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O.F.I. OCCASIONAL PAPERS

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No 48

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of *Pinus patula* and *Cupressus lusitanica*

E R Palmer, R A Plumptre,

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OXFORD FORESTRY INSTITUTE
Department of Plant Sciences
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**EFFECT OF SPACING ON WOOD DENSITY OF *CUPRESSUS*
LUSITANICA AND *PINUS PATULA* GROWN AT RONGAI,
NORTHERN TANZANIA**

by

E R Palmer, R A Plumptre, R E Malimbwi, I D Gourlay, T K Quilter and J Slater

**Oxford Forestry Institute
1995**

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SUMMARY

Samples of *Pinus patula* and *Cupressus lusitanica* grown with three different spacings at Rongai in Northern Tanzania were examined to determine their wood density. Spacing effected the height and diameter of *P. patula*, but only the diameter of *C. lusitanica*. Both species yielded wood with a density around 400 kg m⁻³ (oven dry weight/green volume) and spacing had no appreciable influence. The wood of *P. patula* included a much wider range of density than that of *C. lusitanica*.

The original project document laid down five objectives of which the first dealt with wood density and its variations between and within the two species studied and the other four dealt with the pulping and paper making properties of the species. The X-ray densitometry carried out by OFI has dealt only with objective 1, whereas the pulping work is being done at the University of North Wales, Bangor.

Objective 1 has been achieved in that the variation of wood density has been studied in detail and the results analysed to give the conclusions on page 4 of this report. These findings will be very useful in comparing density with pulping properties, particularly pulp strengths, when the work at Bangor has been completed.

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Introduction

Experiments to determine the effect of spacing on wood properties of *Cupressus lusitanica* and *Pinus patula* were started in 1969. The results of survival, branch diameter, breast height diameter, height, basal area, volume, basic density, heartwood content and some strength properties of *Cupressus lusitanica* have been published (Malimbwi *et al.*, 1992) and similar data for *Pinus patula* will be published.

The primary purpose of the present work was to determine the effect of spacing on pulp properties. The basic density and the distribution of density at breast height were measured to determine the relationship between wood density and pulp properties. The data on density is presented here, the data on pulping properties are still being determined and will be published later.

Materials and Methods

Site and Experimental Design

The site was at the Rongai Forest Project, Northern Tanzania (4°S, 37°31'E, 2000 m above sea level). The slope is about 6 per cent and the soil is of volcanic origin and generally very fertile. The original vegetation was montane rain forest dominated by *Juniperus procera*. The mean annual rainfall is about 900 mm distributed as short rains from October to December and long rains from March to May. Temperatures are fairly cool, the mean annual being temperature 17°C.

The trees were planted in five spacings in a randomized block design and replicated three times. The spacings were as follows and the plots remained unthinned:

A	1.13 x 1.13 m	(7830 stems/ha)
B	1.46 x 1.46 m	(4690 stems/ha)
C	1.88 x 1.88 m	(2830 stems/ha)
D	2.43 x 2.43 m	(1690 stems/ha)
E	3.14 x 3.14 m	(1010 stems/ha)

Each plot measured 0.1 ha, the area of the experiment being 1.5 ha and 1.7 ha without and with surroundings respectively (Malimbwi *et al.*, 1992).

The age of the trees examined in these trials was 23 years.

Material for Pulping Trials

For pulping trials samples were collected for the three wider spacings only (1.88 x 1.88 m, 2.43 x 2.43 m and 3.14 x 3.14 m). The two closest spacings had resulted on so many deaths and such small trees that they were considered non viable without thinning. Each sample consisted of nine trees, three trees randomly selected using a table of random numbers from all live trees within each of the three replicates. From each tree a number of discs each 18 mm thick were cut at 10%, 30%, 50% 70% and 90% of the usable bole (defined as base to 25 cm girth over bark), and one disc about 5 cm thick cut at breast height.

Methodology

For determination of wood density one disc from every sampling point (except breast height) was used. The discs were soaked to simulate green condition and their volume determined by water displacement. The discs were then oven dried (at 105±3°C) and the density as oven-dried weight/green (soaked) volume calculated (the TAPPI method).

The density of the breast height disc was determined by X-ray densitometry using one radius of the disc. Strips 1 cm wide were machined to 5 mm depth, resin extracted in a Soxhlet reflux condenser using a 2:1 benzene:ethanol mixture for 24 hours. The samples were dried in a vacuum oven, conditioned to 12% moisture content and X-rayed. Densitometry was carried out with Joyce-Loebl microdensitometer using a 10X objective, a 200 μm step distance and a single scan per strip (Hughes and Sandinha, 1975).

The proportion of bark was determined by measuring over and underbark girth and calculating the bark by volume. ($go^2 - gu^2/go^2$ where go = girth overbark and gu = girth underbark). This is equivalent to calculating bark proportion using cross sectional areas using the better known formula $\pi^2o - \pi^2u/\pi^2o$.

The actual spacing between trees at the time of harvesting was estimated by measuring the distance from the sample tree to four neighbours and averaging these measurements.

The total volume of the trees was estimated using the formula.

$$\text{Volume} = \pi (\text{Breast height radius})^2 \times \text{total height}/3$$

This assumes a conical shaped tree in the absence of a form factor for these trees.

Results and Discussion

Tables 1 - 3 show differences between species and spacing and Tables 4 - 21 record detailed data for individual trees and within tree samples.

Table 1 summarises the information obtained on the dimensions of trees and wood density. There was a trend for height and diameter of the trees of *P. patula* to increase with increased spacing, but for *C. lusitanica* there was no meaningful difference in height but there was a trend for the diameter to increase. This finding was in agreement with the findings of Malimbwi (1992). The bark content of *P. patula* decreased a little with increasing spacing, but there was no meaningful difference for *C. lusitanica*. Taking into account the different number of trees at the various spacings, *P. patula* would yield a smaller volume of wood at 3.14 m spacing than at 1.88 m or 2.43 m; there is little difference between 1.88 m and 2.43 m. The volume of wood produced by *C. lusitanica* decreased with increasing spacing. *P. patula* in all spacings yielded a higher volume of wood than *C. lusitanica*.

Both species produced wood with a mean density around 400 kg m^{-3} ; there was no meaningful difference due to spacing.

Table 1 includes an estimate of the actual spacing between trees at the time of harvesting. This was obtained by measuring the distance from the sample tree to its four neighbours and averaging these measurements.

Tables 4 - 9 give data on the dimensions of individual trees; Tables 10 - 15 give details of wood density at 10%, 30%, 50%, 70% and 90% of the bole of each tree. Previous experience examining *P. patula* from Kenya (Palmer *et al.*, 1982), Tanzania (Palmer *et al.*, 1984) and Zimbabwe (Palmer and Ganguli, 1988) found that the density of the upper part of trees was significantly lower than in the lower part. These trees of *P. patula* from Tanzania show no consistent pattern, 10 of the 27 trees being of higher density at the top of the tree.

There was little difference in density within any one tree of *Cupressus lusitanica*; this was similar to the finding for samples from the Sudan (Palmer *et al.*, 1986).

Breast height X-ray measurements were made to evaluate the detailed variation of density and the quantity of wood in different classes (see Tables 1 - 3 and 16 - 21) and the average within ring density variation at breast height.

The apparent density figures measured by using techniques normally used in pulp labs were taken from discs at five heights in the trees and give average densities of wood at these heights. They were used to show variation of density with height and to give a weighted overall tree density. Both types of density figures can be correlated with pulp properties when these are determined.

Figure 1 shows the relationship between density measured by x-ray densitometry on breast height cores and dried density (basic density), measured at 10% height .

The best fit regression as tested on the regression package "Nonlin" was very slightly curvilinear but not appreciably different from the straight line regression which was:

$$10\% A = 93.68 + 0.6579 \text{ BHB}$$

where:

10% A = Basic density measured by the TAPPI standard at 10% tree height and BHB = x-ray density of one radius at breast height.

