Performance of Thirty Two Families of *Cupressus lusitanica* at Hambalawei, Lushoto, Tanzania

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Summary

A study was carried out to evaluate the performance of 32 families of *Cupressus lusitanica* (MILL.) in a family trial located at Hambalawei, Lushoto – West Usambara, Tanzania. Data was collected periodically on survival, breast height diameter and height. A final assessment was done at 27 years on all parameters including wood basic density, stem form and *Cinara cupressi* (BUCKTON) infestation.

An ANOVA test for volume production showed that at 27 years, there were significant ($P < 0.05$) differences between families and U1, K152, U3, U6, U2, K10, K87, K162, K160 and U7 ranked highest. A further test involving data for stem canker ($P < 0.01$) and stem form ($P < 0.001$) showed that families U1, K165, K160, U6, K150, K159, U2, U4, U9 and U10 were superior. Families K48, K151, K152, K154, K157, K159, K164, T6, T14, F33, U4, U9 and U10 were tolerant of, or capable of withstanding moderate *Cinara cupressi* BUCKTON infestation and are distinguishable from the rest ($P < 0.05$). No significant ($P > 0.05$) differences in basic density were found.

Based exclusively on the results from this trial, suitable families were K9, K152 and K157, all from Kenya. When the results are evaluated in relation to those from another study, involving more sites, Ugandan families U3, U1, and Kenyan families K150 and K152 merit use as clone/seed sources. These recommendations presuppose slow advances in the current work on biological control of *C. cupressi*. When *C. cupressi* is finally contained, the best 10 families identified in this study, namely K9, K87, K150, K152, K157, K160, K162, U1, U3 and U6 merit use as clone/seed sources. The large number is recommended to widen the genetic base. Because of the small number of families and unequal representation from Kenya, Tanzania and Uganda, the conclusion that Kenyan and Ugandan families are overall best needs to be taken with caution.

Key words: *Cupressus lusitanica,* families, volume production, stem form, stem canker, *Cinara cupressi* resistance, wood basic density, Tanzania, progeny test.

FDC: 232.11; 174.7 *Cupressus lusitanica*; (678).

Introduction

Cupressus lusitanica (MILL.) is widely planted in mountainous areas of Tanzania including Lushoto. In order to improve productivity of cypress plantations in Tanzania, a provenance/land race experiment was established at Hambalawei in Shume Forest Project, Lushoto, Tanzania. LUOGA *et al*. (1994) studied the performance of *Cupressus* species (*C. lusitanica*, *C. lindleyi*, and *C. benthamii*) and provenances of *C. lusitanica* (ex Sokoro, Kenya) and ex Elburgon (Kenya), and of *C. lindleyi* (ex. Mexico, near Mexico city, and ex. San Rafael, Mexico City) in an experiment at Hambalawei. They observed that *C. lusitanica* land races from Kenya showed outstanding performance especially in diameter and height growth for the period of 23 years. Similar observations have been made by DYSON (1973).

Although it is known that *C. lusitanica* land races from Kenya perform better than Mexican provenances, more studies are required to identify mother trees as the source of genetically improved seed for future planting. Against this background, a family experiment was established in 1967 at Hambalawei to evaluate the performance of 32 families of *C. lusitanica*. This paper compares their performance at Hambalawei, Lushoto, Tanzania. The families were collected from Kenya, Tanzania and Uganda.

Materials and Methods

Study area

The family test was established at Hambalawei (4° 40' S, 38°16' E; 1700 m asl) in Usambara mountains, Tanga Region, Tanzania. Soil parent material is derived from metamorphic rocks, mainly gneisses of varying composition (LUNDGREN, 1978). The topography of Hambalawei is broken and undulating. Slopes vary from steep to gentle. The soils are classified as Eutric Nitosols developed in basement complex parent geological material (UNESCO/FAO, 1977). These soils are dominated by clay with varying amounts of sand, with generally neutral or acidic reaction. However, pH values ranging from 3.5 and 9.5 have been recorded (RAUNIO, 1979). Pedon sample means (0 cm to 70 cm depth) of selected soil properties are presented in *table 1*.

The original vegetation was dry montane forest. *Juniperus procera* (HOCHST. ex. ENDL.) was the main species with a fairly thick understorey. Mean annual rainfall varies between 900 mm and 1000 mm and it is distributed in 2 rainy seasons, long rains in March to May and short rains in November to December. The mean minimum and maximum annual temperatures are 7 °C and 27 °C respectively (LUOGA *et al*., 1994).

