper mantle soils of the lower periments. Sorghum and other crops are grown underneath the trees during the rains and yields are considerably greater under them than elsewhere partly due to increased nutrients (organic carbon, nitrogen and phosphorus) and higher moisture levels from the pod and leaf fall at the beginning of the rains, and the dung and urine of cattle which eat the pods and seek the shade of the trees in the dry season. Gives data on analysis of pods and leaves and that in stall-fed steers, 65% of the seeds passed through the animal undigested.

558 RAINTREE, J.B. **Bioeconomic considerations in the design of agroforestry cropping systems**. *Plant Research and Agroforestry [edited by Huxley, P.A.]* (1984) 271-289 [En, 43 ref.]

A review of supplementary, complementary and competitive relationships between crops and trees, using linear programming as a practical bio-economic design tool. The benefits of *Acacia albida* are well documented as an example in agroforestry, particularly when intercropped with millet, sorghum or groundnuts. Due to the particular deciduous foliage habit of this tree legume, the shedding effects are conveniently withdrawn during the rainy season when the grain crops are in the field, leaving only the beneficial effects of improved soil fertility and water regime. Consequently, the tree stands in a net complementary relationship to the understorey arable crop.

559 RAISON, J.P. [**The parklands of Africa: state of knowledge and research perspectives.**] Les parcs en Afrique: Etat des connaissances et perspectives de recherches. In *Encyclopédie des techniques agricoles en Afrique. Document de travail* (1988) [Fr]

*Acacia albida* has been associated with human settlements for many centuries in the Sudano-Sahelian zone of Africa and it is the dominant tree in the parklands that are the characteristic abode of peasant farmers who have livestock and cultivate rain-fed grain crops without artificial fertilization. Its root system is amenable to cultivation beneath and around it by draught animals. *A. albida* is still being used where there is a need to extend the cropping areas out of the valleys into upper infertile dune sands to increase fertility and to control crop parasites such as *Striga helminthica*. The merits of the tree have been much praised in particular in relation to its 'deseasoning' characteristic, observed in both hemispheres, linked with a deep root system which plays a role in raising mineral elements to the surface. The Serer park in Senegal is a classic which can serve as a basis for analysis on account of the precision of the available Information although it has to be borne in mind that it is linked with rigorous rotation; most *A. albida* parklands are cropped continuously without a regulated rotation. The density of trees in the *A. albida* parklands in the Serer is proportional to their age and varies between 12 and 50. Density can also vary with the management of the crown of the tree. It can be conserved in bush form by repeated cutting every two or three years. It shoots from the stump and can be induced to develop a round crown through repeated pruning. Techniques of lopping and pruning could be developed to improve the tree's integration into the agricultural system. It is estimated that the fertilizing effects of a mature tree extend over about 100 $m^2$ and that 10-30 trees $ha^{-1}$ fertilizes 10 - 50% of the land. The original system was a biennial millet-fallow but this was replaced by a three year rotation of millet-groundnut-fallow in the colonial era. Grazing of cattle is controlled precisely to ensure even manuring of the land, to distribute seed for regenerating the trees and to minimize damage to crops by keeping the cattle in the fallow sections. The system is very economic as regards demands on labour. However, demographic growth and increasing needs have provoked degradation of system. This starts with omission of the fallow from the triennial system and it then becomes difficult to ensure food for livestock throughout the year if there is an insufficient bush back-up. The alternatives then become transhumance or the introduction of new fodder crops and artificial fertilization. Whatever its eminent qualities, *A. albida* parkland is not enough in itself to ensure maintenance of fertility. Its efficacy is only complete when its association with livestock is also complete. One hectare of *A. albida* parkland with 20 trees supplies enough fodder in the dry season (*c.* 1 950 kg) to feed six head of cattle, which is enough for fertilization of the fallow. In the rainy season, however, it is the quality of the herbaceous stratum or aerial pastorage - plus the area of surrounding pasturable bush - that determines whether or not there is sufficient browse to balance the system. The Serer system can be balanced with a human population of about 100 inhabitants $km^{-2}$. There are conflicting views on the type of livestock that is most

suitable for keeping in the Serer system. One view is that there is an incompatibility between *A. albida* and large cattle; success is thought to be dependent on the functional symbiosis between small cattle and the classical tree of the Sudanese parks. Another view is that the *A. albida* parkland could not exist without the combined action of large cattle and man, permitting both to survive with security in an otherwise unfavourable ecology. To a large extent, the answer depends on the geometry of land use and the movement of the livestock within the system. If the system demands more movement of livestock to and from pasture, the even distribution of manure is prejudiced; and there can be degradation along the animal passages. The fencing along cattle tracks also becomes critical; if fencing is made of dead material harvested from the trees, they deteriorate. In some parts this problem is overcome by the establishment of living hedges. It is still thought that development of *A. albida* parklands remains the best solution for all Sudanese-Sahelian populations who do not have vast bush at their disposal for extensive cultivation. However, the author wonders about the future of these parklands. Will they become a phenomenon of a past time when intensive agriculture was practised without capital? Their destruction is imposed by circumstances in which there is a race to win the land; and, once it is won, modern techniques will be introduced. This document cites many case studies to illustrate the information that is summarized here.

560 RAMSAY, D. McC. **The forest ecology of central Darfur**. *Forest Bulletins (New Series), Forests Department, Sudan* (1958) No. 1, 84 pp. [En]

A publication in three parts: (a) General description of Darfur and the major environmental factors; (b) The vegetation of Darfur, and its correlation with the vegetation in other areas of Africa; and (c) Detailed description of the vegetation of central Darfur. *Acacia adansonii* (*A. nilotica* ssp. *adstringens*) occurs on hard soils in several climatic associations of the region:- Thorn forest formation: *Acacia mellifera, Commiphora africana, Acacia nubica, Acacia tortilis* association, located between 300 mm and 500 mm isohyets; *Albizia sericocephala, Acacia seyal, Acacia senegal, Acacia mellifera* association, located between 450 mm and 650 mm isohyets; Savanna woodland formation: *Annogeissus schimperi, Acacia seyal, Lannea humilis, Albizia sericocephala* association between 600 mm and 800 mm isohyets The abundance of *A. adansonii* in these associations does not exceed 2.4% of total stocking. The species is also found in the edaphic associations of riparian vegetation:- Riparian thornland formation: *Acacia mellifera, Boscia senegalensis, Acacia nubica, Balanites aegyptiaca* association; Riparian thorn forest formation: *Acacia albida, Acacia tortilis, Ziziphus mucronata, Balanites aegyptiaca* association; the association, which includes *Acacia nilotica* ssp. *nilotica,* is found on sandy silt soils of wadi banks and flood plains.

561 RASHID, F.; HEYNS, J. **Description of *Namibinema scaphovulva* n. gen., n. sp. and *Zeldia punctata* (Thorne, 1925) from Namibia (Nematoda: Cephalobidae)**. *Phytophylactica* (1990) **22** (4) 397-403 [En, af, 4 ref.]

562 RASHID, F.; HEYNS, J.; COOMANS, A. ***Paracrobeles* and *Acrobeles* species from south west Africa/Namibia with description of a new *Acrobeles* species (Nematoda: Cephalobidae)**. *Phytophylactica* (1990) **22** (1) 41-49 [En, af, 14 ref.]

Two known and one new species of *Acrobeles* found under *Acacia albida* and *Stipagrostis* sp. are described and illustrated from South West Africa/ Namibia. *Acrobeles seelyae* sp. nov. closely resembles *Acrobeles sheasbyi* but can be distinguished from it. *Acrobeles thornei* was observed under SEM and some additional information is given. This species has been recorded only from South and South West Africa. *Acrobeles ciliatus*, is compared with *Acrobeles singulus* and the status of *A. singulus* is discussed.

563 RATTRAY, J.M.; WILD, H. **Report on the vegetation of the alluvial basin of the Sabi Valley and adjacent areas**. *Rhodesia Agricultural Journal* (1955) **52** (6) 484-501 [En]

A report of a reconnaissance ecological and botanical survey of part of the Sabi Valley in Zimbabwe bordered by the foothills of the Eastern Border Mountain Range to the east and by the hills of the Bikita and Ndanga Ranges to the west. The altitude lies between 1500 and 2000 ft, with the mean annual rainfall ranging from 15 to 25 inches. Descriptions are given of the typical vegetation types found in seven sub-regions within the valley, six of which are defined according to the soil type and the seventh as the riverine fringe. *Acacia heteracantha* (*A.tortilis* ssp. *heteracantha*) is the most abundant tree species in *Acacia* woodland on alluvium, but *A. albida, A. campylacantha* and *A. subalata* (*A. nilotica* ssp. *kraussiana*) are also common. These trees reach a height of 25 ft, but there are also small trees and shrubs of *Commiphora glandulosa, C. pilosa, Cordia ovalis, Dichrostachys glomerata* and *Grewia inaequilatera*. The most common grasses are *Chloris, Dactyloctenium, Digitaria* and *Urochloa* spp. Where there has been overgrazing the small herbaceous weed *Tribulus terrestris* becomes the dominant ground cover over large areas.

564 RAULIN, H.; RAYNAUD, E. [**Aid to the underdeveloped**] L'aide au sous-développement. IEDES, Coll. Tiers-monde, PUF, Paris, undated [Fr]

565 REDDELL, P.; WARREN, R. **Inoculation of *Acacias* with mycorrhizal fungi: potential benefits**. In *Australian Acacias in developing countries. ACIAR*

*Proceedings, Australian Centre for International Research* (1987) No. 16, 50-53 [En, 25 ref.]

Reviews the potential for using mycorrhizal fungi to improve the survival, establishment and growth of hardwood species in tropical plantations. Both ecto and VA mycorrhizal types have been found in the roots of *Acacia* species, which increase plant growth by enhancing the absorption of nutrients, and may reduce the effects of drought and transplantation stresses. VA mycorrhizas have been found in many species including *A. albida*, *A. nilotica*, *A. senegal* and *A. tortilis* ssp. *raddiana*.

566 REDHEAD, J.F.; MAGHEMBE, J.A. **Agroforestry: integrated land use for rural communities in tropical Africa**. Morogoro, Tanzania; Forestry Division, Dar es Salaam University (1981) 1-19 [En]

Results of various tree/crop combination trials (termed as agroforestry research initiations) at Morogoro in Tanzania are presented. The major tree species used in these trials were *Eucalyptus camaldulensis*, *Eucalyptus melliodora*, *Acacia albida* and *Leucaena leucocephala*. These were intercropped with food crops such as maize, sorghum and beans. The experiments are described and the results analyzed with the aid of five figures at the end of the text. It is concluded that it is possible to obtain food, fodder and fuelwood from the same unit under the same management system.

567 REDHEAD, J.F.; MAGHEMBE, J.A.; NDUNGURU, B.J. **The intercropping of grain legumes in agroforestry systems**. *Plant Research and Agroforestry [edited by Huxley, P.A.]* (1983) 117-124 [En, 12 ref.]

The loss of soil fertility due to the shortening of grass, bush or forest fallow periods, and the shortage in fuelwood supply is becoming a serious problem in many tropical areas. Potential grain legumes and trees are suggested for intercropping, in order to inhibit these adverse trends, including *Acacia albida*, for its capability of repeated lopping for fodder, for nitrogen fixation and for shedding leaves during the wet season. Analysis is made of the Morogoro agroforestry trials, first established in 1978, to investigate intercropping associations in separate trials of *Eucalyptus camaldulensis*, *Acacia albida* and *Leucaena leucocephala* with maize and field beans.

568 REED, J.D.; RITTNER, U.; TANNER, J.; WIEGAND, O. **Nutritive value of leaves and fruits of *Faidherbia albida* and their use for feeding ruminants**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 43-49 [En, 7 ref.]

Reports on a series of studies carried out at ILCA, Ethiopia, looking at the nutritive value of the leaves and fruits of *Faidherbia albida* for feeding ruminants compared to a number of *Acacia sp.* and other multipurpose trees, alfalfa *Medicago sativa*, and oilseed cakes. The importance of these feeds is stressed as a complement to the protein-deficient grasses and cereal crop residues that account for over 70% of the livestock feeds available in the semi arid zone of West Africa. While *F. albida* can contain high levels of protein, its anti-nutritional factors (tannins and related phenolics) may reduce protein digestibility. In feeding trials both the leaves and pods of *F. albida* appear to be good sources of protein in diets for ruminants unlike the Australian Acacias tried. The anti-nutritional factors in *F. albida* did not lower growth rate and intake of sheep fed *F. albida* leaves and pods in comparison with sheep fed oilseed meals or *Medicago* hay in diets based on cereal crop residues. No adverse effects were noted when *F. albida* pods constituted over 50% of intake of goats and sheep, but if it constituted 100% of the feed over 80 days there was some toxicity problem, greater for the sheep than the goats. However using pods as the sole feed is unlikely to occur. Stresses the need for more research to look at variability of nutritive value of leaves and pods between trees and provenances.

569 REHMAN, S.; HUSSAIN, A.; AMEEN, S. **Results of early selection of *Acacia* and *Prosopis* species/seed sources**. *Pakistan Journal of Forestry* (1988) **38** (2) 109-117 [En, 13 ref.]

Survival and height growth of a number of indigenous and exotic species of *Acacia* (*A. tortilis*, *A. albida*, *A. aneura*, *A. holosericea*, *A. cowleana*, *A. nilotica* and *A. senegal*) and *Prosopis* (*P. tamarugo*, *P. chilensis* and *P. cineraria*) in the nursery at Peshawar gave significant differences among sources, indicating the possibilities for selection of the best seed sources for afforestation in Pakistan. Further scope for improvement of the species is discussed. Seed sources of the exotic *A. albida* from Marina-Dakhar and Niakha Fall showed average survival rates of 48.0 and 47.9% respectively, and mean heights of 21.2 and 24.6 cm.

570 RENDELL, S. **Population genetic structure of *Faidherbia albida* (Del.) A. Chev. (Leguminosae, Mimosoidaea)**. *D.Phil. Thesis, University of Oxford, United Kingdom* (1998) 219 pp. [En, 291 ref]

The diversity and population genetics of *Faidherbia albida* (Del.) A. Chev.were investigated. Random amplified polymorphic DNAs (RAPDs) provided information on overall levels of genetic diversity, whilst restriction fragment length polymorphisms (RFLPs) in mitochondrial DNA (mtDNA) provided seed-specific markers. Allozyme data for half-sibs of these individuals made it possible to compare and contrast results from three different molecular marker techniques. RAPD analysis revealed polymorphic bands. Cluster analyses identified groups of populations

corresponding to three geographic regions; eastern, western and southern Africa. Three different methods to partition RAPD variation generated consistent estimates of variation at different hierarchical levels. At the regional level, about 80% of variation existed within geographic regions, whilst at the population level about 45% of variation could be attributed to differences within populations. Hybridization studies of a subset of RAPD products suggested that a high proportion were derived from organellar genomes. Analysis of five mtDNA-RFLPs revealed six different multilocus haplotypes; all were region-specific, one was population-specific. MtDNA polymorphisms differentiated between populations within geographic regions; two groups of populations corresponding to northern and southern Africa were identified. Allozyme data suggested that low variation in southern Africa could be explained through recent colonisation. A low inter-population pollen:seed flow ratio, estimated for the northern region, indicated that seed is migrating over greater distances than pollen. The multilocus out-crossing rate for an Ethiopian population was about 50%, with a high level of correlated matings. The molecular markers used in this study revealed similar geographic regions, which supported previous studies of morphological variation and allozyme diversity. However, measures of marker diversity, and components of variation attributed to different hierarchical levels, varied among techniques according to the genetic basis of the marker. Furthermore, inter-population distance measures derived from different techniques were not correlated.

571 RHOADES, C. **Seasonal pattern of nitrogen mineralization and soil moisture beneath *Faidherbia albida* (syn. *Acacia albida*) in Central Malawi.** *Agroforestry systems* (1995) **29**, 133-145 [En, 28 ref.]

On fertile alluvial soils on the lakeshore plain of Malawi, maize (*Zea mays* L.) yields beneath canopies of large *Faidherbia albida* trees greatly exceed those found beyond tree canopies, yet there is little difference in soil nutrients or organic matter. To investigate the possibility that soil nutrient dynamics contribute to increased maize yields, this study focused on the impact of *Faidherbia albida* on nitrogen mineralization and soil moisture from the time of crop planting until harvest. Both large and small trees were studied to consider whether tree effects change as trees mature. During the first month of the rainy season, a seven-fold difference in net N mineralization was recorded beneath large tree canopies compared to rates measured in open sites. The initial pulse beneath the trees was 60 $\mu g\ N\ g^{-1}$ in the top 15 cm of soil. During the rest of the cropping cycle, N availability was 1.5 to 3 times higher beneath the tree canopies than in open sites. Then total production of N during the 4-month study period was 112 $\mu g\ N\ g^{-1}$ below tree canopies compared to 42 $\mu g\ N\ g^{-1}$ beyond the canopies. The canopy versus open site difference grew from 4% at the beginning of the season to 50% at the end of the cropping season. Both N mineralization and soil moisture were decreased below young trees. Hence, the impact of *F. albida* on these soil properties changes with tree age and size. While maize yields were not depressed below young *F. albida*, it is important to realize that the full benefits of this traditional agroforestry system may require decades to develop. (Author's summary)

572 ROBBERTSE, P.J. **A scanning electron microscopic investigation of the pollen of South African *Acacia* species.** *Journal of South African Botany* (1974a) **40** (2) 91-99 [En, af, 13 ref.]

Uses SEM and light microscopic techniques to gain further details on the surface structures of pollen of South African *Acacia* species, and briefly discusses the taxonomic position of *A. albida* and *A. giraffae* [*A. erioloba*]. *A. albida* is distinct in that (1) unlike all South African acacias it has no glandular appendages on its anthers, (2) it has polyads with ungrooved monads like the *Acacias* in the series Vulgares, which all have 16 cell polyads but (3) it has up to 32 cells in the polyad (4) 2 peripheral monads on each lateral side of the polyad undergo a single division to form a double layer (unlike all others except *A. giraffae*). Concludes that *A. giraffae* and *A. albida* must be relicts of the parental stock of the African *Acacia* species, and *A. albida* should not be separated into *Faidherbia*.

573 ROBBERTSE, P.J. **The genus *Acacia* in South Africa. II. With special reference to the morphology of the flower and inflorescences.** *Phytomorphology* (1974b) **24** (1/2) 1-15 [En]

With this investigation the term 'flowering system' is introduced to describe the branch system on which inflorescences are produced. The South African *Acacia* species are divided into several groups based on the flowering system. The relationship between the type of flowering system, and the time of flowering of the different species is discussed. The possible origin of the involucel of the Gummiferae species and the importance of this phenomenon as a taxonomic criterion is discussed. Sketches of the flowers of all the investigated species are given to emphasize the presence of a cuplike disc in the flowers of the Vulgares species, the structure and the appendages of the ovary and the indumentum of the calyx as taxonomic criteria.

574 ROBBERTSE, P.J. **The genus *Acacia* Miller in South Africa. I. Stipules and spines.** *Bothalia* II (1975a) No. 4, 473-479 [En, 4 ref.]

A large number of seedlings and young twigs of South African *Acacia* species were sectioned and the vascularization of the nodes and internodes studied. In the Gummiferae species and *Acacia albida* the spines are modified stipules. The nodes of all the species examined are trilacunate, and as in the stipules of the *Vulgares*

species, stipules of Gummiferae species are supplied by vascular tissue branching from the lateral leaf traces.

575 ROBBERTSE, P.J. **The genus *Acacia* in South Africa. IV. The morphology of the mature pod.** *Bothalia* II (1975b) No. 4, 481-489 [En, 21 ref.]

The external morphology and anatomy of the pods of all the South African *Acacia* species are discussed, including the inner and outer epidermis, the mesophyll of the pericarp, the parenchymatous and sclereid strata, the fibre stratum, and the orientation of seeds within the pods. It was found that these species can be grouped into a number of distinct categories on the basis of the anatomy of their pods, of which there is quite a marked difference between those of the series Vulgares and those of the series Gummiferae. According to a classification based upon the anatomy of the pod, *Acacia albida* belongs to the series Vulgares, since its pericarp contains both longitudinal as well as latitudinal fibres (Gummiferae have fibre stratum with or without longitudinal fibres only).

576 ROBBERTSE, P.J. **The genus *Acacia* Miller in South Africa. VI. The morphology of the leaf.** *Boissiera* (1975c) **24**, 263-270 [En, 13 ref.]

The author has studied the morphology and anatomy of the heterophyllous (proximal and distal) leaves of 40 South African *Acacia* species. The pinnules have been found to be anatomically different in the Vulgares and in the Gummiferae. From a morphological point of view, *A. albida* differs from the other species and merits to be treated as being a separate, monotypic genus, *Faidherbia*.

577 ROBBERTSE, P.J.; TEICHMAN, I. Von. **The morphology of *Acacia redacta* (Ross, J.H.).** *Journal of South African Botany* (1979) **45** (1) 11-23 [En]

*Acacia redacta* is a small, much-branched shrub which grows in the Richtersveld. Ross (1974) provisionally placed it in the genus *Acacia* as fresh flowers and seeds were not available to aid him in his decision. In this investigation the pollen, seeds, seedling and the anatomy of the pod, seed, wood and pinnules were studied. According to these characters *A. redacta* does not fit in with either of the two subgenera of *Acacia* represented in South Africa, or with *A. albida* (*Faidherbia albida*). If this new information could be supported by a chromosome study it might become necessary to regard *A. redacta* as a new monotypic genus. [Ross (1979) continued to place the species in *Acacia*.]

578 ROBBERTSE, P.J.; VAN DER SCHIJFF, H.P. **The genus *Acacia* Miller in South Africa. V. With special reference to the seedling structure as a taxonomic characteristic.** *Mitt. Bot. Staatssamml. München* (1971) Vol. 10, 170-177 [En, 10 ref.]

Taxonomic characteristics are sought in an attempt to justify the grouping of *Acacia albida*, *A. schweinfurthii*, *A. kraussiana* and *A. brevispica* into a separate suborder called the Farinosae, considering the ambiguities arising when grouped to either the Vulgares or Gummiferae. In a tabulated analysis of seedling observations, *A. albida* is distinguished within the new sub order by having sessile cotyledons, first and second leaves on the seedlings which are bipinnate and 2-jugate, and no spinescent hooks on the internodes.

579 ROBBERTSE, P.J.; VENTER, G.; RENSBURG, H.J. Van. **The wood anatomy of the South African *Acacias*.** *International Association of Wood Anatomists* (IAWA Bulletin) (1980) **1** (3) 93-103 [En, 19 ref.]

Nine anatomical wood characteristics were found to vary sufficiently among 37 *Acacia* species to be useful for differentiating the species by principal component analysis. This examination of morphological characters, however, revealed *Acacia albida* to be so different from other *Acacia* species that it is doubted whether it should classified as one at all.

580 ROBERTS, H. **Forest insects of Nigeria with notes on their biology and distribution.** *Institute Paper, Commonwealth Forestry Institute, University of Oxford* (1969) No. 44, 206 pp. [En, many ref.]

Gives details of the activities of: (a) insects attacking living trees; (b) insects attacking felled and dying trees and lumber; (c) insect parasites, predators and commensals. The following have been found on *Acacia albida*:- Order COLEOPTERA, Family BRENTHIDAE, *Allagogus brunneus* - A parasite or predator found throughout the savanna in a large number of tree species in platypodid galleries; Family CURCULIONIDAE, *Stasiastes glabratus* - particularly *Sinoxylon cerateniae* and *S. senegalense* - a very common weevil in platypodid galleries under the bark of many newly felled species, found throughout Nigeria except for the Sahel zone; Family HISTERIDAE, *Teretrius kraatzi* - found with bostrychids in the Sudan savanna in dry dead stems and branches; Family LYCTIDAE, *Acantholyctus cornifrons* - found in dead branches at Maidugiri in the Sudan savanna; Family PLATYPODIDAE, *Doliopygus bohemanni* - a wood borer found on medium to large newly felled trees in the Guinea savanna; *Doliopygus malkini* - found mostly in the sapwood of medium to large newly felled and dying trees in savanna, particularly the Guinea zone; *Doliopygus terebrans* - a widespread borer which penetrates well into the heartwood of large newly felled and dying trees in savanna up to the northern limit of the Sudan zone; Family SCOLYTIDAE, *Xyleborus ferrugineus* - a very common unselective ambrosia beetle which occurs throughout Nigeria, the galleries penetrate 3-8 cm into the wood on logs and branches of dying trees, either with or without bark, *Xyleborus torquatus* - a common species in the drier

lowland rain forest and savanna, except possibly Sahel savanna, attacks newly felled and dying trees and branchwood where it creates simple galleries in the sapwood. Order LEPIDOPTERA, Family NOCTUIDAE *Crypsotidia conifera* - the larvae defoliate most commonly on *A. nilotica* and *A. albida* in the Sudan zone and are unusual in being active when the harmattan is at its worst (January) but *A. albida* is in full leaf then unlike most trees at this time and up to 50% defoliation of large trees can occur, *Pandesma anysa* - larvae defoliates *A. albida*, feeding at night and, in India, this noctuid defoliates *Acacia* and *Albzia* species.

