material of good quality for subsequent selection (SILEN 1966). This is particular to forest tree breeding, because of the broad variability in wild populations.

With an intensity of selection rather strong (2 % for Douglas-Fir and 5 % for Sitka-Spruce), it is already possible to create commercial clonal seed orchards. It is necessary now to test the quality of commercial seeds to be produced there.

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A basis for selecting Hevea clones stable to unpredictable agro-climatic variability

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Summary

Joint regression analysis for the two characters first height measurement and survival rate showed, that the genotype × environmental interaction among ten *Hevea* clones was mainly non-linear. Thus the regression coefficient alone cannot be used to explain the stability of *Hevea* clones to environmental variation. Therefore the variance of each clone over all environments has been used as the index of stability. A method is described to select *Hevea* clones stable to unpredictable types of agro-climatic variability, with desired levels of mean performance.

Key words: *Hevea*, Genotype-environment interaction, variance, stability, mean performance, selection.

Zusammenfassung

Die durchgeführte Regressionsanalyse für die beiden untersuchten Merkmale hat nachgewiesen, daß die Genotyp-Umwelt-Interaktion bei den 10 *Hevea*-Klonen in erster Linie nicht linear ist. Daher kann der Regressionskoeffizient allein nicht verwendet werden, um die Stabilität der *Hevea*-Klone gegenüber variierenden Umwelteinflüssen zu erklären. Deshalb wurde die Variabilität der einzelnen Klone gegenüber allen Umwelteinflüssen als Stabilitätsindex benutzt. Es wird ein Verfahren zur Selektion von *Hevea*-Klonen beschrieben, die gegenüber unvorhersehbarer Stabilität gegenüber agroklimatischer Variabilität das gewünschte Niveau als durchschnittliche Leistung aufweisen.

Introduction

In the presence of genotype × environment interaction the relative performance of clones varies with the environment.

Results of clone evaluation trials can be used to select and recommend a clone adapted to a particular agro-climatic condition if the agro-climatic differences can be defined and differentiated by factors such as rainfall, light, temperature, humidity and soil. Unfortunately agro-climatic conditions are complex and the factors which go to form them are unpredictable and cannot be controlled. Therefore the only possibility open is to use clones stable to a wide range of agro-climatic variability.

FINLAY and WILKINSON (1963) have used regression coefficients of each clone (obtained by regressing the mean performance of each clone in each environment on the mean of all the clones in that environment) as a parameter of stability. This is useful only if the response of clones to environmental variation is linear.

In the presence of significant non-linear genotype × environment interaction, a stability parameter which takes into account both the linear and non-linear portions of the interaction component has to be used.

In this paper a basis is suggested for selecting *Hevea* clones that are stable to unpredictable types of environ-

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mental variability when the response of clones to such variability is non-linear.

Materials and Method

The experimental material, the method and the two characters — survival rate and first height measurement — have all been described by JAYASEKERA, SAMARANAYAKE and KARUNASEKERA (1977).

Results and Discussion

The analysis of variance by JAYASEKERA, SAMARANAYAKE and KARUNASEKERA (1977) showed a significant genotype × environment interaction component for both characters.

Since the genotype × environment interaction was significant, a joint regression analysis was carried out as suggested by PERKINS and JINKS (1968). The results given in *Table 1* indicate that, for both characters, the heterogeneity of regression is not significant while the residual deviation is significant when tested against the error mean square. This indicates that the differences between the slopes of the fitted regression lines alone do not explain the genotype × environment interaction.

Even if the heterogeneity of regression is not significant we can still use the regression coefficients. Under such conditions, selection could only be practised among those clones that had significant regression coefficients when tested against their residual mean squares (PERKINS and JINKS, 1968; JAYASEKERA, SAMARANAYAKE and KARUNASEKERA, 1977). This will certainly restrict the number of clones available for selection. Therefore a stability parameter which takes into account both the linear and non-linear portions of genotype × environment interaction has to be used, to describe the stability of clones to environmental differences.