Families, seed sources and nursery techniques

Seed sources of 32 families of *C. lusitanica* are shown in *table 2*. Seedlings of each family were raised at the Silviculture Research Centre nursery using standard cultural techniques (Forest Division, 1982).

Design of experiment and field procedures

A randomized complete block design with four replications was used. Each family was represented once in each block. For each family (each plot), 4 x 4 trees were planted at 2.44 m x 2.44 m spacing. The whole experiment has 2 guard rows of *C. lusitanica*. Site preparation involved clearing of all vegetation and burning residues followed by stacking and pitting. The experiment was planted in 1967. During the first few years (before canopy closure), the trees were tended by the taungya system. Farmers grew maize, potatoes and beans. The

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Table 1. – Means of selected soil properties of *Cupressus lusitanica* progeny experimental site at Hambalawei, Lushoto, Tanzania.

Soil depth	pH	Electrical conductivity	Organic carbon	Total N	Total P	Bray I P
cm		$dS.m^{-1}$	%	%	$\mu g.g^{-1}$	$\mu g.g^{-1}$
LFH	–	0.126	–	–	883.3	36.1
0-10	6.16 [a]	0.125	–	0.42	1136.8	6.6
10-20	5.24	0.105	–	0.22	950.0	4.6
20-40	5.00	0.063	–	0.17	658.3	3.2
40-70	4.94	0.048	–	0.09	591.7	3.3

[a]) Number of observations (n) per soil depth increment was 4.

Table 2. – Seed source of *Cupressus lusitanica* families planted at Hambalawei, Lushoto, Tanzania.

Progeny code	Seed origin Locality	Country	Latitude/Longitude	Altitude	Mean annual rainfall	Age at selection
				m asl	mm	years
T6	Rongai	Tanzania	4°S 37° 30'E	2000	9000	32
T14	"	"	"	"	"	31
T16	"	"	"	"	"	32
T33	"	"	"	"	"	32
T71	"	"	"	"	"	11
K9	Elburgon	Kenya	0° 18'S 35° 48'E	2424	1092	37
K10	Elburgon	"	0° 18'S 35° 48'E	2424	1092	–
K48	Kabage	"	0° 23'S 36° 15'E	2121	–	15
K87	Elburgon	"	0° 18'S 35° 48'E	2424	1092	–
K150	Narasha	"	0° 01'N 35° 41'E	1525	–	24
K151	Kigumo	"	0° 30'S 36° 50'E	2121	–	34
K152	Hombe	"	0° 20'S 37° 08'E	1970	–	36
K154	Narasha	"	0° 01'N 35° 41'E	1525	–	24
K157	Kigumo	"	0° 30'S 36° 50'E	2121	–	31
K158	"	"	0° 30'S 36° 50'E	2121	–	31
K159	Elburgon	Kenya	0° 18'S 35° 48'E	2424	1092	27
K160	"	"	"	"	"	34
K161	"	"	"	"	"	33
K162	"	"	"	"	"	"
K163	"	"	"	"	"	"
K164	"	"	"	"	"	"
K165	"	"	"	"	"	"
K166	"	"	"	"	"	"
U1	Lendu	Uganda	0° 32'N 30° 48'E	1500-1800	125	17
U2	"	"	"	"	"	"
U3	"	"	"	"	"	"
U4	"	"	"	"	"	"
U6	"	"	"	"	"	"
U7	Mafuga	Uganda	01° 05S 29° 55'E	1850-2800	1264	14
U9	"	"	"	"	"	12
U10	"	"	"	"	"	14
Control	Sungwi	Tanzania	40° 40' 3° 10'E	–	1090	14

[1]) T-Tanzania, K-Kenya, and U-Uganda

experiment was selectively thinned once in 1974 by removing about 30% of the standing basal area.

Data collection

Data on previous assessments of tree survival, height, breast height diameter (Dbh), and stem canker at ages 1, 3, 5, 7, 14 and 19 were obtained from the Lushoto Silviculture Research Centre of Tanzania Forestry Research Institute (TAFORI).