581 ROBERTSON, J.K. ***Acacia* spp. as shade trees for Coffee**. *East African Agricultural Journal* (1954) **19** (4) 272 [En]

*Albizzia maranguensis* is usually considered the best (with *Cordia holstii* a good second-best) coffee shade-tree in the Northern Province, Tanganyika. *Grevillea robusta* is better for windbreaks. *Acacias* have hitherto not received mention. On the foot-slopes of Meru Mountain, with 51 in. of rain, *Acacia sieberiana* is very promising and *A. tortilis* spp. *spirocarpa* is accompanied in the Southern Highlands by consistently good growth and cropping of coffee. In areas with 50-60 in. of rain, *A. albida* is also successfully used.

582 ROBERTSON, V.C. **Western Darfar and the Jebel Marra**. *Sudan Silva* (1958) **1** (8) 27-30 [En]

Outlines the benefits of cultivating under *Acacia albida* (haraz) around Wadi Azum, and its occurrence up to 8,000 feet or thereabouts. Describes poor or non existent regeneration, with some trees also being killed because of harbouring birds harmful to crops. Where sub-surface water occurs at shallow depths, haraz trees act as shade for dry season crop. Tobacco is the only cash crop produced under its canopy.

583 ROBERTY, G. [**Vegetation associations in the middle Niger valley**] Les associations végétales de la vallée moyenne du Niger. Veroffentlichungen des geobotanischen Instituts Rubel, Zurich (1946) 22 96-97.

584 ROBINSON, P.J. **The dependence of crop production on trees and forest land**. In *Amelioration of soil by trees [edited by Prinsley, R.T.; Swift, M.J.]*. Commonwealth Science Council (1986) 104-120 [En, 56 ref.]

Explores the trends in supply and demand of crop, livestock and wood produce, questioning the feasibility of sustainable crop production through agroforestry development. Some of the potentially most attractive agroforestry systems are those in which the cropland fertility is improved or maintained by woody perennials growing within the cropland, either as scattered trees or as closely planted hedgerows. The case for *Acacia albida* is convincing, with studies showing substantially and significantly higher soil fertility status beneath the tree canopies.

585 ROBISCHON, M.A. **Development of a conservation strategy for *Faidherbia albida* (Del.) A. Chev. on basis of variability in chloroplast and nuclear DNA**. *M.Sc. Disseration, Oxford Forestry Institute, University of Oxford, UK* (2000) 84 pp. [En, 221 ref]

*Faidherbia albida,* a multipurpose Leguminous tree with a wide African distribution shows a distinct morphological variability, adaptations to local environment and human influence on its migration and dispersal. Conserving genetic variability in *Faidherbia albida* is important for maintaining its ability to adapt to environmental changes and the potential for future tree breeding. Conservation programmes require a thorough knowledge of a species genetic structure, which can be obtained using molecular markers. A study of chloroplast DNA, a new approach in *F. albida,* was expected to yield data of phylogenetic relevance. CpDNA regions were selectively amplified and digested with restriction enzymes, but no differences were found between the chloroplast genomes of different African *F. albida* populations. The concept of *Evolutionary Significant Units* (ESUs) and *Management Units* (MUs) integrates evolutionary dynamics in conservation. Three ESUs for *Faidherbia albida* in Africa were defined on the basis of available data from previous studies. The conservation of genetic resources *of F. albida* can be combined with sustainable forest or woodland management by defining *classes of sustained yield* in accordance with MUs on a genetic basis.

586 ROCHELEAU, D; WEBER, F.; FIELD-JUMA, A. **Agroforestry in dryland Africa**. Nairobi, Kenya; ICRAF (1988) 311 pp. [En, 11 pp. ref.]

*Acacia albida* (vernacular names; Apple-ring Acacia, Winter Thorn, Kad, Haraz, Gao, Kababu, Mgunga) is a well-known species for inter-cropping with millet and sorghum. Proper protection of the young trees must be afforded if natural regeneration is to be successful. In trials near Madarounfa, Niger, *A. albida* reached 5-7 m in 11 years, with d.b.h. 15-25 cm. Pod production was already substantial during this period, and crowns were beginning to spread, covering 4-6 $m^2$. It may be used as a fodder tree in alley-cropping, for live fencing, boundary markers and windbreaks, where a fairly tight (10x10 m) grid of the species protects the soil against wind and evaporation.

587 ROEDERER, Y. [**Seed collection of *Acacia albida* in the Republic of Cameroon**] Récolte de graines *d'Acacia albida* en République du Cameroun. CTFT, Nogent-sur-Marne (1986)

588 ROSS, J.H. ***Acacia albida* Del. in Africa.** *Boletin Sociedade Broteriana Série 2* (1966) **40**, 187-205 [E, e, 21 ref.]

Presents information on history, distributional range, growth form, morphological variation and taxonomy of *Acacia albida* Del.

589 ROSS, J.H. **Towards a classification of the African *Acacias*.** *Bothalia* II (1973) **1&2**, 107-113 [En]

Some of the first attempts to subdivide the genus *Acacia* Mill. as a whole are discussed briefly, including certain suggested modifications to Bentham's series Vulgares and Gummiferae. *Acacia albida* exhibits a number of unusual characters, some of which are peculiar to this species alone amongst the African *Acacias*. It differs in having leaves with eglandular petioles but a gland on the rhachis at the point of attachment of each pinnae pair, stamen filaments which are shortly connate basally and large anthers which are eglandular even when in bud. The pollen of *A. albida* forms polyads of 30 cells whereas in all of the other African species investigated the polyads have only 16 cells (except for *A. giraffae [A. erioloba]* with 26 to 48 cells). It has been considered sufficiently distinct to transfer it to the monotypic genus *Faidherbia*, but despite its anomolous position, it does nonetheless share many characters in common with other African Acacias.

590 ROSS, J.H. **A conspectus of the African *Acacia* species.** *Memoirs of the Botanical Survey of South Africa* (1979) No. 44, 155 pp. [En, af, fr, 76 ref.]

A conspectus is presented of the *Acacia* species (Fabaceae) which occur indigenously (including *A. farnesiana* which is doubtfully indigenous) in the continent of Africa west of Suez. The characters traditionally employed to divide the African species into two main groups are reviewed and the advantages of using these characters are discussed. The findings of workers in a number of diverse fields such as pollen, seedling and chromosome morphology, phytochemistry and the amino acid content of seeds are correlated with general morphology to provide a more comprehensive overall picture, and the infrageneric classification of the African species down to the rank of section is provided. Brief notes are given on pollen morphology and pollination, seed production, predation and dispersal, hybridization, and the origin and distribution of the African species. The morphological characters employed in the keys to identification are outlined and keys to the identification of the African species are provided. A brief description of each species is given together with synonymy, bibliographic references and a selection of representative specimens.

591 ROSS, J.H. **An analysis of the African *Acacia* species; their distribution, possible origins and relationships.** *Bothalia* (1981) **13**, 389-413 [En]

592 ROUPSARD, O.; FERHI, A.; GRANIER, A.; PALLO, F.; DEPOMMIER, D.; MALLET, B.; JOLY, H.I.; DREYER, E. **[Water function and depth of water abstraction of *Faidherbia albida* in an agroforestry park in the Sudanian biogeographic zone.]** Fonctionnement hydrique et profondeur de prélèvement de l'eau de *Faidherbia albida* dans un parc agroforestier soudanien.. In *L'acacia au Senegal [edited by Campa, C.; Grignon, C.; Gueye, M.; Hamon, S.]. Actes de la reunion thematique sur l'acacia au Senegal, Dakar, Senegal, 3-5 decembre 1996. Editions de l'ORSTOM, Paris, France* (1998) 81-103, 452-453 [Fr, 19 ref.]

*Faidherbia albida* is an important multipurpose tree in the semiarid climatic zones of sub-Saharan Africa, and exhibits an inverse phenology; it grows, fruits, and retains foliage during the dry season, with leaf fall occurring at the onset of the wet season. This phenological trait makes it an important agroforestry species, as competition with agricultural crops is reduced, and fodder is available during the dry season. Studies were carried out in the Dossi agroforestry park in Burkina Faso into the water balance and water use of adult *F. albida* trees in relation to phenology, seasonal climatic variation, and soil water supply. Root systems of *F. albida* penetrated to the water table (up to 7.5 m depth); during the dry season the water deficit of the soil horizons colonized by the roots reached -0.4 MPa, which was similar to that recorded for foliage (-0.5 MPa). Isotope studies (delta18O) indicated that during the dry season the most important source of water was from the deep water table. Although growth continued through the dry season, it was at a decreasing rate. Leaf fall after the onset of rains, however, appeared to take place independently of the water status of the tree. It is concluded that it is the efficiency of the root system as well as drought resistance mechanisms which allow *F. albida* to exhibit a reversed phenology. Its ability to tap deep water reserves is another important feature of its suitability for agroforestry systems, as it will not compete with agricultural crops for soil water resources.

593 ROUPSARD, O.; JOLY, H.I.; DREYER, E. **[The ecophysiology of *Faidherbia albida*. Hydrological function in agroforestry parks and intra-specific variability of juvenile characteristics.]** Écophysiologie de *Faidherbia albida*. Fonctionnement hydrique en parc agroforestier et variabilité intraspécifique de caractéristiques juvéniles. In *[Faidherbia parklands.] Les parcs a Faidherbia (edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Foret, Montpellier, France (1996) 312 pp. 85-102 [Fr, en]

A study of the behaviour of *Faidherbia albida* in drought conditions involves an examination of its climatic zone and the phenological reversal between the juvenile and adult stages. Our first question is a fundamental one on the strategy adopted by adult specimens to withstand the dry season while in leaf. At the end of the dry season, are the trees subject to any soil related water

restriction? Is this expressed by a physiological response (stomatal closure, reduction or cessation of growth, leaf-shedding...)? Does the species show a certain plasticity in its behaviour when water availability varies, and what are its limits? By comparing several sites in the same parkland, we discovered that where groundwater is consistently accessible, the trees display almost optimum transpiration and growth throughout the dry season with little change in the predawn water potentials and in the sap flow. On the other hand, where there is a more limited water reservoir, there is stomatal regulation of transpiration, and probably an associated growth reduction. The connection between groundwater restriction and growth has been described for potted 18-month-old juvenile specimens. It has been shown that seedlings regulated their transpiration and their growth for very moderate levels of drought. Growth cessation is revealed for a predawn water potential of -1.0 MPa, which is a characteristic behavioural pattern for so-called A drought-avoiding A species. This would suggest that, in natural conditions, adult specimens themselves have not developed resistance strategies, and only grow properly if they have access to substantial water reserves. Our second question is more applied. Why, depending on the sites chosen, do provenances of pan-African origin in trials in Sudanian or Sudano-Sahelian zones show marked differences for growth and survival. Is soil-related drought a significant factor in explaining these interactions between genotype and environment? By examining initial growth rates and water consumption in pots in a batch of seedlings of pan-African origin, we have managed to show that seedlings with high initial vigour consumed more water. This may be due largely to a greater transpiring leaf surface. Higher transpiration, associated with a limited water reservoir (this applies to juvenile trees which have not yet found the groundwater) might well be a disadvantage because the length of the period of soil related drought would be extended. We also show that initial vigour is positively correlated with water use efficiency (biomass/water consumed). This criterion is potentially interesting for the study of drought tolerance, and might serve as a complementary variable in genetic improvement programmes, particularly because it can be estimated by a simple measurement of carbon isotope discrimination. Finally, it appears in this study that the effect of drought on growth is a function of age, phenology, groundwater reserves and accessibility, root morphology, leaf surface, and seed origin.

594 ROUSSEL, J. **[Germination of forest seed]** Germination des semences forestières. Fiche Technique n? 3. C.N.R.F., Dakar, fevrier (1984) 5 pp.

595 RUREDZO, T.J.; HANSON, J. **Plant recovery from seedling-derived shoot tips of *Faidherbia albida* grown in vitro**. *Agroforestry Systems* (1993) Vol. 22, 59-65 [En, 16 ref.]

Describes the *in vitro* culture of *Faidherbia albida* shoot tips taken from seedlings and the successful rapid multiplication and transfer of the rooted cultures to the soil. The most vigorous growth and rooting was achieved on Murashige and Skoog based medium supplemented with 10-7M - naphthaleneacetic acid (NAA) only, where 87% of shoots formed roots. Seventy-one percent of the plantlets which were transferred to the soil established and nodulated with the native *Rhizobium*.

596 RUSSELL, F.C. **The chemical composition and digestibility of fodder shrubs and trees**. In *The Use and Misuse of Shrubs and Trees as Fodder. Imperial Agriculture Bureaux, Joint Publication* (1947) No. 10, 185-231 [En, 134 ref.]

Tabulates the crude chemical compositions of 894 samples of edible parts from fodder trees and shrubs around the world. For each analysis, protein, ether extract, crude fibre, N-free extract, ash, and elements (Ca, Mg, Na, K, Fe, P, Cl, S) are given. A second table gives digestibility data. For *Acacia albida* from Tanganyika (Tanzania) the crude protein of the pods is given as 8.8% and the digestible proteins at 4.5%. There are also analyses on *A. albida* from Rhodesia, Nigeria, and the highest crude protein levels being leaflets (17.1%), and flowers (19.0%), from trees in the Sudan.

597 SAHNI, K.C. **Important trees of the Northern Sudan**. Khartoum, Sudan; Forestry Research and Education Centre, UNDP/FAO (1968) 40-41 [En]

A botanical description of *Acacia albida* Del., with details of distribution and utilization in the Sudan. The very distinctive orange coloured curled or falcate pods are mostly 15 cm long x 2 cm wide and are not to be seen in any other East African *Acacia sp.*

598 SAKA, A.R.; BUNDERSON, W.T. ***Acacia albida* and *Leucaena leucocephala* in Malawi**. *The NRMS Newsletter* (1989a) **10**, 4 [En]

Taken from paper presented at "Trees for Development in sub-Saharan Africa" [see abstract below]

599 SAKA, A.R.; BUNDERSON, W.T. **The potential of *Acacia albida* and *Leucaena leucocephala* for smallholder crop production systems in Malawi**. In *Trees for Development in Sub-Saharan Africa. Proceedings of a regional seminar held by International Foundation for Science (IFS), ICRAF House, Nairobi, Kenya, Feb 20-25* (1989b) 150-161 [En, 36 ref.]

High soil fertility under *Acacia albida* has been attributed to nitrogen-fixation. During leaf shedding, the tree deposits a fine mulch of leaf litter which undergoes rapid decomposition, which greatly enriches the topsoil in plant nutrients whilst improving soil moisture conditions, soil porosity, root penetration, and entrapment of

fine precipitation. Since *A. albida* is bare during the growing season, sufficient light penetrates to crops beneath the canopy for normal photosynthesis. Partial shading produced by the tree's branches helps to reduce heat stress and evapotranspiration which contribute to early season survival of crops as well as improved yields. Millet and sorghum yields under the tree are 50 to 250% higher than in adjacent areas away from the tree, while groundnut yields are 35 to 100% higher, and average maize increases of 76% are known in Ethiopia. Current research is based on a more systematic integration of *A. albida* with crops (particularly maize), with little or no change to cultural tradition. Its potential success lies in the environmental limits of its growth, the successful development and on-farm testing of a sound extension message, and a concerted commitment by the Ministries of Agriculture and of Forestry and Natural Resources to support the effort as a priority activity.

600 SAKA, A.R.; BUNDERSON W.T.; ITIMU O.A.; MBEKEANI Y.; PHOMBEYA H.S.K. **The effects of *Acacia albida* on soils and maize grain yields under smallholder farm conditions in Malawi**. *Paper presented at the regional Agroforestry Conference, June 16-22* (1991) [En, 19 ref.]

See Saka *et al.* (1994) below for abstract of this paper.

601 SAKA, A.R.; BUNDERSON, W.T.; ITIMU, O.A.; PHOMBEYA, H.S.K.; MBEKEANI, Y. **The effects of *Acacia albida* on soils and maize grain yields under smallholder farm conditions in Malawi**. In *Forest Ecology and Management Special Issue: Agroforestry research in the African miombo ecozone [edited by Maghembe, J. A.]. Proceedings of a regional conference on agroforestry research in the African miombo ecozone held in Lilongwe, Malawi, 16-22 June 1991.* (1994) **64** (2/3) 217-230 [En, 16 ref.]

Research conducted in different ecological zones in Malawi indicates that *Acacia albida [Faidherbia albida]* has effects on maize similar to those reported in the Sahel, Sudan and Ethiopia. This paper reports on-farm studies in 3 ecological zones in Malawi, where mature *A. albida* trees are traditionally found on cultivated land. Yield and soil chemical trends were evaluated along transect lines at increasing distances (up to 30 m) from individual trees in different orientations extending away from the tree canopy. The general pattern was for yields to be highest from 5 to 10 m from the bole of the tree, to decline to 20 m and then to level out and sometimes even to increase slightly to 30 m. Exploratory studies at Khombedza, Salima Agricultural Development Division, along the lakeshore plain of Lake Malawi, during the 1987-88 season, showed that yields of local maize under traditional management with *A. albida* were more than double the yield away from the trees. However, the soil fertility status changed little over the length of the transects. Later studies were conducted at Bolero (Mzuzu Agricultural Development Division) in 1988-89 and 1989-90 and at Mvera (Kasungu Agricultural Development Division) in 1989-90, inland from the lake, with hybrid and local maize. Soil differences were again minimal. Hybrid maize (var. NSCM41 and R201) generally out-yielded local maize, but the size and period of sampling were too limited for conclusive results, especially regarding crop sustainability. Overall yield patterns were similar to the lakeshore area, but differences were more variable. This appeared to be a function of variability in tree size and shape, soils, crop management by the farmer, and proximity to neighbouring trees. The relative contributions of these factors are not known, indicating areas for further research. Because of the on-farm nature of these trials, control over external influences was limited, suggesting the need to standardize cropping practices and other factors across sites if the mechanisms affecting yields are to be better understood.

602 SAKA, A.R.; BUNDERSON, W.T.; MBEKEANI, Y.; ITIMU, O.A. **Planning and implementing agroforestry for small-holder farmers in Malawi**. *Planning for agroforestry. Selected contributions from an international symposium held at Washington State University, Pullman, Washington, on 24-27 April 1989 [edited by Budd, W.W.; Duchhart, I.; Hardesty, L.H.; Steiner, F.].* Amsterdam, Netherlands; Elsevier Science Publishers (1990) 247-266 [En, 27 ref.]

Malawi is faced with declining agricultural production. The country is dependent on agriculture and there is therefore an urgent need to develop production-increasing technologies and to preserve the integrity of its natural resources. This chapter describes the process of instituting a national agroforestry programme to help improve the sustainability and self-sufficiency of small-holder agriculture in Malawi. *Faidherbia albida* features prominently among the indigenous species described as being retained by small-holders to improve agricultural production. It is the first species recommended for studies on its functions and uses from the farmer' s perspective at the tree-crop interface. Although quantitative research is limited, *F. albida* is well known for its beneficial effects on cereal crop production and soils and it is also valued as a fodder and, to a lesser extent, as a fuel. Farmers in Malawi have long appreciated the value of the tree; they use it opportunistically and would benefit from more systematic integration to gain improvements in agricultural production without changing cultural traditions. As its value is already known, it can be extended for use into other areas with confidence. Only 25 to 40 trees per hectare are required for it to affect crop and soils uniformly and provide a high quality of fodder during the dry season. A fine mulch of enriching leaf litter falls at the time crops are sown; this reduces evapotranspiration and allows light to penetrate through the canopy to the crops for photosynthesis. It is pointed out that other trees require intensive management to reduce

shading and to spread the leaf manure on the soil. The *F. albida* research programme aims to address the species' possible role in contributing to the solution of the problems of declining soil fertility, increasing costs of imported mineral fertilizers, dry season fodder deficiencies and fuelwood shortages. Exploiting the species' potential will be determined by the environmental limits of the tree's growth, , the development of an effective extension message and commitment by the ministries of agriculture and forestry/natural resources to support the effort.

603 SALL, P.N. **Site effects of *Acacia albida* Del.** In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 103-105 [En, 14 ref.]

Briefly reviews the effects that the *Acacia albida* tree has on crop growth including microclimatic factors, soil properties, especially organic matter and biological activity, and crop yields. The positive benefits of *A. albida* on crops are summarized. However much is still unknown about site effects and an ORSTOM microbiology team in Dakar is using a multidisciplinary approach focusing on this field.

604 SAMBA, S.A.N. [**Study of the physical factors and socio-economic uses in the establishment of an agroforestry management plan: the case of Khayes**] (tude des facteurs physiques et socio économiques utiles a l'établissement d'un plan d'aménagement agroforestier: cas de Khayes. *Memoire de confirmation, Direction des Recherches sur les productions forestières, Institut Sénégalais de Recherches Agricoles, Ministère du Développement Rural, Dakar, Sénégal* (1988) [Fr]

A survey of *Acacia* (*Faidherbia*) *albida* was carried out in five vegetation zones and there were found to be an average of only 2-4 trees $ha^{-1}$ in all of them; but the populations had different structures. There are few young *A. albida* in the *Borassus aethiopium* zone because of the greater economic importance of the latter species. Because there is no fallow period, the seedling or coppice shoots are cut out each year in preparation for planting or weeding crops and larger stems are the target of firewood collectors. *F. albida* is dominant in importance in the *Adansonia digitata* and *Prosopis africana* zones although young trees tend not to survive because of the annual clearing of the land without fallows. In the *Parinari macrophylla* and the *Deterium microcarpum* zones, more distant from villages, although there is a paucity of large trees, due to past exploitation for wood products requiring larger trees, there is abundant natural regeneration which could be protected to build up a stocking of large trees. The rural population does seem keen to reforest the latter zone. *F. albida* is included among the principal firewood species and is also among the most used species for charcoal. It is not, however, a preferred species for these uses. With the disappearance of more favoured species, wood of *A. albida* is also now being used for solid timber products for general use. It is a preferred species for fodder and pods for livestock.

605 SAMBA, S.A.N. **Regeneration of *Acacia albida* with direct seeding**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 139-140 [En, 1 ref.]

A trial to compare direct seeding with out-planting potted seedlings at Thienaba, located in the Sahelian zone of Senegal with an annual rainfall of 400 to 500 mm. Germination and survival after 3 months was high in both treatments, but after 6 months the percentage of potted seedlings surviving declined by 13%, with no mortality occurring with direct seeding in this period. Seedlings from direct seeding showed significantly higher growth compared to the potted seedlings in all parameters measured. Recommends direct seeding provided the soil is moist to over 50 cm depth, and well weeded.

606 SAMYN, J.M.; ZONGO, A. [**Agroforestry: A potential solution to major problems of Burkina Faso.**] L'agroforestierie face aux grands problèmes du Burkina Fasso. *Intercooperation Suisse* (1984) 1-26 [Fr, 26 ref.]

Presents the disastrous effects of three factors of degradation on the woodland savanna on Burkino Faso. The cited factors and analyses are increased population, methods of cultivation and the need for fuel wood. The traditional agroforestry methods, the necessity for soil improvement and their potential contribution towards an integrated rural environment are discussed.