The r^2 for the regression is 70.9%. On the figure the 95% confidence limits of the line are plotted as dotted lines. This shows an interestingly close correlation between the breast height and whole tree densities measured in different ways but it would be dangerous to use the formula for prediction of one density from the other.

Density and the distribution of density within a breast height disc determined by x-ray densitometry are recorded in Table 2. The mean value for density was higher than that recorded in Table 1 because the x-ray technique determines the density at a moisture content of 12%. The results confirm that there was no meaningful difference in density due to spacing and that both species have a similar density. Within each species there was no meaningful difference in density distribution which could be attributed to the effect of spacing, but between species there was a marked difference (see Figures 2-5). Other studies of density in *Pinus patula* (Plumptre, 1976 & 1978) indicate that wood density appears not be closely related to tree spacing but that large individual trees tend to have lower density than average although the correlation between tree size and density is not very good overall. This study also suggests that there is little relationship between tree size and wood density. *P. patula* had the highest proportion in low classes, 35 to 40% in less than 350 kg m⁻³ and 25 to 32% in 350 to 500 kg m⁻³ with around 10% in each of the next three classes (500 to 650, 650 to 800 and 800 to 950). Although the average density for *C. lusitanica* was about the same, the distribution had a sharp peak (about 60%) in class 350 to 500 and about 30% in class 500 to 650 (see Figures 6-8). This difference is likely to cause a difference in the quality of pulp obtained from each species.

Figures 2 and 3 are plots for the two species of tree volume against tree basic density.

Density is the 10% height basic density for the same trees taken from Tables 10 - 15. Individual points on the graphs are labelled P or C for the species and C, D or E for the spacings (see page 1).

The figures show that there is little if any detectable relationship between tree size and wood density for either species. This bears out conclusions from other studies that although there is normally wide between tree variation in density it is not often possible to relate this to differences in rates of growth.

It is clear, however, that the wider spacings tended to produce larger trees.

Similar plots of tree density against tree dry matter (obtained by multiplying tree volume by density) in Figures 4 & 5 show the same trends. The differences in dry matter content between the largest and smallest trees is greater for *P. patula* than for *C. lusitanica* as would be expected for a more light demanding species.

Figures 6-8 illustrate clearly different patterns of density spread between the two species. Spacing appears to have little effect on these patterns.

Details of density distributions for individual trees are found in Tables 16 to 21.

Conclusions

1. There was a trend for the height, diameter and wood volume of the *P. patula* trees to increase with initial spacing.
2. Spacing had no effect on the height of *C. lusitanica* but the trees with the highest diameter and wood volume were those grown at the widest spacing.
3. All spacings of *P. patula* produced a greater volume of wood than *C. lusitanica*.
4. In clear felling *P. patula* is likely to yield most wood from plantations with 1.88 m and 2.43 m spacing; *C. lusitanica* from 1.88 m spacing.
5. Both species yielded wood with a density around 400 kg m⁻³ (oven dry weight/green volume). Density does not appear to be influenced by spacing. Neither tree volume nor tree dry matter showed any detectable relationship with basic density at 10% height.
6. The relationship between x-ray density at breast height and 10% height basic density was moderately good (r^2 70.9%).
7. In the single radius of a breast height core, a significant proportion of the wood of *P. patula* was found in all density classes from under 350 kg m⁻³ to 800 to 950 kg m⁻³; 90% of the wood of *C. lusitanica* was in density classes 350 to 500 kg m⁻³ and 500 to 650 kg m⁻³. The wood of this species is, therefore, more uniform within growth rings than *P. patula*. This fact is likely to be of considerable importance in determining the paper making properties of the two species.

Note:

These conclusions are preliminary ones relating to wood density and rate of growth alone. When information becomes available on completion of the second part of the project at Bangor a comparison of rate of growth, density and pulp properties will be possible.

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Table 1

Dimensions of Tree and Wood Density

Species	Initial spacing m	Average Spacing at Harvesting m	Height		Length of Bole		Diameter, breast height		Bark		Wood Density	
			Average m	Range m	Average m	Range m	Average cm	Range cm	Average %	Range %	Average kg m ⁻³	Range kgm ⁻³
<i>Pinus patula</i>	1.88	2.6	24.4 (0.66)	21.4-26.6	20.9 (0.69)	17.5-23.8	20.3 (1.25)	15.5-26.5	8.3 (0.33)	6.6-10.0	394 (11.7)	345-457
	2.43	2.9	26.1 (0.44)	24.2-28.9	23.1 (0.44)	21.3-25.5	24.7 (1.54)	17.1-32.4	7.2 (0.19)	6.3-8.0	402 (15.6)	343-480
	3.14	3.6	26.7 (0.50)	24.0-28.2	23.9 (0.51)	21.2-25.2	28.6 (1.62)	23.2-37.4	7.1 (0.20)	6.1-8.0	402 (3.7)	379-423
<i>Cupressus lusitanica</i>	1.88	2.4	22.4 (0.70)	18.2-24.7	18.2 (0.61)	15.2-20.5	20.7 (1.03)	16.0-26.1	10.8 (0.48)	8.8-13.9	4.06 (5.4)	385-430
	2.43	2.8	22.6 (0.70)	18.7-24.9	18.2 (0.70)	14.3-20.2	22.7 (1.31)	16.5-26.6	9.8 (0.33)	8.2-11.1	397 (7.8)	375-456
	3.14	3.7	22.0 (0.62)	20.0-25.2	17.9 (0.54)	15.9-20.8	24.4 (1.70)	18.8-32.4	10.5 (0.50)	7.7-12.7	424 (11.4)	385-498

Figures in brackets are the standard error of the mean.

Table 2

Density determined by x-ray Densitometry Distribution within Tree

		Density		Percentage within density class											
				< 350		350-500		500-650		650-800		800-950		> 950	
Species	Initial spacing m	Average kg m ⁻³	Range kg m ⁻³	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
<i>Pinus patula</i>	1.88	480 (19.3)	404-560	37.6 (3.60)	23.9-48.2	24.6 (2.34)	17.6-34.0	14.4 (1.45)	9.2-21.1	12.9 (2.03)	5.8-25.3	9.7 (1.87)	2.3-18.7	0.7 (0.37)	0-2.9
	2.43	470 (17.4)	418-563	34.4 (3.32)	18.5-48.3	31.6 (1.88)	24.4-41.4	14.7 (1.03)	8.6-17.6	11.2 (1.16)	6.8-18.4	7.7 (2.37)	1.7-22.6	0.3 (0.23)	0-1.9
	3.14	460 (4.4)	416-473	39.4 (2.46)	29.2-48.0	28.8 (1.95)	22.2-37.7	12.7 (1.48)	6.2-17.1	10.0 (0.74)	7.3-13.1	8.8 (0.99)	1.6-13.3	0.3 (0.22)	0-1.8
<i>Cupressus lusitanica</i>	1.88	496 (7.3)	473-529	0.7 (0.24)	0-2.2	58.8 (3.57)	45.6-70.7	32.2 (2.42)	21.6-46.0	7.5 (1.27)	3.5-14.7	0.8 (0.25)	0-1.9	0	
	2.43	485 (8.1)	452-531	2.7 (0.76)	0-6.2	62.3 (3.52)	55.0-75.0	26.8 (2.82)	15.8-40.4	7.0 (1.00)	2.9-10.2	1.2 (0.35)	0-3.1	0	
	3.14	466 (36.8)	454-573	0.8 (0.38)	0-2.7	56.9 (5.60)	29.9-76.4	33.5 (4.10)	15.9-55.1	7.9 (2.21)	3.0-24.0	0.9 (0.27)	0-2.2	0	

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Figures in brackets are the standard error of the mean.

