GENETIC VARIABILITY AND INHERITANCE OF QUANTITATIVE TRAITS IN CUPRESSUS LUSITANICA

BY

J.A.F. OBIRI

TREE BREEDING DIVISION

GENETIC VARIABILITY AND INHERITANCE OF QUANTITATIVE TRAITS IN CUPRESSUS LUSITANICA

SUMMARY

Cupressus lusitanica Miller is an important softwood in Kenyan industrial forestry. Cummulative analysis of variance data was collected from two sites within Kenya (Muguga and Elburgon) and used to estimate genetic and environmental variance components for height, diameter, stemform and canker resistance in cypress. Heritability estimates suggests that height, diameter and hence volume may be improved by family (progeny) selection. However stemforms and canker resistance may be best enhanced by individual selection.

Genetic and environmental correlation coefficient between the traits were obtained using covariance components from analysis of covariance. Estimates of genetic correlation coefficient are positively correlated for all the four traits. Thus selection for one trait may be improved by simultaneous selection of any other trait. However the genetic correlation coefficient found between diameter and stemforms limits the use of diameter as a selection parameter when selection is aimed at an overall increase in economic value.

INTRODUCTION

Cupressus lusitanica Miller is an important exotic softwood grown in Kenya for timber production (Dyson 1977). The improvement of economic value of this tree largely relies on selection as a breeding strategy. This selection is generally based on several characters simultaneously and not just one as economic value depends on more than one character. However estimates of genetic variability for the characters are a pre-requisite to selection because they make possible a choice of the most efficient selection method, the prediction of the genetic gain from the selection itself and an estimate of the ultimate cost. Besides, knowledge of genetic correlation between various traits help to improve the efficiency of selection by use of favourable combinations of characters and also minimise the retarding effect of negative correlations. This study was undertaken to determine heritability estimates, genetic and phenotypic correlation coefficient of four characters in Cupressus lusitanica Miller grown at Muguga estate and replicated at Elburgon.

MATERIALS AND METHODS

The experiment (E.P.86) is situated at Muguga estate compartment I(G) while the replicate is at Elburgon (Sokoro compartment 4(F). The former lies within 1° 12' South, latitude; 37° 37' East longitude at an altitude of 6800 ft a.s.l. with a mean annual rainfall of 1100 mm and silty loam soil of aggregate size. The latter is situated at 0° 21' South latitude, 35° 51' East longitude and at 7803 ft a.s.l. Annual rainfall here is 1300 mm with sandy soil of poor structure.

The seeds used were raised from a control pollination set-up that involved five plus trees selected from various localities within Kenya. The pollination resulted into fourteen successful families under a factorial mating design of five males and three females. One family was incorporated as a missing value to add up to a total of fifteen.

The experiment was planted in 1973 under a randomised block design of 4 blocks each with 12 trees per plot spaced at 2.5 m X 2.5 m. The experiment was tended under the normal shamba system for the first three years. Normal plantation management practices were carried out. Hence, the trial was slashed, pruned to half height at three year intervals and thinned to half the original stock at the age of eight. Assessments on heights and survival counts were done one year after planting. From the fifth year onwards, heights, diameter at breast height (DBH), canker scores and stemform scores were assessed on a biannual basis up to the fourteenth year. The Elburgon replicate was not assessed in 1982 and 1987. Damage from canker disease (canker scores) and stem straightness (stemform scores) were assessed on a five point scale as follows:

Canker Damage

(1) No canker observed

(2) Canker on branches only

(3) Stem canker present but negligible distortion

(4) Stem distorted that value of saw-log impaired

(5) Stem not utilizable for saw timber or tree dying or dead from canker

Stem Straightness

(1) Erect and perfectly straight

(2) Slight bend

(3) Moderate bend

(4) Severely crooked, butt log and would require cross cutting before sowing

(5) Stem so crooked that saw-log cannot be cut from it

Statistical Model and Data Analysis

Plot mean values were used as entries into the analysis of variance of the families to estimate variance components between the families and residual error variation. To obtain the quantifying structure of genetic variation in the progenies, the variance between the family means was further partitioned into paternal half-sib covariances between males (σ_M^2), maternal half-sib covariances between females (σ_F^2) and the variance due to interaction effect of males and females (σ_{MF}^2). This is shown on the table below.

TABLE 1: Form Of Analysis Of Variance For Control Pollination Progenies Based On Plot Means.