607 SANDIFORD, M. **Burnt offerings: an evaluation of the hot-wire seed scarifier**. *Commonwealth Forestry Review* (1988) **67** (3) 285-292 [En, 7 ref.]

A test with 10 species of multipurpose tree with hard seed coats showed that hot-wire scarification was at least as good as the best conventional method in six species, *Acacia albida*, *A. mearnsii*, *Adenanthera pavonina*, *Delonix regia*, *Calliandra calothyrsus*, *Caesalpinia spinosa*, better in *Acacia polyacantha*, considerably better in *A. tortilis*, poorer in *A. nilotica*, and much poorer in *A. melanoxylon*. After treatment, the seed could be stored for further periods, enabling the distribution of pre-scarified seed to small nurseries and individuals with limited resources.

608 SANDWIDI, B. [**Contribution to improvement of *Acacia albida* Del.: study of variability of growth in planting and propagation.**] Contribution a l'amélioration

de *Acacia albida* Del.: étude de la variabilité de croissance en plantation et bouturage. *Mémoire de fin d'études. Présente en vue de l'obtention du Diplôme d' Ingénieur du Développement Rural. Université de Ouagadougou, IDR, IRBET, CTFT, CIRAD Burkina Faso Juin 1988.* (1988) 77 pp. [Fr, 44 ref.]

Fifteen provenances were planted in the trials from a limited part of the range of *Acacia albida*. They were from Senegal, Burkina Faso, Mali, Niger and Burundi. They were planted at three trial sites representing three major ecological zones in Burkina Faso. At eight weeks in the nursery, the Burundi provenances had light green, pubescent, tender leaves whereas those of all the other provenances (West African) were dark green, glabrous and more correaceous. Survival was highest for the Cameroon, Mali, Niger and Senegal provenances and lowest for those from Burundi. At ten months, there was still a linear relationship between mean provenance seed size and vigour. This correlation also existed within provenances. From 12 to 30 months after planting out, the exotic provenances could be placed in three categories according to their performance in relation to the indigenous provenances:- Group 1- provenances from Burundi and Senegal which had superior growth; Group 2 – provenances from Mali and Niger whose growth was similar; and Group 3 – provenances from Cameroon which had inferior growth. The variability revealed between provenances should be considered as geographical until its genetic control is established through clonal and progeny tests. Soil fertility was revealed as a limiting factor for the expression of the potential for growth. Best growth was on soils with high moisture availability, a high proportion of clay and silt and a low proportion of sand. Worst growth was on the sandiest soils which was unexpected from experience reported elsewhere but probably explainable in that it was combined with a long dry season and the assessment of the characteristic of early growth. The less well-adapted plants were attacked by a psyllid. The results of the analyses have suggested that an assessment of the effects of rhizobia and mycorrhizae are also required to understand variation. Coppice shoots from stumps were found to be much more successful than cuttings from adult twigs for vegetative propagation. IBA at 0.5% improved rooting and success was higher in September and October and January and February than it was in November and December, winter in Burkina Faso. The experiment has shown that the technique used with eucalypts is not applicable to *A. albida* as cuttings did better in frames than under cloches. The phenological cycle of this tree may be an important criterion for consideration when working towards a better understanding of rhizogenesis. Complementary studies on the medium to use and weaning must be undertaken. Even if interest in *A. albida* has stimulated numerous biological studies, the value of the potential of this tree will not be achieved until certain socio-economic constraints are resolved. Future studies could include the development of a strategy for the utilization of the species.

609 SANGINGA, N. **Nodulation and growth of some nitrogen fixing trees in relation to nutrient levels and *Rhizobium* in Nigeria, Zaire and Zimbabwe.** *Nitrogen Fixing Tree Research Reports* (1988) No. 6, 3-5 [En, 3 ref.]

Pot experiments are reported with various species grown in three soil types from each country. *Acacia albida* was included in the the species tested from Nigeria. Data are tabulated on soil chemical characteristics; all the soils were acid. Dried, sieved soil (5 kg/pot) was used either untreated, or fertilized with 250 mg P (as super phosphate), 50 mg K (as muriate of potash), and micronutrients (1 ml of 0.05% B, 0.005% Zn, 0.005% Mo and 0.002% Cu). The seeds were sterilized in concentrated sulphuric acid for 30 min, and rinsed well, before sowing. Shoot dry weight, and nodule numbers and weight were recorded after 2-3 months. Fertilizing increased shoot weight by two to three times. The mean shoot dry weights for *A. albida* in *Leucaena* fallow, secondary forest and grassland fallow soils were 1.17, 0.81, and 0.91 g respectively, *i.e.*, there was better growth in soil previously cropped to *L. leucocephala* or soyabeans than in grassland or secondary forest. Nodule presence was affected by species and soil. No nodules were found in plants grown in any of the soils from Zimbabwe, or in any of the *L. leucocephala* varieties in forest soil from Zaire. All the other combinations tested showed nodulation, with *A. albida* producing the smallest, 1.47, 1.89 and 2.48 mg per nodule respectively for the three soil types. *Rhizobium* strains were isolated and characterized; those from *L. leucocephala* and the *Sesbania* spp. were fast growing acid producers, while those from *A. albida* were slow growing alkali producers.

610 SANGINGA, N.; BOWEN, G.D.; DANSO, S.K.A. **Assessment of provenance variation in growth and P uptake of *Faidherbia albida* grown at low levels of phosphate.** *Nitrogen Fixing Tree Research Reports* (1990a) Vol. 8, 133-135 [En, 6 ref.]

Phosphorus deficiency appears to be a major factor limiting the establishment of most nitrogen fixing trees in many soils of degraded lands throughout tropical Africa. A collection of *Faidherbia albida* sources was evaluated in a pot trial to examine genetic variation in growth and P uptake at low P levels. The seeds were inoculated before sowing with a 1 ml suspension of *Rhizobium*, and treatments included two levels of P (20 and 80 mg P/kg soil) as $KH_2PO_4$. There were significant differences in shoot dry weight among the eleven provenances at both high and low P levels. These results demonstrated genetic variation in the ability of *F. albida* to grow under low P, a variation which should be exploited as a means of alleviating the problem of P deficiency in low P soils in the tropics.

611 SANGINGA, N.; BOWEN, G.D.; DANSO, S.K.A. **Assessment of genetic variability for N2 fixation**

**between and within provenances of *Leucaena leucocephala* and *Acacia albida* estimated by 15N labelling techniques.** *Plant and Soil* (1990b) **127** (2) 169-178 [En, 16 ref.]

Nitrogen fixed in 13 provenances of *Acacia albida* and 11 isolines of *Leucaena leucocephala* inoculated with effective *Rhizobium* strains was measured by 15N techniques and the total N difference method. In the test soil, on average, *L. leucocephala* derived about 65% of its total N from atmospheric N2 fixation compared with about 20% by *A. albida*. Significant differences in the percentage of N derived from atmospheric N2 (% Ndfa) occurred between provenances or isolines within species. The % Ndfa ranged from 37 to 74% within *L. leucocephala* and from 6 to 37% within *A. albida* (equivalent to 20-50 mg N/plant and 4-37 mg N/plant over three months, respectively) and was correlated with nodule mass (r = 0.91). The time course of N2 fixation of three selected provenances (low, intermediate and good fixers) was followed at 12-weekly intervals over a 36-week period. The % Ndfa of all provenances and isolines increased with time; except for one of the *L. leucocephala* provenances, % Ndfa was similar within species at the 36 weeks harvest. There was a significant correlation between % Ndfa and amount of N2 fixed (r = 0.96). Significant interactions occurred between provenances and N treatments and often growth of uninoculated but N-fertilized plants was less variable than that of inoculated unfertilized plants.

612 SANGINGA, N.; DANSO, S.K.A.; ZAPATA, F.; BOWEN, G.D. **Influence of reference trees on nitrogen fixation estimates in *Leucaena leucocephala* and *Acacia albida* using nitrogen-15 labelling techniques.** *Biology and Fertility of Soils* (1990) **9** (4) 341-346 [En]

An examination was made of the suitability of four reference crops, i.e., two non-fixing trees, *Cassia siamea* and *Eucalyptus grandis* and two uninoculated fixing trees, *Leucaena leucocephala* and *Acacia albida*, for measuring N2 fixed in inoculated *L. leucocephala* and *A. albida* grown for 36 weeks in pots. The 15N isotope-dilution (involving the addition of equal amounts of labelled N fertilizer added to the fixing and the non-fixing plants) and the A-value (with different amounts of labelled N fertilizer added to the fixing and the non-fixing trees) methods were used. The isotope dilution approach gave several large negative estimates of fixed N2 in *A. albida*. Positive and similar values of fixed N2 were measured in all four reference trees using the A-value approach. For *L. leucocephala* the isotope-dilution approach gave different estimates of fixed N2, with the different reference trees; the uninoculated N2-fixing trees indicated significantly less fixed N2 than the non-fixing reference trees. Similar values for N2 fixed in *L. leucocephala* were obtained using the two non-fixing trees, either by the isotope-dilution or the A-value method. On average, *A. albida* derived about twice as much N from fertilizer as *L. leucocephala*. In both species, the atom % 15N excess declined by about 50% in successive harvests.

613 SANGINGA, N.; MULONGOY, K.; AYANABA, A. [**Evaluation of indigenous strains of *Rhizobium* for *Leucaena leucocephala* (Lam.) de Wit in Nigeria conditions.**] Les arbres fixateurs d'azote. L'amélioration biologique de la fertilité du sol. *Actes des séminaires, 17-25 mars, Dakar, Sénégal. Editions de l 5 ORSTOM, Paris, France* (1987) 416-436 [En, 23 ref.]

Experiments were conducted at the International Institute of Tropical Agriculture (IITA) and at Fashola, SW Nigeria, to identify, characterize and evaluate indigenous rhizobia nodulating *Leucaena leucocephala*. The Most-Probable-Number method indicated that leucaena rhizobia were few or absent in soils with no previous history of leucaena cultivation. They were significantly more abundant in a field cropped to leucaena, indicating that leucaena crops build up the population of compatible rhizobia in the root zone. Rhizobia isolated from seven legumes (*L. leucocephala*, *Tephrosia vogelii*, *Sesbania grandiflora*, *S. punctata*, *S. rostrata*, *Acacia albida* and *Vigna unguiculata*) were tested for their N-fixing effectiveness with *L. leucocephala* in standard Leonard jars. Isolates from all plants except *S. grandiflora* and *V. unguiculata* were able to form nodules with leucaena, although a wide range of effectiveness was demonstrated. Based on this experiment, a group of 10 effective rhizobia were tested in pots. Only two rhizobia (IRc 1045 and IRc 1050) isolated from leucaena performed well and were further tested in the field. At IITA, only inoculated plants nodulated, while at Fashola all the plants produced nodules. At both locations, inoculation with Rhizobium IRc 1045 or IRc 1050 increased total N and dry matter of leucaena as compared with the uninoculated plants. This effect was statistically equal to the N treatment. In addition to their effectiveness, these strains were competitive and survived well in the field one year after their establishment.

614 SANGINGA, N.; MULONGOY, K.; AYANABA, A. **Effectivity of indigenous rhizobia for nodulation and early nitrogen fixation with *Leucaena leucocephala* grown in Nigerian soils.** *Soil Biology and Biochemistry* (1989) **21** (2) 231-236.

*Rhizobium* strains isolated from *Leucaena leucocephala*, *Sesbania rostrata*, *S. grandiflora*, *S. punctata*, *Tephrosia vogelli*, *Acacia albida* and *Vigna unguiculata* growing in Nigerian soils were characterized and tested for their ability to nodulate and fix atmospheric nitrogen with *L. leucocephala*. Isolates from *A. albida* were slow-growing and alkali producers. Isolates from all plant species except those from *S. grandiflora* and *V. unguiculata* nodulate *L. leucocephala* but a wide range of effectiveness was observed.

615 SANGINGA, N.; VANLAUWE, B.; DANSO, S.K.A. **Management of biological N2 fixation in alley**

**cropping systems: estimation and contribution to N balance. Management of biological nitrogen fixation for the development of more productive and sustainable agricultural systems.** *Extended versions of papers presented at the symposium on biological nitrogen fixation for sustainable agriculture at the 15th. Plant and Soil* (1995) **174** (1-2) 119-141 [En, 94 ref.]

A review. Alley cropping is being widely tested in the tropics for its potential to sustain adequate food production with low agricultural inputs, while conserving the resource base. Fast growth and N yield of most trees used as hedgerows in alley cropping are due greatly to their ability to fix N2 symbiotically with *Rhizobium*. Measurements of biological N2 fixation (BNF) in alley cropping systems show that some tree species such as *Leucaena leucocephala*, *Gliricidia sepium* and *Acacia mangium* can derive between 100 and 300 kg N $ha^{-1}$ $yr^{-1}$ from atmospheric N2, while species such as *Faidherbia albida* and *Acacia senegal* might fix less than 20 kg N $ha^{-1}$ $yr^{-1}$. Other tree species such as *Senna siamea* [*Cassia siamea*] *and S. spectabilis* [*C. spectabilis*] are also used in alley cropping, although they do not nodulate and, therefore, do not fix N2. The long-term evaluation of the potential or actual amounts of N2 fixed in trees, however, poses problems that are associated with the perennial nature and massive size, the great difficulty in obtaining representative samples and applying reliable methodologies for measuring N2 fixed. Strategies for obtaining representative samples (as against the whole tree or destructive plant sampling), the application of 15N procedures and the selection criteria for appropriate reference plants are all discussed. Little is known about the effect of environmental factors and management practices such as tree cutting or pruning and residue management on BNF and eventually their N contribution in alley cropping. Data using the 15N labelling techniques have indicated that up to 50% or more of the tree's N may be below ground after pruning. In this case, quantification of N2 fixed that disregards roots, nodules and crowns would result in serious errors and the amount of N2 fixed may be largely underestimated. Large quantities of N are harvested with hedgerow prunings (>300 kg N $ha^{-1}$ $yr^{-1}$) but N contribution to crops is commonly in the range of 40-70 kg N $ha^{-1}$ season. This represents about 30% of N applied as prunings; however, N recoveries as low as 5-10% have been reported. The low N recovery in maize (*Zea mays*) is partly caused by lack of synchronization between N release by the hedgerow trees and the associated food crop N demand. The N not taken up by the associated crop can be immobilized in soil organic matter or assimilated by the hedgerow trees and thus remain in the system. This N can also be lost from the system through denitrification, volatilization or leaching beyond the rooting zone. Below-ground contribution (from root turnover and nodule decay) to an associated food crop in alley cropping is estimated at about 25-102 kg N $ha^{-1}$ per season. Timing and severity of pruning may allow for some management of underground transfer of fixed N2 to associated crops. However many aspects of root dynamics in alley cropping systems are poorly understood.

616 SANUSI, S.; VERINUMBE, I.; LADIPO, D.O. ***Faidherbia albida* in Nigeria**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 183-185 [En, 4 ref.]

Summarizes the natural distribution and ecology of *Faidherbia albida* in Nigeria and the role that the tree plays in traditional farming systems. It occurs in the Sudanian and Guinea savanna zones on a wide range of habitats from riparian vegetation to open savanna and cultivated lands and on all soil types from alluvium to sandy-clays. The species occurs on farmlands surrounding the major Northern cities, and has particularly dense stands (20 trees/ha) southeast of Maiduguri where millet and sorghum is cultivated under them. While the Maiduguri parkland was planted and protected in the 1920's substantial felling has occurred more recently. Also notes on work at FRIN Ibadan on successfully rooting juvenile stem cuttings.

617 SARLIN ?? [***Faidherbia albida* (*Acacia albida* Del.) in Ouahigouta**] Le *Faidherbia albida* (*Acacia albida* Del.) à Ouahigouta. Centre Technique Forestier Tropical, Mimeo (1963) 36 pp. [Fr]

Research examining the effect of *Acacia albida* on millet yields and on soil fertility of 29 established sites of various topographies near Ouahigouya. There was an average increase in unthreshed millet yield for all 29 trees of 430 kg/ha (820 to 1,250 kg/ha), but increased yields were only found in 22 of these cases. Five cases showed a decrease, and two showed no change.

618 SARY, H.; SOME, L.M. **Attacks by spermatophagous insects on the seed of three *Acacias* - *A. albida*, *A. nilotica* var. *adansonii* and *A. senegal*.** In *Tropical Tree Seed Research. Proceedings of an international workshop held at the Forestry Training Centre, Gympie, Queensland, Australia, 21-24 August 1989 [edited by Turnbull, J.W.]. ACIAR Proceedings Series* (1990) **28**, 21-23 [En, 4 ref.]

Studies were made of 25 fruits from each of the upper, middle and lower crown levels of five specimens of *Acacia nilotica* var. *adansonii* and 10 each of *A. albida* and *A. senegal* from different sites in Burkina Faso. The endosperm of seeds of *A. albida* was parasitized by adults and larvae of Bruchidae. Caterpillars of *Chilades cleusis* were observed in unripe fruits of *A. nilotica* var. *adansonii*, while dry fruits were attacked by larvae and adults of several bruchid species, including *Callosobruchus maculatus*. Fruits of *A. senegal* showed holes in valves, malformation of seeds, and evidence of

parasitism by bruchid larvae and adults, although no insects were found.

619 SAWADOGO, O. [**Contribution to the study of natural populations of *Acacia albida* Del. in Burkina Faso**] Contribution a l'étude des peuplements naturels d'*Acacia albida* Del. au Burkina Faso. *Mémoire de fin d'études, IDR, Burkina Faso* (1987) [Fr]

620 SCHMIDA, A.; ARONSON, J.A. **Sudanian elements in the flora of Israel**. *Ann. Missouri Botanical Gardens* (1986) **73**, 1-28

*Acacia albida* - unlike in Africa, it is not restricted to riparian or high ground water sites in Israel. It rarely flowers or fruits by vegetative propagation - by sucker is more common. Possibly a recent arrival from the Nile River Basin. Phenology is different. Biannual shedding of its leaves occurs although, there is only one rainy season per year (December to March.)

621 SCHOCH, P.G. [**Influence on the potential evapotranspiration of a tree cover in Senegal and agricultural consequences.**] Influence sur l'évapotranspiration potentielle d'une strate arboreé au Sénégal et conséquences agronomiques. *L'Agronomie Tropicale* (1966) No.11, 1283-1290 [Fr, 10 ref.]

Using the `corrected Piche' formula, potential evapotranspiration was calculated for five plots ranging from a deforested area to an area surrounded by trees and buildings. Results showed that traditional fields with 25-30 *Acacia albida* trees per hectare significantly reduced potential evapotranspiration. Windbreaks increased night-time temperatures by 0.5-1.0C, reducing dry matter losses through respiration. Such modifications of the microclimate increase the vegetative cycle of crops planted under the trees. Modern agricultural methods are not compatible with traditional fields with scattered trees, and hence a possible economic solution is to plant *A. albida* windbreaks.

622 SCHULZE, E.D.; GEBAUER, G.; ZIEGLER, H.; LANGE, O.L. **Estimates of nitrogen fixation by trees on an aridity gradient in Namibia**. *Oecologia* (1991) **88** (3) 451-455 [En, 19 ref.]

Nitrogen (N2) fixation was estimated from 22 woody species along a transect from the highlands of Namibia to near its coast, in March 1987 at the end of the wet season. Annual rainfall varied in the sites varied from 400 mm to 30 mm, and the natural abundance of 15N (15N value) in 11 woody species of the Mimosaceae which were compared with the delta 15N values in 11 woody non-Mimosaceae. Averaging all species and habitats, the calculated contribution of N2 fixation (Nf) to leaf nitrogen (N) concentration of Mimosaceae averaged about 30%, with large variation between and within species. While in *Acacia albida* Nf was only 2%, it was 49% in *A. hereroensis* and *Dichrostachys cinerea*, and reached 71% in *A. mellifera*. In the majority of species Nf was 10-30%. *A. albida* was sampled at Sesriem (lowland savanna, 100 mm ann. rainfall) and Swakop river (coastal desert, 30 mm. ann. rainfall). The large variation in nitrogen isotope ratios could be due to differences in rooting depth and leaf longevity between species, and different grazing and burning practices between sites. There was a marked variation in background 15N values along the aridity gradient, with the highest 15N values in the lowland savanna. The difference between 15N values of Mimosaceae and non-Mimosaceae, which is assumed to result mainly from N2 fixation, was also largest in the lowland savanna. Variations in 15N values of Mimosaceae did not affect N concentrations, but higher 15N values of Mimosaceae are associated with lower carbon isotope ratios (13C value). N2 fixation was associated with reduced intrinsic water use efficiency. The opposite trends were found in non-Mimosaceae, in which N-concentration increased with 15N, but 13C was unaffected.

623 SCOTT, R.C.; SMITH, D.L. **Cotyledon architecture and anatomy in the *Acacieae* (Leguminosae: Mimosoideae)**. *Botanical Journal of the Linnean Society* (1998) **128** (1)15-44 [En, 21 ref.]

A study was carried out to determine the range of cotyledon size, shape, venation pattern and anatomy in *Faidherbia albida* and three subgenera (Acacia, Aculeiferum and Heterophyllum) of *Acacia*, represented by 152 species. In addition, the extent to which cotyledon characteristics may help resolve the interrelationships of the subgenera, their status and their relationship to *Faidherbia* was assessed. The data confirmed that cotyledons in Leguminosae [Fabaceae] provide a complex of characters that correlate with and reinforce taxonomic grouping and demonstrate their potential contribution to elucidating particular taxonomic problems. In the context of the Acacieae, the cotyledons provide evidence in support of the amalgamation of the Acacieae and Ingeae, of the separation of *Faidherbia* from *Acacia*, and of the recognition of subgenera Acacia, Aculeiferum and Heterophyllum as separate groups, although it is considered that they do not indicate the status of these groups or provide information of use in their subdivision.

624 SEABRA, L. DE; FERREIRINHA, M.P.; FREITAS, M.C.P. DE. [**Contribution to the technical knowledge of overseas spp.**] Contribuicones para o conhecimento tecnologico da flora do ultramar. *Garcia de Orta, Lisboa* (1957) **5** (4) 711-726 [Port, fr, en]

Presents informaton on the macro- and microscopic characters of the wood *Acacia albida* and *Casuarina* species. Tests for suitability for pulping gave unpromising results.

625 SECTEUR DE RESTAURATION DES SOLS DE OUAHI-GOUYA : **[European group on the restoration of the Voltaian soils]** Le *Faidherbia albida.* Groupement Européen de Restauration des Sols Voltaïques (GERES), janvier (1965) [Fr]

626 SEELY, M.K.; BUSKIRK, W.H.; HAMILTON, W.J.; DIXON, J.E.W. **Lower Kuiseb River, South-West Africa. Perennial vegetation Survey**. *Journal SWA (South West Africa) Scientific Society* (1979-81) 34-35, 57-86 [En]

The Kuiseb River, located in central South-West Africa, is one of several seasonal rivers flowing through the Namib Desert towards the southern Atlantic Ocean. As a linear oasis, it supports an extensive growth of trees and other vegetation which, in turn, allows many non-desertic or partially adapted animal species to extend their range into the true desert. Today, extensive plans to develop this water source for human use threaten the Kuiseb River ecosystem, particularly in its desert reaches. At least 10 spp. of perennial plants occur in the Kuiseb River system in the Namib Desert: *Acacia albida, A. erioloba, Tamarix usneoides, Euclea pseudebenus, Salvadora persica, Phoenix dactylifera, Ficus sycomorus, F. cordata, Maerua schinzii* and *Acanthosicyos horrida.* Their number and canopy width were measured to allow comparison between transects surveyed from Rooibank to Homeb. Relatively little variation between transects occurred along this lower portion of the Kuiseb River. Differences within the transects, on the flood plane perpendicular to the water course, were greater. Above Homeb, in the narrow Kuiseb Canyon, the relative composition of plant species altered. Measurement of fruit production by *A. albida, A. erioloba* and *F. sycomorus* indicates an acyclic production. Long-term studies are recommended to provide an insight into this ecosystem.