Table 3

Tree Spacings and Volumes

Species	Average spacing m	Number of trees per ha	Volume of average tree m ³	Volume of wood per ha ob m ³	Volume of wood per ha ub m ³
<i>P. patula</i>	2.6	1479	0.338	499.5	458.1
	2.9	1189	0.417	495.4	459.7
	3.6	772	0.571	441.2	405.4
<i>C. lusitanica</i>	2.4	1736	0.251	436.0	388.9
	2.8	1276	0.305	388.8	350.7
	3.7	730	0.343	250.2	223.9

Table 4

Pinus patula. Size of Trees. Planting Spacing 1.88 m

Tree No	Height m	Length of Bole m	DBH ob cm	Bark %	Ave distance to nearest 4/5 trees m
PCI 34	21.8	21.2	17.7	8.1	2.6
PCI 120	25.3	21.4	21.1	7.0	3.4
PCI 125	26.6	23.2	26.5	7.8	2.4
PCII 70	25.5	22.0	24.4	8.8	-
PCII 170	26.5	23.8	21.2	8.1	2.8
PCII 200	21.4	17.5	15.5	8.3	2.2
PCIII 66	26.2	20.9	22.0	10.0	2.1
PCIII 116	23.5	19.0	16.1	8.7	2.8
PCIII 246	23.5	18.9	18.0	6.6	2.1
Means					
PCI	24.6	21.9	21.8	7.6	2.8
PCII	24.1	21.1	20.4	8.4	2.5
PCIII	24.4	19.6	18.7	8.4	2.3
Sample	24.4	20.9	20.3	8.2	2.6
SD	1.99	2.07	3.75	1.00	0.45
SE	0.66	0.69	1.25	0.33	0.16

Table 5

Pinus patula. Size of Trees. Planting spacing 2.43 m.

Tree No	Height m	Length of Bole m	DBH ob cm	Bark %	Ave distance to nearest 4/5 trees m
PDI 59	27.5	24.2	28.2	6.6	3.1
PDI 109	24.2	21.8	23.4	6.8	2.7
PDI 115	27.0	23.8	28.1	7.0	2.6
PDII 18	25.6	22.7	23.0	7.6	3.2
PDII 58	24.9	22.0	17.1	7.7	2.6
PDII 138	28.2	25.5	32.4	6.3	2.9
PDIII 60	25.9	22.9	26.5	7.5	2.8
PDIII 70	26.7	23.5	24.0	7.4	2.8
PDIII 116	25.1	21.3	20.1	8.0	3.1
Means					
PDI	26.2	23.3	26.6	6.8	2.8
PDII	26.2	23.4	24.2	7.2	2.9
PDIII	25.9	22.6	23.5	7.6	2.9
Sample	26.1	23.1	24.8	7.2	2.9
SD	1.32	1.32	4.61	0.56	0.22
SE	0.44	0.44	1.54	0.19	0.07

Table 6

Pinus patula. Size of Trees. Planting Spacing 3.14 m.

Tree No	Height m	Length of Bole m	DBH ob cm	Bark %	Ave distance to nearest 4/5 trees m
PEI 6	26.8	24.7	23.2	7.2	3.3
PEI 16	28.2	24.5	29.0	6.1	3.5
PEI 53	27.6	25.2	34.5	6.8	4.2
PEII 60	26.3	23.1	24.7	7.4	3.5
PEII 75	24.6	21.7	30.0	6.8	3.6
PEII 92	27.5	24.8	29.1	7.1	3.4
PEIII 29	24.0	21.2	24.0	7.9	3.3
PEIII 76	27.7	24.7	25.5	8.0	3.7
PEIII 92	27.8	25.3	37.4	6.7	3.9
Means					
PEI	27.5	24.8	28.9	6.7	3.7
PEII	26.1	23.2	27.9	7.1	3.5
PEIII	26.5	23.7	29.0	7.5	3.6
Sample	26.7	23.9	28.6	7.1	3.6
SD	1.49	1.54	4.87	0.60	0.30
SE	0.50	0.51	1.62	0.20	0.10

Table 7

Cupressus lusitanica. Size of Trees. Planting spacing 1.88 m.

Tree No	Height m	Length of Bole m	DBH ob cm	Bark %	Ave distance to nearest 4/5 trees m
CCI 67	24.7	20.2	22.3	8.8	2.1
CCI 182	23.5	18.6	20.9	10.9	2.2
CCI 189	24.2	19.9	21.6	10.1	2.2
CCII 114	20.8	16.1	16.0	11.8	2.7
CCII 166	21.3	17.1	19.0	9.8	2.1
CCII 202	22.0	18.4	21.0	10.1	2.3
CCIII 20	24.4	20.5	26.1	10.6	2.6
CCIII 71	22.3	18.2	22.4	13.9	2.9
CCIII 167	18.2	15.2	16.7	10.7	2.3
Means					
CCI	24.1	19.6	21.6	9.2	2.2
CCII	21.4	17.2	18.7	10.6	2.4
CCIII	21.6	18.0	21.7	11.7	2.6
Sample	22.4	18.2	20.7	10.8	2.4
SD	2.10	1.84	3.09	1.44	0.28
SE	0.70	0.61	1.03	0.48	0.09

Table 8

Cupressus lusitanica. Size of Trees. Planting spacing 2.43 m.

Tree No	Height m	Length of Bole m	DBH ob cm	Bark %	Ave distance to nearest 4/5 trees m
CDI 29	23.9	19.0	19.9	10.2	2.6
CDI 65	21.7	18.2	26.4	11.0	2.9
CD I 139	18.7	14.3	16.5	11.1	2.7
CDII 87	23.9	20.2	25.1	8.2	3.0
CDII 121	21.8	17.1	18.2	9.5	2.8
CDII 153	24.9	19.7	26.6	8.6	2.8
CDIII 24	23.9	19.7	26.0	10.2	2.9
CDIII 60	24.6	19.9	25.0	10.0	2.9
CDIII 150	20.5	15.6	20.3	9.1	3.0
Means					
CDI	21.4	17.2	20.9	10.8	2.7
CDII	23.5	19.0	23.3	8.8	2.9
CDIII	23.0	18.4	23.8	9.8	2.9
Sample	22.6	18.2	22.7	9.8	2.8
SD	2.10	2.10	3.92	1.00	0.13
SE	0.70	0.70	1.31	0.33	0.04

Table 9

Cupressus lusitanica. Size of Trees. Planting spacing 3.14 m.

Tree No	Height m	Length of Bole m	DBH ob cm	Bark %	Ave distance to nearest 4/5 trees m
CEI 24	22.4	18.8	27.5	11.3	3.5
CEI 49	20.0	15.9	21.3	12.7	3.8
CEI 61	21.2	16.6	18.8	8.6	3.7
CEII 10	24.3	19.1	20.6	10.4	3.8
CEII 16	23.1	19.0	32.4	10.3	3.6
CEII 65	25.2	20.8	24.7	7.7	3.6
CEIII 44	20.7	17.6	21.0	11.0	3.5
CEIII 48	20.1	17.2	32.1	10.8	3.4
CEIII 65	21.2	16.3	21.4	11.4	4.0
Means					
CEI	21.2	17.1	22.5	10.9	3.7
CEII	24.2	19.6	25.9	9.5	3.7
CEIII	20.7	17.0	24.8	11.1	3.6
Sample	22.0	17.9	24.4	10.5	3.7
SD	1.85	1.61	5.11	1.50	0.19
SE	0.62	0.54	1.70	0.50	0.06

Table 10

Pinus patula. Wood Density. Planting Spacing 1.88 m. Apparent Wood Density kg m⁻³.

Tree Number	Position from base of bole					Tree
	10%	30%	50%	70%	90%	
PCI 34	369	349	332	317	316	345
PCI 120	418	419	418	431	393	418
PCI 125	409	397	403	388	453	405
PCII 70	461	463	451	471	415	457
PCII 170	432	413	395	376	360	405
PCII 200	349	349	356	353	369	352
PCIII 66	362	356	382	401	424	374
PCIII 116	445	430	381	390	371	411
PCIII 246	397	387	376	346	370	380
Means						
PCI	399	388	384	379	387	389
PCII	413	406	400	400	381	404
PCIII	401	391	380	379	388	388
Sample	405	396	388	386	386	394
SD	38.7	39.6	34.5	46.2	40.6	35.1
SE	12.9	13.2	11.5	15.4	13.5	11.7

Table 11

Pinus patula. Wood Density. Planting Spacing 2.43 m. Apparent Wood Density kg/m³.

