what we never expected to see. Today, exploratory and confirmatory analysis can--and should--proceed side by side (TUKEY 1977).

During the development of the linear quadratic regression model we assumed that vigor and latitudes were measured without error. In practice, trees seldom respond exactly alike and any repetition of the provenance test, even using the same seed sources at the same locations, would probably exhibit some variation in vigor. Therefore, the regression coefficients are not without variance; variation in estimating coefficients depends on the behavioral variance in vigor. Fortunately, latitudes can be measured without appreciable error. The regression coefficients solved by the method of least squares with fixed independent variable are unbiased. Thus, the response surface plotted from the regression, on the average, is expected to be true, but some variation of the response surface should be expected under similar test conditions.

The response surface model can be fitted by the method of least squares without distributional assumptions. However, the test of regression coefficients requires the usual assumptions that the residuals are independent, have zero mean, a constant variance, and follow a normal distribution. When we examined the fitting errors within each plantation in order to check the validity of the assumptions, we found no outliers and most assumptions appeared to be valid, except that the Wisconsin plantation has a smaller residual variance in height growth than the Illinois and the Ohio plantations. We also applied the natural logarithm transformation to the height data as suggested by a reviewer. The within-plantation error variance does become stable, but the resulting response model has a center of superior seed sources at 58 degrees south latitude. Because we feel that the original measurement unit, cm., is easier to comprehend and to compare than the logarithm of cm. and that the original model is more believable, we sacrified somewhat the rigorousness of hypothesis testing for the practical convenience. Although the height model is not a perfect example for statistical testing, it is nevertheless a suitable descriptive model.

According to our present experimental design which has no truly repeated runs, we were not able to test the goodness of fit of the response surface model. It has been shown that an equation should be regarded as a satisfactory predictor, if the observed F-ratio of the model is at least four times greater than the selected percentage point (DRAPER and SMITH, 1981). Because the observed F-ratios in *Table 2* are more than six times greater than the 99 percentile of the F-distribution, we accept the adequacy of the proposed model for white ash.

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Literature Cited

ANONYMUS: SAS User's Guide: Statistics 1982 Edition. SAS Institute, Inc. Raleigh, North Carolina. 584 pp. (1982). — ANSCOMBE, F. J. and TUKEY, J. W.: The examination and analysis of residuals. Technometrics **5**: 141—161 (1963). — BEY, C.F.: Geographic variation in *Juglans nigra* in the midwestern United States. Silvae Genet. **28**: 132—135 (1979). — BEY, C. F., KUNG, F. H. and DANIELS, R. A.: Genotypic variation in white ash--nursery results. Proc. Cent. States For. Tree Improv. Conf. 10 (1976): 141—145 (1977). — CONKLE, M. T.: Growth data for 29 years from the California elevational transect study of ponderosa pine. For. Sci. **19**: 31—39 (1973). — DRAPER, N. R. and SMITH, H.: Applied Regression Analysis. 2nd Ed. John Wiley & Sons, Inc. New York, New York, 709 pp. (1981). — NAMKOONG, G.: Nonoptimality of local races. Proc. South. Conf. For. Tree Improv. 10 (1969): 149—153 (1969). — NAMKOONG, G.: Introduction to Quantitative Genetics in Forestry. U. S. Dept. of Agr. Tech. Bull. 1588, 342 pp. (1979). — NIENSTAEDT, H. and TEICH, A.: The genetics of white spruce. USDA For. Serv. Res. Pap. WO-15, 24 pp. (1972). — SCANLON, D. H.: Seed source effects on sugar maple. Amer. Nurs. **143**: 13, 76, 78 (1976). — SQUILLACE, A. E.: Geographic variation in slash pine. For. Sci. Monogr. **10**, 56 pp. (1966). — TUKEY, J. W.: Exploratory Data Analyses. Addison-Wesley, Reading, Mass. 506 pp. (1977). — WELLS, O. O. and WAKELEY, P. C.: Geographic variation in survival, growth and fusiform-rust infection in planted loblolly pine. For. Sci. Monogr. **11**, 40 pp. (1966). — WRIGHT, J. W.: Introduction to Forest Genetics. Academic Press, New York, New York. 463 pp. (1976).