627 SEIGNOBOS, C. **[Oils, parklands and agrarian societies (Chad and North Cameroon)]**. Matières grasses, parcs et civilisations agraires (Tchad et Nord-Cameroun). Unpublished. Chercheur au CNRS, Cahiers d'Outre-Mers, (1982) 35 (139), July-September 1982 (ICRAF Lib. No. 4066) pp. 254-269.[Fr, en,]

The parks, which present a sort of domestication of picking, occupy a large place in oleiferous production. In the past, their importance seems to have been even greater in view of the non-distribution of certain crops that are today omnipresent and the need of not only alimentary but above all for vestimentary oils. This study concerns the relationships between oils and agro-systems, and between oils and parklands. It raises questions as regards the notorious absence in certain geographic settings of species such as *Vitellaria paradoxa*, and it attempts to reconstitute the successive recuperation of different oils in order to understand better the landscapes that exist at present. In particular, it compares two contrasting parklands, that of *Acacia albida*, representative of an agro-system including local animal raising, and that of karite, the "butter tree", illustrating an economic system without cattle. It also stresses the importance of the everlasting heritage offered by oleiferous oils and, more indirectly, that of *Acacia albida*, confronted with the changes that are developing in Sudanese-Sahelian agriculture.

628 SEIGNOBOS, C. **[*Faidherbia albida* - the key element in agricultural systems. The example of North Cameroon.]** *Faidherbia albida* - élément décrypter d'agrosystèmes. L'exemple du Nord-Cameroun. In *[Faidherbia parklands.] Les parcs ( Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Fort, Montpellier, France (1996) 312 pp. 153-171 [Fr, en]

To define the place of *Faidherbia albida* in the agrarian systems of different human populations of Northern Cameroon, the author carried out a series of discussions, historical surveys, and field surveys. For the most part, peasants attribute the advantages of the tree that are well-known in the literature: a nutritional supplement for cattle (pods) and soil enrichment. Its effect on the regulation of the water balance of the soil is stated in the following terms:- this tree brings water from the deep underground to the surface. Sorghum and millet farmers think that *F. albida* helps to control the invasion of *Striga hermonthica.* Most of them think that *F. albida* seeds are disseminated by cattle in their faeces, while small ruminants chew them up. However, certain population groups do not favour the propagation of the species and even destroy existing parklands. In the case of dry season crops, the tree casts shade which is especially detrimental to crops during this cool period of shorter days. This is the case with muskwari sorghum or irrigated vegetables. Rural groups have generally been in favour of the species extension and have created a number of regulations on the use of the wood. In the plain, the model of the Masa parkland constitutes a higher stratum of *F. albida* which dominates a sub-stratum of often pruned *Ziziphus mauritiana.* In the mountains, *F. albida* is integrated into very complex parklands which are associated with terrace farming. *F. albida* in this case does not constitute the dominant element. Seen as being able to favour sorghum production, the tree is regenerated and rigorously maintained for wood production as well. Protected by a number of regulations and feared for its magic powers, *F. albida* is the responsibility of the land owner. The movement of the mountain dwellers down to the plaines was accompanied by a very rapid creation of *F. albida* parklands. almost monospecific, especially at the foot of the mountains where these farmers share land with sedentary peul herdsmen. A supply of organic matter from trees and cattle is necessary for the conservation of the fertility of these soils. This is vital in the face of increasing demographic pressure. Unlike the Sudano-Sahelian zone, *F. albida* has not extended in the northern and southern sparsely populated

areas where farming practices are different. In the Sahelian zone, neither the extremely extensive shifting cultivation, nor the dry season crops, nor even the small-sized home gardens which are highly fertilized by animals, require any association with *F. albida.* In the Sudano-Guinean zone, long cycle sorghum cultivation, the maturity of which coincides with the tree's leaf development, as well as extensive agricultural practices do not favour the establishment of *F. albida* parks. But migrants who come from the Sudano-Sahelian zone have started to reproduce their agricultural systems. Nowadays, administrative authorities, after fighting against the presence of trees in farms under the pretext that trees are incompatible with ploughing, protect *F. albida* parks. This protection is, however, sometimes awkwardly carried out as in the case where the farmer is prevented from fetching wood from a tree which he partly maintained for that purpose. In conclusion, the author thinks that *F. albida,* despite its advantages, is not a universal remedy which should be imposed everywhere on everybody. Given a favourable socio-administrative climate, inducements to plant and manage the species could constitute a substitute for the old agrarian disciplines which are on their way out.

629 SELENJE, M.B. **Agroforestry in Lilongwe Agricultural Development Division - as a soil conserving and improving approach**. (1984) ?? 1-9 [En]

Describes an integrated land-use approach with crop ridges on contours, food crop husbandry, buffer strips of perennial crops and integration of livestock in the farming system. Gives suitable agroforesty trees in Malawi, including *Acacia albida*, *Sesbania*, *Cajanus cajan* and *Leucaena*, which are used on the raised contour ridges to abate the declining land productivity caused by erosion. Tests the effectiveness of some forms of agroforestry in Lilongwe, like maize-*Leucaena* alley cropping. Also studies the effect of *Leucaena* leaf as a nitrogen source for maize.

630 SELENJE, M.B. **Agroforestry in Lilongwe Agricultural Development Division** (1989) ?? [En, 2 ref.]

Research was initiated in the 1982/83 season in an effort to find alternative conservation practices providing short-term tangible benefits in Lilongwe. These included maize/*Leucaena* alley-cropping, *Leucaena* leaf nitrogen trials, integrated land-use approach and permanent intercropping with *Acacia albida.* Smallholder farmers are encouraged to plant the latter (with a mature basal area of 100-300 square meters) because it does not shade agricultural crops, yet can enhance their production. A plantation of *Acacia albida* at 10 m x 10 m would attain a tree population of 100/ha that could provide a complete field coverage, thereby maintaining the nutrient requirements of the garden on a sustainable basis.

631 SELLSTEDT, A.; HÖGBERG, P.; JONSSON, K. **Diurnal variation in acetylene reduction and net hydrogen evolution in five tropical and subtropical nitrogen-fixing tree symbioses**. *Journal of Experimental Botany* (1989) **40** (219) 1163-1168 [En]

Diurnal variations in acetylene reduction and net hydrogen evolution were shown in five tropical and subtropical nitrogen-fixing tree symbioses. The symbioses studied in a growth chamber were: *Acacia albida* x TAL 1457, *Leucaena leucocephala* x TAL 1145, *Prosopis chilensis* x TAL 600, *Casuarina glauca* x HFP Cc13 and *C. obesa* x HFP Cc13. In the *A. albida* x TAL 1457 symbiosis, the diurnal variations in acetylene reduction and net hydrogen evolution showed a minor synchrony, and a diurnal variation in relative efficiency of nitrogenase was also revealed. Results showed that a diurnal variation in $C_2H_2$ reduction and $H_2$ evolution occurs, and that diurnal variation in the conversion factor between $C_2H_2$ reduction and $N_2$ fixation could occur.

632 SEYLER, J. **An investigation of internal and external bio-physical and socio-economic factors relating to the decline, maintenance and/or replication of the system in Senegal's North Central Peanut Basin**. *Doctoral dissertation research proposal, Department of Forestry, Michigan State University.* (19??) ??pp. [En, 141 ref.]

One of the oldest traditional agroforestry systems in the Sahel is the inter-cropping of *Acacia albida* with millet or sorghum, often associated with a livestock component. In the past, this system constituted a form of ecological equilibrium for much of Sahelian agriculture, capable of supporting 50-60 people per hectare. Unfortunately, the system is currently breaking down in many areas in spite of government and donor interest in maintaining and expanding it. Much of the conventional wisdom surrounding the system indicates that increased demographic pressure, decreased fallow periods and widespread use of cash crops and animal traction are responsible for its decline. However, an analysis of some secondary biophysical and socio-economic data on the system as practised in Senegal suggests that much of this conventional wisdom may be faulty. A literature review on the system tends to support this hypothesis and suggests that the farmer socio-economic status and perception of the environment are keys in understanding system decline, maintenance and expansion issues. Research is proposed to conduct a farm-level investigation of internal and external biophysical and socio-economic factors relating to the decline, maintenance and replication of the *Acacia albida* system in Senegal's North Central Peanut Basin. Research will draw on a systems model of human ecology conceptual framework; agroecosytems differ from natural ecosystems in that there is an auxiliary energy source, reduced diversity due to human management, artificial rather than natural selection and goal-orientated external control rather than control by system feedback. There will be a combination of two

research methods:- (i) a farm-level biophysical inventory and socio-economic survey to determine the possible relationships that may exist between ceratin socio-economic variables and the decline/maintenance of the *A. albida* system; and (ii) an assessment of farmer perception of the *A. albida* system in relation to farmer goals, perceived needs and expected benefits from the system.

633 SEYLER, J.R. **A systems analysis of the status and potential of *Acacia albida* (Del.) in the North Central peanut basin of Senegal. (Volumes I and II) (Sahelian).** *Ph.D. Thesis, Michigan State University* (1993) 531 pp.

One of the oldest traditional agroforestry systems in the Sahel is the intercropping of the leguminous tree *Acacia albida* with millet or sorghum, often associated with a livestock component. In the past, this system constituted a form of ecological equilibrium for much of Sahelian agriculture. The system is under stress and breaking down in many areas in spite of government and donor interest in maintaining and expanding it. The primary purpose of this research was to investigate internal and external biophysical and socio-economic factors related to the decline, maintenance and replication of the *A. albida* system in Senegal's North Central Peanut Basin. A systems model of human ecology was used and implemented through:- rapid rural appraisal; formal farm-level socio-economic survey; a farm-level biophysical inventory of on-farm tree and soil resources; and focus group interviews. Regression analysis was used to test the majority of hypotheses. Principal components analysis was employed to identify composite variables and their interactions. A benefit-cost analysis examined the financial returns of the system under different input scenarios. The research found that the economic incentives are the primary determinant in on-farm natural resource management. Maintenance and wider use of the system and improved natural resource management are influenced more by general agricultural and economic policies than by policies and projects that focus on the system itself. Changes in agricultural policy through structural adjustment had the greatest positive impact on the system. Internally, a combination of drought, water table depth and cutting for forage had the greatest negative impact. Contrary to conventional wisdom, it was also found that population pressure bears positively on the system through agricultural intensification. The research also found great similarity between the Wolof and Serer *A. albida* systems. This study concludes that increased support for actions that farmers are currently undertaking to protect and manage their natural resources better, is preferable to narrow technical interventions that focus on new methods and technologies. There is a great need for agricultural and forestry/natural resources training to equip farmers better with the skills necessary for improved natural resource management and decision making. Similarly, extension should support existing management systems rather than promote externally conceived systems which seldom conform to local realities. Finally, system-specific and other natural resources policies such as the Forest Code require modification to be brought in line with and supportive of current farmer actions.

634 SHAW, J.E.; REYNOLDS, T.; SPRENT J.I. **A study of the symbiotic importance and location of nod gene inducing compounds in two widely nodulating and two non-nodulating tropical tree species.** *Plant and Soil* (1997) **188** (1)77-82 [En, 37 ref.]

Extracts and exudates of different parts of seedlings of the widely-nodulating *Acacia seyal* and *Faidherbia albida* and the non-nodulating *A. greggii* and *A. brevispica* were tested for their ability to induce a nod::lacZ fusion in a reporter plasmid which had been introduced into 25 rhizobial isolates of other legumes. The two non-nodulating species were found to lack neither the ability to produce potentially nod gene-inducing compounds nor the means to exude them into the rhizosphere. However, it was demonstrated, through the distribution of potentially inducing compounds within the plants and their exudates, that the components of tissue extracts did not necessarily reflect the components exuded into the rhizosphere.

635 SHAYO, C.M.; UDEN, P. **Recovery of seed of four African browse shrubs ingested by cattle, sheep and goats and the effect of ingestion, hot water and acid treatment on the viability of the seeds.** *Tropical Grasslands* (1998) **32** (3) 195-200 [En, 21 ref.]

An investigation was made of the voluntary intake of pods of four tropical browse trees by different classes of domestic ruminants, and the proportion of intact seeds that passed through the digestive tracts. Germination of undigested whole seeds recovered from faeces and non-ingested seeds treated with hot water and acid or untreated was also determined. Pods of *Faidherbia albida*, *Acacia tortilis*, *Acacia nilotica* and *Dichrostachys cinerea* were opened to estimate the percent by weight of intact and damaged seeds in the pods. Whole pods from each species were fed to heifers, calves and mature and young sheep and goats for two weeks. Faeces from the animals were collected daily during the second week and washed through a sieve to retrieve the undamaged seeds. Non-ingested seeds were also soaked either in hot water for 2, 4 or 6 min or in $H_2SO_4$ (70% v/v) for 0.5, 1.5 or 3 h. Germination rates of treated and untreated seeds and seeds collected from faeces were determined over a period of 13 weeks. Pods of *Acacia tortilis* had a significantly ($P<0.05$) higher percentage by weight of seeds (33%) than those of other species, with *F. albida* and *D. cinerea* having the lowest percentage of seeds (10%). Intakes of *F. albida* and *A. tortilis* pods for all classes of animal were similar and significantly ($P<0.05$) higher than intakes of pods of other species. Intakes of *D. cinerea* pods were significantly ($P<0.05$) higher than

those *of A. nilotica* pods, except for young sheep and young goats, and similar to those of *F. albida* and *A. tortilis*, except for heifers and mature sheep. Animal age had no effect on pod intake as % body weight (BW). Average intake (% BW) of pods was highest for *F. albida* (2.4%) and *A. tortilis* (2.4%) followed by *D. cinerea* (1.8%) and *A. nilotica* (0.9%). Both classes of cattle passed a significantly (P<0.05) higher percentage of ingested seeds than did sheep and goats. Sheep and goats digested considerably higher amounts of the seeds, particularly those of *F. albida* and *A. tortilis*, suggesting that cattle would benefit nutritionally from grinding of the pods. Germination was not improved by passage of seeds through the digestive tract of any animal, whereas hot water and acid treatments generally reduced or had no effect on germination. Germination of *A. nilotica* seeds treated with acid for 1.5 and 3 h was significantly (P<0.05) enhanced.

636 SHEIKH, M.I. **New species for afforestation in semi-arid lands.** *Pakistan Journal of Forestry* (1988) **38** (4) 249-254 [En]

Studies are reported from the Thal Desert, Pakistan (annual rainfall 250 mm), using different methods of site preparation and tree species. The site preparation methods involved different water harvesting techniques: sloping catchments with 1 m slopes (1 in 3) with or withkout an 0.3 m deep trench; a trench 0.3 m wide and 0.3 m deep; and pits of 0.5 m diameter and 0.3 m depth. Flat ground was used as the control site. Eight species of trees (5 exotic acacias and three indigenous species) were planted in August 1980 and growth data were recorded annually from May 1981 to 1987. Survival was best in *Tecoma undulata* (av. 97%) followed by *Acacia modesta* (87%), *A. albida* (79%), *A. tortilis* (76%), *Prosopis cineraria* (71%), *Parkinsonia aculeata* (59%), *A. aneura* (51%) and *A. victoriae* (28%). Site preparation method had no significant effect on survival. Best growth was observed in *A. tortilis*, irrespective of site preparation method. Most species grew to a height of more than 4 m by the end of 1987 under water harvesting treatments (slopes with or without trenches and trenches alone); the exceptions were *A. aneura* and *Parkinsonia aculeata*. Promising species besides *A. tortilis* were *A. albida*, *Prosopis cineraria*, *Tecoma undulata* and *A. victoriae*, although the latter had poor survival.

637 SHERPA, S.; JOSHI, L.; UPADHYAY, M. **Interim report on silvicultural research trials.** *P.A.C. Working Paper, Pakhribas Agricultural Centre, Dhankuta, Nepal* (1993) No. 41, 19 pp. [En, nepali, 5 ref.]

Preliminary reports on a number of species and provenance trials undertaken in the eastern hills of Dhankuta district, Nepal, where a range of species was tested at several sites between 640 and 2000 m. Acacias were tried in a species elimination trial and an *Acacia albida* provenance trial. In the *Acacia* species elimination trial, two Zimbabwe provenances of *A. albida* and a local provenance of *A. catechu* were tested with five Australian *Acacia* species at Ghorlikharka (650 m). After a year *A. albida, A. holosericea, A. auriculiformis* and *A. catechu* showed promise with survival rates over 90%. In the *A. albida* provenance trial, only five Zimbabwian provenances were tried at three sites, at 650m, 1000m and 1700m. After 9 months all provenances were affected by tip dieback particularly in the mid and high altitudes. [Most provenances originate from lower altitudes in Zimbabwe.] Mana pools provenance [360 m] proved the most vigorous at the lower site growing over a metre in 9 months.

638 SINA, S. **Observations sur la phénologie d'*Acacia albida* a Kokologho (Burkina Faso).** In *Physiologie des arbres et arbustes en zones arides et semi-arides (edited by Riedacker, A.; Dreyer, E.; Pafadnam, C.; Joly, H.; Bory, G.). Séminaire, Paris, Nancy, 20/3-6/4/1990.* (1993) 229-234 [Fr, en, 7 ref.]

Gives phenological observations of a population of *Faidherbia albida* at Kokologho in Burkina Faso over a two year period (1988 - 1990). The population is one that has seed collections made by CNSF, and phenological observations recorded from 30 individuals. There was considerable variation between trees of different age classes and between years. Also gives a range of diameter classes in the population.

639 SNIEZKO, R.A. **Rangewide provenance variation in nodulation of *Acacia albida* seedlings.** *Nitrogen Fixing Tree Research Reports* (1987) **5**, 20-21 [En]

Reviews tests on 25 provenances of *Acacia albida* from West, East and southern Africa for nodulation and in Zimbabwe at Harare (FRC) and Matopos nurseries. Seedlings of *A. albida*, which were directly sown in pots, were assessed after 12 weeks for the numbers of nodules. All produced some nodules though West African provenances noduled less and were poorer growers.

640 SNIEZKO, R.A.; GWAZE, D.P. **Effect of seed treatments on germination of *Acacia albida* Del.** In *IUFRO Proceedings of the international symposium on forest seed problems in Africa, Harare, Zimbabwe 1987 [edited by Kamra, S.K.; Ayling, R.D.].* Report, Swedish University of Agricultural Sciences (1987) **7**, 325-333 [En, 6 ref.]

The effects of six seed pre-treatment methods on the germination of seed from five *Acacia albida* trees from Mana Pools, Zimbabwe, were studied. The pre-treatments used were sulphuric acid, manual nicking, boiling water, hot water, cold water, and storage of seed for 1 year after treatment with sulphuric acid ($H_2SO_4$). Fresh and one year old seeds were treated with concentrated sulphuric acid for 40 minutes and then washed, and those manually nicked germinated quickly and had high final germination percentages. Treating the seed

with sulphuric acid and then storing it for one year was also found to give excellent germination rates. Germination following the hot or cold water pre-treatment was very slow. Seed from West African provenances, which tend to be significantly smaller, may require shorter periods in acid.

641 SNIEZKO, R.A.; STEWART, H.T.L. **Range-wide provenance variation in growth and nutrition of *Acacia albida* seedlings propagated in Zimbabwe.** *Forest Ecology and Management* (1989) **27** (3) 179-198 [En]

A sample of 33 *Acacia albida* provenances from 14 countries throughout Africa showed significant variation in seed weight and in various seedling traits, including seedling height, leaf colour, number of nodules per seedling, and total dry-weight and nutrient content, at two nurseries in Zimbabwe. Interactions between provenances and nurseries were present, but the southern-African provenances generally showed better growth than the west-African and east-African provenances. In addition to the genetic variation among provenances, variation was also found among families within provenances.

642 SOLTNER, D. [**The tree and the hedge, for agricultural production, for ecological equilibrium and for the quality of rural life**] L'arbre et la haie, pour la production agricole, pour l'équilibre écologique et le cadre de vie rurale. *Coll. Sc. et tech. agricoles.* Angers (1985) 193 pp. [Fr]

643 SOME, L.M.; KABORE, H. **Preliminary results on the study of the influence of light and temperature on the germination of *Acacia albida* Del. seeds.** In *IUFRO Proceedings of the international symposium on forest seed problems in Africa, Harare, Zimbabwe 1987 [edited by Kamra, S.K.; Ayling, R.D.].* (1987) 334-340 [En, fr, 3 ref.]

A study of four temperatures (20C, 25C, 30C, 35C) in dark/light treatments on the germination of mechanically scarified seed of *Acacia albida* over seven days. There is little difference between light and dark on the germination, and at all temperatures near 90% germination is achieved, though at 20°C the rate is slower.

644 SOUTH AFRICA PLANT PROTECTION RESEARCH INSTITUTE. **Check-list of insects on forest trees and shrubs in South Africa.** *Entomology memoir, Department of Agriculture, Pretoria, Republic of South Africa* (1970) No. 21, 81 pp. [En, 17 ref.]

A checklist of insects, mainly from the orders Coleoptera and Lepidoptera, found attacking trees and shrubs growing in South Africa. Many insect species are listed for the genus *Acacia* and two were also specifically noted for *Acacia tortilis* ssp. *heteracantha* (the Umbrella Thorn), *Compsomera elegantissima* (*Cerambycida coleoptera*) which was reared from a dry log and *Tachardina albida* (*Lacciferidae, Hemiptera*).

645 SOUTHGATE, B.J. **A preliminary list of *Acacia* species and the Bruchid Beetles associated with them.** *Bulletin of the International Group for the Study of Mimosoidaea, Toulouse, France* (1975) No. 3, 31-32 [En]

Bruchid beetles are listed for 14 specific *Acacia* host species -including *Bruchus natalensis* Pic. on *Acacia albida*. The list has been collated from either literature references or from data in museum collections, and is by no means considered exhaustive.

646 SOUTHGATE, B.J. **Handbook on seed insects of *Acacia* species.** Food and Agriculture Organisation (1983) 30 pp. [En, 36 ref.]

Provides a review of the current knowledge concerning insect species and levels of infestation suffered by *Acacias*, and gives guidelines for further investigation. Four main groups feed upon the seeds of the family Leguminosae in arid and semi-arid zones; Coleoptera, Heminoptera, Lepidoptera and Hymenoptera. Of these, the Coleoptera are the most important, containing the group Bruchidae (sand beetles). Bruchidae exert by far the greater influence and the basic fundamentals of their life cycle (esp. *Callosoburchus maculatus*) and taxonomic position are outlined, as well as an account given of their effects on seed collection (including preventive measures and the examination of harvested seed). Chemical control methods and the equipment for their application are also detailed. The identification and storage of collected and bred insect material are dealt with in an appendix.

647 SOWERS, F.W.; ISSOUFOU MANZO. **Precolonial agroforestry and its implications for the present: the case of the sultanate of Damagaram, Niger.** In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 171-175 [En, 9 ref.]

This case study presents a pre-colonial system of agroforestry based on the protection of five useful species of which *Acacia albida* (Gao in Haousa) was the most important. The sultanate of Damagaram in the 19th century covered the central and western areas of the present Department of Zinder in Niger. The control of its subjects, the Talakawa, was through a repressive and bureaucratic administration. One of its most famous laws concerns the protection of the five useful tree species (trees of the sultan) and states that "whoever cuts down a [protected] tree cuts off his own head"! The calculated application of the law, together with the distribution of

gao seeds prompted the widespread establishment of agroforestry parklands with *A. albida* as the dominant species. Although this repressive rule disappeared during the colonial period, numerous examples of these parks persist. Suggests that central authority and organisation can prove important for extension of gao trees.

648 STAPLETON, C.C. **Common Transvaal trees.** Pretoria, Union of South Africa; Government Printer. *Department of Forestry Bulletin* (1955) No. 37 [En]

General description of the *Acacia albida* (common names ana tree, apiesdoring) in the Transvaal of South Africa on alluvial flats or river banks. Very large tree, seen to 20' circumference on the Olifant River; grown easily from seed, if soaked for a few minutes in nearly boiling water. Growth in the first year is slow, but thereafter very fast. In Pietersburg an *A. albida* specimen grew to a recorded 18 ft in 3 years.