The final assessment of the experiment was done in August 1994 at the age of 27 years. This involved assessment for Dbh, height, stem form, wood basic density and degree of infestation by *Cinara cupressi* BUCKTON. For each plot, all surviving trees were measured for Dbh, using a diameter tape, and recorded to nearest 0.1 cm. The Dbh tally also gave the tree survival. For height, the 3 tallest trees were measured in each plot to obtain dominant height. Four more randomly selected trees were measured to get average height thus making a total of 7 trees for each plot, of which 2 trees represented small, 2 medium and 3 large trees. Height was measured to the nearest 0.1 m using a suunto hypsometer. Stem form was assessed for all surviving

trees in each plot. The quality of stem was given a score as follows:

Score	Stem quality
1	straight
2	stem with slight bend
3	crooked stem

Cinara infestation was assessed for all surviving trees in each plot. The degree of infestation was judged on the basis of crown vigour, and percentage of needles infested, and was categorised as follows:

Score	Extent of infestation
1	not infested (shows no sign of infestation);
2	slight infested (< 25% of the crown infested);
3	moderately infested (25% to 50% of the crown infested);
4	heavily infested (> 50% to < 100% of the crown is infested);
5	dead (already dead or 100% of the crown is infested).

For determination of wood basic density, 5 defect-free trees with straight bole and representative of the diameter ranges of each plot were sampled. Cores were taken from the selected trees using an increment borer. Each core was inserted in the trough of fluted paper and immediately air dried to prevent fungal growth. In the laboratory, each core was divided into 3 equal portions representing inner, middle and outer wood. The cores were soaked in water for at least 36 hours in order to regain green condition, after which their volumes were measured by water displacement. The cores were then oven-dried at 103 ± 2 °C to constant weight and cooled over silica gel before determining oven dry weight. Basic density for each core was calculated as oven dry weight divided by green volume.

Soil sampling and analysis for site characterization

For each block, soil samples were taken from 10 randomly selected points at the following depth intervals: LFH-layer, 0 cm to 10 cm, 10 cm to 20 cm, 20 cm to 40 cm and 40 cm to 70 cm depth. Soil was bulked by block and soil depth, mixed thoroughly and sub-sampled for laboratory analysis. In the laboratory, soil samples were air dried and passed through a 2 mm sieve. Soil pH was determined by means of a hydrogen electrode pH meter at distilled water:soil ratio of 2:1. A sub-

Table 3. – Overall ANOVAs for indicated traits of *Cupressus lusitanica* families at Hambalawei, Lushoto, Tanzania.

	Age (years)						
Trait	1	3	5	7	14	19	27
Mean survival (%)	ns[a]	ns	ns	ns	ns	ns	ns
C.V.[b]	3.43	4.75	3.80	5.42	2.20	7.44	12.19
Mean height (m)	***	***	***	**	**	–	**
C.V.	9.08	6.82	4.80	4.40	5.02	7.90	4.49
Mean Dbh (cm)	–	***	**	**	*	***	***
C.V.	–	9.70	5.10	4.70	7.20	5.60	6.20
Mean basal area (m^2/ha)	–	–	*	***	***	*	**
C.V.	–	–	12.61	9.50	10.54	12.13	7.90
Stand volume (m^3/ha)	–	–	***	***	**	–	***
C.V.	–	–	8.59	7.05	13.44	n.a.	18.60
Mean stem canker incidence[c]	–	–	**	–	–	–	–
C.V.	–	–	10.00	–	–	–	–
Mean stem form	–	–	–	–	–	–	***
C.V.	–	–	–	–	–	–	6.30
Cinara infestation[d]	–	–	–	–	–	–	*
C.V.	–	–	–	–	–	–	11.4
Wood basic density (kg/m^3)	–	–	–	–	–	–	ns
C.V.	–	–	–	–	–	–	6.4

[a]) ns - not significant at P > 0.05; *) – significant at P < 0.05; **) – significant at P < 0.01; ***) significant at P < 0.001; – data not available.

[b]) C.V. - coefficient of variation (%); n.a. - not available.

[c]) Distinguishable families: U1, K152, U3, U6, U2, K10, K87, K162, K160 and U7.

[d]) Distinguishable families: U1, K165, K160, U6, K150, K159, U2, U4, U9 and U10.

Table 4. – Mean stand basal area and volume development trends of *Cupressus lusitanica* families at Hambalawei, Lushoto, Tanzania.