Stock-scion compatibility in Teak (Tectona grandis)

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Summary

While setting up a National Teak Clone Bank of Plus Trees, large numbers of scions were collected from different states of India with varying environmental conditions; these scions were grafted on root stocks from a single source Tunacadavu in Tamil Nadu. Grafts were kept in a mist-chamber for the first 30 days and thereafter under natural environmental conditions until the 60th day. Analysis shows that scions from different states differed in mortality on 30th day and in 60th day. Under natural tree shade condition mortality was higher. This indicated that unfavourable environment accentuates mortality. Individual state-data analysis shows that mortality in Karnataka and Andhra Pradesh materials differed significantly indicating ecotypic difference leading to incompatibility. However, much more study is necessary to confirm this view.

Key words: *Tectona grandis*, bud grafting, environmental conditions, root stock, scion, incompatibility.

Zusammenfassung

Im Rahmen der Einrichtung einer nationalen Teak *(Tectona grandis)* Klonsammlung mit Plusbäumen wurde aus den verschiedenen Staaten Indiens mit variierenden Um-

weltbedingungen eine große Anzahl von Pfropfreisern gesammelt. Diese Reiser wurden auf Unterlagen einer Herkunft, nämlich Tunacadavu in Tamil Nadu gepfropft. Die Pfropflinge wurden während der ersten 30 Tage in einer Nebelkammer gehalten und danach bis zum 60. Tag unter natürlichen Umweltbedingungen. Eine Untersuchung der Pfropfreiser aus den verschiedenen Staaten am 30. und 60. Tag zeigte Unterschiede in der Mortalität. Unter natürlichen Schattenbedingungen war die Mortalität höher. Dies zeigt, daß eine ungünstige Umgebung die Mortalität beeinflußt. Eine individuelle Zustands-Daten-Analyse zeigte, daß sich die Mortalität bei den Pfropfreisern aus Karnataka und Andhra Pradesh signifikant von den anderen unterschied und ökotypische Unterschiede anzeigt, die zur Unverträglichkeit führen. Es sind jedoch weitere Untersuchungen notwendig um diese Ansicht zu bestätigen.

Introduction

Incompatibility of scion and root stock has been reported on Red pine, Scots pine, White pine, spruces, Douglas fir and other species (Fowler, 1967; Ahlgren, 1962; Silen and Copes, 1972) but in Teak no such reference, is available.

Although bud grafting has been reported in teak by many authors (Alphen De Veer, 1954; Hellinga, 1956; Keiding and Boon-Kird, 1960; Chalmers, 1962; Cameron, 1966; Rawat and Kedharnath, 1968; Rao, 1970; Choudhari, 1970; and Mahapatra, 1970), but only Chalmers, (1962) has reported that budding success varies from clone to clone.

Incompatibility may be regarded as an inherent antagonism or discordant association between stock and scion, the cause or causes of failure or abnormality arising out of the nature of the two plants, and form taken by the failure being governed in greater or lesser degree by factors of environment and treatment. Thus, under conditions which favour union and growth of stock and scion, failure will be delayed, while under unfavourable conditions of environments and treatment it will be accelerated (Argles, 1937). Certain combinations of stock and scion will grow in one locality but may totally fail in another. It would appear that incompatibility exists but may not display itself morphologically owing to favourable growth conditions (Chang, 1937).

The two above mentioned views given by different authors suggest that in some cases incompatibility exists but may not display itself due to favourable growth conditions. In this paper we discuss the stock scion relationships in *Tectona grandis* with emphasis on mortality due to (1) change of environmental condition; and (2) combinations of root stocks from a single locality with scions from different locations. The study is based on grafting done while setting up a National Teak Clone Bank.

Table 1. — Number of buds grafted and suviving.

