Survival, Growth, Yield and Wood Quality of a Species and Provenance Trial of Cupressus lusitanica, Cupressus lindleyi and Cupressus benthamii at Hambalawei, Lushoto, Tanzania

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Summary

The objective of this study was to determine differences in survival, growth, yield and wood quality of a species and provenance trial of *Cupressus lusitanica, Cupressus lindleyi* and *Cupressus benthamii* at Hambalawei, Lushoto, Tanzania.

The experiment consisted of the following species/provenances:

A:	*Cupressus lusitanica*	Ex Sokoro, Kenya
B:	*Cupressus lusitanica*	Ex Elburgon, Kenya
C:	*Cupressus lindleyi*	Ex Mexico, near Mexico City
D:	*Cupressus lindleyi*	Ex San Rafael, Mexico City
E:	*Cupressus benthamii*	Ex El Chino, Hildago State, Mexico.

The layout of the experiment was a simple randomized block design with 3 replications. At the ages of 3, 4, 5, 7, 20 and 23 years. Data was collected of survival, breast height diameter, height and stem form. Basic density was assessed at the age of 23 years. Analysis of variance of the data collected at the age of 23 years and the previous assessments have shown that *Cupressus lusitanica* ex Sokoro, Kenya was significantly better ($P = 0.05$) in diameter growth. Species/Provenances A, B and D had significantly ($p = 0.005$) higher heights than the rest. There were no significant differences between species/provenances in survival, basal area, volume, basic density and stem form.

Generally the Mexican introductions had no advantage over the Kenyan races. However, as a way of broadening the genetic base and species range, it is recommended that all the tested species and provenances be used in large scale planting since their differences were not of practical significance.

Key words: Cupressus lusitanica, Cupressus lindleyi and *Cupressus benthamii* species and provenances, survival, growth, yield and wood quality, Tanzania.

FDC: 232.12; 181.6; 181.7; 812; 174.7 *Cupressus lusitanica;* 174.7 *Cupressus lindleyi;* 174.7 *Cupressus benthamii;* (678).

Introduction

In Tanzania at present, industrial forestry plantations cover a total area of about 80,000 hectares. Out of this area *Cupressus lusitanica* accounts for nearly 15% and is the second to the extensively planted *Pinus patula.*

The earliest seed of *Cupressus lusitanica* was introduced to Kenya and Tanzania from South Africa and Europe. Local collections began in 1915 and a series of seed production areas have been developed in Kenya and Tanzania since 1927 and have led to the production of genetically superior land races (Burley and Nikles, 1973).

As the plantations were extended, it was realised that a broad genetic base was necessary. This would improve the chance of adaptability, give more scope for pest resistance and allow other desirable traits to arise. Emphasis was therefore directed to species and provenance trials, progeny testing, seed orchards, seed stand establishment, selection of plus trees and establishment of clone banks. Selection and breeding was mainly directed to survival, growth and stem form. Selection for desirable wood was however not much emphasized (Madoffe and Chamshama, 1989).

The species/provenance trial reported in this study was intended to re-introduce Central American material for comparison with the local land races. The objective of this study was to determine differences in survival, growth, yield and wood quality of a species/provenance trial of *Cupressus lusitanica, Cupressus lindleyi* and *Cupressus benthamii.*

Materials and Methods

Study site

The species/provenance trial (Experiment 340a) is situated at Hambalawei, Lushoto, Tanzania. The latitude is 4 ° 40' S, longitude is 38 ° 16' E and altitude is about 1700 m.

The topography is broken and undulating with steep to gentle slopes which are intersected at their base by narrow flat valleys. The main rock type of the area may be described texturally as gneisses and are often intruded by quartzite veins. The soils are clay like in character with varying amounts of sand. The soil reaction is generally neutral to acidic although pH values of between 3.5 and 8.5 have been recorded.

Earlier vegetation was a montane, dry forest with *Juniperus procera* as the main species and fairly thick understorey.