Source	D.F.	Expected Mean Square	Observed Component
Replications	(K - 1)		
Males	(M - 1)	$\sigma_W^2 + K\sigma_{FM}^2 + F\sigma_M^2$	$V_E + V_D + V_A$
Females	(F - 1)	$\sigma_W^2 + K\sigma_{FM}^2 + M\sigma_F^2$	$V_E + V_D + V_A$
Males X Females	(M - 1) (F - 1)	$\sigma_W^2 + K\sigma_{FM}^2$	$V_E + V_D$
Residual	(K - 1) (MF -1)	σ_W^2	V_E

Following Kearsy (1965) each of the two half-sib covariances give estimates of a quarter additive genetic variance ($\frac{1}{4} V_A$).

The Male X Female interaction variance component provides direct estimates of a quarter dominance genetic variance ($\frac{1}{4}V_D$). The residual variance component provides estimates of environmental variance (V_E). Thus, the estimates of variance components of additive genetic variance V_D and environmental effects V_E were obtained and used to calculate narrow sense heritabilities of the four traits.

Falconer (1960, 1981) defines narrow sense heritability (h^2) of metric characters as the ratio of additive genetic variance (V_A) to total phenotypic variance (V_P).

Hence

$$h^2 = \frac{V_A}{V_P} = \frac{V_A}{V_G + V_E} = \frac{V_A}{V_G + V_D + V_E}$$

RESULTS

TABLE 2: Heritability estimates, means and S.E. of means of 4 traits of <u>Cupressus lusitanica</u> calculated of five ages from Muguga site.

Year of Assessment	Age From Field Planting	Height (m)			Diameter (cm)			Stemform			Canker Damage		
		h^2	Mean	S.E.	h^2	Mean	S.E.	h^2	Mean	S.E.	h^2	Mean	S.E.
1978	5	0.21	6.37	±0.20	0.30	9.73	±0.40	0.92	3.11	±0.08	0.70	2.16	±0.17
1980	7	0.23	8.8	±0.21	0.49	13.78	±0.38	0.47	3.3	±0.09	0.58	2.6	±0.3
1982	9	0.56	10.9	±0.26	0.75	18.27	±0.47	0.96	2.78	±0.08	0.79	2.41	±0.11
1986	13	0.35	14.9	±0.27	0.85	21.86	±0.57	0.56	2.81	±0.09	0.63	2.18	±0.12
1987	14	0.47	15.3	±0.35	0.76	22.18	±0.53	0.76	2.60	±0.10	0.78	1.98	±0.79
Average h^2		0.36			0.64			0.73			0.70		

TABLE 3: Heritability estimates, means and S.E. of means of 4 traits of <u>Cupressus lusitanica</u> calculated at three ages from Elburgon site.

Year of Assessment	Age From Field Planting	Height (m)			Diameter (cm)			Stemform			Canker Damage		
		h^2	Mean	S.E.	h^2	Mean	S.E.	h^2	Mean	S.E.	h^2	Mean	S.E.
1978	5	0.62	6.9	±0.20	0.27	10.2	±0.28	0.53	3.07	±0.03	0.13	2.8	±0.08
1980	7	0.40	9.9	±0.15	0.23	16.42	±0.38	0.41	2.56	±0.11	0.49	2.26	±0.08
1986	13	0.22	15.2	±0.29	0.43	23.6	±0.61	1.12	2.0	±0.84	0.99	1.9	±0.12
Average h^2		0.41			0.31			0.69			0.54		

TABLE 4: Heritability estimates, means and S.E. of means of 4 traits of *Cupressus lusitanica* calculated at three ages from pooled sites (Muguga/Elburgon).

Year of Assessment	Age From Field Planting	Height (m)			Diameter (cm)			Stemform			Canker Damage		
		h^2	Mean	S.E.	h^2	Mean	S.E.	h^2	Mean	S.E.	h^2	Mean	S.E.
1978	5	0.19	6.64	±0.16	0.41	10.0	±0.29	0.50	3.09	±0.05	0.86	2.48	±0.11
1980	7	0.34	9.32	±0.15	0.42	15.02	±0.35	1.10	2.93	±0.09	0.20	2.38	±0.09
1986	13	0.17	15.03	±0.23	0.48	22.71	±0.55	0.76	2.39	±0.08	0.58	2.03	±0.11
Average h^2		0.23			0.44			0.79			0.55		

TABLE 5: Genetic correlation coefficient between four traits in *Cupressus lusitanica*.

Trait	Diameter	Canker Damage Score	Stem Form Score
Height	+0.682**	-0.763***	-0.240
Diameter	-	-0.066	+0.04
Canker Damage Score	-	-	+0.836**

TABLE 6: Environmental correlation coefficient between four traits in *Cupressus lusitanica*.

