from one tree of the conifer Cupressus *lusitanica* produced seedlings with 2 to 8 cotyledons. Plants with 2, 3 and 4 cotyledons were picked out and planted in an arboretum. Tetracots at first grew slower than di- and tricots, but later tetracots and tricots showed significantly greater heights than the dicots during the year after field planting. This example illustrates the possible use of pleiocotyly for practical ends in forestry.

Among forest trees, albinos and chlorophyll-deficient seedlings have been reported in Conifers and in a few others, but not so far in Eucalyptus. The frequency of occurrence of these mutant traits can be used to estimate the degree of natural selfing (see SQUILLACE & KRAUS, 1963 on Slash pine) that normally occurs in Eucalypts and of which practically nothing is known at present, even for a single species of this large and important genus (PENFOLD & WILLIS, 1961).

Summary

The incidence of polyembryony, pleiocotyly, abnormal, albino and chlorophyll deficient seedlings is reported in Eucalyptus. With the exception of tricotyly this may be the first record of other occurrences for this genus. The possible use of these phenomena in genetical studies and their practical use in Eucalyptus breeding are briefly discussed.

Key words: Eucalyptus, progenies, genetics, aberrant seedlings.

Zusammenfassung

Es werden das Vorkommen von Polyembryonie, Pleiocotylie, anomalen weißen und chlorophyll-defekten Sämlingen bei *Eucalyptus* mitgeteilt. Mit Ausnahme der Tricotylie sind diese Erscheinungen erstmals bei dieser Gattung gefunden worden. Über ihre Anwendbarkeit für genetische und praktisch züchterische Arbeiten wird kurz diskutiert.

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Effect of Partial Measureinent on Statistical Precision and Efficiency in a Nursery Study of Pinus ponderosa

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In the assessment of genetic information in the nursery, plot means are frequently used as items in an analysis of variance. Other common practices are measurement of the tallest seedling or the use of mean values based on the two tallest trees per plot in the analysis. Apparently partial measurement is sometimes done for convenience although its statistical soundness remains unverified.

Most nursery experiments consist of multi-tree plots with 10 to 40 seedlings per plot planted in the beds. Time may be saved if not all trees are measured; if done, the amount of genetic information lost should be determined and evaluated. It is also important to analyze what type of sampling (random or deliberate) should be employed to more efficiently derive the necessary genetic information.

This study was undertaken at the Institute of Forest Genetics, Placerville, California, in the summer of 1973 to determine the amount of information lost and time gained by two types of partial measurement.

Material and Methods

This study consists of measurement of 1-0 ponderosa pine (Pinus ponderosa) seedlings in a 28-family half-sib progeny test established March 1972 by Dr. JAMES L. JENKINSON, Forest Genetics staff of the Pacific Southwest Forest Experiment Station, Berkeley, California. The experiment was planted in two adjacent, parallel seedbeds, each 47 feet long and 6 feet wide, which extended east-west and were separated by a path. Spacing between each seedling was 6 X 6 inches. The experiment was a randomized complete block design with 6 replications, each containing one 12- tree north-south plot per family. In addition to the experimental plots, each seedbed contained 10 unmeasured buffer plots between blocks and at the ends of the seedbeds.

The height of each seedling was measured to the nearest 5 mm. and plot means were then computed in 17 different ways, i.e. based on all 12 trees, based on the 1, 2, 3, 4, 5, 6, 8 or 10 tallest seedlings in each plot, or based on 1, 2, 3, 4, 5, 6, 8 or 10 seedlings chosen randomly with replacement in each plot.

Analysis of variance and estimated variance components were computed for each of the 17 sets of height data according to the following tabulation:

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Source of variation	D.F.	MS	Expected mean squares
Replication	$n - 1 = 5$	M_1	$\sigma^2 + f\sigma_R^2$
Families	$f - 1 = 27$	M_2	$\sigma^2 + n\sigma_F^2$
Error	$(n-1)(f-1) = 135$	M_3	σ^2

Simple correlations were calculated between the height measurements based on all 12 trees per plot and those based on 1, 2, 3, 4, 5, 6, 8 and 10 trees per plot. For these, family means were used as items so that there were 26 degrees of freedom.