Serial No.	Buds grafted	Survival on 30th day No.	%	60th day No.	%
KERALA					
1.	11	10	90.9	10	90.9
2.	24	6	25.0	4	16.7
3.	10	6	60.0	6	60.0
4.	10	7	70.0	7	70.0
5.	24	15	62.5	11	45.8
6.	11	8	72.7	4	36.4
7.	11	10	90.9	6	54.6
8.	30	14	46.7	14	46.7
TAMIL NADU					
1.	20	15	75.0	13	65.0
2.	15	11	73.3	11	73.3
3.	13	9	69.2	9	69.2
4.	24	10	41.7	10	41.7
5.	14	4	28.6	4	28.6
6.	25	15	60.0	15	60.0
7.	9	9	100.0	9	100.0
8.	10	9	90.0	9	90.0
ANDHRA PRADESH					
1.	12	10	83.3	9	75.0
2.	21	18	85.7	14	66.7
3.	20	18	90.0	15	75.0
4.	25	21	84.0	18	72.0
5.	36	26	72.0	21	58.0
6.	17	15	88.0	12	71.0
7.	20	16	80.0	10	50.0
8.	36	21	58.0	16	44.0
ORISSA					
1.	8	8	100.0	5	63.0
2.	17	12	71.0	12	71.0
3.	19	19	100.0	19	100.0
4.	13	12	92.0	11	85.0
5.	12	7	58.0	7	58.0
6.	8	5	63.0	3	38.0
7.	17	9	53.0	7	41.0
8.	13	8	62.0	5	38.0
KARNATAKA					
1.	14	10	71.0	7	50.0
2.	30	20	67.0	4	13.0
3.	15	5	33.0	3	20.0
4.	20	4	20.0	2	10.0
5.	19	6	32.0	2	11.0
6.	7	1	14.0	0	0.0
7.	36	15	42.0	8	22.0
8.	23	7	30.0	3	13.0

Materials and Methods

The scion wood was collected from different plus trees ranging from 25 to 80 years in age. Each tree was outstanding in growth and form in its own locality. The budwood was taken from 8 different plus trees from each of the states of Tamil Nadu, Kerala, Karnataka, Andhra Pradesh and Orissa. The scion were collected, paraffined, packed with moist sawdust in a polythene bag and despatched by air to Coimbatore. The root stock came from a single source namely Tunacadavu Range of Topslip Reserve Forest in Tamil Nadu. The bud grafting was done from 9th March to 11th May 1979, according to differing availability of buds from the different states. All the grafts were made by 'H' or flap budding technique. The grafted stumps were planted in polythene containers 6 × 9 inches in size and placed in a mist-chamber. The grafts were covered by a polythene cap until they sprouted.

The data were analysed by analysis of variance and the results are presented in *Table 1.*

Observations

As noted above the grafted stumps were kept in a mist-chamber and as soon as the buds started sprouting the polythene caps were removed. The grafts were kept in the mist-house for 30 days and then placed under the shade of trees until 60th day after grafting. *Table 1* shows the number of bud-grafts made and their survival on the 30th and 60th day after grafting.

Table 2 shows that the survival of scions from various states on root stocks from Tamil Nadu (Tunacadavu) varied significantly.

From *Table 3* it may be seen that scions from Karnataka and Andhra Pradesh were significantly different from others in their survival. When the grafted plants were transferred from the mist-chamber and placed under tree shade the Karnataka and Andhra Pradesh bud grafts showed higher mortality whereas those from Tamil Nadu, Kerala and Orissa did not.

Discussion

The bud grafting time in field conditions for teak varies from state to state in India depending on the environmental conditions. The best time for bud grafting in field conditions at Dehra Dun is from April to May (Rawat and Kedharnath, 1968) with a success of 77.5% to 82.5% in Andhra Pradesh from February to March (Rao, 1970), in Maharashtra during May (Choudhari, 1970), in Orissa

Table 2. — Mean squares for survival of bud grafts on 30th and 60th days.

Source of variation	df	Mean squares 30th day	60th day
Between States	4	1800.8325**	2426.0765**
Within States	114	279.0847	391.712

** Significant at 1% level

Table 3. — Mean squares of survival of scions from different states.

