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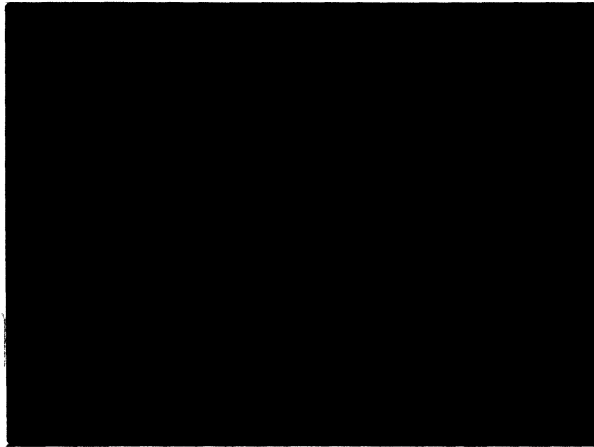
ASH DIEBACK SURVEY

by

R.G. Pawsey

Summer 1983

DEPARTMENT OF FORESTRY
COMMONWEALTH FORESTRY INSTITUTE
UNIVERSITY OF OXFORD



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SUMMARY

Details are given of the results of a survey of ash dieback carried out in the east-central region of England, from Humberside southward to Buckinghamshire. Ash dieback was prevalent throughout the area, the incidence of the disease being highest in Northamptonshire and adjacent areas in neighbouring counties, where the occurrence of dieback on ash trees over 25 ft in height was frequently over 40%. General observations made during the main survey, and the results of two other special surveys, indicated clearly that the incidence of ash dieback is related to the intensity of agricultural activity, particularly in areas of arable farming. The incidence of ash dieback recorded in the two special surveys was approximately eight times higher on trees in the agricultural countryside as compared with those in towns and villages.



Hedgerow ash trees in Northamptonshire seriously affected by dieback.

1. INTRODUCTION

On 24th May 1983, the following letter was sent from the Department of Forestry, Oxford University to the Chief Executive Officers of all Local Authorities and Development Corporations (except those in East Anglia) in the east-central region of England, from Humberside south to Buckinghamshire.

"Dear Sir,

Ash Dieback Survey Appeal

Ash dieback is a widespread disease condition in Britain often leading to serious disfigurement and death of affected trees. Although several agents, e.g. atmospheric pollution, water stress, viruses and insects have been suggested as factors contributing to the development of ash dieback, the actual cause of the disease is not known. The disease has been recognised by tree pathologists in this country for more than thirty years, but it has caused increasing concern over the last decade as ash has assumed greater importance in both rural and urban environments largely due to the devastating impact of elm disease.

In order to make an accurate assessment of the distribution and severity of ash dieback in the apparently worst-affected parts of the country, the Department of Agricultural and Forest Sciences is proposing to initiate an ash dieback survey during the summer of 1983. Hopefully, the information provided by the survey will enable a case to be made for government funds to support research into the cause of the disease. The survey will be based at the Commonwealth Forestry Institute, Oxford, and co-ordinated by Dr R G Pawsey, one of the most experienced tree pathologists in Britain. The need for the survey and further work on ash dieback is endorsed by Mr D A Burdekin, Chief Research Officer at the Forestry Commission and by Mr W E Matthews, Chairman of the Tree Council.

Previous, rather cursory, observations on the incidence of the disease in Britain indicate that damage is most prevalent in the east-central area of England, from Humberside southward to Oxfordshire and Buckinghamshire. It is therefore proposed to confine the initial survey to this area, and an appeal is being made to appropriate local authorities for contributions towards the funding of the survey. The fund will be controlled by the Administrator of the Commonwealth Forestry Institute, Mr L L Tuke.

The period of the survey is from mid-June to mid-September 1983, and the survey report will be available and sent to contributors to the appeal in October.

This letter is being sent to all local authorities in the proposed survey area. We should like to suggest that appeal contributions from local

authorities might be of the order of £100 for District Councils and £300 for County Councils, Metropolitan Borough Councils and Development Corporations. The intensity of the survey will naturally depend on the success of this appeal, and all the funds received will be spent on the survey and on its administration by the Department at Oxford.

In order to start the survey as soon as possible, we should be most grateful for an early response from your Council. Cheques should be made payable to the Oxford University Ash Dieback Survey Fund, and sent to the Administrator, Commonwealth Forestry Institute, South Parks Road, Oxford OX1 3RB.

We estimate that about £5,000 will be required for an adequate survey. It might be possible to mount a survey of limited extent in selected areas (related to sources of contribution) on a fund of about £2,000, but if contributions fail to reach this figure by 30th June all funds will be returned to contributing councils.

We hope the present and potential importance of ash dieback in your area and over the country as a whole, and the need to learn more on the cause of the disease if any control measures are to be effectively applied, will enable you to persuade your Council to make an appropriate contribution to this appeal.

Yours faithfully,

M.E.D. Poore
Professor of Forest Science

The appeal raised over £4,500. Donations were received from Milton Keynes Development Corporation; Bedfordshire, Buckinghamshire, Humberside, Leicestershire, Lincolnshire, Northamptonshire, Nottinghamshire, Oxfordshire, South Yorkshire and Warwickshire County Councils; Aylesbury Vale, Boston, Cherwell, Chiltern, Derby City, East Yorkshire, Great Grimsby, Luton, Mid-Bedfordshire, Milton Keynes, North-west Leicestershire, Oadby and Wigston, Rushcliffe, Scunthorpe, South Bedfordshire, South Buckinghamshire, South Holland, South Kesteven, South Oxfordshire, Stratford-upon-Avon, West Oxfordshire and Wycombe District Councils, to whom we should like to express our gratitude.

We offer our apologies to the contributing District Councils whose areas were not specifically covered by the survey. The distribution of the Councils that responded to the appeal was discontinuous and to make best use of the funds by optimising travelling, it was decided to confine the survey to the roughly rectangular block of country shown in Figures 1 - 3. A special effort will be made to survey the omitted areas when central government or other funds are made available for further work on ash dieback. It should be mentioned that a small number of detached local surveys would probably have added little to the value of this initial general survey, and that in helping to mount the project, all donating councils made an important contribution, enabling us not only to record

the incidence of ash dieback in the area surveyed, but to give some firm indications on factors associated with its development.