649 STERCK, F.J.; VAN DER ZANDT, G.J.A.W.; OLDEMAN, R.A.A. **Archrtectural development of *Faidherbia albida* (Del.) A. Chev.** In *Physiologie des arbres et arbustes en zones arides et semi-arides (edited by Riedacker, A.; Drieyer, E.; Bory,G.; Pafadnam, C.; Joly, H.).* Paris, France; Groupe d'Études de l'Arbre (1991) 489 pp, 249-256. [En, fr, 22 refs]

An architectural analysis was made of *Faidherbia albida* (Del.) A. Chev. (synonym *Acacia albida*) by studying two tree populations in Mali. Shoots of *F. albida* flush at the start of the dry season which is the period of fodder scarcity. Because of the flushing pattern and the high nutrient quality of the new leaves, local cattle holders pollard or prune trees to make young leaves accessible to their cattle. *F. albida* conforms to Troll's model in which the axes are plagiotrophic. In these trees, every meristem may produce the same kind of axis of which extension growth and secondary thickening are adjusted to available environmental sources. Because of this, trees regenerate easily after damage or environmental stress making them highly adaptable. Architectural tree development was described according to a sequence of architectural phases, their number of branch orders increasing from 0 to 7 which is high compared with most other tree species. Eight architectural development phases were distinguished based on the number of branch orders within trees. In the first phase, up to one year old, the seedling is has an orthotropic axis but a root sucker is orthotropic and its axis has the typical zigzag pattern. In the second year, extension growth of the main stem ceases in the root sucker and first order branches grow along the main axis whereas in the seedling, although branching starts, extension of the man axis continues. In phase three, the tree remains about 0.6 m high, only the base can be considered part of the main axis and development of some of the first order axes gives the tree a shrubby appearance. In the fourth phase at about seven years, one of the dominating branches becomes a trunk and the others have died. The trunk attains its final height of about 4.5 m in the fifth phase when the tree is about 16 years old. At stage six, at about 30 years, first order axes have reached their maximal extension and maximum crown diameter has been achieved. At stage seven, at 55 years, the tree reaches its maximum height of about 17 m and at stage eight, 85 years, some branches at the base of the first order axes have died so that the crown is more open and sub-crowns can be distinguished. A ninth phase covers dieback of trees at the age of about 100 years when no new branch orders develop. Environmental stress and damage is commonly caused by physical factors such as climate and soil, as well as by human factors such as pruning and pollarding and by grazing of cattle but *F. albida* regenerates easily after these setbacks. Pruning and pollarding may have different effects on the leaf and pod production of trees. An architectural analysis of *F. albida* may be helpful for the understanding of both the influence of the physical environment and different harvesting techniques on tree development, and for devising practices to improve harvesting techniques to maximize leaf and pod production in a sustainable manner.

650 STEWART, H.T.L **Survival and early growth of *Acacia albida, A. auriculiformis, Casuarina cunninghamiana*, and *Eucalyptus camaldulensis* fertilized with nitrogen and phosphorus at planting.** *East African Agricultural and Forestry Journal* (1989) **54** (4) 185-190 [En, 7 ref.]

Results, after nine months, of a growth trial comparing four species fertilized with varying levels of P and N at planting, at an infertile sandy site in central Zimbabwe. *Acacia albida* had a high level of survival 94%, the other exotics suffering from termite damage. Fertilization of *A. albida* with N increased height growth by 31% and diameter growth by 40%, and there was also significantly increased diameter growth with P application. Growth was slower than the exotics though the seed of *A. albida* was from Mana Pools (360 m.a.s.l.) and was planted at a much higher altitude (1370 m.a.s.l.) at Chibero College of Agriculture, central Zimbabwe.

651 STEWART, H.T.L.; GWAZE, D.P. **Effect of fertilizer and sowing date on establishment and early growth of direct-seeded *Acacia albida* in Zimbabwe.** *Nitrogen Fixing Tree Research Reports* (1988) **6** 40-42 [En, 2 ref.]

Experiments are reported from a field site at Harare, Zimbabwe, with medium sandy clay soil of pH 4.7. Acid scarified seeds of *Acacia albida* were sown on two planting dates (in December 1986 and January 1987) at 1 cm depth and 50 cm apart (with three seeds per sowing position) in rows 2 m apart. The seeds were covered with a thin layer of sand. Viable seeds of two exotic species, *Casuarina cunninghamiana* and *Eucalyptus camaldulensis*, were sown at the same time on the soil surface, after mixing with sand. In half the sowings, fertilizer (20 g

or 40 g $m^{-2}$, equivalent to 35 kg N $ha^{-1}$ and 24 kg P $ha^{-1}$) was placed on either side of each sowing position in a band 10 cm from the seeds and 5 cm below the soil surface. Germination was assessed at 18 days and 8 weeks after sowing. Emergence of the two exotic species was poor (germination 1-2%) and they were not studied further. Seedlings of *A. albida* were thinned to one per position at 8 weeks, and height was measured at 8, 20 and 30 weeks after sowing, with the experiment ending in August 1987. Every fourth plant was harvested at 30 weeks for determination of shoot dry weight. The plots were kept clean weeded. Germination of *A. albida* was rapid, mostly occurring within 12 days of sowing. After 18 days, germination was 77% and 52% respectively in first and second sowings, resulting in seedlings at 92% and 78% of sowing positions; subsequent mortality was <3%. Height growth was rapid up to 20 weeks after sowing then decreased due to low soil moisture contents (especially for the second sowing). Fertilizer significantly increased height growth only at 20 and 30 weeks. For the first sowing, fertilizer increased shoot dry weight three-fold, but for the second sowing, where both height and shoot dry weight were lower, shoot dry weight was increased only two-fold by fertilizer. Only 367 mm of rainfall was recorded during the trial period (50% of the usual average), and the results demonstrate the value of sowing early (i.e. in December rather than January) in the rainy season.

652 STURMHEIT, P. **Alley cropping in Zambia: the potential of alley cropping in Mazabuka District**. *M.Sc. Thesis, University College of North Wales, Bangor, U.K.* (1989) [En]

The profitability of a sole maize cropping system in the Mazabuka District of the Southern Province of Zambia was compared with profitability in an alley strip cropping system using *Cassia siamea* and in an indigenous *Faidherbia albida* agroforestry system. The agricultural land in this district lies between 900 and 1200 m above sea level with a unimodal annual rainfall of 800 mm which may vary from 600 to 1000 mm causing drought in one season and water-logging in the next. The soils are chromic luvisols, deep reddish sandy clay loams, typically very deficient in phosphorus but rich in potassium; heavy clay pellic vertisols dominate the Kafue Flats the fringes of which are dominated by farmed parklands of *F. albida* where tree densities are about 2-8 trees $ha^{-1}$. This can be built up to 25 trees $ha^{-1}$ by conserving naturally regenerated trees; when established from nursery-raised seedlings the aim is to achieve a stocking of about 50 $ha^{-1}$. The trees are assumed to become productive at 15 years, mature by 25 years and have a life span of 80 years. A mature tree yields 55 to 135 kg $y^{-1}$ per tree. The pods are highly prized especially during droughts. They are estimated to have a nutritive value of 0.7 forage units $kg^{-1}$ and a digestible protein value of 20% of the FU (Montgolfier-Kouevi *et al.* 1980) and give a live-weight gain of 0.3 kg $day^{-1}$ with a daily feed supplement of 2 kg of maize residue and groundnut cake. A value of US$0.04 $kg^{-1}$ for pods was estimated on the basis of liveweight gain; this compares with market prices of US$0.23, US$0.02 and US$0.18 $kg^{-1}$ in Senegal, Ethiopia and Nigeria respectively. The wood production from *F. albida* was estimated at 400 kg per mature tree and was valued in charcoal equivalents. At low discount rates, the *F. albida* system was found to be the most profitable option but at discount rates in excess of 10%, alley strip cropping was found to maximize the return to land and labour. On sloping ground, both agroforestry systems were far more profitable than the existing maize mono-cropping practice. Profitability would be optimized over the whole range of discount rates through using a combination of alley strip cropping with interspersed *F. albida* trees.

653 STURMHEIT, P. **Agroforestry and soil conservation needs of smallholders in Southern Zambia**. *Agroforestry Systems* (1990) **10** (3) 265-289 [En, 26 ref.]

An agroforestry and soil conservation needs assessment survey conducted in southern Zambia revealed valuable information on needs, constraints and development options as perceived by smallholders themselves. The survey was based on interviews by questionnaire with a sample of 479 farmers and their adult dependents (2.4% of the population). Inadequate efforts to conserve soil were found to be due to technical and socio-economic factors, and did not result from a lack of awareness of the widespread erosion threat. Fruit tree planting, windbreak establishment, as well as the protection of natural *Faidherbia albida* regeneration in cropland were popular agroforestry interventions, whose positive effects were widely acknowledged. Commonly perceived disadvantages of natural regeneration or coppice regrowth of *F. albida* included its unpopularity with barefoot walking people who tended to regard most thorny plants as undesirable, the possible interference with cultivation, and low canopies depressing yields. 42 perennial species were found to contribute directly to people's diet. Although certain shortages were recognized, only a few respondents envisaged agroforestry solutions such as fuelwood and fodder tree planting or live fencing. Most smallholders were interested in tree planting but had so far planted few trees; those planted were usually exotic fruit trees and it is recommended that drought hardy, termite and browse resistant perennials adapted to smallholder tree planting be provided by the extension services. The widespread exclusion of women from decision making and the lack of tenure security hampered female participation of agroforestry development and consequently threatened sustainable development.

654 SUDAN FORESTRY DEPARTMENT. ***Acacia arabica* forests along the Blue Nile and Dinder, Sudan**. In *Report of the Chief Conservator of Forests for*

*the year 1949. Forestry Division, Ministry of Agriculture, Sudan* (1950?) 13 [En]

The 43 forests along the Blue Nile and Dinder are the most important forests in the Northern Blue Nile Circle. They are all basin forests irrigated by flood water. The principal forestry species is *Acacia arabica* (*A. nilotica* ssp. *tomentosa*?) which occurs as pure stands in the basins. Further up the river banks are thickets of *Acacia albida*, *A. sieberiana* and *Ziziphus spinachristi*. The main species on higher sites on the inland sides of the basins are *Gymnosporia* sp., *A. mellifera* and *A. seyal*.

655 SUDAN FORESTRY DEPARTMENT. **Land and water resources survey in the Jebel Marra area, the Sudan.** *No. FAO/SF: 48/SUD-17* (1968) 70 pp. [En]

A comprehensive report, including descriptions of the natural vegetation (thorn savanna, thorn scrub, thorn woodland, savanna woodland *etc.*), with special reference to the importance of *Acacia albida*, and an account of experience and prospects in plantation forestry, especially with *Eucalyptus*.

656 SURESH, G.; RAO, J.V. **Intercropping sorghum with nitrogen fixing trees in semiarid India.** *Agroforestry Systems* (1998) **42** (2) 181-194 [En, 13 ref.]

The influence of three nitrogen fixing tree (NFT) species (*Faidherbia albida, Acacia ferruginea, Albizia lebbeck*) and four nitrogen levels (0, 20, 40 and 60 kg N $ha^{-1}$) on intercropped rainfed sorghum was investigated at Hyderabad, Andhra Pradesh. The trees were established in shallow alfisols during 1985 with a spacing of 4 x 4 m. Intercropping was done in 1993 and 1994. The effect of trees on radiation interception, soil moisture, crop growth, yield components and yield of sorghum was examined. Association with tree species reduced grain and dry-fodder yields of sorghum by 12-40% compared with the sole crop situation. The reduction was maximum under *A. lebbeck*, minimum *with F. albida* and moderate under *A. ferruginea*. Application of 40 kg N $ha^{-1}$ resulted in increased grain and dry-fodder yields over other N levels. Crop growth in terms of LAI (leaf area index) and dry matter had similar responses. The receipt of photosynthetically active radiation (PAR) was low under NFTs compared with the open situation. The relative PAR intercepted under the trees was in the order: *F. albida* > *A. ferruginea* > *A. lebbeck*. Soil moisture status was more favourable under *F. albida* than under the other tree species. Soil moisture at all stages of crop growth was more in the sole crop situation.

657 SWIFT, J. **Desertification and man in the Sahel. Environment.** Review Unit, International African Inst., London (1977) pp. 171-178 [En]

658 SYED, ISMAIL; BHEEMAIAH, G.; SUBRAHMANYAM, M.V.R.; ISMAIL, S. **Vegetative propagation of *Faidherbia albida*.** Indian Forester (1995) **121** (1) 64-66 [En, 5 ref.]

Tests done on *Faidherbia albida* in the rainy and summer seasons of 1991-92 with air layering, ground layering, and branch cuttings planted in polybags and nursery beds are reported from Hyderabad, Andhra Pradesh. Four IBA treatments (0, 1000, 2500 and 5000 ppm) were tested for each method. Best results were obtained from the air layering treatment in the summer; the branch cuttings failed to root. IBA increased rooting of the air layers at all concentrations (2500 or 5000 ppm were best), but only increased rooting of the ground layers at 1000 ppm.

659 TANGANYIKA FOREST DIVISION. **Timbers of Tanganyika -*Acacia albida*.** Utilization Section. Forest Division, Moshi (1967) 3 pp. [En]

660 TANNER, J.C.; REED, J.D.; OWENS, E. **The nutritive value of fruits (pods with seeds) from four *Acacia* spp. compared with extracted noug (*Guizotia abyssinica*) meal as supplements to maize stover for Ethiopian highland sheep.** *Animal Production* (1990) **51** (1) 127-133 [En]

Forty Menz rams weighing 20 to 22 kg and aged 13 to 18 months were individually offered 1.0 kg/day of chopped maize stover and one of five supplements over a 70-day growth trial followed by a 10-day metabolism trial. The amounts of supplement offered were designed to supply 4.4 kg of nitrogen per day and with stover, sufficient nutrients to allow growth rates of 50 kg/day. The control supplement, 80 g dry matter (DM) per day extracted noug (*Guizotia abyssinica*) meal, was compared with 194 to 212 g DM per day of fruits (pods with seeds) of *Acacia tortilis*, *A. albida*, *A. nilotica* and *A. sieberiana*. For the *A. albida* supplement, mean growth rate was 21g/day and mean stover intake was 401 g DM per day. *A. tortilis* and *A. albida* would appear to be of comparable nutritive value to noug meal as supplements to maize stover. Unlike noug meal, *Acacia* fruits are widely available in rural areas of Africa.

661 TANZANIA, FOREST DEPARTMENT. **Amenability to preservative treatment.** *Forest Department Report, Tanganyika 1957* (1958) 27

Tests on treatability gave the following results: *Cassipourea elliottii*, permeable except for small heart core; *Baikiaea eminii* moderately resistant; *Manilkara cuneifolia*, *Brachystegia spiciformis* and *B. microphylla* impermeable; *Acacia albida* permeable (vessel penetration).

662 TANZANIA, FOREST DEPARTMENT. **The natural durability of local timbers. (Interim Report).** *Technical Note, Utilisation Division* (1958) No. 14 [En]

This note gives the results, from October 1955 to June 1958, of tests on various species placed in the Tanga and Moshi graveyards up to December 1957, and in particular their durability against fungal attack. All specimens of *Acacia albida* had been destroyed, with an average life span of only six months.

663 TANZANIA, FOREST DEPARTMENT. **Checklists of Tanganyika Territory; *Acacia albida*.** *Technical note* (1958) No. 15

Part I gives a checklist for regional names of *Acacia albida* in Tanzania. Part II documents the anatomical and mechanical properties of the species, and also structure, seasoning, durability, sand papering and working properties. The timber is course, open textured, but not uniform in density. Hardness is uneven owing to irregularity in the grain. There is a strong susceptibility to attack by the pin hole borer when the wood is green.

664 TANZANIA, FOREST DEPARTMENT. **Timbers of Tanganyika: *Acacia albida* (Kababu).** Utilisation Section, Forest Division, Moshi (1967) 3 pp.

One of five pamphlets in the series. *Acacia albida* (Kabubu) is a pale brown timber, soft, of medium density with coarse texture and irregular or interlocked grain. Refractory in seasoning, drying rapidly with high shrinkage and severe distortion; moderately stable in changing atmospheric humidity. Difficult to work by machine or hand, but nails well. Mechanical properties variable but generally very poor. Perishable, but treatable in complete penetration of creosote by both open tank and pressure methods.

665 TASSIN, J. [**Agroforestry for the amelioration of soil.**] L'agroforesterie au secours des sols. *Nature et Progres* (1990) No. 113, ??-?? [Fr]

Summarizes the possibilities of agroforestry with respect to soil conservation, and some reasons for the lack of response to these. The Serere system, an agro-sylvopastoral system on a three-year cycle, previously practised in Senegal is discussed. This system centred on the use of *Faidherhia albida (Acacia albida),* the misnamed 'miracle tree' with the counter-seasonal habit of producing foliage in the dry season and defoliating in the rainy season. During the dry season, after the harvest, the land becomes 'common land' used for fallow grazing, the manure and decomposing foliage re-fertilizes the land for continued agricultural use. Increasing population pressure and the dissociation of agriculture from cattle farming has lead to the system's demise. The trees are no longer maintained or replaced resulting in deterioration of soil fertility and increased erosion. The success of the system did not come solely from the use of *F. albida,* but the incorporation of the animals into the system. In the wet season alternative food resources were required and these are no longer available. The emphasis is on the need for constant updating of existing practice to meet future demands. Even in densely populated areas successful systems have evolved - the banana plantations in Rwanda and Burundi, the 'jungle gardens' of Java which can produce >40% of the calorific needs of the inhabitants, and similar developments in Brazil, southwest of Bahia.

666 TEEL, W. **A pocket directory of trees and seeds in Kenya.** Kenya Energy Non-Governmental Organisations (KENGO) (1990) 150 pp. [En]

*Acacia albida* (Ol-erai, Seretuet, Larai, Eldurukoit, Dalyet, Mukababu, Apple-ring Acacia) is a tree of drier areas having a high water table and sandy, clay soils that drain well. Most commonly found in the Kerio Valley in riverine settings. Nitrogen fixing, deep rooted, well known for its use in agro-forestry intercropping with millet and sorghum. The seed is large for *Acacia*, with around 10,000 $kg^{-1}$, and will store almost indefinitely in cool, dry storage free from insects. Seeding best done in February or March (nick or soak in water for 24 hours). Germination rates good, initial growth rate quite fast.

667 TESSEMA CHEKUN AWOKE. **The culture of coffee in Ethiopia.** *Agroforestry Today* (1997) **9** (1) 19-21 [En, 4 ref.]

An account is given of the multistorey smallholder cropping system used for coffee (*Coffea arabica*, an indigenous species) production in Ethiopia, based on interviews. The upper storey of such systems consists of shade trees used for timber production. Coffee forms the next layer, along with food crops such as maize, sorghum and legumes, and root crops, vegetables and spices are raised on the ground. The closed nutrient cycling system operating amongst the crops is described. The characteristics of the multi-storey system a large variety of shade trees is used, many naturally grown, and they are conserved as much as possible. *Faidherbia albida* is included among those in the eastern zone (the lowest coffee producing zone, which uses the Harer coffee variety to produce Mocha coffee) The trees are regarded as very important and are carefully managed (no cutting or pruning) as they have an essential water conserving role in the system.

668 THERON, G.K.; VAN ROOYEN, N.; VAN ROOYEN, M.W. **Vegetation of the Lower Kuiseb River South West Africa.** *Madoqua* (1980) **11** (4) 327-346 [En]

The withdrawal of water from the lower Kuiseb River for mining and industrial purposes may influence the vegetation along the river [*Acacia albida*, *A. erioloba*, *Tamarix usneoides*, *Salvadora persica*, *Euclea pseudebenus*, *Suaeda plumosa*, *Eragrostis spinosa*, *Pechuel-loeschea leubnitziae*, *Acanthosicyos horrida*, *Psilocaulon* sp. cf. *salicornioides*, *Zygophyllum simplex*,

*Z. stapfii* and *Odyssea paucinervis*]. The maintenance of this vegetation is essential to the Kuiseb River ecosystem as a whole and the vegetation acts as a barrier checking the northwards movement of the Namib dune-sea. Physiognomic structural areas were distinguished on aerial photographs and these areas were investigated in the field for homogeneity and woody species composition. A vegetation map of the area between Nareb and Rooibank was compiled and 14 different communities were distinguished. Some communities were subdivided into variations and 40 variations were distinguished. Four additional units, consisting mainly of dead herbaceous species, were mapped between Gobabeb and Rooibank.

669 THOYER, A. **[Medicinal plants of Mali]** Plantes medicinales du Mali. Ed. 2. *Editions l'Harmattan*, Paris (1986) [Fr]

670 TIMBERLAKE, J. **Handbook of Botswana Acacias**. Division of Land Utilization, Ministry of Agriculture, Botswana (1980) 119 pp. [En, 48 ref.]

Describes 32 *Acacia* species that occur in Botswana and gives keys for the species, general descriptions of the plants, their distribution and habitat, and vernacular names. *Acacia albida* is found in Botswana mostly on alluvial soils in riverine woodland and margins of swamps of the Limpopo, Okavango and Chobe rivers, but nowhere very common. It is also found along dry sandy watercourses or where there is a high water table. It is fast-growing, and can withstand flooding for considerable periods, but is sensitive to frost. The wood is light, pale in colour and coarse-grained, thus is not of much use; however the trunks are used to make canoes on the Zambezi. The leaves are browsed by livestock and game, and contain up to 10% protein and 50% carbohydrate. The powdered pods have been used as fish-poison, and the bark used against diarrhoea, inflammation of the eyes, bleeding and as an emetic. *Acacia albida* is easily raised from seed but does not take well to transplanting. It prefers deep, moist porous soils and tolerates slight salinity and termites.

671 TIMBERLAKE, J.; FAGG, C.; BARNES, R. **Field guide to the acacias of Zimbabwe**. Harare, Zimbabwe; CBC Publishing (1999) 160 pp. [En, 142 refs]

This field guide provides botanical and habit drawings, distribution maps and descriptions of the 44 taxa in the genus *Acacia* that are indigenous to Zimbabwe. Also included are notes on the distribution and ecology of each species and an introduction and 16 boxes that describe the status, features, attributes and uses of the genus as a whole. *Faidherbia albida* is included in the book, with full description and illustrations, because it is still commonly known as an acacia in the country. In Zimbabwe, the species grows mainly on sandy alluvium along large seasonally flooded rivers. It is common in pure stands on flood plains and there is rarely any regeneration beneath it. Old stands have the appearance of parkland. Regeneration is episodic and occurs in substantial amounts only after severe flooding. Subsistence cultivation is practised beneath the tree in parts of the Zambezi Valley. Mentioned is made of the geographical races, Race A with glabrous twigs and small leaflets which is found from central Tanzania northwards to Ethiopia, and Race B which has pubescent twigs and larger pubescent leaflets and occurs from central Tanzania southwards; the races are well-defined except in West Africa so that they have not been distinguished taxonomically. The southern African populations, including those in Zimbabwe, are of race B and are faster-growing but shallower rooting than the West African populations. The pods are relished by livestock and game and are particularly valuable because they are produced at the end of the dry season and before the rains when they are most needed. The seeds have been used as famine food and the bark, roots and powdered pods as fish poison. The largest stands in the country are along the Zambezi River but the construction of the Kariba dam has regulated the flow of the river, so eliminating the occurrence of catastrophic floods. Therefore future stands of the species in the Zambezi River and not likely to be as extensive.

672 TONDER, S.J. Van. **The systematics of some South African *Acacia*-inhabiting Bruchidae (Coleoptera)**. *M.Sc. Thesis, University of the Orange Free State, Bloemfontein, South Africa* (1981) 125 pp. [En, 56 ref.]

A study of the seed-attacking insects found in the pods of 41 *Acacia* species growing in South Africa. A total of 3,300 bruchids were studied, and 23 species are described, seven of them new. No bruchids were found in *Acacia exuvalis*, *A. swazica* and *A. newbrownii* and small numbers from *A. mellifera*, *A. arenaria*, *A. tenuispina* and *A. albida*. From *A. albida* pods, *Bruchidius albidus* Decelle (MS name) and *B. auratopubens* Decelle (MS name) were found.

673 TONDER, S.J. Van. **Annotated records of southern African Bruchidae (Coleoptera) associated with Acacias, with a description of a new species.** *Phytophylactica* [Pretoria] (1985) **17**, 143-148 [En, af, 27 ref.]