Progeny code	Age (years)								
	5	7	14	19	27	5	7	14	27
	Basal area (m^2/ha)					Standing volume (m^3/ha)			
T6	22.38	23.93	33.95	37.4	42.10	97.0	137.9	286.1	356.7
T14	17.70	20.34	32.05	35.97	42.20	106.9	129.0	266.9	383.5
T16	19.69	23.27	33.89	40.16	43.00	112.6	139.9	288.4	360.4
T33	19.80	23.70	30.70	41.10	44.90	113.4	138.9	262.1	404.7
T71	18.12	21.62	35.07	41.94	75.20	106.2	130.1	326.1	395.6
K9	20.36	23.50	40.19	40.25	55.80	114.7	139.9	361.7	490.1
K10	20.08	25.12	36.50	40.55	46.60	116.3	149.2	321.5	370.0
K48	18.88	21.90	33.45	37.29	40.20	110.2	131.7	290.4	350.8
K87	20.07	24.14	40.62	46.90	55.90	111.8	147.6	371.8	475.2
K150	19.44	24.96	37.81	46.06	50.10	113.6	144.6	339.1	406.0
K151	16.79	20.98	33.90	38.74	39.80	99.6	129.7	293.6	320.9
K152	23.05	28.60	48.20	56.64	73.30	120.6	162.3	466.8	618.7
K154	18.10	21.28	28.02	30.50	31.10	104.5	128.7	230.1	237.9
K157	18.70	23.34	35.90	40.24	50.20	115.3	137.1	315.1	383.5
K158	19.24	23.15	33.60	40.90	46.20	111.0	136.6	292.0	378.0
K159	18.34	23.02	32.10	42.70	53.4	107.9	136.0	273.0	331.5
K160	17.75	21.50	35.70	41.18	49.10	105.4	133.1	312.1	434.9
K161	19.98	21.74	33.22	38.68	42.20	110.5	133.2	307.7	354.4
K162	21.08	23.95	39.49	44.70	53.70	110.4	143.0	339.3	458.9
K163	16.50	21.41	32.41	33.50	35.10	100.1	129.5	265.2	295.4
K164	16.80	21.37	31.86	35.40	36.20	109.1	125.7	267.6	298.0
K165	18.21	20.88	30.48	34.15	38.20	106.3	127.1	254.0	319.8
K166	16.54	20.93	32.90	38.79	35.80	101.9	125.7	279.3	295.7
U1	22.79	27.93	47.40	55.82	70.00	134.9	172.5	459.1	627.4
U2	22.13	25.81	37.50	46.24	53.80	114.9	149.5	347.6	487.9
U3	20.65	25.54	44.39	51.26	65.30	122.8	145.3	418.6	554.8
U4	17.63	20.96	30.98	35.53	38.60	104.8	129.8	259.4	339.4
U6	22.85	27.95	42.16	48.91	61.20	125.3	162.1	380.8	547.9
U7	20.14	24.77	39.20	45.90	51.70	118.0	152.7	353.9	433.8
U9	19.49	23.80	36.20	41.02	49.50	123.1	138.9	326.0	411.0
U10	19.40	23.12	35.80	40.80	46.30	115.1	141.7	315.3	402.6
Sungwi	23.50	26.42	37.53	44.50	51.30	126.3	151.7	342.7	420.3
Pr>F-ratio	*	***	***	*	**	***	***	**	***
C.V. (%)[3]	12.61	9.50	10.54	12.13	???	8.57	7.05	13.44	18.60

[1]) T-Tanzania, K-Kenya, and U-Uganda

[2])*) – significant at $P < 0.05$, **) – significant at $P < 0.01$, ***) – significant at $P < 0.001$;

[3]) C.V. - coefficient of variation (%)

sample was digested in sulphuric acid followed by oxidation by hydrogen peroxide (LOWTHER, 1980). Total N in the digest was determined by the microkjeldahl procedure. Total P in the digest was estimated by the ascorbic acid method. Available P was determined by the Bray I method. Carbon was estimated by the loss on ignition method.

Data analysis

Statistical analyses were carried out using SAS (SAS Inst. Inc., 1987). Each tree variable (Dbh (cm), survival %, height (m), stem form, canker incidence, degree of *Cinara* infestation, wood basic density (kg/m^3), stand basal area (m^2/ha) and stand volume (m^3/ha)), were subjected to analysis of variance (ANOVA) using plot means. Individual tree volume was calculated using an equation (MALIMBWI *et al.*, 1992) shown below. Standing volume per plot was calculated as summation of individual tree volumes in a plot. For each plot, standing total wood volume was then expressed on a hectare basis.

$$V = 0.0355 + 0.00003D^2H$$

where:

V = Individual tree volume (m^3/tree)

D = Diameter at breast height (cm)

H = Tree height (m).