We wish to acknowledge here our thanks to all those who have assisted with the survey, either actively or in providing useful information through discussion or by making available previously unpublished reports. We are especially grateful to Robert Strouts and David Rose of the Forestry Commission's Pathology Advisory Service for their general interest and in providing free access to the Commission's disease records on ash; to Mr J.E.Garfitt for his particularly valuable response to the appeal for information published in July in the Quarterly Journal of Forestry; and to Dr J.I.Cooper of the N.E.R.C. Institute of Virology, Oxford, for helpful advice and information, and for permission to reproduce Figure 4.

2. BACKGROUND TO ASH DIEBACK IN BRITAIN

The first significant reference to ash dieback in Britain was by Peace (1962) who suggested that the condition occurred mainly on old hedgerow trees, and attributed its development to moisture stress associated with major variations in soil water content, particularly on heavy soils.

In an internal Forestry Commission memorandum (dated October 1960) with special reference to the incidence and severity of dieback on ash in Northamptonshire, Peace noted that though it was worse on older trees, smaller trees were also affected, and that it occurred on trees growing on loam as well as on clay soils. Despite Peace's comment "that it is hard to turn a blind eye to something so obvious and widespread," the availability of pathology staff in the Forestry Commission at that time and commitment to work on important diseases of forest plantation crops, prevented the start of any detailed study of ash dieback. Because of shortages of staff and research funds, and to some extent because of the priority given to Dutch elm disease in recent years, ash dieback has not been the subject of any serious study either by the Forestry Commission or by other research institutions in the country.

Pawsey (1973) in his Chairman's address to the Forestry sub-section of the British Association for the Advancement of Science, Canterbury, stated that the general condition of ash in Britain had shown a marked deterioration over the previous ten years or so, on the cause of which there appeared to be complete ignorance. Scale insects and a range of unproven adverse site and climatic conditions had been mooted as being at least partially responsible, and other agencies, notably viruses and mycoplasma-like organisms, were also suggested as being possible causes.

Cooper and Edwards (1981) recorded widespread infection of hedgerow ash by arabis mosaic virus (AMV) but concluded that dieback was not directly associated with the presence of virus infection.

A condition known as ash dieback occurs on *Fraxinus* species (*F. americana* L. and *F. pennsylvanica* March) in north-eastern U.S.A. (Ross, 1966; Hibben and Silverborg, 1978) but the symptoms of the disease and factors associated with it, appear to be different from dieback of *F. excelsior* L. (the Common ash) in Britain. In North America, early symptoms of ash dieback include chlorosis and reduction in the size of leaves, whereas in Britain leaf abnormalities are not characteristics of the disease. Water stress in affected trees and invasion of shoots by canker-forming fungi are described as the primary causal factors on American ash, with atmospheric pollution, fungal infection of leaves and infection by viruses and mycoplasma-like organisms being cited as ancillary factors.

During the course of their virus infection survey of hedgerow ash in Britain, Cooper and Edwards (1981) made some numerical assessment of the incidence of ash dieback in different localities in the country. The criterion for recording dieback was 10% or more of the branches without leaves or with leaves only present at the shoot tips. Over Britain as a whole (in the localities examined), the incidence of dieback varied from 29% to 84% with the highest incidence in the east-central area of England.

A number of unpublished observations on insect damage and fungal infection on ash, relevant to ash dieback, came to light during the course of the survey, the importance of which will be considered later. A review of the literature revealed a surprising lack of knowledge on a) the changes in development and growth of ash shoots which take place with increasing age of trees, and b) on the patterns of flowering and fruit production of ash. Both of these features could be of considerable importance in relation to the development of ash dieback, and will be discussed later when reviewing the possible aetiology of the disease.

3. SURVEY METHODS

After preliminary trials in Oxfordshire, the main survey was based on counts of healthy and affected trees made from a car travelling along a complete series of E/W traverses, at 10km intervals over the whole survey area (using the 10km grid base of 1:50,000 Ordnance Survey maps). These numbers were recorded on counters mounted on a board attached to the steering wheel of the car.

The criterion for recording the presence of dieback was the same as that used by Cooper and Edwards (1981) i.e. 10% or more of the branches without leaves or with foliage only present at the shoot tips. To avoid variation in the assessment of this necessarily rather poorly-defined disease condition, all recordings were made by one observer (R.G.Pawsey), although the general validity of the assessment was confirmed by other observers over large areas of the survey.

The incidence of dieback was recorded after travelling along each 10km (nominal) section of the traverse (although the length of road covered often exceeded this considerably), together with a note of the actual distance travelled and notes on relevant conditions observed during that particular section. Where possible and practicable, the route of the survey was along secondary roads and avoided the centres of large towns.

The survey count was limited (a) to the immediate roadside and the area of country (exclusive of any form of woodland) on either side (normally not more the 150-200 yards) in which ash trees could be distinguished clearly from other tree species, and (b) to single-stemmed trees over 20-25 ft in height, i.e. it excluded saplings and coppice growth, which preliminary observations indicated were virtually free of dieback.

Preliminary observations, and those made during the survey (confirmed by independent sources) indicated that dieback was absent or of very low incidence in woodlands, including copses and larger shelter-belts, hence the exclusion of these from the survey count. Apart from roadside and hedgerow trees, the survey included ash trees in gardens, open parklands, recreation grounds and amenity areas.

4.RESULTS

The records of numbers of normal and dieback-affected ash trees, and the percentage incidence of dieback in the individual 10 km (nominal) sections of the survey traverses are given in Table 1 overleaf.

Table 1

Incidence of dieback recorded on trees along each section of survey traverses.

Column A: Reference of 1 kilometre grid intersection closest to starting point.
 Column B: Reference of 1 kilometre grid intersection closest to finishing point.
 Column C: Number of healthy ash trees recorded.
 Column D: Number of dieback-affected ash trees recorded.
 Column E: Percentage incidence of ash dieback.
 Column F: Place closest to finishing point.