Results published from the M.Sc. thesis, see above abstract . Sixteen species of bruchid beetles are recorded from southern Africa with their *Acacia* host species. One new species of Bruchidae, *Bruchidius montisustis*, is described from *Acacia montis-usti*. A table 37 species of southern African acacias and their associated bruchids are provided, noting 2 undetermined species on *A. albida*.

674 TOTHILL, J.C. **Application of Agroforestry to African Crop-Livestock Farming Systems**. *ILCA Bulletin, Addis Ababa* (1987) **29**, 20-23 [En]

The potential of leguminous trees (inc. *Acacia albida*, *Leucaena leucocephala* and *Gliricidia sepium*) to increase crop-livestock production in sub-Saharan Africa is discussed. Key management issues influencing tree introduction and contributions to these systems are described followed by a detailed account of the management techniques suitable for different agro-ecological zones.

675 TOTHILL, J.D. **Agriculture in the Sudan.** London, UK; Oxford University Press (1948) 973 pp. [En, 22 pp. of ref.]

Before reaching its limiting altitude, *Acacia albida* exists only as dwarf trees or bushes on the upper slopes of Jebel Marra, with a dominant but scarce *Olea chrysophylla* Lam. In Darfur Province, and along the Upper Nile Province, soft volcanic dusts are deposited as excellent riverine soils to form the 'har_z' (*Acacia albida*) of Zalingeri. As an animal foodstuff, young shoots and fruits are eaten with relish by camels. In Kordofan Province, uncultivated 'q_z' soil (undulating, sandy) generally supports a thin covering of grass and herbs, and a fair stand of light to medium bush, the commonest varieties being *A. senegal* (hashab) *A. raddiana* (seyal) *A. albida* (har_z), *Balanites aegyptiaca* (hegl_g), *Adansonia digitata* (tebeldi) and *Zizyphus* spp. (s_dr).

676 TOURE,S.F; MICHALET, DOREAU, B; TRAORE, E; FRIOT, D; RICHARD, D. **Occurrence of digestive interactions in tree forage-based diets for sheep.** *Animal Feed Science and Technology* (1998) **74** (1) 63-78 [En, 46 ref.]

The effect of browse level in the diet on *in vivo* DM digestibility (DMD) in sheep and the DM degradation of groundnut hay in the rumen of cattle fed tree forage-based diets were investigated to detect the occurrence of digestive interactions between diet components. Selected browse species *Acacia albida* pods, and *Pithecellobium dulce*, *Adansonia digitata* and *Calotropis procera* leaf samples were collected in the central regions of Senegal, sun-dried and stored in for *in vivo* trials. Classical in vivo balance trials were performed for each tree forage sample. The proportion of browse in the diet varied between 0 and 75% of DM. Regression and difference procedures were tested to estimate the DMD of the browse component of the diet. DMD capacity in the rumen of three young Gobra bulls fed the browse-based diets was estimated by measurement of the *in sacco* DM degradation profile of a standard sample, groundnut hay. For each sample, large variations were observed when the browse DMD was calculated by difference. Total ration DMD and rumen DM degradation capacity were influenced ($P<0.001$) by browse level in the diet. However, non-linear response of total diet DMD to increasing levels of browse was observed only in *A. digitata* and *P. dulce* indicating occurrence of digestive interactions in those species. Rumen DM degradation capacity varied according to plant species which played a major role in the observed digestion profile. Results suggest that the digestion of tree forage-based diets may be influenced by digestive interactions but the large variations observed in plant species show their importance. Optimal DM degradation occurred at 15-30% of browse level in the diet for *A. albida* and *A. digitata* while for *P. dulce* it was at 50%. Corresponding browse digestibility was 50, 47.1, 51.3 and 60.7% DM for *A. albida, A. digitata, P. dulce and C. procera,* respectively.

677 TOUTAIN, B. **The role of browse plants in animal production in the Sudanian zone of West Africa.** In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le.].* Ethiopia; ILCA, (1980) 103-108 [En, 28 ref.]

Discusses the feed aspects of a number of ligneous browse species used in animal production in rural areas of the Sudanian savanna environment. *Faidherbia albida* (common names; cade, gao) is a large tree which typifies the Sudanian agro-pastoral system. Fallen leaves enrich the soil, giving rise to increased sorghum and millet yields without the necessity for fallow periods. The nutritive value of the foliage and especially the pods is significant; they are consumed by cattle and small ruminants. They are gathered by hand for household animals.

| | Feed Units ($kg^{-1}$ DM) | Digestible protein ($g\ kg^{-1}$ of DM) |
|---|---|---|
| Whole pods | 0.67 | 70 |
| Green leaves | 0.88 | 103 |

678 TOUZEAU, J. [**Fodder trees of the sahelian zone of Africa**] Les arbres fourragers de la zone sahélienne de l'Afrique. Thèse de Docteur Vétérinaire, E.N.V. de Toulouse (1973) pp. 7-11 [Fr]

679 TREE, A.J.; BARBER, H. **Bird species diversity in *Acacia albida* woodland of the middle Zambezi.** *The Zimbabwe Science News* (1982) **16** (4) 79-81 [En]

Details the bird species found in the *Acacia albida* woodlands and concluded that the woodlands provide a better dry season feeding resort than the *Combretum* and Mopane [*Colospermum mopane*] bush inland. The proposed damming of the Zambezi at Maputa Gorge would cover much of the floodplain *A. albida* woodland, with a likely serious decline in a number of bird species that depend on it.

680 TRIBOULET, C. [**Identification of *Faidherbia albida* parklands by remote sensing. First works realized from northern Cameroon**] Identification des parcs à *Faidherbia albida* par télédétection. Premiers travaux

réalisés au Nord-Cameroun. In *[Faidherbia parklands.]* Les parcs a *Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Foret, Montpellier, France (1996) 312 pp. 203-216 [Fr, en]

A remote sensing analysis and ground field surveys were carried out to describe the area and density of several types of parkland in northern Cameroon. These were followed by a mapping operation. In remote sensing images, it is possible to identify the active chlorophyllous vegetation . In January, at the height of the dry season, *Faidherbia albida* is covered with green foliage, while many tree species are leafless, and rain-based crops are not present at all. The trees can therefore be identified from images from this period although there are a few other species, such as *Ficus* spp and *Azadirachta indica*, that are in leaf and cannot be distinguished from *F. albida*. A survey of 30 plots of one hectare each, situated in zones identified as tree parklands, was drawn up. This showed that *F. albida* is largely dominant in these plots, but also that it is associated with numerous local tree species *(Balanites aegyptiaca. Acacia nilotica, Ziziphus mauritiana, Adansonia digitata, Borassus aethiopum)* and with one very frequent exotic species, *Azadirachta indica.* On average, we found that the rate of canopy coverage was 13% (11% just for *F. albida)* and that the number of trees was 23 specimens per hectare. Remote sensing helps to draw up location maps of *F. albida* parklands, which makes subsequent studies and surveys much easier.

681 TROCHAIN, J. L. [**Contribution to the study of the vegetation of Senegal**] Contribution à l'étude de la végétation du Sénégal. Ed. Larose, Paris (1940) 433 pp. [Fr]

682 TROCHAIN, J. L. [**Some relic plants of the plains of French West Africa**] Quelques plantes relictes des plaines de l'Afrique occidentale Française. C.R. XVI$^{e}$ Congr. Intern. Géographique, Lisbonne (1949) Sect. III pp. 848-866 [Fr]

683 TROCHAIN, J. L. [**The unusual phenological rhythm of *Faidherbia albida*.**] Le rhythme phénologique aberrant de *Faidherbia albida. Annales Scientifiques de l'Université de Besançon, Série Botanique* (1969) **3** (6) 7-13 [Fr, 16 ref.]

Discusses on the basis of published literature, the aberrant behaviour of *A. albida*, which, in every part of its wide range in Africa, sheds its leaves during the rains. No satisfactory explanation has yet been given. It is suggested that *A. albida* could be highly useful as a shade tree for crops and as a source of green manure.

684 TYBIRK, K. **Regeneration of Woody Legumes in Sahel**. AAU Reports No 27, Botanical Institute, University of Aarhus, Denmark. ISBN 8787600358. 81 pp. [En]

685 TYBIRK, K.; JORGENSEN, A. **Floral biology and pollination of some African Acacias and *Faidherbia albida*.** In *Plants for the people. Proceedings of the XIII th plenary meeting of AETFAT, Zomba, Malawi, 2-11 April 1991 [edited by Seyani J.H.; Chikuni A.C.].* National Herbarium and Botanic Gardens of Malawi, Box 528, Zomba, Malawi (1994) **1**, 589-602 [En, 34 ref.]

Data is presented on pollinator attraction, floral morphology and pollination of *Acacia senegal, A. mellifera, A. polyacantha, A. ataxacantha, A. nilotica, A. tortilis* and *A. seyal* and compared to that in *Faidherbia albida*. The flowers in the spicate inflorescence of *F. albida* and *A. senegal* usually progressively open from the proximal end and are open for 24-48 hours. The inflorescence may have open flowers over a period of 3 days. The sourish odour is produced in the androecium of the flowers of *F. albida*. A wide range of insects from the Lepidoptera, Coleoptera, Hymenoptera and Diptera were found visiting the flowers of all species. Double carpels were found in 1.6% of the bisexual flowers of *F. albida*. Supports the separation of *F. albida* from Acacia. *F. albida* differs in reproductive characters from the African Acacias in timing of flowering; different flower smell; larger polyads; occurrence of two polyads on a stigma (in 6.3% of pollinated stigmas studied); higher number of ovules/ovary correlated with number of pollen grains; and lacking an anther gland.

686 TYBIRK, K.; SCHMIDT, L.H.; HAUSER, T. **Notes on soil seed banks of African acacias. Notes and Records.** *African Journal of Ecology* (1992) **32**, 327-330 [En]

The dynamics of soil seed banks of tropical ecosystems are poorly known but they are important in a consideration of the degradation and resilience of African savannas. Seeds of African Acacia species have hard coats and are long-lived with seed dormancy well adapted to a strategy of seed dispersal over time. These studies of Acacia soil seed banks were carried out in Senegal, Kenya and Zambia. The upper 3-5 cm of soil in plots beneath the crown of the trees was sifted or hand sorted. *Acacia albida* was located in cultivated land in Senegal and Kenya and in wooded grassland in Kenya. Whereas high numbers of seeds of *A. melifera, A. seyal,* and *A. hockii* (from 810 to 2439 seeds $m^{-2}$) were found in Kenya, far fewer seeds were recorded of other species(0-80 $m^{-2}$) with only two seeds of *A. albida* being found. The seed bank of African acacias is influenced by annual seed production, dispersal, predation and germination. African acacias produce from a few hundred to several million seeds on a large tree of *A. albida* but mostly 5000-100,000 per tree. *A. albida* is typically ungulate-dispersed. The most important positive

effect of mammalian dispersal is the removal of seeds from the parent plant, for seedlings will rarely develop under parent trees. Seeds may be defecated in more suitable places for germination for instance, abandoned goat or cattle enclosures that may result in important new tree populations. The main negative effect is the digestion of seeds during passage through the alimentary canal. Bruchid beetles destroy large quantities of seeds (up to 100%) in many African species. Fresh seeds of animal-dispersed species are able to germinate during the first rainy season but, if seeds are kept dry, they will remain dormant in the soil for many years. Fire affects the soil seed bank by breaking the seed coat. The contrasting findings here give rise to the question: what really happens to the large annual seed production of *A. albida*, for example, when the seeds are not found in the soil seed bank?

687 UCHIMURA, E. **Green shelterbelts and afforestation in semiarid zones - a case study of Nigeria.** *Tropical Forestry* (1986) No. 5, 42-51 [Jp, 10 ref.]

The general conditions of various areas of Nigeria are described and the establishment of shelterbelts is discussed. For semiarid areas, the species recommended include *Acacia albida, A. nilotica, A. senegal, Azadirachta indica, Cassia siamea* and *Eucalyptus camaldulensis*. For each of these species the conditions required and notes on its cultivation in shelterbelts are given. The wider range of species available for use in less arid areas is also discussed.

688 ULLMANN, I. [**Diurnal courses of transpiration and stomatal conductance of Sahelian and Saharian *Acacias* in the dry season.**] Tagesgänge vontranspiration und stomatärer leitfähigkeit Sahelischer und Saharischer Akazien in der Trockenzeit. *Flora (Jena)* (1985) **176** (5/6) 383-409 [De, en, 39 ref.]

A study of water relations, and stomatal movements in leaves of eight species of African acacias, in the middle of the dry season in the Sahelian and southern Sahara zones. Daily leaf diffusion conductance, transpiration rate under porometer conditions, leaf temperature and leaf microclimate were measured in *Acacia albida, A. erythrocalyx, A. ehrenbergiana, A. laeta, A. nilotica* ssp. *tomentosa, A. tortilis* ssp. *raddiana, A. senegal* var. *senegal* and *A. seyal* growing either in the region of Niamey (Sahel) or Kori Teloua (Sahara). Deciduous acacias including *A. albida* were found to have high transpiration rates, with a maximum around noon. Despite accentuated drought conditions during the measuring period in spring 1983, little change was detected in water loss, probably due to rooting into the ground water table. A drought response was noted in some shrubs of *A. ehrenbergiana*, growing in granite foothills, where there was a decrease in maximal stomatal conductance and a restriction of water loss. [from Author's summary]

689 USA NATIONAL RESEARCH COUNCIL ADVISORY COMMITTEE ON THE SAHEL. **Agroforestry in the West African Sahel.** Washington D.C., USA; National Academy Press (1983) 86 pp. [En, 46 ref.]

The report provides an overview of agroforestry in the Sahel today, the basic problems encountered in the current practice of agroforestry, and the opportunities available to donors such as USAID to promote agroforestry in the region. "Agroforestry", or more properly, agro-silvo-pastoralism, is a new term for the old practice of growing woody plants with agricultural crops and/or livestock on the same land. Unlike people in many areas of Africa, rural Sahelians have long practised agroforestry. Agricultural crops such as millet, sorghum, maize, cowpeas, and groundnuts are often grown by Sahelian farmers under a park of *Acacia albida* (applering *Acacia*, or gao) precisely because the farmers realize that they will reap better harvests when they plant their crops in close proximity to *A. albida* stands.

690 USMANI, T.H.; AHMED, T.W.; AHMAD, S.Z. **Activated carbon from indigenous inferior woods. Part-III. Adsorption of copper, hexavalent chromium and zinc-carbon selection and pH influence.** *Pakistan Journal of Scientific and Industrial Research* (1991) **34** (1) 26-29 [En, 17 ref.]

Activated carbon samples were prepared from seven exotic and indigenous species growing in Pakistan, including *Acacia albida*. Their adsorption capacity of copper, hexavalent chromium and zinc was evaluated, as they occur in industrial wastes. The activated carbon from the less dense woods (pakar, poplar and partal) proved to generally show lower adsorption than the other species including keekar (*A. albida*). *E. camaldulensis* showed better absorbing behaviour overall. The pH of the metal solution was the principal variable affecting the adsorption.

691 VAN WYK, P. **Trees of the Kruger National Park.** Cape Town, South Africa; Purnell and Sons (1972) 128-167. [En]

692 VANDENBELDT, R.J. **Agroforestry in the semi-arid tropics.** *In Agroforestry: classification and management (Edited by MacDicken, K.G.; Vergara, N.T.).* New York; Wiley (1990a) 150-195. [En,110 ref]

This chapter describes the climate, soils, and major crops of the semi-arid tropics and provides examples of how agroforestry can influence farm production. A two-tiered system characterized by a parkland of mature trees widely-spaced in cropped fields is described as probably the largest single agricultural land use in sub-Saharan Africa. The *Acacia albida*-grain system predominates in Sahelian zone and down through parts of East Africa. Research reports are quoted showing increases in yield under the trees, without

fertilizer, of 36% to 100% for sorghum, 30% for groundnuts, *c.* 100% for millet and 76% for maize. The yield components that were improved under the trees were grain weight, plants per hectare and number of kernels suggesting that water-availability was greater. Many soil characteristics were improved under the trees over time as well including organic carbon and nitrogen (+40%), exchangeable calcium (+42%) and phosphorus and potassium availability all amounting to the equivalent of a green manure addition of over 100 t $ha^{-1}$. Lopping for wood and fodder is also practised which is important because it raises the canopy and reduces light competition for the crops although *A. albida* is renowned for having its active growth phase in the winter when it accesses water and nutrients from zones 15-20 m down where they are inaccessible to the crops.

693 VANDENBELDT, R.J. **Differences in rooting patterns between western and southern African origins of *Faidherbia albida* A. Chev.** *Nitrogen Fixing Tree Research Reports* (1990b) Vol. 8, 136-137 [En, 3 ref.]

In trials at the Sahelian Center, Niamey, Niger, 22 *Faidherbia albida* sources from the Sahel were compared with nine from southern and eastern Africa. Growth rate and mortality were monitored for 1.5 years. By the end of the first year, only 36% of the plants among the southern origins were alive, while over 99% of the Sahelian plants were alive. By the middle of the second dry season, all plants of the southern and eastern African origins had died, whilst survival among all plants of Sahelian origins still exceeded 97%. Associated with mortality was lower root biomass production, though there was little difference in basal diameter or above-ground biomass. Maximum rooting depth was also similar. Such differences in root biomass production may have evolved because of differences in habitat. In southern and eastern Africa *F. albida* grows in riparian stands while in the Sahel it is associated with agriculture, often on plateaux with deep water tables.

694 VANDENBELDT, R.J. (Editor) ***Faidherbia albida* in the West African semi-arid tropics.** *Proceedings of a workshop, 22-26 April 1991, Niamey, Niger* (1991a) 206 pp. [En.]

This workshop brought together scientists and development workers (primarily those working in the West African region) to review past and present research findings on *Faidherbia albida*, discuss development issues and lessons learned, list research priorities for the future, and promote collaboration between research and development programmes. It provides a major list of ongoing research, particularly from west Africa, and the 36 papers (which have been individually abstracted) cover botany and distribution; uses; genetics, provenance trials, and vegetative propagation; site effects, silviculture, and rhizosphere; and social and development issues. After an opening paper on the socio-cultural and economic functions of *F. albida* in West Africa, 36 papers by various authors are presented in five sessions, each containing one invited paper and a varying number of session papers. Session 1, Botany and distribution, has two session papers. Session 2, Uses, also has two session papers. Session 3, Genetics, provenance trials, and vegetative propagation, has eight session papers, two on genetics, four on provenance trials and two on vegetative propagation. Session 4, Site effects, silviculture, and symbiosis, has 12 session papers, six on site effects, and three each on silviculture and symbiosis. The final session, Social and development issues, has five session papers. Working group recommendations and three appendices are included.

695 VANDENBELDT, R.J. **Rooting systems of western and southern African *Faidherbia albida* (Del.) A. Chev. (syn. *Acacia albida* Del.) - a comparative analysis with biogeographic implications.** *Agroforestry Systems* (1991b) **14** (3) 233-244 [En, fr, 13 ref.]

This paper reports on the results of provenance trials of *Faidherbia albida* near Niamey in Niger, West Africa, where mean annual rainfall is 562 mm falling mostly between June and September and soils are sandy with poor water retention, low nutrient status and a water table at about 20 m. The trials included 32 provenances ranging from Burkina Faso to Chad (typically upland sites) and from Kenya to South Africa (typically riverine sites), but excluding any from the Sudan/Ethiopian or the Namibian parts of the species' range. For the first year, the east and southern African provenances were superior for height growth, but not for above-ground biomass, but at 1.5 years these provenances were suffering mortality and those from west Africa had by then twice the height and basal diameter. Excavation of the roots at nine months showed that, although roots of all provenances had penetrated to about 3.5 m, those from west Africa had a much greater below-ground biomass especially in the zone down to 1.5 m. It is suggested that there are two distinct ecotypes of *F. albida*, **A**, the west African plateau type adapted to severe seasonal drought and deep water tables and **B**, the east and southern African riparian and lowland type requiring high water tables to survive drought and seasonal dry periods. Riparian and lowland *F. albida* in west Africa behaves like Ecotype A. Of the provenances not included in these trials, those from Namibia are limited to riverine environments and are likely to be Ecotype B but it is probable that both ecotypes occur in Ethiopia because there is a distinction between a montaine type that appears to be independent of a perennial groundwater table and a riverine type that has perennial access to water. The results of these trials are taken as evidence that the Sudan/Ethiopia region is the centre of origin of the species and that the two ecotypes diverged when **A** moved westwards with human pastoral and agricultural activities and **B** followed the Nile system southwards. This

division into two ecotypes does not fit in with Brenan's (1983) division of the species into two races on the basis of leaflet size and pubescence but their distinction on the basis of rooting behaviour and photosynthate partitioning is held to be more important in explaining the centre of origin. There have been similar findings in India where trials have been established on sandy soils; but in trials on heavier soils, the southern and east African provenances are still superior at five years. It is recommended that trials of this species should include both ecotypes and suggested that the populations of Sudan/Ethiopia may be crucial to the genetic improvement of *F. albida*.

696 VANDENBELDT R.J. (Editor). **Problems with range-wide provenance trials of *Faidherbia albida* on sandy soils in Niger**. In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger*. ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 83-86 [En, 6 ref.]

A *F. albida* provenance trial of 32 provenances from west Africa and nine from east and southern Africa was established in Aug 1988 at the ICRISAT Sahelian Centre, Niamey, Niger. All southern and east African provenances died by the end of the second dry season. Analysis of height growth of the remaining west African provenances was continued; however selection of superior seed origins proved impossible due to a high degree of site micro-variability which confounded plot growth data. Essentially the best plots were situated around micro-highs and eroded termite mounds, and the worst around micro-lows and sheet eroded surfaces. Caution is urged to those establishing or analysing data from provenance trials on sandy Sahelian soils.

697 VANDENBELDT, R.J. [**An original method for planting and managing *Faidherba albida*. Initial growth of plants and microclimatology under adult trees.**] Une méthode originale pour planter et gérer *Faidherbia albida*. Croissance initiale des plants et micro climatologie sous arbres adultes. In *[Faidherbia parklands.] Les parcs a Faidherbia. [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Forêt, Montpellier, France (1996) 312 pp. 217-225 [Fr, en]

This article puts forward new hypotheses about the improvement mechanism for crop production by *Faidherbia albida* based on studies carried out at the ICRISAT Sahelian centre in Niamey, Niger. Data analysis showed that the differences in *Faidherbia albida* seedling growth, observed over relatively short distances, are mainly due to soil fertility variations. Zones with the best growth have chemical and physical soil characteristics that are superior to those of neighbouring areas where the trees grow poorly; this suggests that good fertility under *F. albida* might in effect precede the establishment of the tree. Light interception by the *F. albida* canopy during the crop-sowing period produces a 10°C drop in ground temperature, which helps the seeds to germinate. Pedological and micro-climatic conditions under *F. albida* are comparable to those found further south, so it is possible to refer to an ecological shift, which substantially explains the better growth rate of crops. The author then makes certain proposals for parklands management. This involves, on the one hand, the planting of young *F. albida* in fertile micro-stations, pre-identified during the previous subsistence crop (instead of classic planting with regular 10 x 10m spacing) and, on the other hand, the introduction, beneath the canopy, of cash-crops (*e.g.* cotton, maize) normally used in better soil and climate conditions.

698 VANDENBELDT, R.J.; GEIGER, S.C. **Does soil fertility under *Faidherbia albida* precede the tree?** *Nitrogen Fixing Tree Research Reports* (1991) Vol. 9, 105-106 [En, 2 ref.]

Reports on work showing that clusters of rapidly growing trees in a *Faidherbia albida* trial at ICRISAT, Niamey, are on fertile microsites associated with abandoned termite mounds. Found that the height of 3.5 year old trees decreased with increased distances from the termite mound. Soils from the good growth areas had significantly increased clay contents, exchangeable acidity and bases to depths of 1.4 m, suggesting that regeneration of *F. albida* would be faster on these fertile microsites. These microsites would contribute to the increases in crop yields found in association with *F. albida*.

