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INCREASING PLANTING STOCK SIZE BY FAMILY SELECTION IN CALIFORNIA PONDEROSA PINE

James L. Jenkinson

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CONTENTS

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SUMMARY

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Oxford: 174.7 *Pinus ponderosa* (794)–232.41:265.5:181.25.
Retrieval Terms: Pinus ponderosa; Sierra Nevada; planting stock; progeny tests; genetic variation; seedling growth.

This paper describes family differences in 1- and 2-year nursery growth of ponderosa pine from natural stands in the northern Sierra Nevada. Wind-pollinated seed was obtained from 48 parent trees selected in eight stands. The stands sampled four geographic areas—three west and one east of the Sierra crest—to represent climates typical for ponderosa pine. In each area, one stand was selected on a fertile soil and the other on infertile ultramafic soil.

Large and significant differences in 1-year height were found among families from every area, and in 2-year height of families from the three west-side areas. Heritabilities of family means varied from 0.35 to 0.50 for 1-year height and from 0.14 to 0.55 for 2-year height. After two seasons, family mean stem volumes ranged from 56 percent below to 61 percent above the native area means. No difference was found between offspring from trees on the two soil types, but differences in seedling growth between areas were significant.

Family height was weakly correlated with family seed weight and was not correlated with germination speed. Two-year family height and stem volume were strongly correlated with 1-year height. Family stem volume was not correlated with stem volume of the seed parent.

The family differences in 1-year height are sufficiently large to justify evaluation of family performance in the nursery. Selecting the tallest half of the total number of families from each area for nursery production could increase mean seedling height by 9 to 13 percent. Small-grade seedling production could be decreased from the average of 15 percent to below 5 percent.

The results indicate that ponderosa pine trees selected to provide seed for artificial reforestation should be screened by nursery testing their wind-pollinated families. Subsequent production nurseries would not include offspring from seed trees whose families showed poor growth, and future seed collections would include trees whose offspring showed average or better growth.