Source of variation	df	Kerala	Tamil Nadu	Karna-taka	Andhra Pradesh	Orissa
Groups						
Between	1	249.0637	2.4571	791.2703*	436.601*	319.605
Within	14	208.9035	320.3673	156.2987	51.7353	322.4994

* Significant at 5% level.

during March, April (MAHAPATRA, 1970) with 58.7% of success.

ALPHEN DE VEER (1954) reported that 80% success was obtained in budding of teak in an experiment during 1938 in Indonesia. Renewed trial on budding done in a glass house gave a success of 95%. Again 1951 in the field conditions it was only 60%. Depending upon the availability of bud it is better to keep the grafts in glass house rather than in field, because one can maintain temperature and humidity for higher success of grafting. In the present study the bud grafts were kept in the glass house for first 30 days and the highest budding success recorded for Kerala, Tamil Nadu, Andhra Pradesh, Orissa and Karnataka is 90.9%, 100%, 90%, 100% and 71% respectively. This budding success is much higher as compared to the field budding at Dehra Dun, except for Karnataka.

HARTMAN and KESTER (1972) have described several external symptoms of incompatibility and three are discussed here.

Fig. 1 a

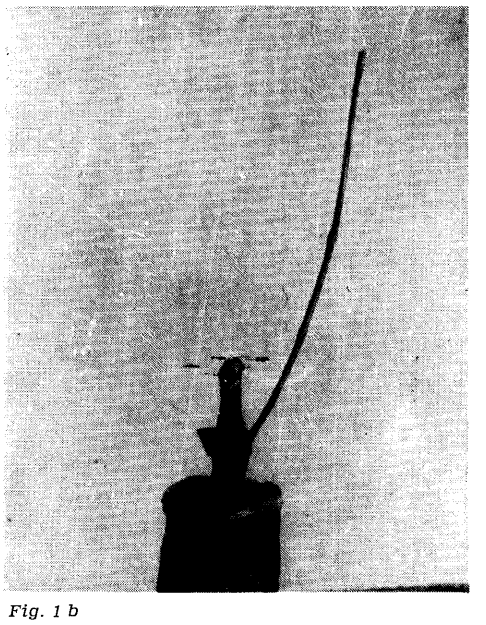

Fig. 1 b

Fig. 2 a

Fig. 2 b

1. Failure to form a successful graft or bud union in a high percentage of cases.

2. Appearance of shoot dieback and general ill health of grafted tree.

3. Premature death of the tree in the nursery.

It is evident from *Table 2* that ability to survive at 30 days and 60 days are significantly different indicating that under varied environmental conditions mortality was accentuated, confirming incompatibility. This confirms the view of CHANG (1937) that symptoms of incompatibility appear most quickly and in the severest manner when the tree is grown under adverse environmental conditions. On the other hand under favourable conditions, the symptoms may take some time to appear, although incompatibility actually exists in the tree. The major cause seems to be the discontinuity between wood and bark shown in *Figure 2a* and *2b*. CHANG (1937) says "that the distinctive groups of incompatibility as shown by bark and wood discontinuity seem to be directly correlated with a high degree of incompatibility. Possibly this crevice at the union hinders or lessens the upward and downward transport of water, soil solution and manufactured food, thus causing a weaker growth of shoot and root". *Figure 1a* and *1b* show successful and unsuccessful bud grafts respectively. The unsuccessful graft is associated with shoot dieback and premature death of tree.

On the basis of these observations it can be suggested that incompatibility may exist in teak clones, when they are grafted.

A systematic study must be done to determine the extent of incompatibility using different combinations, viz scion on stock, stock on scion and stock on stock.