Tree Number	Position from base of bole					Tree
	10%	30%	50%	70%	90%	
PDI 59	403	395	378	364	376	386
PDI 109	375	376	374	353	385	372
PDI 115	387	395	388	379	358	386
PDII 18	465	502	487	475	466	480
PDII 58	373	383	388	374	358	378
PDII 138	339	338	336	382	335	343
PDIII 60	397	388	390	404	489	400
PDIII 70	382	390	379	482	372	392
PDIII 116	453	471	448	553	477	478
Means						
PDI	388	389	380	365	373	381
PDII	392	408	404	410	386	400
PDIII	411	416	406	480	446	423
Sample	397	404	396	418	402	402
SD	39.6	50.4	44.5	68.6	58.6	46.7
SE	13.2	16.8	14.8	22.9	19.5	15.6

Table 12

Pinus patula. Wood Density. Planting Spacing 3.14 m. Apparent Density of Wood kg/m³.

Tree Number	Position from base of bole					Tree
	10%	30%	50%	70%	90%	
PEI 6	414	406	401	431	356	407
PEI 16	397	405	402	429	391	405
PEI 53	434	465	394	399	390	423
PEII 60	389	407	393	415	371	397
PEII 75	413	391	401	375	519	404
PEII 92	380	400	391	382	391	388
PEIII 29	371	373	368	422	397	379
PEIII 76	397	395	403	388	408	397
PEIII 92	458	394	404	430	400	421
Means						
PEI	415	425	399	420	379	412
PEII	394	399	395	391	427	396
PEIII	409	387	392	413	402	399
Sample	406	404	395	408	403	402
SD	27.3	25.2	11.3	22.2	46.4	14.2
SE	9.1	8.4	3.8	7.4	15.5	3.7

Table 13

Cupressus lusitanica. Wood Density. Planting Spacing 1.88 m. Apparent Wood Density kg/m³.

Tree Number	Position from base of bole					Tree
	10%	30%	50%	70%	90%	
CCI 67	443	413	418	450	422	430
CCI 182	381	375	390	400	448	385
CCI 189	403	408	398	393	394	400
CCII 114	433	433	421	412	401	425
CCII 166	396	404	395	381	374	395
CCII 202	435	420	425	431	429	425
CCIII 20	406	385	393	387	415	395
CCIII 71	423	388	392	445	418	400
CCIII 167	399	414	424	369	356	400
Means						
CCI	407	399	402	414	421	405
CCII	421	419	414	408	401	415
CCIII	407	396	403	400	396	398
Sample	413	404	406	408	406	406
SD	21.0	18.5	15.2	28.8	28.4	16.2
SE	7.0	6.2	5.1	9.6	9.5	5.4

Table 14

Cupressus lusitanica. Wood Density. Planting Spacing 2.43 m. Apparent Wood Density kg/m³.

Tree Number	Position from base of bole					Tree
	10%	30%	50%	70%	90%	
CDI 29	409	386	377	376	382	391
CDI 65	393	383	407	392	407	394
CDI 139	392	387	373	367	396	385
CDII 87	385	400	396	397	435	395
CDII 121	393	361	361	375	373	375
CDII 153	402	379	374	400	396	390
CDIII 24	454	440	454	466	507	456
CDIII 60	393	409	393	405	397	399
CDIII 150	403	378	376	377	364	386
Means						
CDI	398	385	386	378	395	390
CDII	393	380	377	391	401	387
CDIII	417	409	408	416	423	414
Sample	403	391	390	395	406	397
SD	20.6	22.7	27.8	29.7	42.9	23.3
SE	6.9	7.6	9.3	9.9	14.3	7.8

Table 15

Cupressus lusitanica. Wood Density. Planting Spacing 3.14 m. Apparent Wood Density kg/m³.

Tree Number	Position from base of bole					Tree
	10%	30%	50%	70%	90%	
CEI 24	427	417	417	416	419	421
CEI 49	497	503	497	493	500	498
CEI 61	396	373	383	384	370	385
CEII 10	404	405	427	415	367	407
CEII 16	411	397	412	408	454	410
CEII 65	396	377	382	395	399	388
CEIII 44	433	408	433	427	419	425
CEIII 48	466	448	440	401	462	444
CEIII 65	416	457	459	439	393	435
Means						
CEI	440	431	432	431	430	435
CEII	404	393	407	406	407	401
CEIII	438	438	444	422	425	435
Sample	427	421	428	420	420	424
SD	34.1	41.8	36.1	32.0	44.4	34.1
SE	11.4	13.9	12.0	10.7	14.6	11.4

Table 16

Pinus patula. Densitometry. Spacing 1.88 m.

Tree Number	Density kgm ⁻³	Percentage within density class					
		< 350	350-500	500-650	650-800	800-950	> 950
PCI 34	433	42.1	30.2	12.8	9.9	5.1	0
PCI 120	489	25.4	34.0	20.3	12.4	8.0	0
PCI 125	474	47.7	18.0	9.2	9.9	14.0	1.2
PCII 70	554	28.6	21.7	12.1	16.0	18.7	2.9
PCII 170	454	46.2	19.4	15.5	9.7	7.9	1.3
PCII 200	420	46.8	23.6	21.1	5.8	2.7	0 Year 71-85 only
PCIII 66	404	48.2	32.3	10.6	6.6	2.3	0
PCIII 116	560	23.9	17.6	20.0	25.3	13.3	0
PCIII 246	470	38.3	24.8	14.9	13.1	8.4	0.4
Means							
PCI	465	38.4	27.4	14.1	10.7	9.0	0.4
PCII	504	37.4	20.5	13.8	12.9	13.3	2.1
PCIII	478	36.8	24.9	15.2	15.0	8.0	0.1
Sample	480	37.6	24.8	14.4	12.9	9.7	0.7
SD	54.4	10.19	6.62	4.09	5.75	5.29	1.03
SE	19.3	3.60	2.34	1.45	2.03	1.87	0.37

Table 17

Pinus patula. Densitometry. Spacing 2.43 m.

Tree Number	Density kgm ⁻³	Percentage within density class					
		< 350	350-500	500-650	650-800	800-950	> 950
PDI 59	459	32.8	35.4	14.5	12.7	4.6	0
PDI 109	438	35.5	36.1	17.5	9.3	1.7	0
PDI 115	454	40.4	24.4	16.4	14.0	4.7	0
PDII 18	555	18.5	29.2	17.6	18.4	16.3	0
PDII 58	438	46.2	26.2	10.8	9.4	7.6	0
PDII 138	418	48.3	30.8	8.6	8.4	2.8	1.1
PDIII 60	461	28.9	41.4	16.0	6.8	6.8	0
PDIII 70	442	36.4	34.5	16.6	10.2	2.3	0
PDIII 116	563	22.9	26.2	14.6	11.8	22.6	1.9
Means							
PDI	448	36.2	32.0	16.1	12.0	3.7	0
PDII	470	37.7	28.7	12.3	12.1	8.9	0.4
PDIII	489	29.4	37.1	15.7	9.6	10.6	0.6
Sample	470	34.4	31.6	14.7	11.2	7.7	0.3
SD	52.3	9.95	5.65	3.10	3.49	7.11	0.69
SE	17.4	3.32	1.88	1.03	1.16	2.37	0.23

Table 18

Pinus patula. Densitometry. Spacing 3.14 m.