A	B	C	D	E	F	A	B	C	D	E	F
OS map 105/106/107 continuous											
West to East						West to East					
441451	451451	66	8	11	Long Marston	441441	441431	77	6	7	Kippax
451451	461451	35	15	30	York	441431	451431	94	8	8	Mark Fryston
461451	471451	41	13	24	Kexby	451431	461431	19	4	17	Brayton
471451	481451	77	12	13	Broad Ings	461431	471431	77	16	17	Wressle
481451	491451	92	8	9	Southwold	471431	481431	65	16	20	Owesthorpe
491451	501451	64	16	20	Watton Grange	481431	491431	104	31	23	South Cave
501451	511451	80	25	24	N.Frodingham	491431	501431	51	24	32	Willerby
511451	521441	85	45	35	Withernwick	501431	511431	21	1	4	Hull (Toll Br.)
East to West						OS map 111/112 continuous					
521441	511441	34	11	24	Long Riston	West to East					
511441	501441	72	26	27	Molescroft	441421	451421	64	6	9	Darrington
501441	491441	33	3	8	North Newbald	451421	461421	117	17	13	Pollington
491441	481441	106	11	9	Everingham	461421	471421	60	7	10	Rawcliffe Br. (via Snaith)
481441	471441	33	12	27	Whitegate Br.	471421	481411	71	14	16	Crowle(via Thorne)
471441	461441	80	27	25	Stillingfleet	481411	481411	37	7	16	Garthorpe 'Loop'
461441	451441	58	19	25	Kirkby Wharf	481411	491411	36	4	10	Scunthorpe
451441	441441	51	8	14	Bramham	491411	491421	59	23	28	West Hatton
						491421	501421	42	16	28	Barton-on-Humber
						501421	511421	44	8	15	Goxhill
						511421	511411	79	41	34	Melton Row

A	B	C	D	E	F
East to West					
511411	501411	50	10	i7	Brigg
501411	501401	54	4	7	Redbourne
501401	491401	47	20	30	Scotten
491401	481401	34	6	15	Wildsworth
481411	471411	25	8	24	Stoupers Gate
471411	461411	60	4	6	Kirk Bramwith
461411	451411	100	8	7	Skellow

West to East					
451411	451401	24	7	23	High Melton
451401	461401	7	0	0	Bessacarr
461401	471401	16	13	16	Finningley
471401	461391	35	6	15	Styrrup
461391	451391	37	3	8	Carr

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West to East					
441381	451381	82	10	11	Thorpe Salvin
451381	461381	24	0	0	Manton
461381	471381	10	2	17	E.Retford
471381	481381	67	6	8	S.Leverton

East to West					
481381	481371	26	14	35	Fledborough
481371	471371	44	15	25	W.Markham
471371	461371	75	9	11	Theresby
461371	451371	59	10	14	Bolsover
451371	441371	31	1	3	Calow

West to East					
441371	441361	47	12	20	Tibshelf
441361	461361	48	2	4	Rainworth
461361	471361	83	3	3	Hockerton
471361	481361	115	5	12	Gomwell

East to West					
481361	471351	85	18	17	Southwell
471351	461351	69	15	18	Oxton
461351	451351	35	5	13	Newstead

OS Sheet 121

West to East					
481391	491381	89	14	14	W.of Harpswell
491391	501391	78	13	14	E.of Normanby
501391	511391	81	35	30	Market Rasen

A	B	C	D	E	F
East to West					
511391	511381	77	8	9	Lissington
511381	501381	97	18	14	Welton
501381	491381	147	105	42	Thorpe-in-the-Fallows
491381	481381	75	19	20	Marton

West to East					
481381	481371	29	14	33	Newton-on-Trent
481371	491371	38	7	15	Doddington
491371	501371	20	0	0	Washingborough (thro' Lincoln)
501371	511371	71	11	13	Patter Lanworth

East to West					
511371	511361	89	21	19	Blankney
511361	501361	27	3	1	Navenby
501361	491361	84	34	29	Carlton-le-Moorland
491361	481361	104	17	14	Collingham

West to East					
481361	481351	22	7	24	Coddington
481351	491351	47	19	29	Stragglethorpe
491351	501351	48	8	14	Brouncewell Grange
501351	511351	101	22	18	Alnwick

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West to East					
441341	451341	44	1	2	Strelley
451341	461341	13	0	0	Carlton (thro' Nottm.)
461341	471341	93	4	4	Bingham
471341	481341	106	20	16	Alverton

East to West					
481341	481331	83	21	20	Plungar
481331	471331	85	47	36	Colston Bassett
471331	461331	80	34	30	Plumtree
461331	451331	54	5	8	Gotham
451331	441331	47	7	13	Castle Donington

West to East					
441331	441321	63	17	21	Worthington
441321	451321	139	20	13	Dishley
451321	461321	56	16	22	Burton-on-the-Wolds
461321	471321	238	78	25	Saxelbye
471321	481321	110	17	13	Melton Mowbray

A	B	C	D	E	F
East to West					
481321	481311	62	30	33	Leesthorpe
481311	471311	150	46	23	Ashby Polville
471311	461311	166	28	14	Wanlip
461311	451311	51	17	25	Copt Oak

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West to East					
491341	501341	130	5	4	Kelby
501341	511341	155	28	15	Scredington
511341	521341	152	22	13	Helpringham

East to West					
521341	521331	95	36	27	Quadring
521331	511331	50	16	22	Little Dowsby
511331	501331	158	64	29	Ingoldsby
501331	491331	159	80	33	Great Ponton

West to East					
491331	491321	78	31	28	Gunby
491321	501321	171	26	13	Creeton
501321	511321	120	25	17	Bourne

East to West					
511321	511311	60	12	17	Barholm
511321	501311	154	22	13	Tolethorpe Hall
501311	491311	154	26	14	Exton

OS Sheet 140

451301	441301	109	26	19	Sutton Cheney
441301	441291	149	43	22	Stretton B'ille
441291	451291	109	31	22	Frolesworth
451291	461291	198	73	27	Shearsby
461291	461281	312	166	35	S.Kilworth
461281	451281	230	113	33	Churchover
451281	441281	130	19	13	Peter Hall
441281	441271	68	23	25	Princethorpe

OS Sheet 141

West to East					
471301	481301	179	109	38	Belton
481301	491301	187	60	24	Morcott
491301	501301	111	25	19	Collyweston Greatwood