Trait	Diameter	Canker Damage Score	Stem Form Score
Height	-0.479	-0.856*	-1.13**
Diameter	-	+0.386	+0.163
Canker Damage Score	-	-	+0.705

Significance levels - *** P = 0.001
** P = 0.01
* P = 0.1

RESULTS AND DISCUSSION

(1) Genetic Variability

Tables 2, 3 and 4 show heritability estimates for Muguga, Elburgon and that of the two sites pooled together. At Muguga site, height and diameter showed much lower heritability than stemforms and canker resistance. The same trend was observed at Elburgon site. When the two sites were pooled together, the results also showed the same trend as in the individual sites. The mean height and mean diameter as indicated in Tables 2, 3 and 4 showed a substantial increase with the age of the crop. However, the mean stemform score and mean canker score gradually dropped with increased age of the trees. The decrease of canker with age could be envisaged as the effect of the trees gradually healing the original canker wounds with time. Similarly, the drop in stemform scores is as a result of the gradual rectification of stem distortions with the age of the crop.

Several reasons have been put forward for requiring heritability. Falconer (1981) outlines two main reasons as determining the criterion of selection and estimating expected improvement from the selection. The fact that canker resistance and stemform showed higher heritabilities than diameter and height suggests that improvement of stemform and canker resistance should be done by individual selection. However for diameter and height, emphasis should be placed on family (progeny) selection. The advantage of family selection as in the latter case is based on the fact that individual deviations due to the environmental variations tend to cancel each other in the family means. Hence, the family phenotypic means is a close representation of the genotypic constitution. This advantage is magnified when a large portion of phenotypic variance is due to the environment or when the heritability is low. High inheritance of canker resistance in cypress has been suggested by Olembo (1969) who showed that canker incidences in plantations dropped from 22% in 1942 to as low as 4% in 1969 through the efforts of selection work. Further improvement on canker resistance could be realised through individual selection in the present progeny trials.

(2) Correlation Between Characters

Genetic and environmental correlation for four characters is shown in Tables 5 and 6. The results show that the associations between height/diameter and canker/stemform scores have a significant positive genetic correlation coefficient. This indicates that these characters are pleiotropic or have a common genetic background acting in the same direction on all characters. The relations between height/canker scores and height/stemform scores show a strong negative environmental correlation coefficient at significance levels of P = 10% and P = 0.1%. This suggests that the environment is exerting a common influence on these characters.

Very significant genetic correlation coefficients were found between the associations of height/diameter, height/canker score and stemform/canker score. Negative correlation coefficients were found for the relation between height/canker scores, height/stemform score and diameter/canker score. From these results, it is evident that increase in height is strongly correlated with low canker score (or low attacks of canker). Similarly, height increase showed corresponding drop of stemform scores thus the stemform improved with height. However, diameter increase showed a corresponding rise in stemform score and thus the tree bole becomes poorer as the diameter increases. These results suggest that selection on the basis of diameter is not strategic as it will only yield positive response on height and canker resistance with the stemforms being poor. Height would however be a better selection parameter as it yields a more positive response by trees having better stemforms, thicker diameter and higher resistance to canker attacks.

CONCLUSIONS

Correlation coefficient between characters is very important for better planning of selection programs geared to improving production characters like height, diameter and volume. It is possible to improve various characters by selection for one character only. Increase in response to selection for one character; for instance resistance to canker disease can be improved by selecting at the same time for another character like height which is more detectable. This aspect for indirect selection may lead to more rapid progress.

In addition to correlation studies, heritability estimates can help to predict genetic gain and hence help in drawing more viable breeding programs. Although initial estimates may not be precise, they are important in breeding as the go along way in improving the final outcome.

REFERENCES

Bishop O.N., Statistics for Biology Microcomputer Edition (1983).

Burly J., Burrows P.M., Armitage F.B. and Burns R.D. Progeny test designs for Pinus radiata in Rhodesia Silva Genetica 15: Pgs 166 - 172 (1966).

Dyson W.G. and Patterson D.N. Selection and appraisal of plus trees in East African tree breeding programme E.A.A.F.R.O. For. Tech. Note No.17 (appendix 2) (1966).

Dyson W.G. and Raunio A.L. Revised heritability estimates for Cupressus lusitanica in East African Silvae Genetica 26: Pgs 193 - 196 (1977).

Falconer D.S. Introduction to quantitative genetics (2nd Edn). Longman Inc. New York (1981).

Hanson W.D. and Robinson H.F. Statistical genetics and Plant Breeding NAC-NRD Publication 982 (1963).

Kearsy M.J. Biometrical analysis of a random mating population: a comparison of five experimental designs Heredity 20: Pgs 205 - 235 (1965).

Sinha S. and Sinhal V. Cytogenetics, Plant Breeding and Evolution. 5th Edn. (1974).

Olembo T.W. The incidences of cypress canker disease in East Africa. East Afr. Agric. For. J. 35(2). Pgs 166 - 173 (1969).

Wright J.W. Genetics of Forest improvement. F.A.O. 1962 (Pgs 87 - 113).