Tree Number	Density kgm ⁻³	Percentage within density class					
		< 350	350-500	500-650	650-800	800-950	> 950
PEI 6	463	45.7	22.2	9.0	8.1	13.3	1.8
PEI 16	462	38.2	28.8	13.4	13.1	6.5	0
PEI 53	473	35.1	30.6	14.7	9.2	10.1	0.2
PEII 60	462	42.2	22.6	16.8	9.0	9.5	0
PEII 75	470	31.7	33.6	17.1	11.3	6.3	0
PEII 92	441	45.2	30.9	6.2	7.3	10.4	0
PEIII 29	416	42.6	33.2	13.2	9.4	1.6	0 Year 71-83 only
PEIII 76	440	48.0	24.2	8.7	9.4	9.6	0
PEIII 92	467	29.2	37.7	16.0	12.5	4.6	0
Means							
PEI	466	39.7	27.2	12.4	10.1	10.0	0.7
PEII	458	39.7	29.0	13.4	9.2	8.7	0
PEIII	454	38.6	31.0	12.4	11.0	7.1	0
Sample	460	39.4	28.8	12.7	10.0	8.8	0.3
SD	12.5	6.95	5.52	4.20	2.09	2.80	0.63
SE	4.4	2.46	1.95	1.48	0.74	0.99	0.22

Table 19

Cupressus lusitanica. Densitometry. Spacing 1.88 m.

Tree Number	Density kgm ⁻³	Percentage within density class					
		< 350	350-500	500-650	650-800	800-950	> 950
CCI 67	504	0	62.3	30.5	5.3	1.9	0
CCI 182	505	1.4	55.4	33.4	8.4	1.6	0
CCI 189	494	0.3	59.2	34.9	5.6	0	0
CCII 114	529	0	45.6	38.4	14.7	1.3	0
CCII 166	478	0.5	67.6	24.8	6.8	0.3	0
CCII 202	527	2.2	38.6	46.0	12.6	0.5	0
CCIII 20	473	1.0	70.7	21.6	5.5	1.2	0
CCIII 71	473	0.3	67.6	28.6	3.5	0	0
CCIII 167	480	0.9	62.6	31.9	4.7	0	0
Means							
CCI	501	0.6	59.0	32.9	6.4	1.2	0
CCII	507	0.9	50.6	36.4	11.4	0.7	0
CCIII	475	0.7	67.0	27.4	4.6	0.4	0
Sample	496	0.7	58.8	32.2	7.5	0.8	0
SD	21.9	0.72	10.71	7.25	3.80	0.75	
SE	7.3	0.24	3.57	2.42	1.27	0.25	

Table 20

Cupressus lusitanica. Densitometry. Spacing 2.43 m.

Tree Number	Density kgm ⁻³	Percentage within density class					
		< 350	350-500	500-650	650-800	800-950	> 950
CDI 29	488	4.4	55.0	30.8	9.1	0.8	0
CDI 65	452	6.2	70.8	18.6	3.3	1.1	0
CDI 139	-	-	-	-	-	-	-
CDII 87	484	0.7	67.8	22.4	6.9	2.2	0
CDII 121	465	2.9	75.0	15.8	5.6	0.7	0
CDII 153	489	0.7	63.0	27.9	7.9	0.5	0
CDIII 24	531	2.9	43.3	40.4	10.2	3.1	0
CDIII 60	490	4.0	59.3	25.9	9.9	1.0	0
CDIII 150	481	0	64.5	32.7	2.9	0	0
Means							
CDI	470	5.3	62.9	24.7	6.2	1.0	0
CDII	479	1.4	68.6	21.9	6.8	1.1	0
CDIII	501	2.3	55.7	33.0	7.7	1.4	0
Sample	485	2.7	62.3	26.8	7.0	1.2	0
SD	22.9	2.14	9.95	7.98	2.84	1.00	
SE	8.1	0.76	3.52	2.82	1.00	0.35	

Table 21

Cupressus lusitanica. Densitometry. Spacing 3.14 m.

Tree Number	Density kgm ⁻³	Percentage within density class					
		< 350	350-500	500-650	650-800	800-950	> 950
CEI 24	504	0	61.1	27.9	9.3	1.6	0
CEI 49	573	0	29.9	43.9	24.0	2.2	0
CEI 61	454	1.5	76.1	19.1	3.0	0.3	0
CEII 10	453	2.7	76.4	15.9	4.7	0.3	0
CEII 16	488	0	65.6	29.8	3.9	0.6	0
CEII 65	491	0.5	61.8	31.7	5.0	1.0	0
CEIII 44	492	0	57.9	37.5	4.5	0	0
CEIII 48	553	0	31.7	55.1	11.5	1.7	0
CEIII 65	488	2.6	51.7	40.7	5.0	0	0
Means							
CEI	506	0.5	55.7	30.3	12.1	1.4	0
CEII	477	1.1	67.9	25.8	4.5	0.6	0
CEIII	511	0.9	47.1	44.4	7.0	0.6	0
Sample	466	0.8	56.9	33.5	7.9	0.9	0
SD	110.4	1.15	16.80	12.29	6.64	0.81	
SE	36.8	0.38	5.60	4.10	2.21	0.27	

Figure 1. Gravimetric / X-ray Density

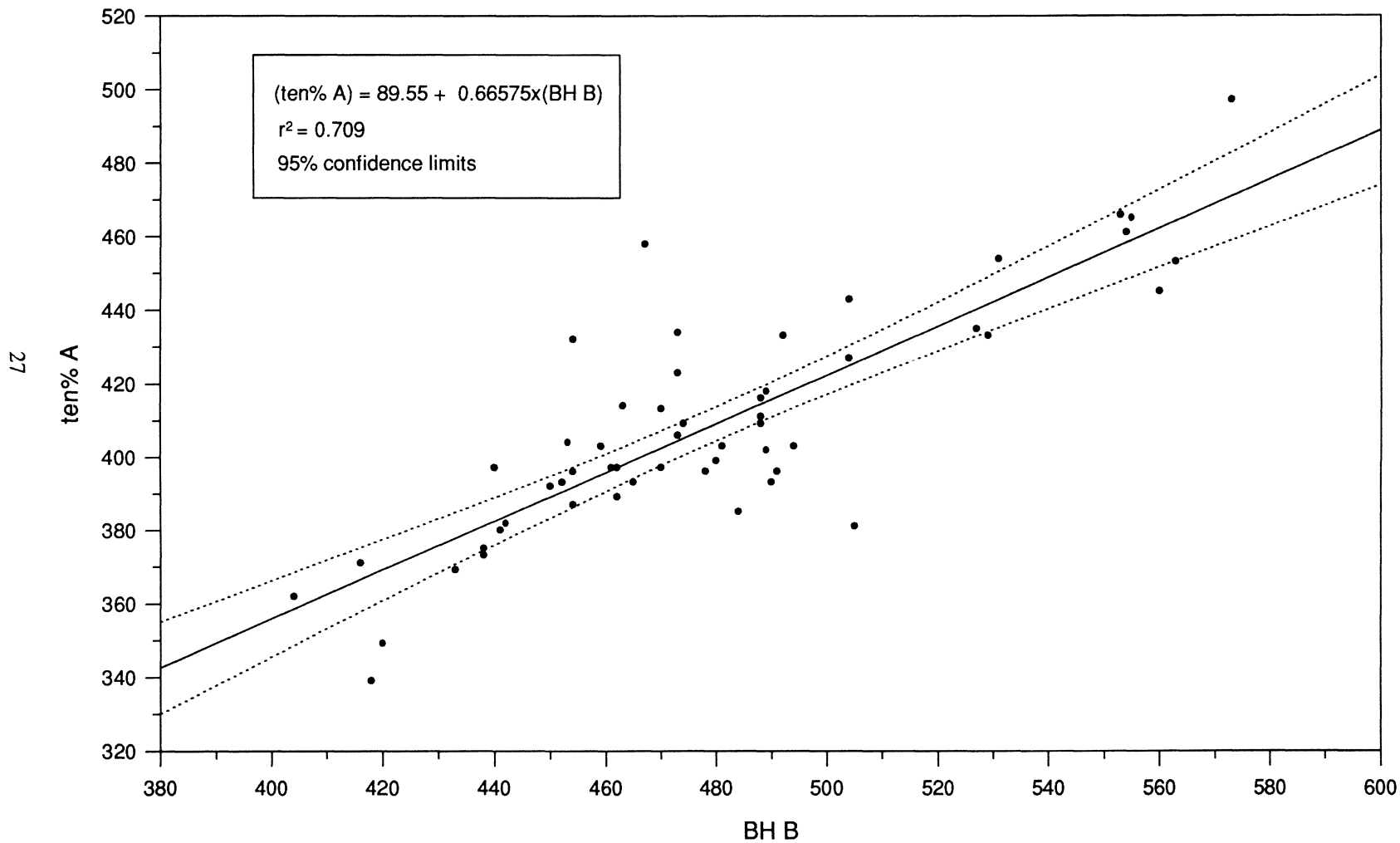


Figure 2. *P. patula* Dens/Vol.