Prior to ANOVA, survival % data were subjected to arc sine transformation and score data were transformed by square root transformation to force normality and equal variance (SOKAL and ROHLF, 1969; KILINGANIRE and HALL, 1993).

To identify the best and the worst overall performing family at 27 years, ordinal ranking was developed. For each block and each growth parameter evaluated, families were assigned

Table 5. – Performance of 32 families of *Cupressus lusitanica* from Kenya, Tanzania and Uganda at Hambalawei, Lushoto, Tanzania.

Traits	Origin of progenies	Age (years) 1	3	5	7	14	19	27
Survival (%)	Kenya	92.8	97.3	97.0	94.0	68.0	65.9	58.2
	Tanzania	96.9	97.5	97.5	94.0	68.2	66.3	59.7
	Uganda	98.7	98.1	86.3	97.2	68.6	76.6	62.7
	Control	100.0	95.3	98.8	98.8	68.8	65.5	59.3
	Pr > F-ratio[1]	ns	ns	ns	ns	ns	ns	ns
	C.V. (%)[2]	3.4	3.8	4.8	5.4	2.2	7.4	12.2
Height (m)	Kenya	0.8	5.4	7.6	9.6	17.6	–	21.6
	Tanzania	0.9	5.6	7.6	9.6	17.5	–	21.6
	Uganda	0.9	6.0	8.0	9.9	17.6	–	22.3
	Control	0.9	5.9	8.1	9.8	18.2	–	20.8
	Pr > F-ratio	***	***	***	*	**		*
	C.V. (%)	9.1	6.8	4.8	4.4	5.0	–	4.5
Dbh (cm)	Kenya-	–	8.4	12.5	13.8	19.9	21.5	24.4
	Tanzania	–	8.9	12.6	13.7	19.7	21.6	23.7
	Uganda	–	9.2	13.2	14.4	20.7	23.0	25.6
	Control	–	9.2	13.2	14.8	21.5	23.0	25.9
	Pr > F-ratio		***	**	**	*	**	***
	C.V. (%)	–	9.7	5.2	4.7	7.2	5.6	6.2
Basal area (m^2/ha)	Kenya	–	–	18.9	22.9	35.4	40.4	42.6
	Tanzania	–	–	19.3	22.6	33.1	39.3	43.6
	Uganda	–	–	20.6	24.9	39.2	45.7	48.4
	Control	–	–	23.5	26.4	37.5	44.5	51.3
	Pr > F-ratio			*	***	***	*	*
	C.V. (%)	–	–	12.6	9.5	10.5	12.1	16.9
Stand volume (m^3/ha)	Kenya	–	–	100.9	136.7	310.0	-	378.9
	Tanzania	-	-	107.2	135.2	283.9	-	380.2
	Uganda	-	-	119.9	119.9?	357.6	-	475.5
	Control	–	-	126.3	126.3?	342.7	-	420.3
	Pr > F-ratio			***	***	***	–	***
	C.V. (%)	–	-	8.6	8.6?	13.4	–	18.6
Stem form	Kenya	-	1.5	-	1.6	1.2	–	1.3
	Tanzania	-	1.5	-	1.6	1.3	-	1.3
	Uganda	-	1.5	-	1.6	1.2	-	1.2
	Control	-	1.5	-	1.6	1.3	-	1.4
	Pr > F-ratio	-	ns	-	ns	ns	-	ns
	C.V. (%)	–	–	–	–	–	–	–
Canker infestation	Kenya	–	1.2	–	1.3	–	–	–
	Tanzania	-	1.2	-	1.3	-	–	–
	Uganda	-	1.2	-	1.2	–	–	–
	Control	-	1.3	–	1.2	–	–	–
	Pr > F-ratio	-	ns	-	ns	-	–	–
	C.V. (%)	–	–	–	–	–	–	–
Cinera infestation	Kenya	–	–	–	–	–	–	1.2
	Tanzania	–	–	–	–	–	–	1.4
	Uganda	–	–	–	–	–	–	1.3
	Control	–	–	–	–	–	–	1.3
	Pr > F-ratio[1]	-	–	–	–	–	–	*
	C.V. (%)[2]	–	-	–	–	–	–	–

[1]) ns - not significant at P > 0.05, *) – significant at P < 0.05, **) – significant at P < 0.01, ***) – significant at P < 0.001;

[2]) C.V. - coefficient of variation (%)

Note: For each assessment date and each assessment attribute, country with low mean score was the best performer.

ranks from the best (assigned 1 point) to the worst (assigned 32 points) performing family. Thereafter, ranks were added, averaged, and the overall score was taken as a basis of the overall species/provenance ranking.