Results and Discussion

The two seedbeds received standard care such as irrigation, fertilization and weed control. They appeared to provide uniform growing conditions for the majority of seedlings. This was reflected in the small amount (= 4 percent) of the total variance component attributable to the block effect when mean height of all 12 seedlings per plot was used as an item in the analysis *(Table 1)*. The differences between the two seedbeds in mean height of the 1,008 (= 28 × 12 × 3) seedlings per bed were so small as to support an assumption of uniform growth conditions in the two beds: 160 mm. for the first bed and 156 mm. for the second. I also computed the bed 1 — bed 2 correlation using row means based on 84 (= 28 × 3) seedlings located in the identical row positions as items. The rank correlation coefficient (= 0.892) was strong at the 1 percent level with 10 degrees of freedom. In other words, rows of the ponderosa pine seedlings that grew fast in the first seedbed also performed well in the second bed.

An overhead irrigation pipe runs south to north at the center of the two seedbeds. The westerly wind that prevails in the Placerville area may cause an irregular distribution of irrigation water. Therefore, it was expected that seedlings located on the leeward side (blocks 3 and 6) had received more irrigation water than those on the windward side (blocks 1 and 4). To test this, mean heights based on 56 (= 28 × 2) seedlings located in the identical row positions individually for the western (blocks 1 & 4 combined), center (blocks 2 & 5 combined) and eastern (blocks 3 & 6 combined) blocks were calculated. The mean heights obtained in this manner were used as items in calculating the rank correlations. The rank correlation coefficients between western and center, between western and eastern and between center and eastern blocks were 0.752, 0.791 and 0.864 respectively, all significant at the 1 percent level with 10 degrees of freedom. Mean heights of 672 seedlings (= 28 × 12 × 2) for the western (windward side), center and eastern (leeward side) blocks were 158, 156 and 161 mm. respectively. Apparently, height growth was relatively uniform regardless of the positions of the seedlings in the seedbeds. It was, therefore, assumed that there was no adverse effect of irrigation water pattern on height growth.

A possible existence of border effect is another concern of many nursery managers. According to the definition, trees on the border have faster growth than those in the inner rows of the seedbeds. To the casual observer, there was a gradual decrease in seedling height from the south to the north edge of the beds. The height data collected support this observation: mean heights of 504 (= 28 × 6 × 3) seedlings for rows 1 through 3 in the south edge; 4 through 6, 7 through 9 and 10 through 12 in the north edge were 168, 162, 153, and 149 mm. respectively. If border effect had been functioning, mean seedling height of the three rows in the north edge would have been taller than that of the center rows (4 through 9). Actually it was not the case. However, the causes of the south-to-north height gradient were not determined. The seedbeds were level, and there was no indication of the fertilizer and water movement toward the south edge of the seedbeds.

Effect of sampling schemes and plot sizes: The between-family differences in height growth were significant at the 1 percent level for the two sampling schemes at all plot sizes studies *(Table 1)*. Estimate for genetic gains was considerably in error when only a few trees were measured per plot. However, the estimates were improved when deliberate sampling was used for all plot sizes.

Standard deviation (the square root of the experiment error variance) is in common use by many researchers to define a minimum sample size as conditioned by the design of their experiment. GOGGANS' study (1962) on loblolly pine *(Pinus taeda* L.) wood properties is a good example. For biological data, he indicated a coefficient of variability

Table 1. — Analysis of variance comparing the effect of sampling schemes and plot sizes

Sampling Scheme	No. of Seedlings Per Plot	F	Variance Components			C. V.
			Families	Replications	Error	
				Percent		Percent
Random	1	3.80	31	2	67	7.31
	2	3.80	32	0	68	6.01
	3	4.62	37	1	62	4.70
	4	8.27	54	2	44	4.16
	5	8.77	55	2	43	4.11
	6	9.80	58	3	39	3.75
	8	10.23	59	3	38	3.69
	10	12.10	63	3	34	3.47
Deliberate	1	9.34	56	4	40	3.61
	2	12.45	63	4	33	3.26
	3	15.13	67	4	29	2.99
	4	16.27	69	4	27	2.87
	5	17.18	70	4	26	2.76
	6	17.43	70	4	26	2.77
	8	18.34	71	4	25	2.71
	10	18.58	71	4	25	2.63
All twelve		18.90	71	4	25	2.60

F values of 1.75 were needed for significance at 1-percent level with 27/135 degrees of freedom.

(= C. V.) of 6 percent or less was considered very acceptable; even 8 to 10 percent was not excessively high. I calculated the C. V. values for various plot sizes under the two sampling schemes by dividing the square root of the experiment error variance by the sample mean height. The results are presented in *Table 1*. If GOGGANS' criteria are followed, the results were all acceptable regardless of sampling schemes and plot sizes.