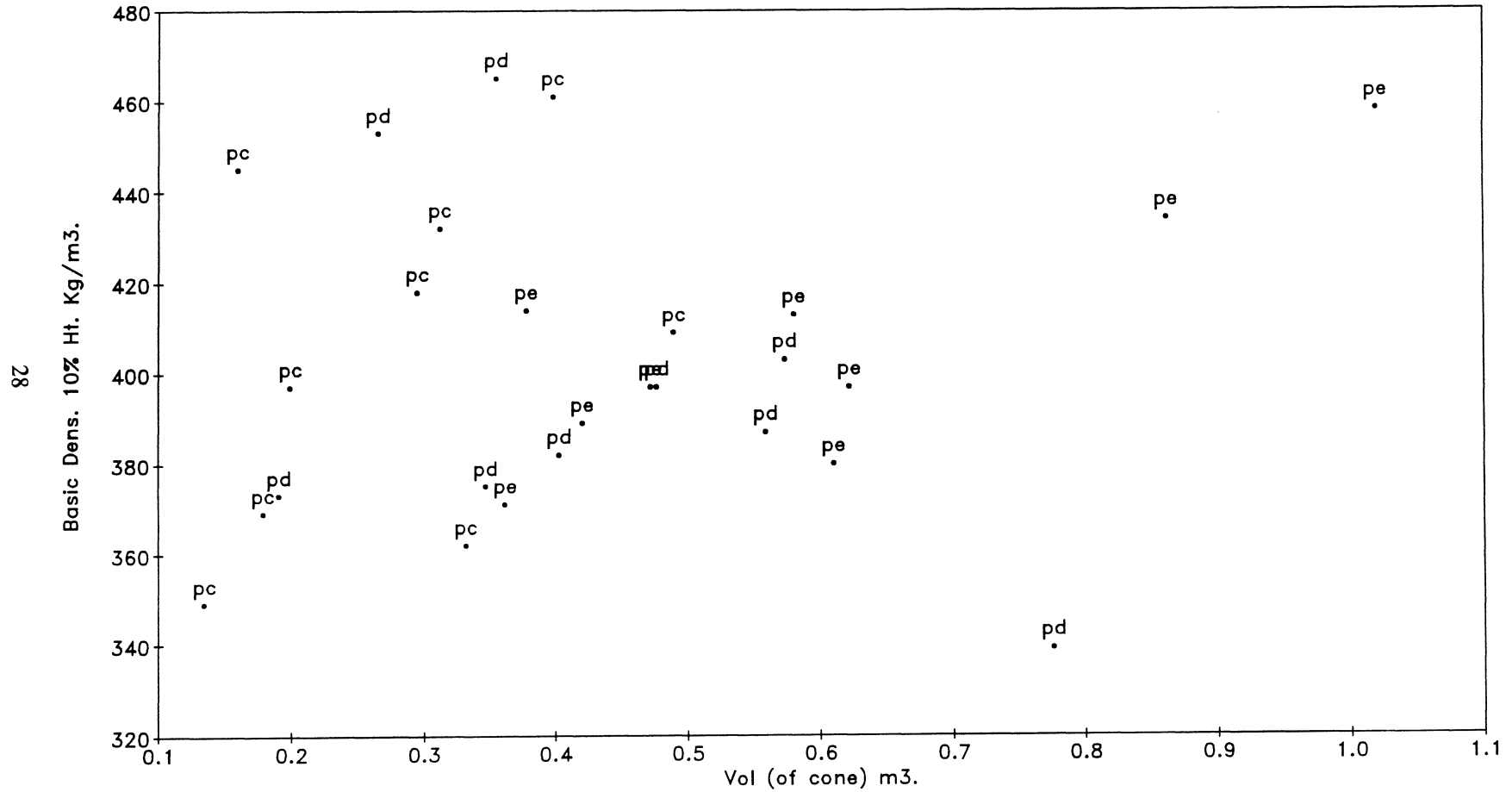


Figure 3. *C. lusitanica* Dens/Vol.