Results

Observation of the families en bloc

The experiment was assessed for survival, height, Dbh, basal area, standing volume, and stem canker incidence on each assessment date and *Cinara* infestation on final assessment and wood basic density. These data were subjected to ANOVA. Specific reference to each test is likely to mask salient findings. *Table 3* is an attempt to overcome this problem. Significant ($P < 0.05$) differences were observed for all traits studied except for mean survival and wood basic density were none ($P > 0.05$) were detected. Coefficients of variation do not seem to show a consistent trend as high levels of significance (e.g. in *Table 4*) do not always correspond with high coefficients of variation.

Observation of the families on the basis of origin

Table 5 shows family performance in terms of survival, height, Dbh, basal area and standing volume by country of origin. Different levels of significance are observed in all traits assessed except survival. Coefficients of variation maintained the characteristic of showing no consistent trend.

Ordinal ranking of families

Ordinal ranking of the 32 families is shown *table 6*. The overall top 10 families are K9, U6, K152, U1, U162, K87, K150, K160, and K162.

Discussion

A 5 year post establishment assessment of this trial (PERSSON, 1972), focused on height, diameter, stem straightness, and canker attacks. Analyses of variance gave significant differences between families for all traits except canker attacks. In this paper 5 additional traits have been added. As the trial has approached its 30 year rotation age, it is appropriate to amplify statements made in the foregoing sections as users of the resulting information are sawmillers and forest managers.

Stand volume production is of considerable interest as this carries with it other parameters namely: survival, height, Dbh and basal area, stem canker, stem form, and *C. cupressi* infestation. Wood basic density does not call for further comments as no significant differences ($P > 0.05$) were found

Table 6. – Ordinal ranking of tree and stand attributes of 27 year old *Cupressus lusitanica* families grown at Hambalawei, Lushoto, Tanzania.

Progeny code	Stand attribute								Mean	Overall rank
	Stocking	Height	Dbh	BA	Volume	B.D.	S.F.	C.I.		
T6	6	7	10	17	20	32	2	1	11.9	24
T14	4	4	11	17	16	14	4	2	8.9	17
T16	8	7	8	16	19	25	4	4	11.4	23
T33	6	5	9	15	13	20	3	3	9.3	19
T71	10	3	7	1	15	29	4	6	9.4	20
K9	5	2	6	6	5	1	4	4	4.1	1
K10	6	8	7	13	18	4	4	7	8.4	16
K48	8	2	10	19	22	6	3	2	9.0	18
K87	7	2	4	6	7	17	5	6	6.8	6
K150	9	4	5	10	12	3	5	7	6.9	7
K151	11	5	8	20	25	12	5	2	11.0	21
K152	2	2	2	2	2	30	4	2	5.8	3
K154	13	8	11	26	30	31	1	2	15.3	28
K157	1	6	9	10	16	7	4	3	7	8
K158	3	6	10	14	17	2	4	5	7.6	11
K159	7	6	10	18	24	23	4	3	11.9	24
K160	4	4	8	12	9	8	6	6	7.1	9
K161	5	5	11	17	21	22	3	4	11.0	21
K162	6	5	6	6	8	15	4	8	7.3	10
K163	12	6	9	25	29	11	4	6	12.8	27
K164	13	7	8	23	27	5	4	2	11.1	22
K165	8	7	11	22	26	18	5	2	11.1	22
K166	14	5	8	24	28	10	6	5	12.6	26
U1	2	1	3	3	1	28	5	7	6.3	4
U2	3	4	6	7	6	27	5	6	8.0	14
U3	8	2	1	4	3	26	3	5	6.5	5
U4	7	6	12	21	23	19	5	2	12.0	25
U6	1	2	6	5	4	9	5	6	4.8	2
U7	6	4	6	8	10	21	5	2	7.8	12
U9	5	6	7	11	12	16	4	2	7.9	13
U10	7	4	7	14	14	13	5	3	8.4	16
Sungwi	7	7	6	4	11	24	2	4	8.1	15

[1]) T - Tanzania, K - Kenya, and U - Uganda.