A	B	C	D	E	F
East to West					
501301	501291	111	14	11	Southwick
501291	491291	154	40	21	Weldon Lodge
491291	481291	168	14	8	Ashley
481291	471291	307	45	13	Foxton

West to East

471291	471281	247	94	28	Clipstone
471281	481281	283	104	27	Rothwell
481281	491281	105	8	8	Grafton Underwood
491281	501281	78	21	21	Thrapston

East to West

501281	501271	183	58	24	Raunds
501271	491271	83	24	22	Finedon
491271	481271	163	38	4	Hannington
481271	471271	243	33	12	Little Creaton

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441270	451270	109	66	37	N. of Willoughby
451270	451261	60	88	59	Lr.Shuckborough
451261	441261	92	118	56	Southam
441261	431261	129	71	36	Bishops Tichbrook
431261	431251	65	27	29	Combroom
431251	441251	106	73	41	Fenny Compton
441251	451251	127	49	28	Aston-le-Walls
451251	451241	103	27	21	Thenford
451241	441241	100	21	17	Shutford
441241	431241	134	44	25	Upper Brails

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West to East					
461270	471270	138	99	42	Spratton
471270	481270	95	78	45	Sywell
481270	491270	108	48	31	Wellingborough

East to West

491270	491261	66	12	16	Bozeat
491261	481261	51	28	35	Cogenhoe
481261	471261	10	4	29	Upton
471261	461261	55	62	53	Dodford

A B C D E F

West to East

461261	461251	97	93	49	Blakesley
461251	471251	132	137	51	Tiffield
471251	481251	132	94	42	Eakley
481251	491251	38	52	58	Olney

East to West

491251	491241	27	54	67	Milton Keynes
491241	481241	3	5	63	Wolverton
481241	471241	89	47	35	Lillingston Lovell
471241	461241	62	66	52	Whitfield
461241	461231	38	68	64	Cottisford

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West to East

501271	511271	160	86	35	Longa
511271	521271	70	22	24	Brampton
521271	531271	49	22	32	St.Ives

East to West

531271	531261	59	24	29	Eltisley
531261	521261	87	30	26	Eynesbury Hardwicke
521261	511261	112	46	29	Bushmead Cross
511261	501261	104	78	43	Sharnbrook

West to East

501261	501251	50	14	22	Bedford
501251	511251	52	23	31	Willington
511251	521251	42	6	13	Everton
521251	531251	52	5	9	Croydon

East to West

531251	531241	30	9	23	Litlington
531241	521241	62	18	23	Edworth
521241	511241	45	31	41	Ireland
511241	501241	88	13	13	How End

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West to East

431230	441230	87	60	41	Great Tew
441230	451230	70	26	27	Somerton
451230	461230	98	43	30	Fringford

A B C D E F

East to West

461230	461221	53	48	48	Ambrosden
461221	451221	74	12	14	Kirtlington
451221	441221	99	5	5	Glympton Park
441221	431221	150	18	11	Chaldington
431221	431211	61	1	2	Minster Lovell

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West to East

471231	481231	61	50	45	Shingleborough
481231	491231	160	87	47	Little Brickhill

East to West

491231	491221	67	6	8	Ledburn
491221	481221	59	53	47	Whitchurch
481221	471221	42	20	33	Shipton Lee
471221	461221	35	54	61	Blackthorn

West to East

461221	461211	16	16	50	Boarstall
461211	471211	45	25	36	Chearsley
471211	481211	43	33	43	Bishopstone
481211	491211	47	7	13	Buckland Wharf

East to West

491211	491201	72	8	10	Great Missenden
491201	481201	87	29	25	Loosely Row
481201	471201	44	12	21	Tetsworth
471201	461201	67	24	26	Stadhampton

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West to East

501231	511231	50	9	15	Hexton
511231	521231	30	11	27	Hitchin
521231	531231	72	17	19	Rushden

East to West

531231	531221	47	13	22	Watton-at-Stone
531221	521221	39	5	11	Codicote
521221	511221	66	7	10	Luton
511221	501221	14	1	7	Dunstable

The incidence of dieback in each survey section is indicated graphically in Figures 1,2 and 3. Figures 1,2 and 3 have been constructed by amalgamating photocopied panels from the covers of 1:50,000 Ordnance Survey maps and superimposing the 10 km grid over the whole. The figure in a record frame (circle, diamond or square) is the percentage incidence of dieback recorded along a route roughly following the grid line closest to that particular frame.

The general incidence of dieback indicated in Figures 1,2 and 3 is much lower than that given by Cooper and Edwards (1981), Figure 4. This could be partly explained by the observations of Cooper and Edwards being confined to selected areas in the agricultural countryside (see later), and partly by differences in personal judgement of the intensity of symptom expression on trees. The possibility exists, of course, that the incidence and severity of ash dieback was significantly higher in the period prior to 1981, although this is unlikely.

When making an assessment of current dieback in ash trees, it is difficult not to be influenced by the obvious signs of previous long-standing dieback, particularly when a considerable proportion of the crown consists of large, dead, completely-bare branches. It is even more difficult to assess (especially from a moving vehicle) how long the terminal parts of small branches have been dead, and whether or not active dieback is present at that particular time. An individual observer will inevitably make subconscious adjustments and subjective judgements when making rapid assessments of passing trees, but provided these are relatively consistent, it is probably more satisfactory for one observer to carry out a complete survey of this type than to attempt to amalgamate the assessment of two or more observers.

The results given in Table 1 and in Figures 1,2 and 3 confirm that ash dieback is of widespread general incidence over the whole area surveyed, but demonstrate that incidence can vary considerably between closely adjacent areas. The highest incidence of dieback was recorded in Northamptonshire and in adjacent areas of neighbouring counties.

Soon after the start of the survey it became evident from general observations made (and recorded) along the individual transect sections, that ash dieback was most prevalent in areas of countryside outside of towns, villages and other protected residential environments. There appeared to be a strong (but not invariable) positive correlation between incidence and severity of dieback and the intensity of arable farming. In certain regions, notably over large areas of Northamptonshire, and neighbouring parts of Buckinghamshire, Leicestershire and Warwickshire, the incidence of dieback was particularly and consistently high, suggesting that some soil factor or factors might enhance the intensity of dieback. However, even in these areas, a marked reduction in the incidence of dieback was apparent on ash trees in villages and towns as compared with that in the general agricultural countryside.