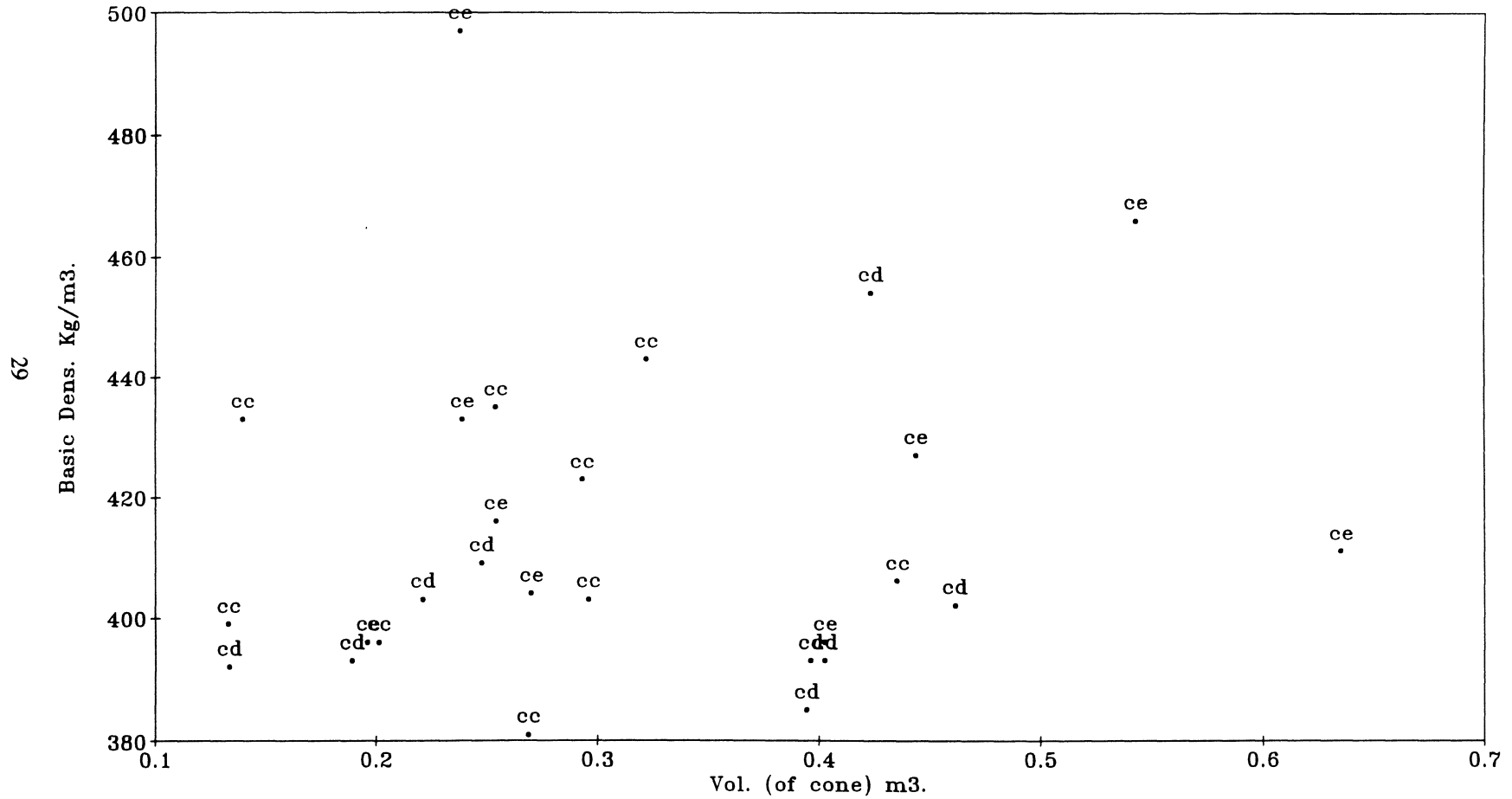


Figure 4. *P. patula*, Dens./Dry Matter

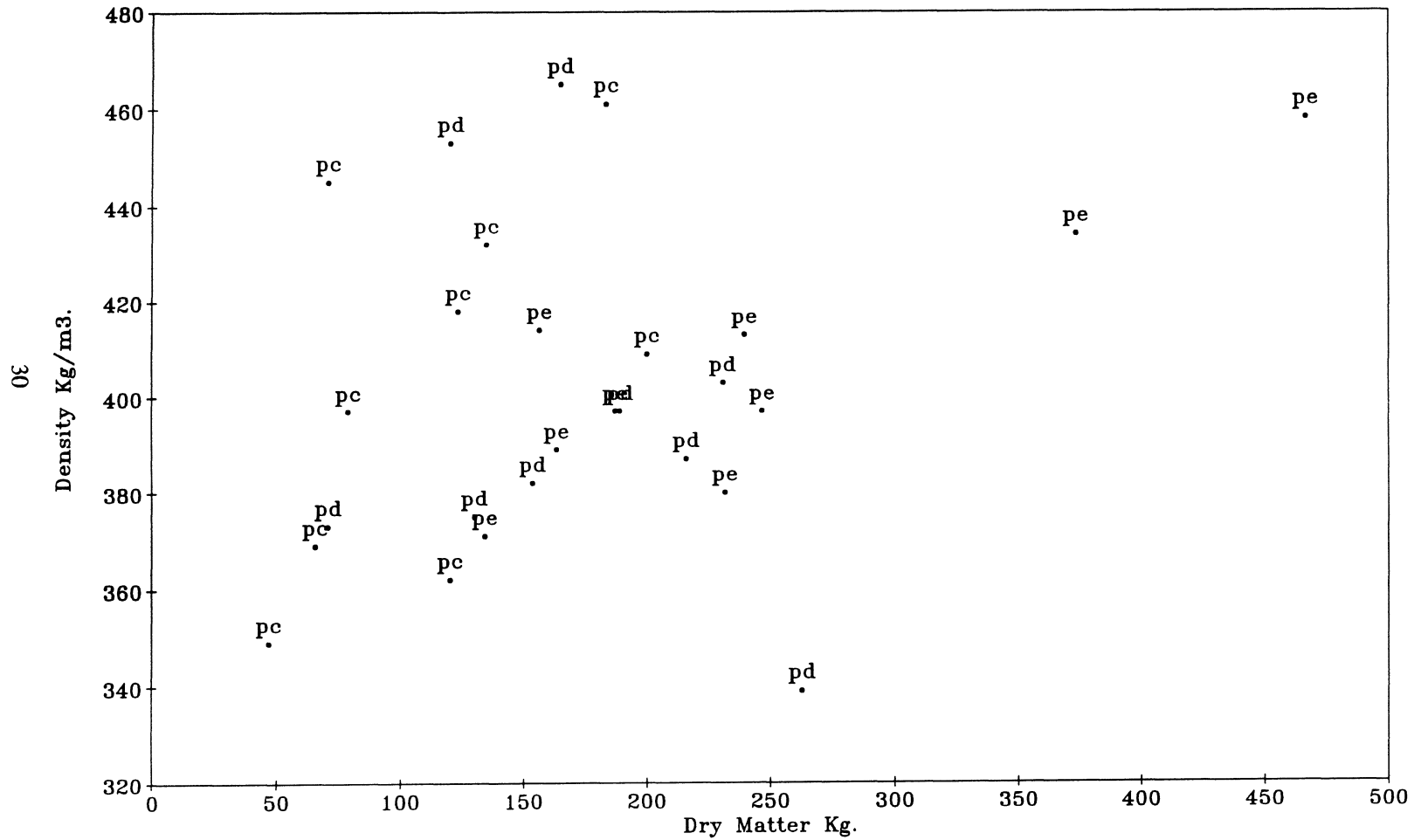


Figure 5. *C. lusitanica* Den./Dry Matter

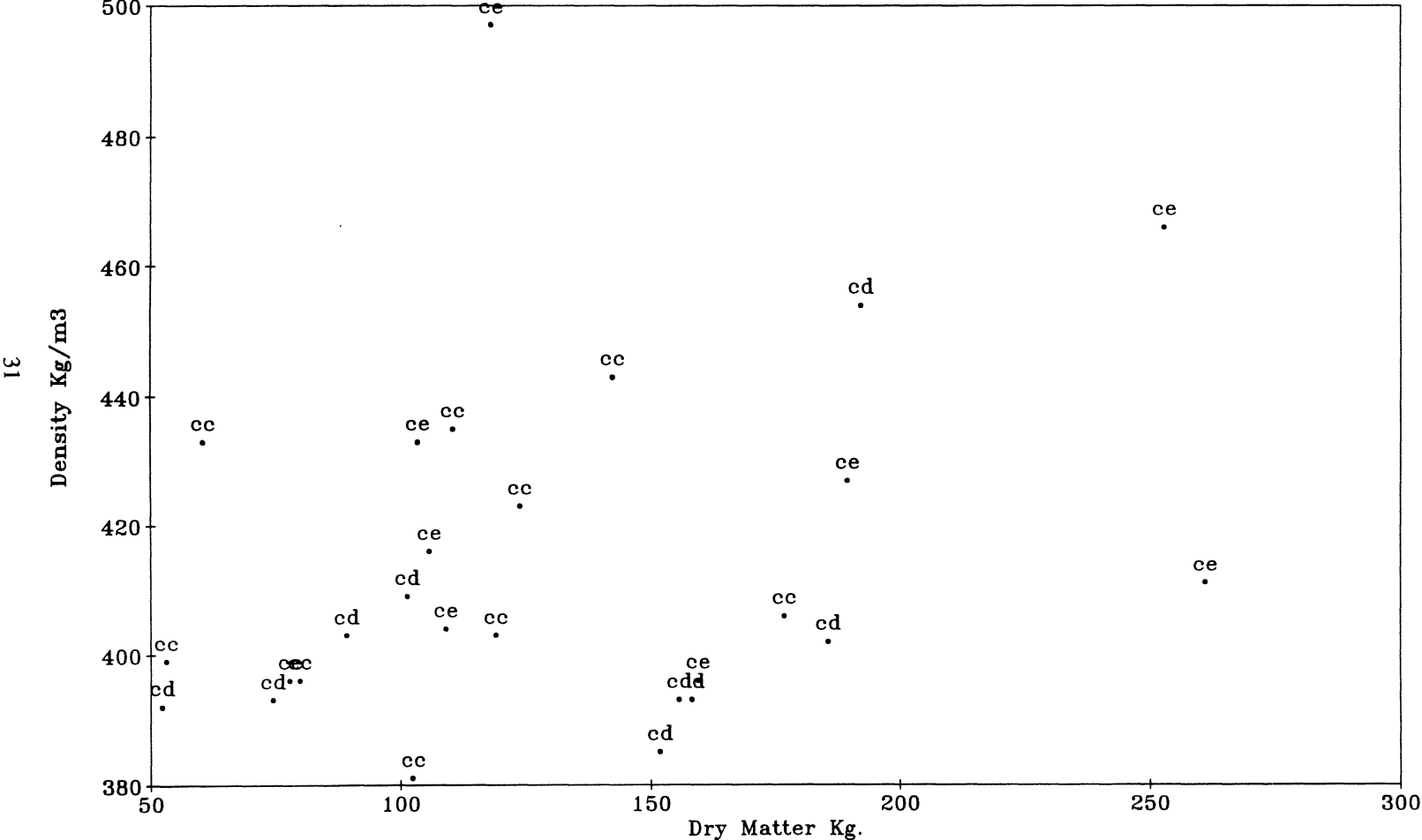