The rains are mainly distributed in two rainy seasons. Long rains in March to May and short rains in November to December. Mean annual rainfall is 795 mm. The average minimum and maximum temperatures are 7 °C and 27 °C respectively.

Source of seeds

The seed source of the 5 species/provenances planted at Hambalawei, Lushoto, Tanzania are summarized in *table 1.*

Nursery techniques

The seeds were sown at Lushoto nursery on 6th April 1966 using a potting mixture appropriate for the species. The seeds germinated towards the end of April and beginning of May. The seedlings were transplanted on 15th June 1966 to polythene tubes in which they were tended up to the planting date.

Table 1. — Origin of *Cupressus* species/provenances seed planted at Hambalawei, Lushoto, Tanzania.

Species/ Provenance	Batch No.	Origin	Latitude	Longitude	Elevation, a.s.l. (m)	Rain-fall (mm)
A C. *lusitanica*	327	Sokoro Kenya	0°18'S	35°50'E	2450	1100
B C. *lusitanica*	-	Elburgon Kenya	0°18'S	35°55'E	2250	1092
C C. *lindleyi*	-	Mexico Near Mexico City	19°13'N	99°10'W	3000	-
D C. *lindleyi*	-	San Rafael Mexico State	19°13'N	98°49'W	2700 to 3100	1107
E C. *benthamii*	-	El Chino Hildago State, Mexico	20°15'N	98°44'W	2320	1568

Experimental design

The plots are square measuring 14.64 m and each plot has 49 trees. Data was collected in the inner 25-trees. The plots are arranged in 3 blocks in a simple randomized block design.

Field procedures

Planting was done on 21st and 22nd of April 1967. Site preparation involved clearing of all vegetation and burning of residues. Seedlings were spaced at 2.44 m x 2.44 m. During initial growth, the trees were tended by squatters who grew maize, potatoes and beans.

Data collection methods

Data was collected on diameter, height, survival, stem quality and wood quality. Previous assessment data (3 to 20 years) was obtained from Lushoto Silviculture Research Station files and has never been published.

All the surviving inner 25 trees were measured for breast height diameter. Diameter was measured using a steel calliper and recorded to nearest 0.1 cm. The diameter tally also gave the survival data.

Two fattest trees were measured in each plot to obtain dominant height. In getting average height, 4 other trees were measured from each plot to make a total of 6 measured trees out of which 2 trees represented small trees, 2 medium sized trees and 2 large trees. Height (m) was measured using suunto hypsometer.

Stem quality assessment was done on all surviving inner 25 trees in a plot. The quality was categorized into 3 groups:

1. Straight stem.
2. Stem with slight bend.
3. Crooked stem.

Four trees were sampled in each plot of a species/provenance for wood quality assessment. The selected trees were free from defects, with straight boles and also representative of the diameter ranges for each plot. An increment borer was used to bore at breast height taking 1 core from each selected tree.

The cores were then stored in polythene bags sterilized with 95 % ethanol. In the laboratory, each core was divided into 3 equal portions representing inner, middle and outer

wood. The cores were saturated in distilled water for at least 24 hours in order to regain green condition. Volume of the cores was measured by water displacement. The cores were then oven dried at a temperature of 103 °C ± 2 °C to constant weight and cooled over silica gel before determining oven dry weight.

Data analysis

Data were analyzed for survival (%), breast height diameter (cm), height (m), basal area per ha (m^2 ha^{-1}), volume (m^3 ha^{-1}), stem quality and density (kg m^{-3}) using routine procedures. Volumes of individual trees was obtained using local volume tables for these species (PAIVINEN and MÄÄTA, 1986). Basic density was calculated as sample oven dry weight divided by sample saturated volume.

Analysis of variance was done on survival, breast height diameter, height, yield, and wood quality. Stem quality was compared by Chi-square test. Arcsine transformation of percentage values was done before analysis of variance. Significant treatment differences were separated by the least Significant difference (LSD) test at P = 0.05.