Variances of clones or genotypes over environments which combines the linear and non-linear variances could be used as a measure of stability (JINKS and MATHER, 1955; BUCIO ALLANIS, 1966). According to HILL (1975), a lower variance indicates a greater stability in coping with environmental differences.

Table 1. — Joint regression analyses for the two characters.

A. First height measurement.

Source of variation	D.F.	M.S.	P
Heterogeneity of regression	9	214.33	N.S.
Residual deviation	54	977.34	***
Pooled error	400	526.40	

B. Survival rate.

Source of variation	D.F.	M.S.	P
Heterogeneity of regression	9	495.46	N.S.
Residual deviation	54	617.34	***
Pooled error	720	343.00	

N.S. = Not Significant
*** = Significant at 0.1% probability level.

Table 2. — The mean performance and the grand mean of the ten *Hevea* clones.

Clone	Mean performance: First height measurement	Mean performance: Survival rate
PB 86	54.90	70.12
RRIC 100	46.45	71.62
RRIC 101	42.12	62.62
RRIC 102	58.13	67.50
RRIC 103	43.80	63.00
RRIC 52	44.94	66.00
RRIM 600	62.54	75.56
RRIC 36	54.01	69.18
RRIM 623	56.98	77.06
IAN 45/710	51.13	74.81
Grand Mean	51.50	69.74

In selecting a clone, stability is not the only criterion. It's average or the mean performance (mean over all environments) must also be considered. Depending on the character, the breeder would like to select a clone with either above-average performance or below-average performance.

In *Hevea,* height of plant has no direct economic value but it is generally accepted that tall trees are more suceptible to wind damage than short trees. In this context selection for shortness i.e. clones with below-average performance will be advantagous. On the other hand for survival we need a clone with high survival rate. Hence clones with above-average survival rates are preferred. In selection for average mean performance, the population mean or grand mean is used as the point of truncation. The mean performance of each clone calculated as the mean over all environments, and the population mean (grand mean) are given in *Table 2.*

For the first height measurement, the correlation coefficient between the mean performance of the ten clones and their variances was found to be 0.6737. This is significant at 5% probability level and indicates that it would be difficult to select against the direction of the correlation. But the correlation is not strong enough to make selection a complete failure if selection were practised against the direction of correlation.

In the case of survival rate, the correlation between mean performance and the variance was not significant with a correlation coefficient of 0.3249. This indicates the possibility of selecting clones with all four combinations of high and low mean performance with high and low sensitivity to agro-climatic variability. JINKS, JAYASEKERA and BOUGHY (1977) have discussed the possibility of selecting genotypes with different combinations of mean perfor-

mance and stability over environments when the two criteria are not completely correlated.

In the selection of stability too, the mean stability or the mean variance of the ten clones was used as the point of truncation. The variances of the ten clones and their mean (mean stability) appear in *Table 3*.

In the joint selection for the two criteria the scatter diagram, obtained by plotting the mean performance of each clone against it's stability of variance, could be used. *Figures 1* and *2* show the scatter diagrams for the two characters. Each diagram has ten points indicating the positions occupied by the ten clones under consideration. The broken lines indicate mean stability and the grand mean or population mean. These two lines divide the diagram into four quarters and help to classify the ten clones into four groups with different levels of mean performance and stability as follows.

Description	Symbol
High stability with high mean performance	HH
High stability with low mean performance	HL
Low stability with high mean performance	LH
Low stability with low mean performance	LL

With respect to height the selected clones should have below-average variances and below-average heights and will occupy the HL quarter of the diagram. It is seen from the *Figure 1* that out of the ten clones under consideration, RRIC 101, RRIC 103 and RRIC 102 have the required qualities of stability and mean performance.

Another fact which is apparent from the *Figure 1* is that there are clones occupying the LL and HH quarters. This indicates the possibility of selecting clones against the direction of correlation confirming the earlier statement that correlation between the two selection criteria is not very strong.