Figure 6. Density Groups 1.88m Spacing

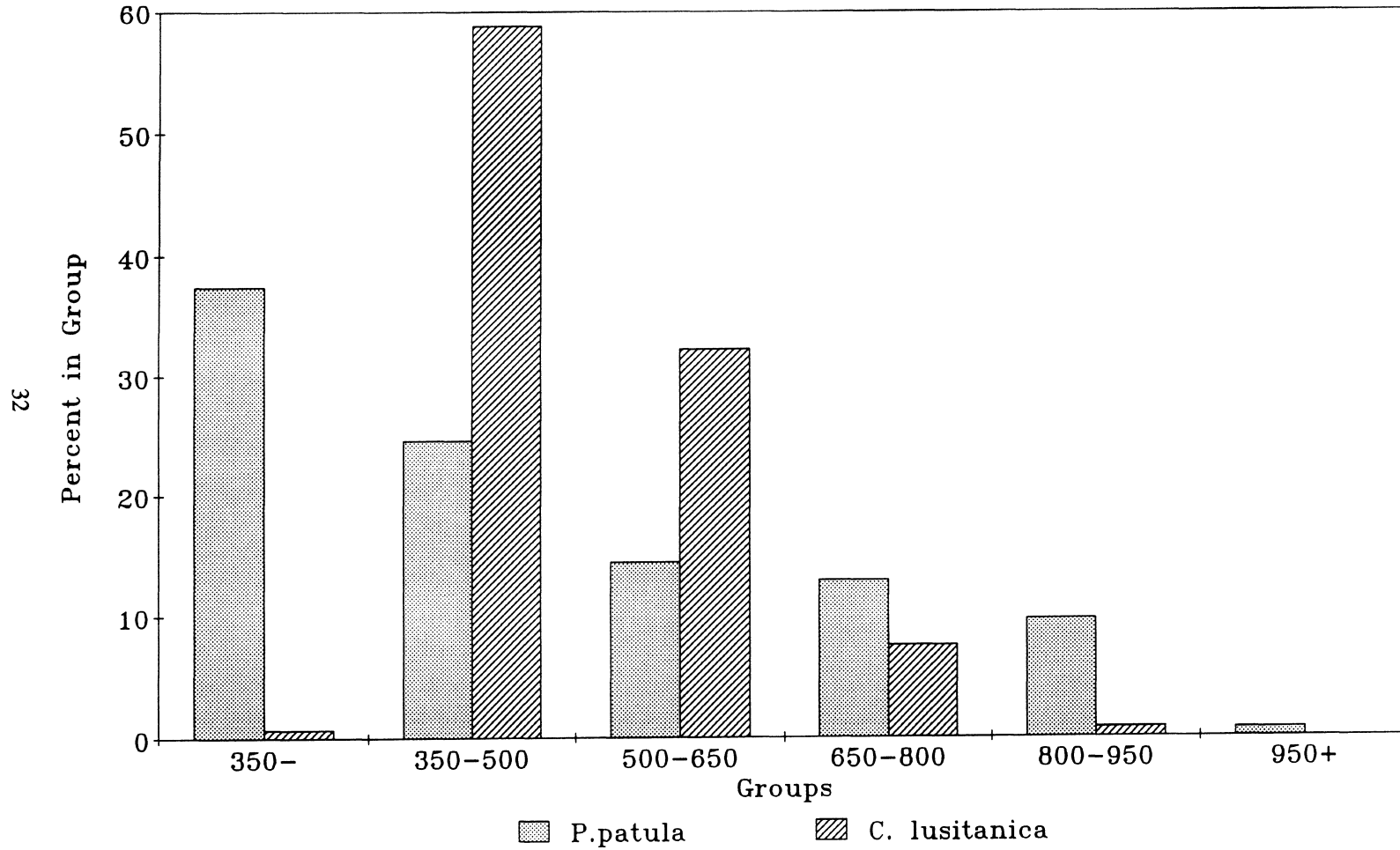


Figure 7. Density Groups 2.43m Spacing

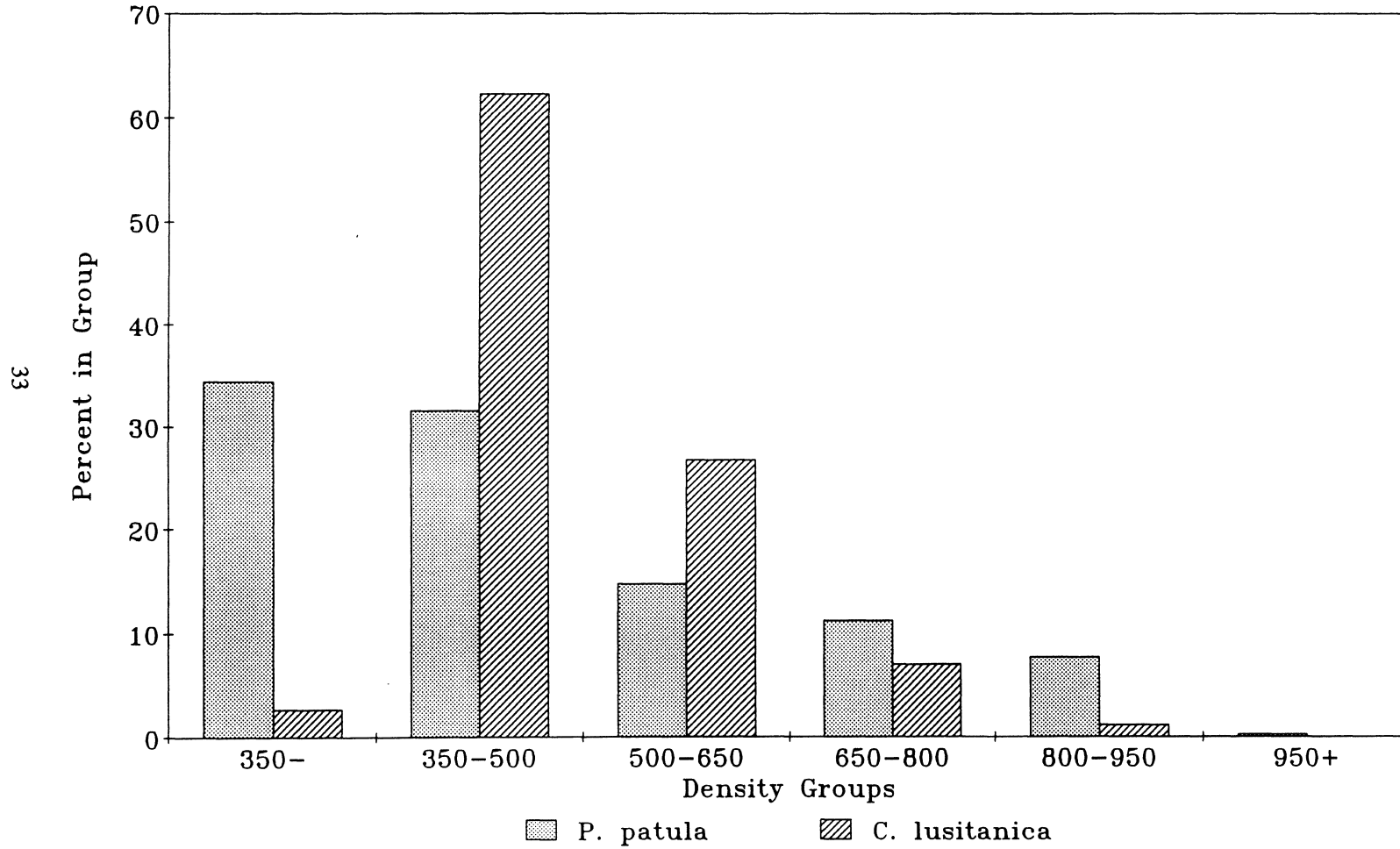


Figure 8. Density Groups 3.14m Spacing