Results and Discussion

Survival, stem quality, growth and yield

Survival assessment at ages 3, 4, 5, 7, 20 and 23 years is shown in *tables 2* and *3*. Statistical analysis showed that there were no significant differences between survival of different species/provenances. The drop in survival from age of 7 years to age of 23 years (*Tables 2* and *3*) was due

Table 2. — Survival, growth and stem form assessments at ages 3, 4, 5, 7 and 20 years of a *Cupressus* species/provenance trial at Hambalawei, Lushoto, Tanzania.

		AGE AFTER PLANTING, years				
Trait	Species/provenance	3	4	5	7	20
	A: *C.lusitanica*	98	98	98	98	61
	B: *C.lusitanica*	93	93	93	91	65
	C: *C.lindleyi*	93	93	92	92	61
SURVIVAL	D: *C.lindleyi*	99	99	99	98	66
(%)	E: *C.benthamii*	98	98	98	98	64
		NS	NS	NS	NS	NS
	A: *C.lusitanica*	-	11.3	12.7	14.1	22.6
BREAST	B: *C.lusitanica*	-	11.8	13.1	14.6	22.3
HEIGHT	C: *C.lindleyi*	-	11.0	12.5	14.1	21.6
DIAMETER	D: *C.lindleyi*	-	11.4	12.6	14.3	20.9
(cm)	E: *C.benthamii*	-	11.2	12.6	14.2	21.5
			NS	NS	NS	NS
	A: *C.lusitanica*	6.1a	7.2a	8.6a	10.7a	20.3
	B: *C.lusitanica*	6.0a	7.2a	8.5a	10.8a	20.8
HEIGHT	C: *C.lindleyi*	5.2b	6.2b	7.5b	9.5b	19.6
(m)	D: *C.lindleyi*	5.6b	6.7b	8.0b	10.1b	20.9
	E: *C.benthamii*	5.3b	6.3b	7.4b	9.9b	19.8
		***	***	***	*	NS
	A: *C.lusitanica*	-	2.4a	-	-	-
	B: *C.lusitanica*	-	2.5a	-	-	-
STEM	C: *C.lindleyi*	-	2.5a	-	-	-
FORM	D: *C.lindleyi*	-	2.4a	-	-	-
	E: *C.benthamii*	-	2.8b	-	-	-
			**			

Within a column figures under same trait followed by the same letter are not significantly different
*) significant at P = 0.05
**) significant at P = 0.01
***) significant at P = 0.001
NS) not significant at P = 0.05

Table 3. — Average survival, growth, yield, stem form and wood density of a 23 year old *Cupressus* species/provenance trial at Hambalawei, Lushoto, Tanzania.

Species/ provenance	Survival (%)	Dbh (cm)	Height (m)	Basal area (m^2/ha)	Volume (m^3/ha)	Stem form	Basic density
A: *C. lusitanica*	52.0a ± 6.928	25.04a ± 0.951	22.44a ± 0.951	34.10a ± 3.975	350.17a ± 40.943	1.975a ± 0.095	397a ± 6.064
B: *C. lusitanica*	62.7a ± 2.667	23.37b ± 0.150	22.06a ± 0.087	35.20a ± 0.876	352.37a ± 11.902	1.911a ± 0.059	394a ± 9.644
C: *C. lindleyi*	58.7a ± 3.528	22.00b ± 0.361	21.25b ± 0.208	28.45a ± 1.255	282.15a ± 12.808	1.975a ± 0.059	396a ± 22.850
D: *C. lindleyi*	61.3a ± 4.807	21.88b ± 0.653	22.17a ± 0.536	29.08a ± 1.043	285.13a ± 15.988	2.011a ± 0.099	420a ± 6.642
E: *C. benthamii*	57.3a ± 3.528	22.57b ± 0.636	21.69b ± 0.104	29.70a ± 1.041	293.50a ± 8.969	2.012a ± 0.134	396a ± 15.506
Level of significance	NS	*	*	NS	NS	NS	NS

Within a column figures followed by the same letter are not significantly different.
*) Significant at P = 0.05
NS) Not significant at P = 0.05
±) Standard error of plot means.

to competetion and subsequent death of trees as no thinning was carried out.