In the case of survival we select for the above average survival rate and the below average variance and the clones, with desirable mean performance and stability will occupy the HH quarter of the *Figure 2*. As evident from the *Figure 2*, clones RRIM 600 RRIC 100 and IAN 45/710 have stable and above average survival when compared with other clones.

Thus it is seen that the variance and the mean performance could be used as parameters in the selection of *Hevea* clones that are well buffered and show general

Table 3. — The variances of the ten clones and their mean (mean stability).

Clone	Variance	
	First height measurement	Survival rate
PB 86	31.81	130.34
RRIC 100	70.23	63.48
RRIC 101	22.46	91.125
RRIC 102	74.50	64.29
RRIC 103	13.53	51.43
RRIC 52	67.72	46.29
RRIM 600	105.91	48.17
RRIC 36	53.78	122.42
RRIM 623	80.66	160.03
IAN 45/710	37.49	70.35
Mean Variance	55.81	84.79

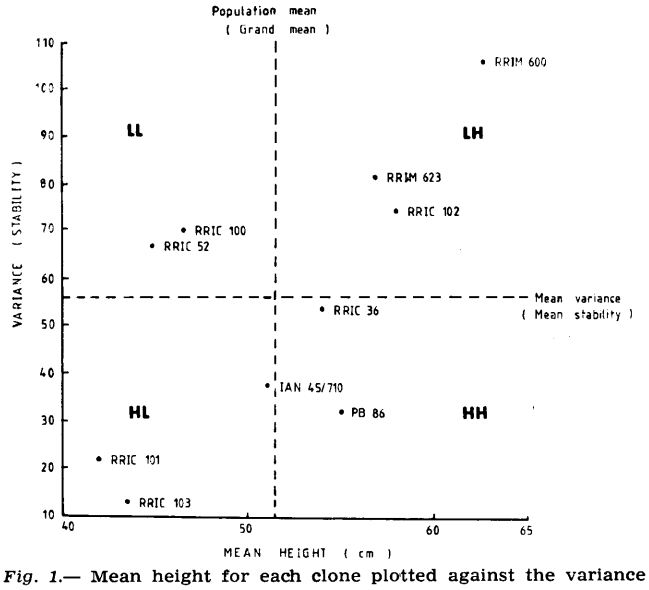

Fig. 1.— Mean height for each clone plotted against the variance over environments.

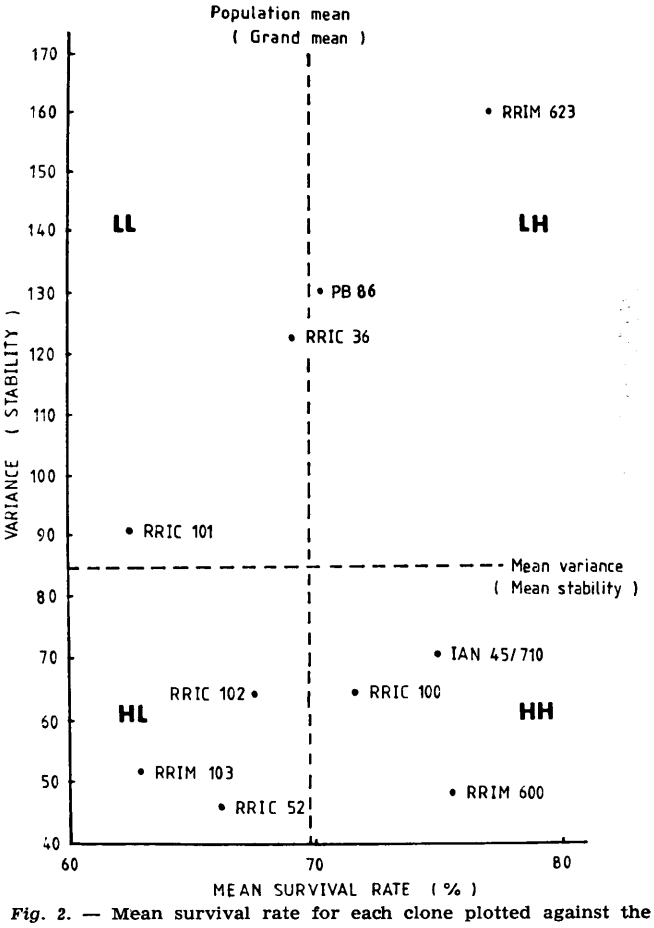

Fig. 2. — Mean survival rate for each clone plotted against the variance over environments.