B.A. - basal area; BD - wood basic density; C.I. - *Cinara cupressi* infestation; S.F. - stem form.

(*Table 3*) among the families tested. However, it is important to note that wood basic density observed in this study is comparable to that observed for *C. lusitanica* at Lushoto (LUOGA *et al*., 1994) and North Kilimanjaro (MALIMBWI *et al.,* 1992).

Stand volume production

Tables 3 and *4* show that at 27 years families U1, K152, U3, U6, U2, K10, K87, K162, K160 and U7 rank highest, with mean standing volume varying between 434 m^3/ha and 627 m^3/ha. These stand volumes are well above those published viz. 380 m^3/ha at 23 years of age (ADLER, 1975), 351 m^3/ha at 23 years of age (LUOGA *el al*., 1994) and 349 m^3/ha at 19 years of age (MALIMBWI *et al*., 1992). It is worth noting that in this trial, thinning was selectively carried out only once. This partly explains the somewhat high standing volume.

Volume production considerations should not be viewed in isolation. The results need be linked with site conditions, and where conditions allow, the quality of the wood that is produced. As this study involves a family test it is well ahead of a provenance test. This may further explain high volume production reported here. Reference to site conditions, Hambalawei soils (*Table 1*) are poorer than the soils derived from volcanic ash and those from biotite gneisses covered by volcanic ash. In Tanzania, such soils dominate the Meru and Kiwira Forest Projects, respectively (MOSHI *et al*., 1989). The planting of the tested families in these projects is expected to give higher volume production than that recorded hitherto. Thus indicating the need and potential gains resulting from planting improved genetic material.

The omission of some thinnings affected basal area and volume distribution among families (*Table 4*). If thinnings were carried out according to schedule, trees destined for final felling would have developed bigger basal area and corresponding volume; as a result of reduced competition. This would have meant experiencing logging and sawmilling difficulties as unusually large sized logs are difficult to handle. Such problems would be compounded by favourable site conditions such as those earlier reported for Kiwira and Meru Forest Project plantations. To contain this problem a revision of spacing and thinning prescription would be mandatory.

Stem canker and stem form

Significance test results for these 2 parameters are shown in *table 3*. It can be noted that families U1, K165, K160, U6, K150, K159, U2, U4, U9 and U10 were superior to the rest. It is interesting to note further that with the exception of U1, U2, U6, and K160, these families are not outstanding in terms of volume production. Volume production in cypress however is considerably influenced by both stem canker and straightness. Fortunately, selection may be used for the improvement of both these parameters. Maximum damage resulting from the cypress canker disease is known to occur between 3 and 8 years (GILL, 1963). If the tree is unattacked up to 8 years, it will no longer be susceptible. Furthermore, cypress canker can to some extent be controlled by thinning out diseased trees at the earliest opportunity. The planting of *C. lusitanica* in favour of *C. benthamii* and its hybrids has considerably checked the prevalence of this disease (Forest Division, 1982).

Infestation resistance

Cinara cupressi, the cypress aphid was accidentally introduced into Malawi in 1986. The aphid has since spread to some of the Preferential Trade Area (PTA) countries namely: Burundi, Kenya, Malawi, Rwanda, Tanzania and Zambia. The PTA sub-region industrial forest plantations were established at an estimated cost of US$ 2 billion and currently are valued at hundreds of millions of dollars in wood products. *Cupressus* species account for a significant proportion of these plantations notably in Burundi (4740 ha), Kenya (168,000 ha) and Rwanda(110,475 ha) (PTA, 1990, 1991).

Tanzania has some 15,000 hectares of *C. lusitanica* plantations whose value (1986 prices) were US$ 0.103 billion (MTUY, 1986). The aphids feed on smaller twigs in the main part of the crown of the trees. This feeding reduces tree vigour and causes branch dieback. Heavy aphid infestation results in the death of trees.

Although the extent of damage resulting from aphid infestation in cypress plantations in Tanzania has not been quantified, it is clear that current family tests need take resistance against aphid infestation into consideration.