Figures 1,2 and 3

Graphical representation of the percentage incidence of ash dieback over the whole of the survey area. The figures in the frames give the incidence of dieback along the traverse section closest to the frame concerned.

The general notation of the frames is:-

over 60% dieback

50 - 59% dieback

40-49% dieback

30-39% dieback

20-29% dieback

below 20% dieback

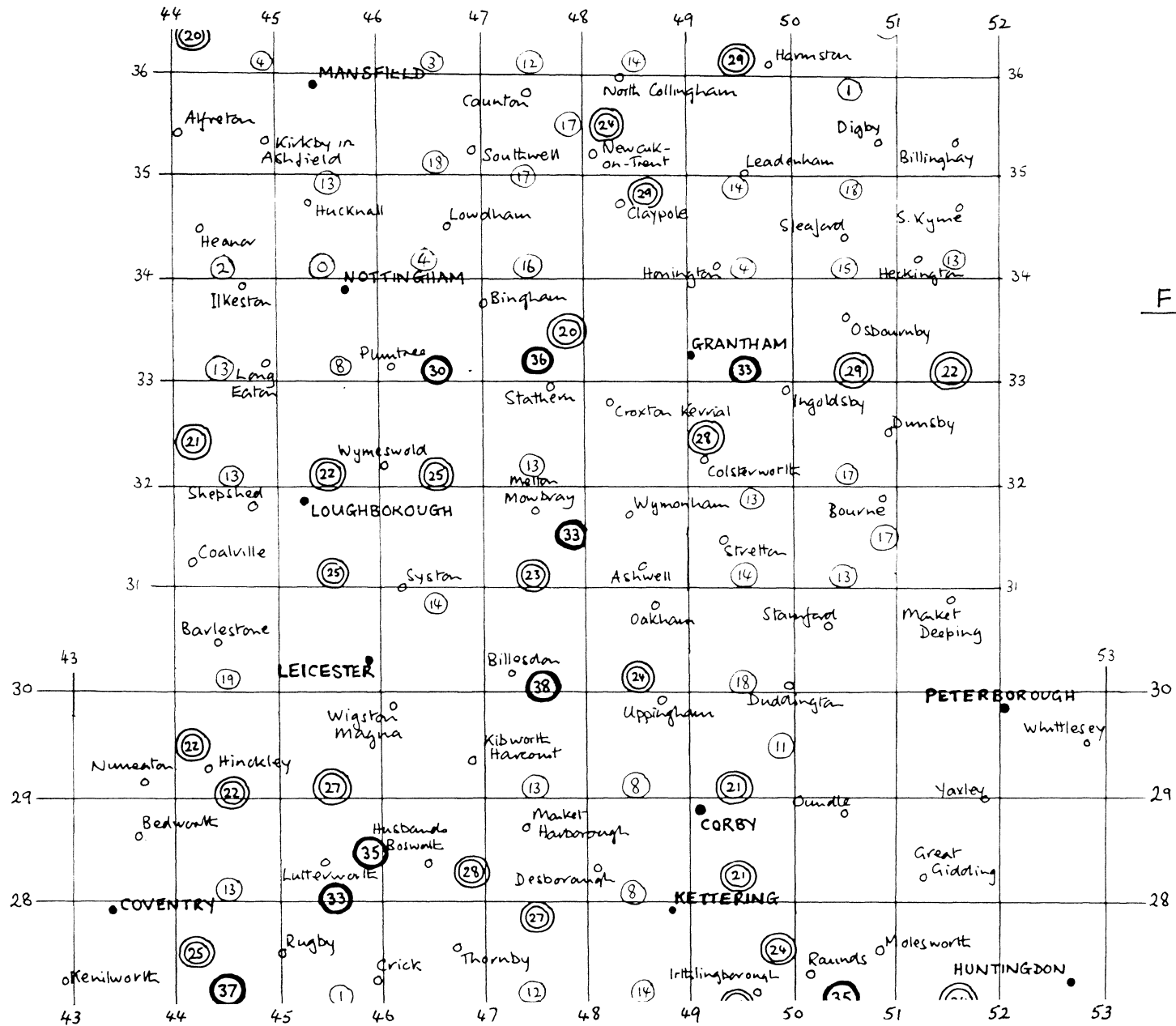


Figure 2.