At the age of 4 years, stem quality assessment had indicated that species E which is *Cupressus benthamii* was significantly worse in form than the other species/provenances (P = 0.01) and the straightest was species/provenance A. Assessment at age of 23 years (*Tables 3* and *4*) also indicated that *Cupressus benthamii* had the poorest rank in stem form although there were no significant differences between the species/provenances (P = 0.05, Chi-Square test). Poor stem form of *Cupressus benthamii* has also been observed at Muguga, Kenya (Thogo and Dyson, 1974).

At the age of 23 years species/provenance "A" with the diameter of 25.04 cm was significantly better (P = 0.05) in diameter growth than the rast of species/provenances A attained the highest mean of 22.44 m and the no significant differences although species/provenances A and B from Kenya had large diameters (*Table 2*). In the experiment no thinning had been carried out and consequently diameter growth was poor due to high stocking. For example yield tables for an average site class and age of 23 years indicated a breast height diameter of 38 cm which was higher than the mean diameters for all species/provenances (Mathu and Philip, 1979; Malimbwi, 1984; Pikkavainen, 1986).

In height growth, at the age of 23 years species/provenances A attained the highest mean of 22.44 m and the least was species E (*Table 3*). Analysis of variance showed that at P = 0.05 species/provenance height differed significantly. Species/provenance C and species E were significantly lower than the rest. Previous assessments between ages of 3 to 7 years also indicated that species/provenances

Table 4. — Ranking in survival, growth, yield, stem form and wood quality of *Cupressus* species/provenances at the age of 23 years, at Hambalawei, Lushoto, Tanzania.

Traits	Species/provenance ranks				
	A: *C. lusitanica*	B: *C. lusitanica*	C: *C. lindleyi*	D: *C. lindleyi*	E: *C. benthamii*
Survival %	5	1	3	2	4
Breast height dia (cm)	1	2	4	5	3
Height (m)	1	3	5	2	4
Basal area (m^2/ha)	2	1	5	4	3
Volume (m^3/ha)	2	1	5	4	3
Stem form	2.5	1	2.5	4	5
Density (kg/m^3)	2	5	3.5	1	3.5
Average performance	2.2	2.0	4.0	3.1	3.6
OVERALL RANK	2	1	5	3	4

The smaller the figure the higher the performance

C, D and E were significantly lower in height (P = 0.01) than species/provenances A and B which are Kenyan races (see *Table 2*). The heights obtained in this study are similar to those in yield tables (Mathu and Philip, 1979; Malimbwi, 1984; Pikkavainen, 1986). This is expected as height growth is often not significantly influenced by stand density.

In the case of basal area, the assessment at 23 years indicated that although the highest value of 35.20 m^3 ha^{-1} was recorded from species/provenance B, analysis of variance showed no significant differences between species/provenances (*Table 3*) and the standing basal area values correspond with those of yield tables (Mathu and Philip, 1979; Malimbwi, 1984; Pikkavainen, 1986).

Wood quality

The assessment done at the age of 23 years has indicated that species/provenance B had the lowest mean basic density of 394 kg m^{-3} while species/provenance D had the highest value of 420 kg m^{-3} (*Table 3*). The differences however were not significantly different.

When the basic density means of *Cupressus lusitanica* are compared for different locaties in Tanzania it is found that Meru plantation had the lowest mean density of 378 kg m^{-3} (Lema et al., 1978), Rongai spacing trail had a mean of 391 kg m^{-3} (Malimbwi et. al, 1992) Hambalawei trial had a mean of 401 kg m^{-3} while the Bunduki Forest Reserve, Morogoro, had a mean of 424 kg m^{-3} (Masunga, 1989).