699 VANDENBELDT, R.J.; WILLIAMS, J.H. **The effect of soil surface temperature on the growth of millet in relation to the effect of *Faidherbia albida* trees**. *Agricultural and Forest Meteorology* (1992) **60** (1-2) 93-100 [En, 14 ref.]

Field experiments were conducted at the ICRISAT Sahelian Centre, Niger in 1990, examining the effect of shade-induced reductions in surface soil temperatures on pearl millet (*Pennisetum glaucum*) seedling establishment and growth. Vertical shade barriers were used to vary soil surface temperature by varying the duration of soil exposure to direct sunlight. Also studies were undertaken measuring soil temperatures under a nearly leafless *Acacia albida* canopy, at the beginning of the Sahelian rainy season. Millet germinated and grew best in a partially shaded environment but failed in fully exposed conditions where surface soil temperatures regularly exceeded 50°C. Shoot growth was inversely related to mean soil temperatures during seedling establishment. The *A. albida* canopy intercepted about half of the incoming radiation resulting in up to a 10°C decrease in maximum soil temperature at 2 cm depth, depending on position relative to the tree and time since the last rainfall during the *P. glaucum* establishment phase. It was

concluded that the enhanced crop growth under *A. albida* canopies was due to the shade-induced reduction of soil temperatures.

700 VASSAL, J. [**The seedlings of *Acacia albida* Del. (*Faidherbia albida* (Del.) A. Chev.).**] La plantule d'*Acacia albida* Del. (*Faidherbia albida* (Del.) A. Chev.). *Bulletin de la Societie d'Histoire Naturelle de Toulouse*, (1967) **103** (3-4) [Fr, 13 ref]

*Acacia albida*, described by Delile (1813) from samples collected in Egypt, is widespread across Africa. Bentham (1875) revised the Mimosaceae and placed *Acacia albida* in the Gummiferae, characterized by spinescence of the stipules. Chevalier (1934) created a new monotypic genus *Faidherbia* for *Acacia albida*. Baillon (1863-1864), in his 'Revision of medicinal Acacias', had already noted that the stamens were 'lightly joined' to each other at the base and that the free petals were joined at their base to the filaments. Chevalier established that the septas between the seeds in the fruit were very similar to *Enterolobium* Mart. D'Amerique. This, combined with differences in the wood of *albida* and *scorpioides* he had already reported, justified to Chevalier the creation of the new genus, establishing a link between the tribes of Acacieae (free stamen) and Ingeae (stamens more or less joined in a bundle). Only Aubreville, Gilbert and Boutique, and Cufodontis adopted the new ranking. Guinet found *albida* not to be an *Acacia* due to the morphology of the pollen and suggested reviving *Faidherbia* and including it in Ingeae. This is a study of the development of *A. albida* from the seed to establish if it is more closely related to the *Acacia* (Gummiferae). Trials were carried out in different African countries. It took about two weeks for the cotyledons to open and develop above ground. The hypocotyl was 10-35 mm long, thicker towards the collar, glabrous, greenish white to ash colour. The epicotyl was 0-5 mm, greenish white to ash colour. Cotyledons were fleshy, sessile, 8-15 mm long by 5-10 mm wide in cotyledon and secondary leaf stages, with a green upper surface and a violet tinted underside, two small oval-elliptical to slightly oblong openings at base. The first five leaves were studied in detail. Bipinnate leaves were established from start with pairs of young leaves persisting a long time. Petioles and rachis can be lightly pubescent. Leaflets elliptical-ovoid to oblong with rounded end, hairy; mid rib 'eccentric'. Leaves follow double spiral theory of Plantefol (to left or right depending on plant), not the single spiral theory of Schimper and Braun. Spinescence of stipules shows itself early. Seedlings resemble *Acacia* (Gummiferae) for following characteristics - method of germination, shape and vein structure of cotyledons, phyllotaxa and spinescence. These are also the characteristics of the Mimosoideae as a whole except for the spinescence of the stipules. Gummiferae young develop a pinnate leaf structure before the bipinnate leaf structure develops. *A. albida* is immediately bipinnate, as are several Mimosoideae. Ontogenic observations cannot answer all taxonomic questions and comments on the development of the seedlings should be considered in association with morphological and anatomical data. While the characteristics of the seedlings match the *Acacia* (Gummiferae), they also match other genera, three of which are in the Ingeae. If the folial development of young *A. albida* is combined with morphological characteristics cited (female parts, fruit, pollen) it is not illogical to exclude *A. albida* from Gummiferae (and *Acacia*) and to place in the Ingeae within *Faidherbia*.

701 VASSAL, J. [**The application of the seminological and ontogenetic facts to research into a natural classification of some African acacias**] Apport des données seminologiques et ontogénétiques à la recherche d'un classement nature de quelques acacias africains. Mitt. Bot. Staatssamml. Munchen (1971) No. 10 pp. 178-197 [Fr]

702 VASSAL, J. [**The application of ontogenetic and seminological research to the morphological, taxonomic and phylogenetic study of the genus *Acacia***] Apport des recherche ontogénétiques et seminologiques de l'étude morphologique, taxonomique et phylogénique de genre Acacia. *Bull. Soc. Hist. Nat. Toulouse* (1972a) Vol. 108, 125-247 [Fr]

703 VASSAL, J. **Ontogenetic and seed research applied to the morphological, taxonomic and phylogenetic study of the genus Acacia**. [??] *Travaux de Laboratoire Forestier de Toulouse* (1972b) Tome 1, Vol. 8, art. 17, 125 pp. [Fr, 165 ref.]

A synthesis of present knowledge on the genus *Acacia*, based on the literature and on the author's own studies (here summarized) on the seeds and seedling morphology of 127 species. A new 'natural' classification of the Acacieae is proposed, based on phyletic characters. The monotypic genus *Faidherbia* is restored, and the genus *Acacia* is divided into three subgenera: Aculeiferum ( = series Vulgares Benth.), Acacia ( = series Gummiferae Benth., excluding *A. albida*), and Heterophyllum ( = series Pulchellae, Botryocephalae, Phyllodinae Benth.). Further subdivisions are given, and a key is presented. Finally, the evolution of *Faidherbia* and *Acacia* is discussed on the basis of ontogeny, phylogeny and chorology.

704 VASSAL, J. *et al.* **Distribution maps of African *Acacia* species**. Groupe international pour l'étude des *Mimosoideae* (1977) No. 5 pp. 31 [ ??]

705 VASSAL, J. [**Interest in leaf ontogeny for the taxonomy and phylogeny of the genus *Acacia***] Intérét

de l'ontogénie foliaire pour la taxonomie et la phylogénie du genre *Acacia*. Bull. Soc. Bot. Fr, 126, Actual Bot. (1979) No. 3 pp. 55-65.

706 VASSAL, J. **Tribe 4. *Acacieae* Benth (1842) Nom. conserv. prop.** In *Advances in Legume Systematics [edited by Polhill, R.M.; Raven, P.H.].* (1981) Part 1. 169-171 [En]

The description of the genus *Faidherbia* is given as:- Tree; branches with spinescent stipules; adult leaves bipinnate; petiole eglandular; inflorescences spicate; stamen filaments shortly connate basally; anthers eglandular; ovary shortly stipitate; pollen porate with an areolate tectum and columellae; pods twisted, indehiscent; seeds exalbuminous, with a filiform funicle; seedlings with a first leaf bipinnate; diploid. The unusual features of *Acacia albida* warrant the exclusion of the species from the genus *Acacia* and its inclusion in the genus *Faidherbia* (stamen filaments: see Chevallier, 1934; pollen: see Guinet, 1969; seedling:see Vassal, 1967; pod and petiole anatomy: see Robbertse, 1975; biochemistry: see Evans et al., 1977; phenology: see various authors.)

707 VASSAL, J. [**Acacias in Senegal. Taxonomy, ecology and importance.**] Les acacias au Senegal. Taxonomie, écologie, principaux intérêts.] In: *[Acacias in Senegal.] L'acacia au Senegal (edited by Campa, C.; Grignon, C.; Gueye, M.; Hamon, S.]. Actes de la réunion thématique sur l'acacia au Sénégal, Dakar, Sénégal, 3-5 décembre 1996. Editions de l'ORSTOM, Paris, France* (1998)15-33, 449 [Fr, 42 ref.]

A key to *Acacia* species is presented, and nomenclature and taxonomic changes are noted. Brief details are also included on the geographical distribution in the country, and main uses of wood and non-wood products. The species include *Faidherbia albida*.

708 VASSAL, J.; LESCANNE, N. [**Cytology and taxonomy of the genus *Acacia***] Cytologie et taxonomie genre *Acacia*. Trav. Lab. For. de Toulouse (1976) t. I, vol. IX, art. IX, 10 pp. [Fr]

709 VERINUMBE, I; JARVIS, P.G. **Agroforestry development in northeastern Nigeria**. *Special issue. Agroforestry: principles and practices. Proceedings of an international conference 23-28 July 1989 at the University of Edinburgh, Edinburgh, UK. Forest Ecology and Management* (1991) **45** (1-4) 309-317 [En]

Some results of recent agroforestry development efforts and research in northeastern Nigeria are summarized, and briefly discussed. An initial diagnostic survey of farms and local markets indicated local agroforestry practices used in arable farming, livestock rearing, fishing and forestry, and identified promising indigenous tree species. Some 26 of these are listed in a table, indicating their local uses and the extent of seed infestation by insects (which averaged 28%). *Acacia albida* was particularly popular among farmers. Nursery studies on the indigenous species indicated poor germination and seedling survival. *Acacia albida* increased the soil nutrient content under its canopy. Work is in progress to develop agroforestry systems on (difficult) vertisol soils, and plans to investigate the social and economic prospects of alternative agroforestry systems among farmers in the region.

710 VERWEY, J.A.; OUEDRAOGO, A.S. **Relation between height growth and phenology of leaves for six provenances of *Faidherbia albida***. In *Breeding tropical trees: Population structure and genetic improvement strategies in clonal and seedling forestry. Proc. IUFRO conference, Pattaya, Thailand, November 1988 [edited by Gibson, G.L..; Griffin, A.R; Matheson, A.C.].* Oxford, United Kingdom; Oxford Forestry Institute and Arlington, Virginia, USA; Winrock International (1989) 400-401 [En]

Trials were established of six provenances of *Faidherbia albida* from three different ecological zones in Burkina Faso. No significant differences in height growth between provenances were found due to great heterogeneity within provenances. Nevertheless, for all provenances, height growth for early-flushing plants was always the best. Soil heterogeneity in the trials did not have an important effect on height growth. It is recommended that:- 1) fast-growing juvenile trees may be used for selection of plus trees; 2) that flushing date of fast-growing plus trees is highly hereditary and that these trees provide monogenous progeny; and 3) it is possible to make early plus tree selection on the basis of early flushing and to establish seed orchard with this material.

711 VILJOEN, P.J.; BOTHMA, J.Du P. **The influence of desert-dwelling elephants on vegetation in the northern Namib Desert, South West Africa/Namibia**. *Journal of Arid Environments* (1990) **18** (1) 85-96 [En, 24 ref.]

The effects of elephants (*Loxodonta africana*) are discussed based on a survey of three sets of aerial photographs covering a 20-year period from 1963. The 70 elephants representing the desert population in 1983 had no known detrimental effect on the desert vegetation. Monitoring the relative age structure of large trees in river courses (recorded species greater than 4 m tall included *Acacia albida*, *A. eriolaba*, *A. tortilis*, and a few *Colophospermum mopane* and *Combretum imberbe*) also suggested that for at least the last 20 years these elephants have had no marked detrimental effect on the large-tree population. It is concluded that the present number of elephants is well below the region's elephant-carrying capacity.

712 VUUREN, N.J.J.Van; BANKS, C.H.; STÖHR, H.P. **Shrinkage and density of timbers used in the Republic of South Africa**. *Bulletin, Department of Forestry, South Africa* (1978) No. 57, 55 pp. [En, 5 ref.]

Information is given on the wood properties of 391 South African timber species. For *Acacia albida*, the following values for shrinkage and density are given:- green moisture content – 109%; green density – 0.91 g $cm^{3-1}$ (range 0.70 – 1.02 g $cm^{3-1}$); density at 10% moisture content – 0.51 g $cm^{3-1}$ (range 0.40-0.58 g $cm^{3-1}$); shrinkage from green to oven dry, volume – 9.4%, radial – 2.86%, tangential – 5.9%, longitudenal – 0.24%; % shrinkage from green to 10% moisture content, radial – 1.79%, tangential – 3.56%, mean of radial + tangential – 2.68%.

713 WAHBA KHALIL, S.K.; ELKHEIR, Y.M. **Dimethyltryptamine from the leaves of certain *Acacia* species of Northern Sudan**. *Lloydia* (1975) **38** (2) 176-177 [En, 15 ref.]

Reports on a study looking for alkaloids in the leaves of 11 Sudanese *Acacia* taxa, including *Acacia albida*. An alkaloid was identified by TLC and GLC chromatography as dimethyltryptamine in only three species, *Acacia polyacantha, A. nubica [A. oerfota]* and *A. senegal*.

714 WAISEL, Y.; ALON, A. ***Acacia albida* Del**. In *Trees of the Land of Israel*. Tel Aviv, Israel; Division of Ecology Ltd. (1980) 6 [En]

A brief account of *Acacia albida* Del. (Shita Malbinah), a winter-deciduous tree growing to a height of 5-10 metres in a few isolated stands in Israel: in Nahal Tavor, in Shimron (near Migdal Ha'emeq), Nahal Ha'ela, Dor, and around Ashdod. Flowering season is between September and February. Tree reproduces vegetatively via root buds.

715 WANE-CONDE, C. [**Participation: strategic and means. For an effective participation of the population in the defence and rehabilitation of trees**] Participation: stratégique et moyens. Pour une participation effective des populations à la défense et à la réhabilitation des arbres. *Aménagement et nature, Printemps* (1986) No. 81 17-20 [Fr]

716 WANYANCHA, J.M.; MILLS, W.R.; GWAZE, D.P. **Genetic variation in *Acacia albida (Faidherbia albida)* and its agroforestry potential in Zimbabwe**. In *Forest Ecology and Management Special Issue: Agroforestry research in the African miombo ecozone [edited by Maghembe, J.A.]. Proceedings of a regional conference on agroforestry research in the African miombo ecozone held in Lilongwe, Malawi, 16-22 June 1991.* (1994) **64** (2/3) 127-134 [En, 25 refs]

Gives results from a large provenance trial planted at Matopos, Zimbabwe in 1986. Nursery-raised seedlings of 30 provenances of *Faidherbia albida* from 14 countries were planted out four months later at 3 x 3 m spacing on a ploughed and disc-harrowed site. The site consisted of shallow brown clay soil at 1180 m altitude and a mean annual rainfall of 560 mm; *F. albida* does not naturally occur in this area. Weeding was done three months after planting and grass was slashed once a year. The trial was fenced to prevent browsing by wild animals. Total height was measured 3.5 years after planting. There were significant differences among provenances in height growth. Best performers were Wonji (Ethiopia) with a mean height of 2.31 m and Hwange (Zimbabwe), Bignona (Senegal), Chilanga and Bwanje (Malawi) and Katima Mulilo (Namibia) whose heights did not significantly differ. Overall most west African provenances were the slowest growers. [These perform much faster in west African sites.]

717 WARD, J.D.; BREEN, C.M. **Drought stress and the demise of *Acacia albida* along the lower Kuiseb River, Central Namib Desert: preliminary findings**. *South African Journal of Science* (1983) **79** (11) 444-447 [En, 20 ref.]

The Kuiseb river had flooded annually for at least 11 years during the period 1962/63 to 1978/79. In contrast, there has been no surface flow in the last four years (1979/80-1982/83) and the water-table has dropped markedly over this time. The demise of mature *A. albida* trees in the Harubes-Soutrivier sector of the lower Kuiseb can therefore probably be attributed to plant water stress induced by the lower water-table.

718 WATT, J.M.; BREYER-BRANDWIJK, M.G. ***Acacia albida***. In *The medicinal and poisonous plants of southern and eastern Africa*. Edinburgh and London; E. & S. Livingstone Ltd. (1962) 538 [En, many ref.]

A review of the literature on the composition and medicinal uses of the bark, pods, gums and leaves of *Acacia albida*. Reference is made to the dietetic value of the pods, and that both fruit and bark are taken in East and West Africa as an anti-diarrhoeal. Lists many other medicinal uses, including the bark being used as an emetic for fever by the Masai.

719 WEBER, F.R. **Reforestation in arid lands**. Appropriate Technologies for Development. Peace Corps (1977)

*A. albida* and *A. raddiana* need 10-14 weeks in plastic pots prior to transplanting whereas *A. nilotica* and *A. senegal* needed 14-18 weeks (8 cm diam. x 30 cm deep).

720 WEBER, F.R.; DULANSEY, M. **Midpoint evaluation: Chad Reforestation Project**. CARE, Inc. (1978) 52 pp. [En, 40 ref.]

Presents a comprehensive review of *Acacia albida*, and current knowledge, literature and field experience available. Technical questions regarding silvicultural techniques are studied in depth, including planting methods, artificial vs. natural reproduction, rainwater harvesting, containerized transportation of plants, choice of species for live fencing (*Parkinsonia aculeata*), and protection against animals and disease. Tree loss was analysed according to a number of causes; domestic animals (25%), sparcity of rainfall (25%), poor planting techniques, including poor stock (20%), elephant damage (15%), caterpillars (10%) and fires (5%). Other considerations for mid-point evaluation of the Chad Reforestation Project are the training function, educational materials, operational management and host country personnel. Appendix D offers concise notes on the advantages and disadvantages of growing *Acacia albida* for agroforestry practice.

721 WEBER, F.; HOSKINS, M. **Agroforestry in the Sahel**. Virginia Polytechnic Institute (1983) 102 pp. [En, 42 ref.]

Summarizes the basic findings of the 1983 Niamey Agroforestry Seminar, and the Sahelian ecology, land tenure experience and the use and rights of trees. Describes the traditional agroforestry systems, and some modern techniques, in the Sahel. Examines the present day problems and gives criteria assessment for further agroforestry activities in the Sahel, in the form of a proposed framework strategy.

722 WEIGEL, J. [**The GAO-DOSSO forestry project. Report of Activities from 01-01-1983 to 31-07-1984**] Projet forestier G.A.O.-D.O.S.S.O. Rapport d'activité du 01/01/1983 au 31/07/1984, République du Niger (1984) [Fr]

723 WENTLING, M.G. ***Acacia albida*: arboreal keystone of successful agro-pastoral systems in Sudan-Sahelian Africa**. Department of Animal Science, Cornell University (1983) 38 pp. [En, 65 ref.]

A comprehensive account of the range and habitat of *Acacia albida*, its major botanical and agronomic features, salient aspects with regard to livestock (shade, browse fodder value), other uses, and additional points of interest. Commonly cited disadvantages of the species are its initial slow growth, not reaching full maturity until 12-15 years after planting, and the necessity for protection methods of young seedlings in the early years, especially from the damage caused by free-ranging goats.

724 WERGER, M.J.; ELLIENBROEK, G.A. ***Acacia albida* Del.: Does its phenological cycle determine its crown form?** *Tropical Ecology* (1982) **23** (2) 316-318 [En, 5 ref.]

Recent research work in the Kafue area of Zambia records *Acacia albida* as a Sudano-Zambezian tree typical of river floodplains, seasonally inundated lake shores and other areas with at least temporarily high groundwater tables. The anomalous, asymmetrical crown shape, leaning in a northerly direction is suggested to result from the unusual phenological cycle of the species, whereby leaf shedding begins at the beginning of the rainy season and flushing of new leaves at the start of the dry season. Growth occurs in the dry season when the sun is continually in the north, hence its asymmetrical growth for capturing optimum light.

725 WEST, O. **Indigenous tree crops for Southern Rhodesia**. *Rhodesian Agricultural Journal* (1950) Vol.47, 204-217 [En, 11 ref.]

Describes *Dichrostachys glomerata*, *Piliostigma thonningii* and five species of *Acacia*, all producers of large crops of edible pods suitable for fodder. *Acacia albida* reaches 80 ft tall, characteristic of flood plains, banks and sandy banks of lowveld rivers. Sensitive to frost, trees along the Khami river at 3500 ft exhibit peculiar growth due to dying back of the branches by exceptional frosts. Elephants are very fond of its pods, estimates up to 1 ton of pods/tree in a good season! Tap root development of seedlings is very fast, with 2-3 inches tall seedlings found with a 25-inch + long tap root on sandy banks of Sesame river. Notes are presented on their botanical characteristics and distribution, and data given as to the chemical composition and feed value of the pods (percentage of digestible nutrients and starch equivalents). It is thought that the larger trees, such as *Acacia albida*, *A. giraffe [A. erioloba]* and *A. woodii [A. sieberana var. woodii]* could be grown on perennial grassland at 4-8 trees/acre, and the smaller trees at 10-20/acre, without damage to the grass yield. At a conservative estimate of one crop every two years, the average annual yield of pods would be 1,000-2,000 lb/acre for the large trees, and 250-500 lb/acre for the smaller ones. They should be grown in the habitats to which they are naturally adapted, *e.g. A. albida* on deep alluvial floodplains in the low veld. Stocking may often be easily affected by selective clearings and thinning of too dense bush. All the species produce good seed which may be planted *in situ* after notching or abrasion, or else germinated in small compost pots which are afterwards planted entire.

726 WEZEL, A.; BOECKER, R. **Fallow plant communities and site characteristics in semi-arid Niger, West Africa**. *Journal of Arid Environments* (1998) **40** (3) 269-280 [En, 49 ref.]

The factors contributing to the regeneration of vegetation in rotational or shifting cultivation fallows were studied at 196 sites in SW Niger in 1994-96. The most important factors for the differentiation of the sites were soil texture and soil organic matter. Most fallows were

shrub savannas, typically with *Guiera senegalensis* and sometimes with trees (*Combretum glutinosum, Faidherbia albida* and *Piliostigma reticulatum* [*Bauhinia reticulata*]). Sites in depressions or with laterite soils or compact soil surfaces due to heavy grazing could be distinguished by the presence of characteristic plant species. Fallow age had no importance for the differentiation of the plant communities.

727 WHITE, F. **Forest Flora of Northern Rhodesia (Zambia)**. London; Oxford University Press (1962) 82 [En]

Botanical description of *Acacia albida*, the sacred tree of the Batwa people. The pods, which when dry look not unlike dry apple-rings, are used in Northern Rhodesia for stupifying fish. The tree flowers in April, August and October, and fruits in June and December.

728 WHITE, F. **The vegetation of Africa**. Natural Resources Research, UNESCO (1983) 20, 356 pp. [En, 50pp. ref.]

A descriptive memoir to accompany the UNESCO/AETFAT/UNSO Vegetation Map of Africa (three sheets and legend; scale 1:5,000,000). In Part One, brief introductory chapters deal with environment, land use and conservation. Part Two describes regional framework, classification and mapping units. Part Three, comprising the greater part of the text, describes the vegetation of the main floristic regions individually in 22 chapters; for each region, the salient features of the flora, geology and climate are also described. A geographical index to the bibliography and a species index are provided. *Acacia albida* is widespread throughout the drier areas of Africa and is mentioned as being dominant or an associate in five floristic zones (phytochoria): (1) Zambesian, (2) Karoo-Namib and (3) Sudanian regional centres of endemism, and (4) Sahel and (5) Sahara regional transition zones. In the Cape Verde Islands, it is now the most characteristic species of pastures up to c. 1000 m with *Ficus sycomorus*. It was possibly introduced, but is now thoroughly naturalized, though often deformed by wind, and sometimes occurring only as very spiny bushes to 2-3 m high.

729 WHYTE, R.O. **Africa (other than the Union)**. In *The Use and Misuse of Shrubs and Trees as Fodder. Imperial Agriculture Bureaux, Joint Publication* (1947) No. 10, 94-109 [En, 42 ref.]

Briefly describes the important fodder trees on a country basis. In Uganda, *Acacia albida* is the recommended tree for the drier parts of the Karamoja district to provide dry season forage. In Sudan, it occurs on the edge of the flooded areas of in the Nile riverine forests, and has the advantage that its pods can be stored and fed dry unlike some other Acacias. In Nigeria, young trees and stool shoots are freely browsed along with shrubs of *Boscia* and *Gardenia* spp. In the Northern territories of the Gold Coast (Ghana), it and *Afzelia africana* are used extensively in anti-rinderpest immunization camps to provide shade and fodder and both are commonly lopped for fodder in the region.