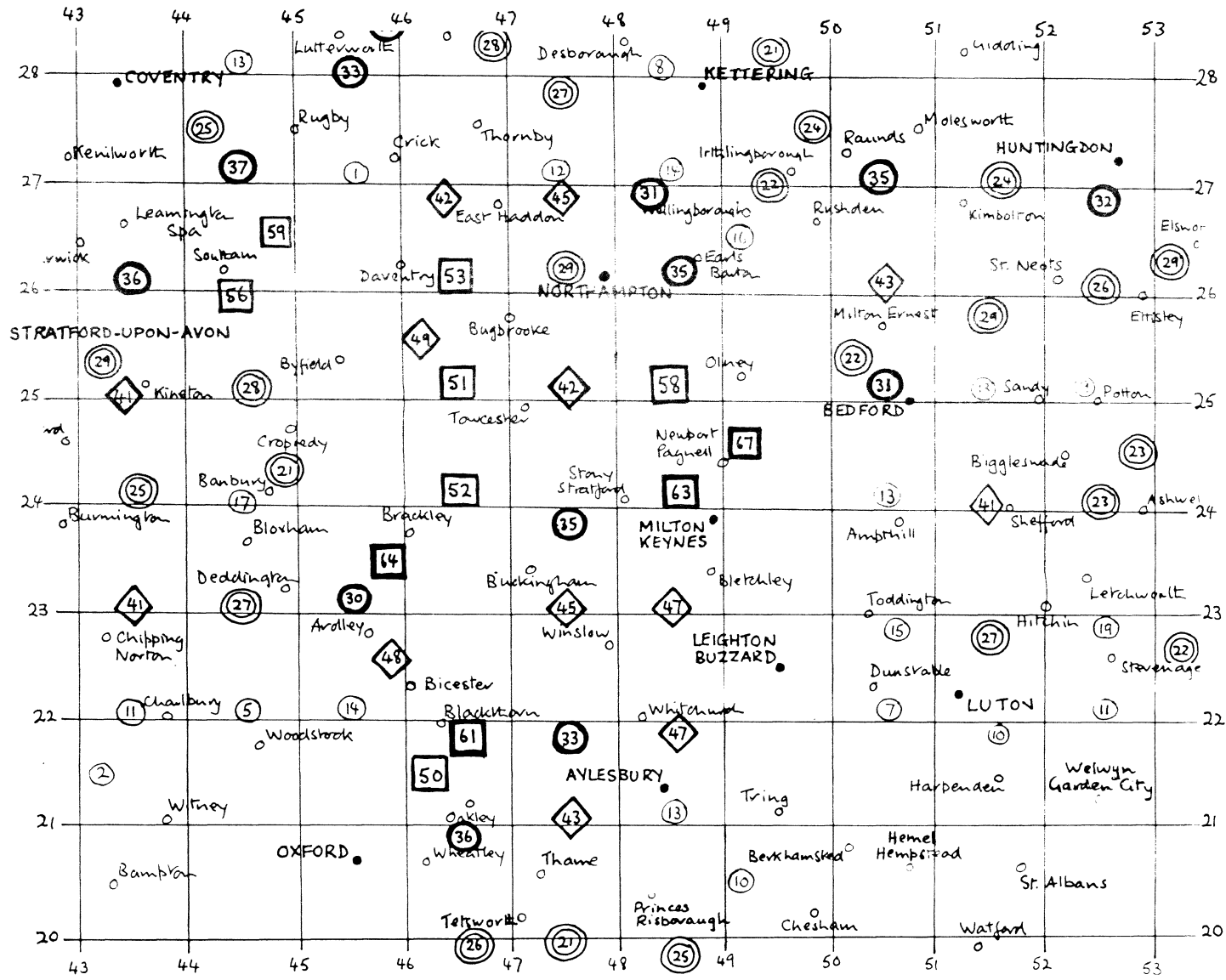
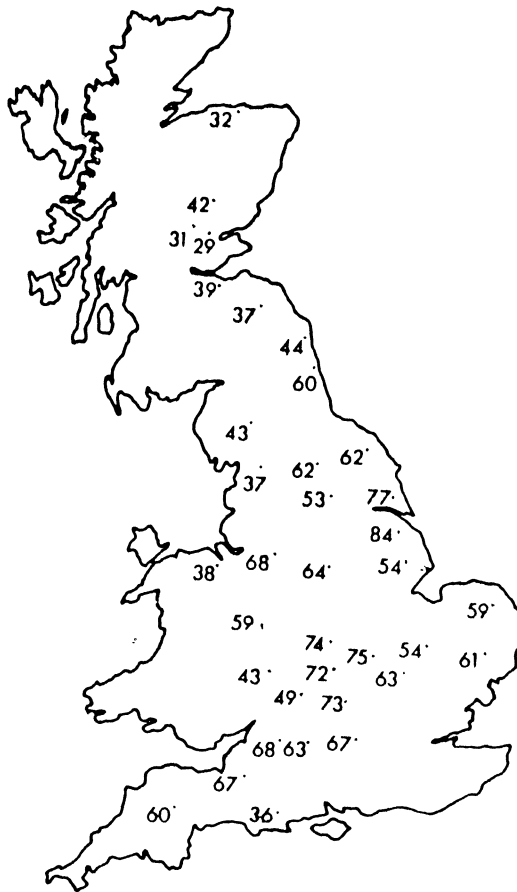


Figure 3.



Frequency of ash dieback (trees with 10% or more branches from which leaves were absent except at the tips) recorded as a percentage of totals examined in each of 36 counties/metropolitan districts.

Figure 4.

From Cooper & Edwards, 1981

To obtain numerical data on the difference in incidence of ash dieback in agricultural countryside as compared with towns, villages etc., surveys were made along two roughly E/W transects, selecting routes passing through a number of villages separated by agricultural countryside. Specific counts were made while passing through each village and through the intervening sections of countryside. No subdivision of the countryside into arable, mixed farming, permanent pasture etc. was attempted.

The two routes were:-

i) Halford, Warwickshire to Newport Pagnell, Buckinghamshire (75 miles), passing through the villages of Idlicote, Whatcote, Oxhill, Middle Tysoe, Shennington, Hanwell, Great Bourton, Cropredy, Williamscot, Upper Wardington, Sulgrave, Helmdon, Wappenden, Abthorpe, Silverstone, Whittlebury, Perry End, Yardley Gobion, Castlethorpe, Haversham and part of Newport Pagnell.

ii) Princethorpe, Warwickshire, to Raunds, Leicestershire (72 miles), passing through the villages of Stretton-Dunsmore, Wolston, Newbold-on-Avon, part of Rugby, Clifton-upon-Dunsmore, Yelvertoft, Arthingworth, Desborough, Rushton, Rothwell, Broughton, Burtin Latimer, Finedon, Irthlingborough and Raunds.

The percentage incidence of ash dieback in villages as compared with agricultural countryside was:- Halford to Newport Pagnell, 6%:46%: Princethorpe to Raunds, 5%:43%.

General observations made during the main survey suggest strongly that the results recorded in the above two special surveys were reasonably representative of the survey area as a whole. It should be pointed out that the populations of ash trees in towns and villages are generally much smaller than those in the agricultural countryside, and it could be argued that severely-affected trees in "urban" environments might be felled more quickly than in field hedgerows etc. Conversely, in the two special surveys (above) some of the trees in villages recorded as "affected" were probably situated on the outskirts of the villages concerned, immediately adjacent to fields.

The results of the survey suggested strongly that modern farming practices are directly associated with the development of ash dieback in hedgerow trees. No serious attempt was made to gain information on which practice or practices might be particularly involved but these could include regular deep cultivation close to hedgerows, drainage operations, spraying with pesticides and herbicides, fertilisation and stubble-burning.

Although no numerical evidence was obtained on the relationship between different types of farming and the incidence of ash dieback, general observations indicated that there was usually a direct positive correlation between the intensity of arable farming and the incidence of dieback. However, when traversing large continuous areas of cereal farming land, noticeable changes occurred in the incidence of dieback, suggesting that agriculture as practised by different farmers or estates could significantly influence the development of dieback. Generally-speaking, where the impression was gained that farmers were concerned with tree conservation, as indicated for example by the preservation of relatively

small trees, or the planting of new trees in hedgerows, the incidence of dieback appeared to be lower than elsewhere.