These variations, however, could be attributed to age differences since at Meru the trees measured had an age of 16 years, at Rongai age of 19 years, at Hambalawei age of 23 years and at Bunduki trees had an age of 35 years.

However, all these 4 means from different locaties in Tanzania are lower than the mean density of *Cupressus lusitanica* grown in its natural habitat which is reported to be 430 kg m^{-3} ([Chudnops, 1987] as cited by Zobel et al., 1987). This indicates that in its natural habitat, *Cupressus lusitanica* has denser wood than when it is grown as an exotic.

Conclusions and Recommendations

Conclusions

Species/provenance "A" and "B" which are *Cupressus lusitanica* from Sokoro, Kenya and Elburgon, Kenya respectively have shown outstanding performance especially in height and diameter growth for the period of 23 years. The species/provenance ranking for all traits is shown in *table 4*.

Basing on previous years assessments and the ranking of species/provenances at age of 23 years (*Table 4*), it can be concluded that Mexican introductions of *Cupressus lindleyi* which are provenances C and D and *Cupressus benthamii* which is species E have shown no advantage over the Kenyan provenances of *Cupressus lusitanica*. This conclusion supports the observation by DYSON (1972) in BURLEY and NIKLES, (1973) that in East Africa, Kenyan races of *Cupressus* species/provenances were performing better than the Mexican ones. ZOBEL et al., (1987) also cite OWINO (1977) to have found that for *Cupressus lusitanica* in Kenya, the advanced "land race" selections were highly superior. He also found that selections from second to third generation exotic plantations were far superior to the best provenances newly introduced from the natural range of the species.

Recommendations

For an afforestation programme with exotics to be successful, sufficient seeds of good quality must be available from the desired seed source (ZOBEL et al., 1987). In this study, although the Kenyan races have proved to be superior, the differences are very small. Therefore, all species/provenances should be considered for afforestation to broaden the genetic base and to improve and allow other desirable traits to arise.

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Morphometric and Electrophoretic Analysis of Two Populations of European Black Pine (Pinus nigra Arn.)

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Abstract

This paper examines genetic and phenotype variation of seeds from 2 populations of *Pinus nigra* ARNOLD *subsp. salzmanii* (DUNAL) FRANCO. Seeds size are compared with an image analyzer, showing significant differences between the 2 populations, which could be induced by observed environmental differences. The genetic distance is analysed, using the isozyme variation. The x^2 test shows that the allele frequencies of the ACO-1 and GOT-1 isozymes are significantly different, which means that these isozymes would appear as genetic markers capable of differentiating the 2 populations studied.

Key words: Pinus nigra, isozymes, morphometric analysis, genetic markers, population origin.

FDC: 165.3; 165.5; 174.7 *Pinus nigra.*

Introduction

This paper presents methods to measure geographic variation in *Pinus nigra:* the conventional electrophoretic analysis and the novel use of an image analysis to examine morphometric variation.

The remarkable increase of computerized image analyses in recent years has brought about a great improvement in morphometric characterization and a speeding up of the process of measuring the different characteristics. Not only are the measurements more accurate, but the number of data that can be handled by the computer is much greater (ORTIZ et al., 1990).

Electrophoresis techniques have come to be used routinely in the study of variations in enzyme systems, and they have been instrumental in determining the origin of populations of unknown ancestry (FALKENHAGEN, 1985). The allozyme variation expressed as the differences found in the allelic frequencies, is used to characterize the different populations under study.

Pinus nigra is found in 3 main locations in Spain: the Pyrenees, the Iberian Range and the Cazorla and Segura Mountain Ranges, in the Mediterranean area. The forest of the different zones exhibit great morphological differences with respect to the form of trunk, the size of crown and

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