adaptation with a desired level of mean performance. The wide unpredictable variations in agro-climatic conditions found in *Hevea* growing areas of Sri Lanka make it important that clones with general adaptition or stability to agro-climatic variability should be selected for commercial planting.

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Karyotype Analysis in Pinus caribaea var. hondurensis Barr. and Golf[1])

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Summary

The karyotypes of six provenances of *Pinus caribaea* var. *hondurensis* Barr. and Golf. were analysed using the Feulgen technique on meristematic cells of the root tips.

Significant differences were detected in some of the chromosomes, mainly due to the provenances Limones and Guanaja.

The haploid number of chromosomes is n = 12 in this variety; chromosomes are simple, long, and very similar between pairs, as has been found in most of the pine species.

The first 11 chromosomes are metacentric. Three secondary constrictions were observed but two were more persistent within the first six chromosomes. It was not possible to stain the heterochromatin regions using the Giemsa technique.

Key words: Pinus caribaea var. *hondurensis* Barr. and Golf., Provenances, Karyotype, Chromosomes, Analysis of variance.

Zusammenfassung

Es wurden die Karyotypen von 6 Provenienzen von *Pinus caribea* var. *hondurensis* Barr. and Golf. analysiert, indem die Feulgen-Technik an Meristemzellen der Wurzelspitzen angewandt wurde. In einigen Chromosomen wurden signifikante Unterschiede gefunden, hauptsächlich in solchen der Provenienzen Limones und Guanaja.

Die haploide Chromosomenzahl ist bei dieser Varietät n = 12; die Chromosomen sind einfach, lang und innerhalb der Paare sehr ähnlich, wie von den meisten Kiefernarten bekannt ist.

Die ersten 11 Chromosomen sind metazentrisch. Drei sekundäre Einengungen wurden beobachtet, wobei zwei innerhalb der ersten 6 Chromosomen beständiger waren. Es war nicht möglich, die Heterochromatin-Regionen mit der Giemsa-Technik anzufärben.

Introduction

The haploid number of chromosomes in all the species of the genus *Pinus* already studied has been reported as n = 12. The chromosomes are very similar and only a small amount of inter specific differences has been found (Sax and Sax, 1933; Saylor 1964; Pederick 1970; Borzan and Papes 1978).

According to Sax and Sax (1933), Santamour (1960) and Saylor (1961) the stability in the morphology of the chromosomes in the conifers may indicate that evolution in this group of plants has passed the climax and the existing forms are survivors of a long natural selection.

They also suggested that it is possible that the intra- and interspecific variation that is visible could be the result of alterations at gene level. Pederick (1970) suggested that small but significant differences in arm length in the corresponding chromosomes of certain pine species may be attributed to the gradual accumulation of duplications.

Saylor (1961) in a comparative study between the karyotypes of *P. strobus* L., *P. taeda* L., *P. palustris* Mill., *P. virginiana* Mill. and *P. resinosa* Ait., did not find intraspecific variation in terms of the relative arm length. However, it was possible to detect interspecific variation with respect to arm length. The secondary constrictions proved to be an unreliable diagnostic trait.

The present is the first attempt to determine morphological variations in the karyotype of six different collections of *P. caribaea* var. *hondurensis* at the chromosomal level; the populations represent extreme points in the distribution of the variety. Any difference detected could

1) The paper is adapted from part of the author's D. Phil. thesis, Forestry Department, Oxford University, England, 1981.