In areas where permanent, or apparently permanent, pasture predominated, the incidence of ash dieback was usually noticeably less than in arable areas. However, considerable dieback was noted in several predominantly dairy-farming areas, particularly in parts of Leicestershire and Northamptonshire. There are obvious pitfalls in attempting to classify agricultural use of land during a single transit in a vehicle, particularly in relation to the relative incidence of a tree disorder which has probably affected individual trees for several years. Recently-established grass leys can look misleadingly permanent to a passing observer.

From time to time in areas where intense agricultural activity was associated with high general incidence of ash dieback in hedgerow trees, examples were seen of broad country roads or avenues with wide areas of grass on one or both sides of the road. Where ash trees occurred in these broad grassed roadside strips, their generally healthy condition and low incidence of dieback (except in very old specimens) often contrasted markedly with the poor condition of nearby trees in fieldside conditions.

Although numerical observations were confined to ash, there appeared to be a higher incidence of dieback and general debility on other tree species, notably oak and willow, in hedgerows in the agricultural countryside as compared with more urban environments, but this was not as clearly marked as with ash.

5. GENERAL OBSERVATIONS

The results of the survey and what little other information is available, indicate fairly clearly that ash dieback is a chronic disease condition, of fluctuating but generally high incidence, which has developed in hedgerow populations of ash over the last thirty years or so. Although insects, fungi and other pathogens may be associated with the development of dieback on affected trees, there is no evidence that the disease is an infectious condition capable of spreading through the ash population of the country as a whole.

A complex of interacting factors is probably responsible for the initial development of dieback in trees, with other more secondary agencies influencing its further development in individual trees. The survey results give a firm indication of the general implication of agricultural practices in the development of the disease, but it is not relevant here to enter into speculation on the relative importance of individual farming techniques which may be involved, or the degree to which the effect of these factors may be influenced by adverse soil and climatic conditions, or vice versa.

The likelihood of the death of ash resulting directly from a prolonged period of dieback is not known, but the number of dead ash trees (although not specifically recorded) was certainly considerably less than 5% of the trees affected by dieback. A specific count of dead ash trees would not have been feasible during the present survey, partly because of the very

large numbers of dead and dying elms in hedgerows from which dead ash trees would have been difficult to distinguish, quickly and accurately. A considerable proportion (possibly 15-20% in certain areas) of ash trees affected by dieback over a period of years carry long-dead branches on over 30% or more of their crown volume. Bearing this in mind, it seems likely that the proportion of trees which will eventually die as a direct result of the disease, may increase in future, particularly if the influence of factors responsible for disease development continues or becomes more widespread and intensive.

Reference has already been made to the non-specific nature of the symptoms of ash dieback. There seems little doubt that ash trees under sufficient stress, directly or indirectly related to adverse water relationships within the tree, express their condition by a failure to produce foliage and by death of young, and then progressively older, shoots at the periphery of the crown. The dieback symptoms that can be seen on individual trees (in otherwise healthy populations) obviously affected by building operations, road-making or other serious disturbance close to the base of the mainstem, are very similar, if not indistinguishable from the symptoms of dieback seen on hedgerow trees in the agricultural countryside.

Many cases have also been seen of large old ash trees in protected parkland and such-like areas showing crown symptoms of many years standing, very similar to those on much younger trees in field hedgerows. This "stag-headed" condition of very old trees would appear to be the result of stresses imposed on the trees by senescence, as well as by adverse environmental factors. No attempt was made during the present survey to distinguish between "active" dieback and that associated with senescence.

The lack of distinct foliage symptoms regularly associated with the early stages of ash dieback is a great disadvantage when making field assessments on large trees. Cooper (1975) recorded the widespread incidence of distinctive leaf symptoms due to infection by arabis mosaic virus (AMV), but as mentioned earlier, virus infection is not directly associated with the incidence of dieback (Cooper and Edwards, 1981), and in any event the symptoms of virus infection cannot be recognised reliably at a distance. A number of fungi colonise ash leaves still attached to the tree in the period shortly before leaf fall, but there is no evidence of serious leaf infection by fungal pathogens during the course of the growing season which might be significant with respect to the onset of the dieback of shoots.

The general population of Common ash (Fraxinus excelsior L.) in Britain appears to be extremely heterogenous with respect to the size, shape and colour of leaves and leaflets. Leaves may vary between being relatively small with pale green narrow leaflets on some trees, to large, with thick coarse dark green leaflets on others. On several occasions trees of the latter type were seen on which leaflets showed a tendency to become confluent with their immediate neighbours through band-like developments from the main leaf rachis. No attempt was made to assess the occurrence of any variation in susceptibility to dieback between trees exhibiting different foliage characteristics but there were no striking indications that such variation existed.

The assumption is made that the entire population recorded during the survey consisted of Common ash (F. excelsior L.), although an insignificant proportion of the trees seen in towns and villages may have been specimens of Manna ash (F. ornus L.) or, less-likely, Narrow-leaved ash (F. angustifolia Vahl), White ash (F. americana L.) or Red ash (F. pennsylvanica March): see Mitchell, 1974. The number of these exotics would have been very small and in no way would they invalidate the results of the survey.

Only two instances were seen, during the whole survey, of damage to the foliage of ash trees similar to that caused by herbicide sprays, but lack of time prevented examination of the circumstances at the sites concerned. The general absence of this type of symptom suggests that damage to foliage caused by inaccurate application or spray drift of herbicides is unlikely to be a significant direct cause of ash dieback.

Atmospheric pollution has been described by American workers as a significant contributory factor in the development of ash dieback in the northeastern region of the United States. Although it is commonly asserted that atmospheric pollution is an important factor associated with ash dieback in Britain, there was no evidence of this during the present survey. As the survey passed through heavily industrialised areas and close to sites of particular industrial activity, such as steelworks, brickworks, fertiliser plants etc., especial vigilance was maintained for signs of foliage abnormalities and other signs on ash of the toxic effect of atmospheric pollutants, as well as for dieback. No significant difference was observed between the condition of ash in these areas as compared with that of ash in similar countryside well away from general and particular industrial influences.