It is not clear from an analysis of variance as to how much information on family means may be lost due to partial measurement of nursery plots. The correlation analysis was employed for this purpose as suggested by WRIGHT (1970). Plot means were computed based on all 12 trees per plot and also based on measurement of 1, 2, 3, 4, 5, 6, 8 and 10 trees per plot randomly and deliberately selected, then simple correlations (with 26 degrees of freedom) were calculated among them. The results are presented in *Table 2*.

Table 2. — The correlation coefficients comparing the effect of different plot sizes and sampling schemes

Sampling Scheme & trees per plot	r	Sampling Scheme & trees per plot	r
All 12 vs Ran 1	0.917	All 12 vs Delib 1	0.978
All vs 2	0.905	All vs 2	0.989
All vs 3	0.941	All vs 3	0.991
All vs 4	0.963	All vs 4	0.994
All vs 5	0.971	All vs 5	0.983
All vs 6	0.966	All vs 6	0.999
All vs 8	0.987	All vs 8	1.000
All vs 10	0.994	All vs 10	1.000

The 5 percent point of r with 26 degrees of freedom = 0.374.
The 1 percent point of r with 26 degrees of freedom = 0.479.

The random — deliberate correlations were strong at the 1 percent level regardless of the number of seedlings measured per plot. It implies that both sampling methods are useful for my study purpose. As expected, the correlation coefficients tended to increase with an increase in plot sizes.

The correlations were higher for the deliberate sampling scheme without regard to the number of seedlings measured per plot. In that sampling scheme, measurement of the tallest seedling instead of all 12 individuals was accompanied by a 4 percent loss in accuracy of estimate for the family means, for the coefficient of determination (= r^2) was 0.96. In other words, measurement of the tallest seedling per plot would result in a saving of more than 90 percent in measurement effort while it is accompanied by a loss of only 4 percent in amount of information. Frequently, experimental plots containing the same amount of study material will be laid out in a number of selected localities (nursery sites) aimed at wider applicability of the test results. In addition, a significant genotype × environment interaction has been reported for a number of tree species. Under the circumstances, there appears to be no justification to take highly accurate measurements on a single species at a single locality. The tallest seedling in each plot is very easy to locate at a glance and its measurement is a one-man job without any extra assistance.

The correlations were lower for random sampling at all plot sizes studied. In that sampling scheme, measurement of 5 randomly selected seedlings was necessary in order to obtain a comparable amount of information to that from measurement of the tallest seedling per plot deliberately chosen.

My results are based on a single species at a single locality in a single growing season. For more information and wider applicability, similar work should be expanded to cover more tree species at more other localities extended over more growing seasons.

Analysis of variance and simple correlations were useful in deriving the necessary information for the present study. Both techniques yielded similar and comparable results.

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Summary

Seed from twenty eight ponderosa pine *(Pinus ponderosa)* wind-pollinated families was sown in the Institute of Forest Genetics' nursery at Placerville, California using a randomized complete block design with six replications, each of which contained 28 twelve-seedling south-north plots. Height growth of the 1—0 seedlings at the end of the 1972 growing season was used to study border effect, distribution of irrigation water and to analyze the statistical precision and efficiency of the random versus deliberate sampling schemes as affected by the different plot sizes. No border effect was detected, nor was there any noticeable evidence of irregular distribution of irrigation water. Data collected from the tallest seedling per plot appeared adequate to furnish the necessary genetic information on height growth in a research nursery.

Key words: *Pinus ponderosa*, random and deliberate sampling, border effect, randomized complete block design, plot sizes.

Zusammenfassung

Saatgut von 28 frei abgeblühten Familien von *Pinus ponderosa* wurde in der Baumschule des Instituts für Forstgenetik in Placerville, Californien, als randomisierter vollständiger Blockversuch mit 6 Wiederholungen ausgesät, von denen jede 28 Parzellen mit je 12 Sämlingen enthielt. Das Höhenwachstum der Sämlinge am Ende des Jahres 1972 benutzte man zu Untersuchungen über Randeffekte, die Verteilung des Beregnungswassers und die statistische Genauigkeit sowie die Auswirkungen von zufallsmäßigen gegenüber gezielten Probenahmen, wie sie sich sonst bei verschiedenen Parzellengrößen auswirken. Es konnten weder ein Randeffekt noch eine unregelmäßige Verteilung des Beregnungswassers entdeckt werden. Die Meßdaten von jeweils dem größten Sämling jeder Parzelle scheinen auszureichen, um die notwendige genetische Information über das Höhenwachstum in einer Versuchsbaumschule zu liefern.

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