Literature Cited

AHLGREN, C. E.: Some factors influencing survival, growth and flowering of intraspecific and interspecific pine grafts. J. Forest **60**: 785—789 (1962). — ALPHEN DE VEER, E. J. VAN: Teak cultivation in Java. Proc. IVth World Forestry Congress, Dehra Dun **3**: 322—338 (1954). — ARGLES, G. K.: A review of the literature on stock-scion incompatibility in fruit trees with particular reference to Pine and Stone - fruits. Tech. Communications, No. 9, Imp. Bar. Fruit Prod. East Malling (1937). — CAMERON, A. L.: Genetic improvement of teak in New Guinea. Australian Forestry **30**: 76—87 (1966). — CHALMERS, W. S.: The breeding of Pine *(Pinus caribaea)* and Teak *(Tectona grandis)* in Trinidad. Some early observations. Caribbean Forester **23**: 100—111 (1962). — CHANG, W. T.: Studies in incompatibility between stock and scion with special reference to certain deciduous fruit trees, Jour. Pom and Hort. Sci. **15**: 267—325 (1937). — CHOUDHARI, N. R.: Experience with raising of teak seed orchard in Maharasthra state. Proc. Seminar-cum-workshop on genetic improvement of Forest tree seeds in India, February 7 to 12, 1970. Forest Research Institute and Colleges, Dehra Dun. 56—65 (1970). — FOWLER, D. R.: Low grafting and deep planting may prevent mortality due to incompatibility in pine. Forest Sci. **13**: 314—315 (1967). — HARTMAN, H. T. and KESTER, D. E.: Plant propagation principles and practices (Second edition). Prentice Hall of India Private Limited, New Delhi, L. F. 357—370 (1972). — HELLINGA, G.: On forest tree improvement in Indonesia. Proc. I.U.F.R.O. meetings **22**: 101 (1956). — KEIDING, H. and BOON-KIRD, S.: Vegetative Propagation of teak. Unasylva **14**: 193—194 (1960). — MAHAPATRA, P.: Experiment of grafting on teak in Orissa. Proc. Seminar-cum-workshop on genetic improvement of Forest tree seeds in India. February 7 to 12, 1970. Forest Research Institute and Colleges, Dehra Dun. 30—33 (1970). — RAWAT, M. S. and KEDHARNATH, S.: Field grafting and budding in Teak *(Tectona grandis* L. f). Indian Forester **94** (3): 259—262 (1968). — SILEN, R. R. and COPES, D. L.: Douglas-fir seed orchard problems a progress report. J. Forest **70**: 145—147 (1972).

A chromosome study of coast redwood, Sequoia sempervirens (D. Don) Endl.[1])

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(Received 3rd March 1983)

Summary

A detailed karyotype analysis was made on the somatic chromosome complement of *Sequoia sempervirens*. The species has 2n = 6x = 66 chromosomes which concurs with previous reports. Chromosomes with unusual or specific structures are present in the complement. Two pairs of SAT-chromosomes have unusually long secondary constrictions and are believed to be associated with nucleolar organization regions. Previous studies show that *Sequoia* has six nucleoli, four large and two small, which indicates that there are two other active NOR present, likely associated with microsatellites which may not be visible due to pretreatment effects. Amphiplasty may have been responsible for the morphological differences among the nucleolar organizing chromosomes. Tentatively, *Sequoia* appears to be a segmental allopolyploid, $A_1A_1A_1A_1A_2A_2$, though the possibility that *Sequoia* is an autoallopolyploid, AAAABB, cannot be discounted.

Key words: Sequoia sempervirens, redwood, *Taxodiaceae*, chromosome, karyotype analysis. hexaploid, segmental allopolyploid, autoallopolyploid, amphiplasty.

Zusammenfassung

Am Wurzelspitzenmeristem von *Sequoia sempervirens* wurde eine detaillierte Analyse des Karyotyps durchgeführt. Von den aus früheren Untersuchungen bekannten 2n = 6x = 66 Chromosomen weisen einige spezifische Strukturen auf. 2 SAT-Chromosomen haben ungewöhnlich lange sekundäre Einschnürungen, die für Nucleolus-Organisator-Regionen (NOR) gehalten werden. Da in früheren Untersuchungen 6 Nucleoli nachgewiesen werden konnten, 4 große und 2 kleine, werden 2 weitere NOR-aktive Chromosomenpaare angenommen, deren Mikrosatelliten aber durch die hier angewandte Vorbehandlung des Materials

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