Particular attention was paid to the possibility of pollution damage around large brickworks in south Bedfordshire, and the route of the survey was modified to some extent to accommodate this. Although there was considerable evidence of discolouration of foliage of some other hardwood tree species, notably lime and poplar, this was not apparent on ash. There was no evidence from more intensive numerical surveying in areas close to individual brickworks of any significant relationship between the incidence of ash dieback and distance (or direction) from brickwork sites.

The impression was gained at various times during the survey that the incidence of ash dieback might be directly related to the degree of exposure. Overall, however, this relationship was not consistent, particularly in areas of higher broken countryside where contrasting conditions of exposure occurred in regions of varied land use. Many areas of intense arable farming (with high incidence of ash dieback) coincide with a flat terrain, with little shelter provided by variation in land-form or woody vegetation. Although the degree of exposure of trees (and related high transpirational losses) in such conditions might be relevant to the intensity of dieback development, it seems likely that this is a factor compounding the effect of agricultural practice rather than vice versa. The same situation probably exists with regard to increased moisture stress in trees growing in deep heavy clay soils, as occurs over much of Northamptonshire, where the severity of dieback has apparently increased so markedly in recent years.

Over much of the survey area, ash was commonly observed growing in hedgerows in close juxtaposition to elms either killed or seriously infected by Dutch elm disease. The form of ash trees exposed by the death of neighbouring elms was often extremely poor and irregular. It was difficult to judge whether apparent dieback was in fact death of shoots caused by the previously intense crown competition with healthy elms, or whether the drastic, relatively sudden increase in exposure caused by the death of the elms had been a significant influence in causing dieback of ash shoots.

It is well-known that the Common ash varies enormously in the proportion of flowers of different sex produced on individual trees. Trees may be predominantly male or female, with others between these two extremes apparently exhibiting a complete range in the proportions of male and female flowers produced. This is reflected in the very heavy fruit production which occurs on a small proportion of ash trees, whilst a larger proportion appear to bear no, or very few, fruits.

Examination of many trees, both young and old, during the survey suggested that the flowering behaviour of older trees might exert a considerable influence on the form of development of vegetative shoots, and might be indirectly significant in relation to dieback. Most ash trees are probably between twenty and thirty years old before regular annual production of flowers occurs. Recent observations suggest that on older trees, a high proportion of lateral buds produced on shoots in the previous year develop only to form inflorescences, with vegetative extension in the following year originating predominantly from apical buds. Factors which lead to the death of buds, particularly apical buds, could have a profound effect on the extent of vegetative growth and foliage production during the following season, and on overall shoot development and crown form.

The possible adverse effects of agricultural practices in relation to the development of dieback might be linked directly or indirectly with their influence on bud survival.

The small extent to which ash had been studied with respect to the effect of environmental influences on vegetative development and sexual reproduction (Wardle, 1961) was a surprising feature of the broad, but not exhaustive, literature review carried out in conjunction with the survey.

In recent years, Forestry Commission pathologists have recorded considerable damage to, and death of, buds on older ash trees caused by Ash bud moth, Prays curtisellus Dup. (R.G.Strouts and S.Gregory, personal communications, 1983). The incidence of activity of Ash bud moth and other insects associated with the dieback of shoots removed from large trees with a long-arm pruner, was confirmed during the present survey. In Britain, damage by P.curtisellus has long been regarded as being significant only on young ash, destroying terminal buds and causing repeated forking (Chrystal, 1937; Gent, 1955). However, more recent continental accounts (Novak, 1976; Anon, 1983) indicate that in Europe, P.curtisellus commonly attacks old ash trees, both in woodlands and those growing along roadsides. It seems very likely that older British accounts have presented a misleading picture of the occurrence and importance of Ash bud moth in this country, and that killing of buds and terminal parts of shoots on older ash trees in this country is extremely common.

R.G. Strouts and D. Rose (personal communication, 1983) have also observed that bud and shoot damage by Ash bud moth is commonly followed by infection of shoots by the fungus Nectria galligena f. sp. fraxini (Flack and Swinburne, 1977). N. galligena Bres. has long been known as a cause of canker formation on ash and a wide range of other trees, notably apple and pear (Phillips and Burdekin, 1982; Peace, 1962), but there has been some uncertainty about the incidence and importance of infection by this fungus because of the similarity of Nectria cankers with those of the more prevalent canker-forming bacterium, Pseudomonas savastanoi (Smith) Stevens f. sp. Fraxini Dowson. Boa (1981) has recently described differences in the two types of canker on ash, but there is at present very little information on the ability of N. galligena to cause progressive infection of ash shoots, not associated with canker production.

6. FUTURE DEVELOPMENTS

The implications of the present survey have led the Department of Forestry, Oxford University to apply to the Agricultural Research Council for the award of a grant to fund a three year research programme on ash dieback.

The core of the proposed research programme will be an examination of the importance of agricultural practices and associated soil, climatic and pathological factors associated with ash dieback development. This will involve detailed analysis, in selected areas, of the history of agricultural treatment in relation to dieback development, against a background of study of other environmental factors over a past period of several years. The co-operation of farmers and farm managers, and of agricultural colleges and research institutes will be very important to this work. Comparison will be made of different agricultural regimes, such as regular production of cereals and other arable crops, zero-tillage, mixed grassland/arable farming and permanent pasture, in an effort to eliminate or confirm specific practices as factors causing ash dieback.

The general growth and condition of healthy and dieback-affected ash will be assessed and compared by morphological studies, by growth-ring analysis and by nutrient analysis of shoots and foliage. Similar studies will be directed towards roots of trees growing in different circumstances. The role of insects, fungi and other pathogens in relation to ash dieback will be critically examined.

In anticipation of the granting of government funds early in 1984 for the research programme outlined above, the Forestry Department at Oxford, wishing to maintain the impetus created by the survey, has launched an appeal to fund an interim programme of research on ash dieback. As in the survey, the research fund will be administered by the Forestry Department Administrator through the University finance office. Donations to the fund should be sent to the Administrator, Commonwealth Forestry Institute, South Parks Road, Oxford, and cheques should be made payable to the Oxford University Ash Dieback Research Fund.

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