Table 5 shows families: K48, K151, K152, K154, K157, K159, K164, T6, T14, T33, U4, U7, U9, and U10, as being relatively tolerant of aphid infestation. A 3 year observation (OBIRI *et al*., 1994) involving 30 clones (families) revealed that U3 and T71 were overall best clones. In this study family U3 showed slight infestation while T71 has been destroyed by the aphids. It is worth observing that although the Mkusu seed orchard and Hambalawei are both in the Usambara Mountains and are less than 20 km apart, the Mkusu seed orchard is relatively wetter than the Hambalawei trial site. This seems partly to explain differences in family performance since the cypress aphid is sensitive to wet conditions.

Families K9, K159, K161 K165, U3, Sungwi, and T16 were heavily infested with aphids (*Table 6*). Families that displayed poorest aphid infestation tolerance were: K10, K87, K150, K160, K162, K163, K166, T71, U1, U2 and U6. Thus based on the consideration of aphid infested tolerance alone, the heavily infested and poorest performing families should be rogued out.

Suitable families

The best 10 families (*Table 6*) have been listed in descending order as: K9, U6, K152, U1, U3, K87, K150, K157, K160 and K162. This assessment however, is based on overall family performance. When aphid infestation resistance is put into consideration only families K152 and K157 are suitable. This observation is in contrast with OBIRI *et al*., (1994) where is it reported that the most resistant clones were U3, U1, and U2. It is further observed that clones T71, T72 and T73 also displayed remarkable resistance and good growth vigour. For the Kenyan clones, it was reported that only K152, K186, and K150 showed outstanding features of resistance. Clones in brackets were not used in this study.

Though contradictory, these 2 studies must both be used in making recommendations concerning family suitability; strengths and weaknesses of each study must be taken into consideration. OBIRI *et al*. (1994) used 5 sites located in an area in which mean annual rainfall was in excess of 1000 mm. The traits studied were mean: aphid damage, height and diameter. In this study, one site receiving some 900 mm mean annual rainfall was used, and 9 traits have been studied.

As earlier observed, mean annual rainfall differences between Hambalawei and the 5 sites of the other study seems to explain differences in family performance. Thus, a combination of the findings from the 2 studies (involving overall best families) suggests that families U1, U3, K152, and K150 emerge as the overall best.

Based solely on the findings of this study i.e. overall best performance and mean aphid infestation resistance score of 4 points or lower suitable families are K9, K152 and K157. This recommendation assumes that aphid damage will not be

controlled in the immediate future. If the work being done by TAFORI in collaboration with the International Institute of Biological Control (IIBC) gives immediate results for the biological control of *C. cupressi* a revisit of these recommendations is imperative.

Conclusion and Recommendations

Results from this study call for a qualified set of recommendations concerning suitable families that merit further breeding work.

Based exclusively on the results from this trial, suitable families 'judged on the basis of high volume production and resistance to *Cinara* infestation' that merit further breeding work are K9, K152, and K157. When the results are combined with those from another study (OBIRI *et al*., 1994) involving more sites, families U1, U3, K152, K150 and K157 merit further breeding work. These recommendations pre-suppose slow advances in the biological control of the *C. cupressi* infestation.

When *C. cupressi* is finally contained, the best 10 families identified in this study namely: K9, U6, K152, U1, U3, K87, K150, K157, K160, and K162 merit further breeding work. This large number of families will widen the genetic base.

As family representation does not involve equal numbers from Kenya, Uganda and Tanzania the conclusions given call for further caution.

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Isozyme Characterization of *Eucalyptus urophylla* (S. T. BLAKE) and *E. grandis* (HILL ex MAIDEN) Populations in Brazil

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Abstract

Seedling taken from 2 species of *Eucalyptus* growing in Brazil were electrophoretically analysed at 14 isozyme loci representing 6 enzyme systems: α-EST, ß-EST, SKDH, IDH, MDH, and LAP. Genetic variability measures were determined using 11 putative isozyme loci. On average, 81.8% and 54.5% of the loci were found to be polymorphic by the criterion of 95% in *E. urophylla* and *E. grandis*, respectively. The mean number of alleles per loci was 3.0 in *E. urophylla* and 2.5 in *E. grandis*. Observed mean heterozygosity was 0.283 in *E. urophylla* and 0.166 in *E. grandis*. Levels of genetic diversity in these species were similar to those in other *Eucalyptus* species which have

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