730 WICKENS, G.E. **A study of *Acacia albida* Del. (*Mimosoideae*)**. *Kew Bulletin* (1969) **23** (2) 181-202 [2 pp. ref.]

A detailed study of distribution of *Acacia albida*, and a taxonomic discussion, with a review of pollen, anatomy, ecology, pests and diseases and its economic significance (timber properties, chemical composition, fodder value and agricultural importance). In Eastern and Southern Africa, it is a constituent of well defined riparian communities, but in West Africa it also occurs away from river banks in open savanna woodlands and cultivated lands. Often found in association with *A. senegal* (Darfur) and *A. tortilis* (Uganda, Rhodesia). Altitudinal distribution ranges from 270 m in Palestine, to 2500 m on Jebel Marra, Republic of the Sudan.

731 WICKENS, G.E. **Speculations on long distance dispersal and the flora of Jebel Marra, Sudan Republic**. *Kew Bulletin* (1976) **31** (1) 105-150 [En, 12 ref.]

Jebel Marra, an isolated volcanic massif 3000m high, in Darfur Province, lies on the divide between the Nile and the Chad river basins. The surrounding plain is mainly thorn savanna in the 400-600 mm rainfall belt. On the massif, rainfall ranges from 800-1200 mm. The piedmont and lower slopes are covered mainly by *Anogeissus leiocarpus* woodland, often much degraded by man, gradually changing to upland grassland on the upper slopes, with a scattering of *Olea laperrinei* and *Acacia albida* in the valley bottoms. The author discusses the long-distance dispersal of plant propagules by man, air, birds and mammals and the manner in which boreal, Afro-montane and Saharo-montane elements of the upland flora and the flora of the gallery forests could have reached the massif, with reference also to possible palaeoclimatic changes.

732 WICKENS, G.E. **Alternative uses of browse species**. In *Browse in Africa; the current state of knowledge [edited by Houérou, H.N.le,]*. Ethiopia; ILCA (1980) 155-182 [En, 75 ref.]

The seeds of *Acacia albida* are eaten in times of famine. The species is also recorded as having various medicinal purposes; the gum and leaves are used for diarrhoea, opthalmia, and haemorrhages, as is the bark, but also for fever, coughs, vomiting and pneumonia. In peasant agriculture, the increased yields obtained by growing crops beneath the tree are well documented.

*A. albida* provides both a humus fertilizer and live fences. The timber is used for oil presses, mortars, drums, boat building, dugout canoes, furniture, joinery, interior fittings, boxes, shutters, light carpentry, structural purposes, saddles and benches. For the domestic economy, the bark is used to make beehives and saddle stuffing, the wood ash for soap and as a depilatory, and the pods as fish poison.

733 WICKENS G.E.; SIEF EL DIN, A.G.; SITA, G.; NAHAL, I. **Role of *Acacia* species in the rural economy of dry Africa and the Near East**. *FAO-Conservation-Guide* (1995) No. 27, ii + 56 pp. [En, 12 pp. of ref.]

This paper reviews the role of *Acacia* spp. in the rural economy of the drier regions of Africa and the Near East from the eastern Mediterranean and Red Sea to the Indian Desert. There are five main parts to the paper: (1) *Acacia* in the ecosystem; (2) The uses of *Acacia* in the rural economy; (3) The role of *Acacia* in the rural economy (by country); (4) Selected species (*A. nilotica, A. senegal, A. tortilis, Faidherbia albida* and exotics); and (5) Multipurpose management of *Acacia* formations. These are followed by references and an extensive compilation of tables and other annexes. *F. albida* is included among 160 *Acacia* species native to Africa and the Near East, in the drier regions of which 78 (97 taxa) are reported to be utilized for fuel, timber, forage, gum, tannins, fibre, medicine, food, handicrafts, domestic utensils, environmental protection, soil fertility, shade and shelter, game refuge, amenity and ornamental plantings, and agroforestry. Information on these uses is provided by the tables. *F. albida* is one of the four most important species to be treated separately. The unusual foliage behaviour of the species occurs throughout its distribution range on either side of the equator; in areas of bimodal rainfall two changes of foliage may occur annually. It occurs on alluvial soils of riverine woodland and in deciduous woodland. The natural distribution would appear to be riverine where the root system is almost entirely below the water table during the rainy season. The species also occurs inland, where it is not subjected to any seasonal inundation of the root system. It is possible that two races may have developed anaerobic or aerobic root respiration as the norm. It is suggested that this may explain why some provenances have failed in trials when introduced outside their normal habitat. Reports on natural regeneration of *Faidherbia albida* in Senegal have mentioned that seed germinates in cattle dung although others have observed that all the *F. albida* seed observed germinating in cattle dung became etiolated and soon died. *F. albida* is used for:- **firewood** – varying between occasional use to a preferred source of firewood and charcoal - Calorific value – 4700 kcal/kg; **timber** – sapwood and heartwood not clearly differentiated, yellow to white, 560 kg/m$^{-3}$, coarse grained, soft, easy to work, susceptible to fungal and insect attack but easily preserved, boat building, hut construction, furniture, oil presses, mortars, bowls, domestic utensils, drums, boxes, saddles, troughs, dugouts, fencing, wood wool; **bark** – huts; **browse** – lopped branches browsed by livestock, pods relished by camels, cattle, game, baboons; **medicine;** *root* – febrifuge – coughs, fever, diarrhoea; *gum* – emollient – inflammation, haemorrhage, diarrhoea, opthalmia; *gum + bark* – ears, diarrhoea; *bark* – astringent and febrifuge – bronchitis, vomiting, liver, wounds, ulcers, fever, malaria, psychological disorders, vomiting diarrhoea, kidney diseases, post-partum complications, haemorrhage, opthalmia, pneumonia, coughs, colds, gripe, leprosy; *leaves* – astringent – teeth (may contain fluorine); *pods* – astringent – opthalmia, diarrhoea, haemorrhage, colds; **food** – seeds boiled, skins removed, pods high in starch and eaten or used as condiment. Macro nutrient composition (g/100g) of seeds:- moisture – 6.5; ash – 3.9; protein – 24.8; fat – 2,2; fibre – 6.8; carbohydrate – 55.8; thiamin – 0.9; riboflavin – 0.17; nicotinic acid – 2.04; energy (kJ/100g) – 1437. Inorganic constituents (mg/100g):- Ca – 252; Mg – 276; Fe – 6.81; Na – 18.3; K – 1125; Cu – 1.57; Zn – 2.55; P – 390. *F. albida* is used for soil fertility, the thorny branches are used for fences, it is grown for live hedges, windbreaks and shade and it is a valuable source of pollen and nectar for bees.

734 WIEGAND, R.O.; REED, J.D.; COMBS, D.K.; SAID, A.N. **Leaves from tropical trees as protein supplements in diets for sheep**. *Tropical Agriculture* (1996) **73** (1) 62-68. [En, 33 ref.]

The effects of forage supplement and level of maize (*Zea mays*) grain offered on intake, digestibility, N balance, and rate of gain were determined in rams fed on teff straw (*Eragrostis abyssinica* [E. tef]). Supplements (leaves from five trees, *Faidherbia albida, Carissa edulis, Dichrostachys cinerea, Leucaena leucocephala,* and *Sesbania sesban*, or chopped lucerne hay (*Medicago sativa*) provided CP 40 g/day. Maize was supplemented to half of the sheep at 100 g/day. Rams fed on leaves of *F. albida, L. leucocephala, S. sesban*, and lucerne hay gained 49 g/day with maize and 23 g/day without maize. Higher content of proanthocyanidins and related polyphenols in *F. albida* had no detrimental effect on N balance and rate of gain in comparison to lucerne. The high content of proanthocyanidins and related polyphenols in *C. edulis* and *D. cinerea* resulted in low intake, digestibility, and rate of gain (6 g/day) when fed with maize, and high weight loss (63 g/day) without maize.

735 WIELAND, R.G.; ORR, B.D.; HELIN, W. **Species elimination trials for reforestation in south-west Somalia**. *Nitrogen Fixing Tree Research Reports* (1985) Vol. 3, 42-45 [En, 4 ref.]

A report on the nursery and out-planting phase of the Inter-Church Response Forestry Program's research in determining which species should prove most successful for reforestation of cut-over areas around refugee camps at Luqq. *Acacia albida* seeds were provided by ICRAF.

736 WILD, H.; FERNANDES, A. **Vegetation map of the Flora Zambesiana Area**. *Flora Zambesiana Supplement, Salisbury, Rhodesia* (1967) 70 pp. [En, 88 ref.]

Presents and describes a vegetation map, in two parts, of the Flora Zambesiana area (Botswana, Zambia, Zimbabwe, Malawi, Mozambique), which is divided into 74 vegetation types (scale 1:2 500 000).

737 WILLAN, R.G.M. **Notes on the vegetation of Northern Nyasaland**. *Empire Forestry Journal* (1940) **19**, 48-61 [En.]

Floristic notes on various regions in the northern two-thirds of Nyasaland, with a condensed commentary by Dr. J. Burtt Davy. Reference is made to the potential importance of two unidentified species of Bamboo, one of which is carefully cultivated by the Sukwa tribe of the Misuku Hills, and to the native use of *Acacia campylacantha*, *A. woodii*, and *A. albida* as indicative of the more fertile soils.

738 WILLIAMS, D. [***Acacia albida*, famous but little known**.] L'*Acacia albida,* célèbre main mal connu. *Bulletin de presse SYFIA* (1990) No. 20, 9-10 [Fr]

A tree with counter seasonal leafing, it provides shade, fodder and soil nutrients during the dry season. It can double the yield of millet and increase that of maize by 75%. Traditionally used by the Serer, the oldest agricultural group of west Africa. *Rhizobium* in root nodules of young *Acacia albida* (rare in old plants except in the top soil) fix atmospheric N in exchange for sugars from the plant. High densities of *Rhizobium* are found just above the water table. The N taken up is transported to the leaves which, when shed fertilize the soil. There is the possibility of inoculating young plants to increase growth rates. The use of *A. albida* is recommended to prevent desertification . The need for an intensification of research and dissemination of information to villagers is highlighted. *A. albida* is in decline, however, and with it the Sahelian soils. This is the result of two extremes; over exploitation by man and cattle combined with 20 years of drought and excessive protection (*e.g.* Senegal making the tree 'untouchable') leading to a loss of interest by villagers in its management and the protection of seedlings against grazing. There is still a lot unknown about the genetics and ecology of this tree and more research is needed if plants that are adapted to the needs of the agriculturalists and the environment are to be produced.

739 WILLIAMS, J.H. **The Agro-ecological significance of *Faidherbia albida***. In *Faidherbia albida in the West African semi-arid tropic. Pproceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF. ISBN 92-9066-220-4 (1992) 127-129 [En, 4 ref.]

Reviews the major determinants of crop adaptation in the Sahelian belt, where pearl millet can be the only crop that survives. He shows how changes in the microclimate in association with *Faidherbia albida* can provide the opportunity for increasing the diversity of crops grown. The beneficial changes include reductions in soil temperatures (see Vandenbeldt and Williams 1992), and improved soil fertility (with higher clay and pH) in the vicinity of *F. albida* trees that provide for a more favourable agro-ecological environment.

740 WILLIAMSON, J. **Useful plants of Nyasaland**. Zomba, Nyasaland; The Government Printer (1956) 168 pp. [En]

*Acacia albida* is described in the dictionary section of this book. It is a majestic tree, found mainly below 200 feet where it is gregarious on rich alluvial soils and can be used as an indicator of underground water supplies. The trunks are used for making canoes which last up to five years. The wood is yellowish white, liable to attack by borers and white ants, used for long pick handles and pestles and mortars. Fruits are a valuable stock feed and it is said to yield a good gum. The bark is boiled and drunk to cure diarrhoea.

741 WILSON, J.G. **Nutritional value of some common cattle browse and fodder plants of Karamoja, Northern Province, Uganda**. *East African Agricultural and Forestry Journal* (1963) **28** (4) 204-208 [3 ref.]

Tabulates the dry matter % of crude protein, fat, fibre, and the total ash etc. in the young shoots or pods of 25 herbs and 23 woody species, the latter including *Acacia albida*, *A. nilotica* var *subulata* and *A. senegal*. For 10 of these woody species the CaO, $P_2O_5$, $K_2O$, Mg, and Mn contents are listed.

742 WOLDU, Z.; TADESSE, M. **The status of the vegetation in the Lakes Region of the Rift Valley of Ethiopia and the possibilities of its recovery**. *Ethiopian Journal of Science* (1990) **13** (2) 97-120. [En, 21 ref.]

The classification of the vegetation based on tree and shrub components suggested that there were four vegetation types in the region. The first of these is an *Acacia* (*Faidherbia*) *albida* dominated type near Debrezeit and Mojo. Here, the species occurs on black clay soils which are invariably cultivated. Because it provides shade, fodder and pods in the dry season, farmers tend to leave some trees on their farms. The recovery potential of the species was gauged to be high in the grazed, cultivated and fallow land sites although dispersal capacity of the species was poor and dependent on propagules from mature trees.

743 WOOD P.J. **The Botany and Distribution of *Faidherbia albida***. In *Faidherbia albida in the West*

*African semi-arid tropic. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 9-17 [En, 25 ref.]

General summary of the botany, distribution and ecology of the species. Treats the species as *Faidherbia albida* Del. A. Chev., in the Acacieae tribe of the Mimosoideae. The bulk of the paper and illustrations derive from CTFT (1989) monograph. Its ecological optimum is on sites with deep sandy soils and an annual rainfall of 500 - 1000 mm. It is a plant that looses much water by evaporation and therefore can only develop on moist soils or on soils that allow development of an extensive root system down to the water table.

744 WOODWARD, A.; REED, J.D. **The influence of polyphenolics on the nutritive value of browse: a summary of research conducted at ILCA**. *International Livestock Centre for Africa Bulletin* (1989) No. 35, 2-11 [En, 50 ref.]

In this summary of work at ILCA, it is shown that the contents of proanthocyanidins and soluble phenolics in browse plants are related to nitrogen digestibility in ruminants. Browse with moderate phenolic compound contents, such as leaves of *Acacia brevispica*, *A. seyal* and *A. nilotica* and fruits of *A. albida* and *A. tortilis* are promising protein supplements. Although the phenolics in these species reduce nitrogen availability, the negative effect is partially offset by lower urinary loss of nitrogen. Both *Sesbania sesban* and *A. seyal* were considered suitable for ruminants after an adaptation period. Leaves of *A. cyanophylla* and fruits of *A. sieberiana* and *A. nilotica* were not considered suitable for ruminants, however, the phenolic content may vary with region.

745 WORKMAN, S.W. **Nodulation trails with selected arboreal legumes of Burkina Faso, West Africa**. *Nitrogen Fixing Tree Research Reports* (1986) **4**, 7-8 [En, 1 ref.]

Reports on 23 species of legumes that were examined for root nodules, with or without *Rhizobium* inoculation, at the Moundasso nursery, near Dedougou. Both *Acacia albida* and *Acacia nilotica* formed nodules without inoculation, and when inoculated with *Rhizobium* from Mircen/Niftal Hawaii, nodulation was increased with *A. albida* and most other *Acacias* but not *A. nilotica*. [Only 15 seedlings studied per species after 60 days.]

746 YAMEOGO, U.G. [**Propagation of *Acacia albida* by cuttings under glass**.] Bouturage sous châssis de *Acacia albida*. In *[Comparative study and improvement of the propagation of shrub and tree species.] (tude comparée et amélioration de l'aptitude de diverses espèces arbustives et forestières au bouturage*. Mémoire de Fin d'(tudes du Diplôme d'Ingénieur des techniques du développement rural. Universite de Ouagadougou, Burkina Faso IDR/CTFT (19??) 62-3 [Fr]

*Acacia albida* cuttings taken from the main shoot and axillary shoots of coppice shoots and root cuttings were either left untreated or treated with 0.5% IBA or IAA. Two months after planting, all of the axillary cuttings had died. Best results were obtained with main shoot cuttings treated with IBA, which had 70% survival. Root cuttings also gave good results, with 51.7% survival.

747 YOUNG, R.G.N. **The *Acacia* species with spicate inflorescence in the Transvaal; Taxonomy and Distribution**. *Candollea* Geneva (Dec 1955) XV, 79-123 [En.]

Presents a key to 11 species of Transvaal Acacias with spicate inflorescenses, followed by a short taxonomic description and a list of localities by area from botanical specimens. These are then plotted on a distribution map for each species. *Acacia albida* occurs in a relatively small area of the northern and north-eastern Transvaal and also in the extreme south east (Barbiton dist.) Also lists its uses as a useful forage plant, that it has many native names and in some places is deliberately preserved.

748 ZAMBIA FOREST DEPARTMENT. **Checklist of vernacular names of the woody plants of Zambia**. *Forest Research Bulletin* (1965a) No. 3, p. 73 [En]

*Acacia albida*: mbiwa (Kaonde), munga (Lozi), nsangu (Nyanja) and musangu/mujagwe (Tonga).

749 ZAMBIA FOREST DEPARTMENT. **Checklist of plant names in the Bemba languages**. *Forest Research Bulletin* (1965b) No. 5, p. 2 [En]

*Acacia albida*: muchesi (Bemba).

750 ZAMBIA FOREST DEPARTMENT. **Poisonous plants of Zambia**. *Forest Research Bulletin* (1967) No.1, p. 2 [En]

*Acacia albida* Del.: Winter thorn, Ana tree, musangu, munga, mwiba, nsangu, muchesi, mujagwe. A large, deciduous tree of alluvial flats along the rivers, flowering in winter, locally common in the low rainfall areas. The pods are spirally twisted like apple rings. There have been some cases of game poisoning from eating pods which have produced prussic acid, possibly as a result of over-fast ripening. Pounded roots are occasionally used to stupefy fish.

751 ZAMBIA FOREST DEPARTMENT. ***Acacia albida*, *Acacia nigrescens***. *Technical Note, Timbers of Zambia, Division of Forest Products Research, Forest Department, Zambia* (1979a) No. 1/79, 5 pp. [En, 5 ref.]

752 ZAMBIA FOREST DEPARTMENT. **Timbers of Zambia, *Acacia albida*.** *Technical Note, Division of Forest Products Research, Forest Department, Zambia* (1979b) No. 1/79, 2 pp. [En, 3 ref.]

Gives a brief description of habit and distribution in Zambia (North, Central, Southern and Eastern provinces) on clay flats and Chipya woodland. Lists wood properties. Density:- 640 (575-705) kg $m^{-3}$ air dry; 1070 kg $m^{-3}$ green at 101% M.C. Yellow brown sapwood, pale creamy brown heartwood. Irregular, sometimes interlocked grain, course texture. Unpleasant odour when fresh, but not apparent when dry. Sapwood is liable to insect attack and sapstain. Both sap and heartwood are permeable. Weak mechanical properties. Easy to work and saw but interlocked grains may pick up on planing. Locally used for canoes, paddles, school benches. one piece doors, pestle and mortars and handles. Good firewood. Bark contains 28% tannin, pods 5%. Fruit is used for cattle food, and good gum.

753 ZEH-NLO M.; JOLY, H. **First observations on the phenology of *Acacia albida*: study of a population in northern Cameroon.** In *Faidherbia albida in the West African semi-arid tropics. Proceedings of a workshop, 22-26 April 1991, Niamey, Niger [edited by Vanderbeldt, R.J.].* ICRISAT, Patancheru, A.P. 502 324, India & ICRAF ISBN 92-9066-220-4 (1992) 63-66 [En, 5 ref.]

Gives results of the first two years of phenological study, monitoring 162 trees of population of *F. albida* in Kongola, northern Cameroon. Average heights of the trees was 14.5 ± 3.75 m, crown height 10.75 ± 3.05 m, and a circumference at 1.3 m of 1.95 ± 0.55 m. At a population level, the flowering period was variable. It peaked at the beginning of the dry season, followed by a pod setting peak which did not include the end of the flowering period. Pollination seemed to be a critical stage, an inflorescence spike has around 100 flowers, but only produce 1-5 pods which mature with relatively low losses. Some individual trees varied from the annual trend, most having been pruned by herders.

754 ZEH-NLO, M.; JOLY, H.I. .[**Management of the genetic resources of *Faidherbia albida*. Evaluation of within population gene flow**.] Gestion des ressources génétiques de *Faidherbia albida*. Evaluatiol des flux de gènes intrapopulation. In *[Faidherbia parklands.] Les parcs a Faidherbia [edited by Peltier, R.]. Cahiers Scientifiques* No. 12, CIRAD-Foret, Montpellier, France (1996) 312 pp. 297-308 [Fr, en]

The authors studied the genetic diversity of 277 *Faidherbia albida* trees in two parklands in northern Cameroon. The Kongola parkland is still being widely used for crops and livestock grazing. There are many young trees growing towards its boundaries. Little use is made of the Zamay parkland, on the other hand, and it has few young specimens. The individual trees were spatially located. Their phenology and flowering were monitored; gene flows within population were estimated using isozyme markers. It was noted that the long flowering period, which is likely to be prolonged by pruning at Kongola (September to May), favoured cross-fertilization. There were no groups of flowering trees based on height and circumference, with the result that there may be crosses between old and young trees. Genetic variability was significant at Zamay ($H_T = 0.39$), but even more so at Kongola ($H_T = 0.53$). At Kongola, the random spatial distribution of *F. albida* genotypes might be due to seed input by livestock. Cross-pollination between trees is higher in periods of intense flowering, but is not associated with tree density. The genetic composition of the pollen pool varied considerably during the flowering season. The findings have implications for the study and management of the genetic resources of *F. albida*:- to evaluate the genetic diversity of a population, it is important to harvest seeds coming from a period of high flowering density, or from several successive phases; it is important to take into account the spatial distribution of the trees to make a proper sampling; pruning cannot be banned, because when it remains moderate and staggered, it prolongs the flowering season, and increases the gene flow within population and provides products for local people. Consequently, the management of the genetic resources of *F. albida* has to be established as a dynamic process involving farmers and herdsmen whose activities may modify genetic diversity. The *ex situ* conservation of seed lots in a seed bank will only be a complementary action, useful for endangered stands.

755 ZINDEREN BAKKER, E.M. Van; COETZEE, J.A. **South African Pollen Grains and Spores.** Cape Town, South Africa; A.A. Balkema (1959) Pt.3, 115-118 pp. [En]

Divides the South African *Acacia* species into two groups (pollen grains with or without furrows,) based on a morphological study of the pollen grains of 36 species. *A. albida* Del., is placed in the group without furrows, composed of a polyad of 30 cells. Polyads measure 81.1-101.4 x 46.8-62.4 μ and individual cells 20-22 x 16-25 μ. Thickness of the exine on the distal face is 1 μ, two layers of equal thickness, with a very vague and minute pattern of dots; surface granulate.

756 ZOHARY, M. **The Arboreal Flora of Israel and Transjordon and its Ecological and Phytogeographical Significance.** *Institute Paper, Imperial Forestry Institute, University of Oxford* (1951) No. 26, 59 pp. [En, 72 ref. 2 maps]

Presents a summary of the author's phytogeographical and ecological observations on the native trees of Palestine. *Acacia albida* Del. shows a wide range of ecological adaptability, with an unusual distribution in Palestine. Describes is localities, all being at low altitudes, (less than 300 m) and well protected against low

temperatures. Its very disjunct distribution in the Mediterranean and Irano-Turanian territories, and occurrence on a wide range of soil conditions, suggest it formally was much more widespread and continuous in Palestine. This occurred when a Sudano-Deccanian flora dominated most of Palestine in the Oligocene and Miocene. Notes it reaches a maximum height of 10 m near Shimron where the roots penetrate the rock and spread horizontally producing vigourous suckers. Its arabic name Sent corresponds to ancient Hebrew name Shittah.

757 ZOHARY, M. **Plant life of Palestine, Israel and Jordan**. New York; The Ronald Press Co. (1962) 262 pp. [En]

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