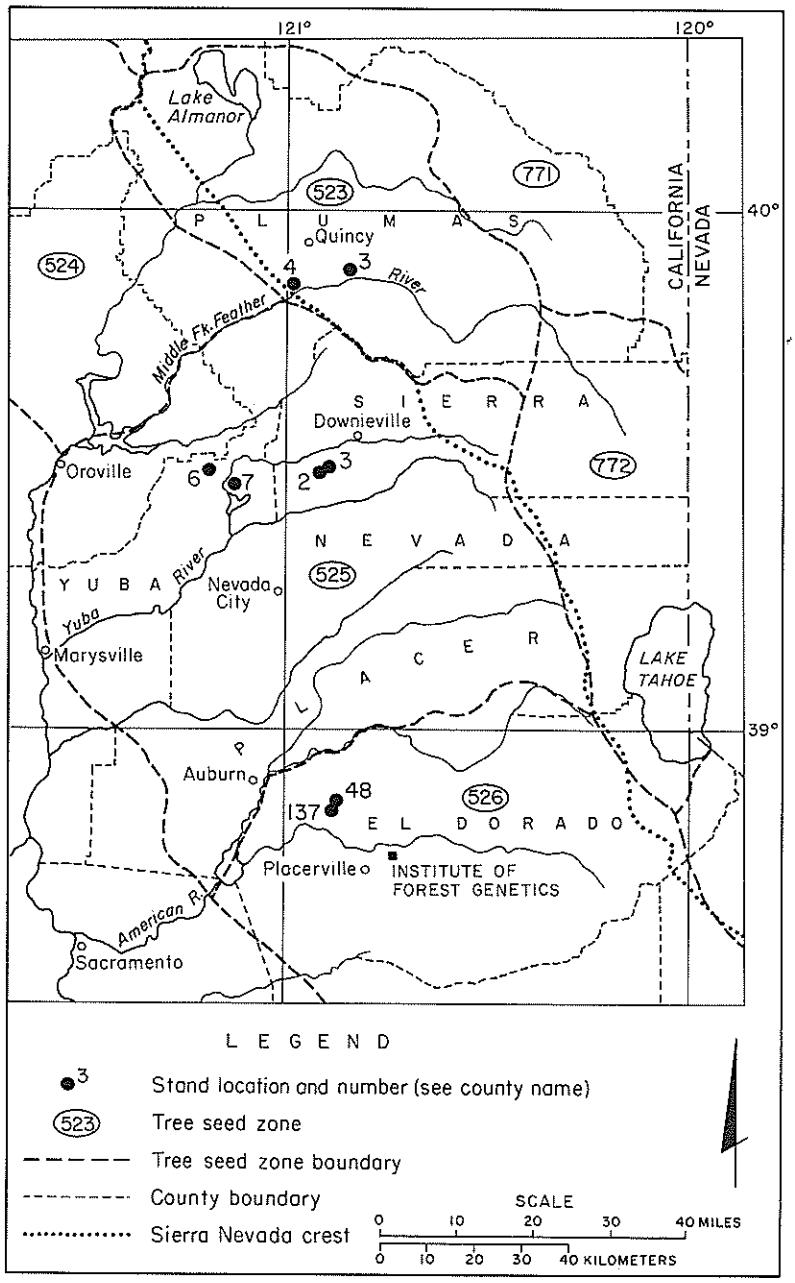

Figure 1—Growth of wind-pollinated families of ponderosa pine from eight stands in the northern Sierra Nevada was evaluated in the Institute of Forest Genetics nursery.

In the absence of test information to the contrary, the accepted guide for selecting seed for reforestation is "local source is best." This guide prevents plantation failures that result from using stock that is not adapted to the local environment, and it reflects the pronounced variation in growth and survival demonstrated in provenance trials (Silen 1970), including those defining elevational variation in ponderosa pine (Callaham and Liddicoet 1961, Conkle 1973, Mirov and others 1952). In California, seed origin is controlled by using revised tree seed zones (Buck and others 1970).

Improved growth of planting stock for reforestation may be gained by nursery selection of wind-pollinated, single-tree families. Work with many conifers[1] has shown that genetic variation in growth is often large among families from individual stands. Because adaptation of a local source is expressed in traits other than growth rate, selection to improve growth should be made among families (seed trees) native to environments that are similar to the planting site (Squillace and Bingham 1958, Squillace and Silen 1962).

This paper reports the inherent variation found in nursery growth of ponderosa pine families from stands selected to represent a wide range of climatic and edaphic environments in the Sierra Nevada.

PROCEDURES

Four areas were chosen to represent diverse climates characteristic of ponderosa pine in the northern Sierra Nevada. Three areas—El Dorado, Yuba and Sierra—were west and one—Plumas—was east of the Sierra Nevada crest (*table 1, fig. 1*). Two natural stands were selected in each area, one growing on fertile soil and one on infertile (ultramafic) soil; other site factors were similar except for associated vegetation.[2]

Twelve trees were selected as seed parents in each stand. The trees were located along transects ranging from 0.3 to 0.6 mile (0.5 to 1 km), were generally of good form, and were fair-to-good cone producers. No effort was made to identify and collect dominants and codominants or to avoid intermediate and smaller trees.

Tree height, age, and diameter at breast height were recorded. In each area, the stand on fertile soil was essentially even-aged, naturally regenerated second growth, and current volumes of individual trees were extrapolated to a common age to estimate their relative growth. The stand on infertile soil consisted of several age classes, and only trees in the dominant age class were considered. Seeds from each tree were extracted in sunlight, cleaned, and stored at 1° to 2° C. The mean seed weight for each family was determined from the air-dry weight of 400 full seeds.

Germination and growth of all families were evaluated in laboratory and greenhouse tests at the U. S. Forest Service's Institute of Forest Genetics, Placerville, California. In those tests, offspring from trees in stands within each area showed large differences in family germination rate and first-year seedling height and weight. No specific adaptation of stand offspring to native soil was identified, although individual families showed significant differential response to soil type.[2]

Subsequently, 1- and 2-year growth of 48 of these families, 6 from each stand in each area, were evaluated in the nursery. Seeds were stratified 60 days at 1° to 2° C, then sown in early May. The experimental

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[1] *Picea abies* (L.) Karst. (Dietrichson 1969, Giertych 1969); *P. Glauca* (Moench) Voss (Holst and Teich 1969, Jeffers 1969); *P. mariana* (Mill.) B.S.P. (Morgenstern 1969b); *Pseudotsuga menziesii* (Mirb.) Franco (Silen 1966); *Pinus elliottii* Engelm. (Beinecke and Perry 1966, Webb and Barber 1966); *P. ponderosa* Laws. (Silen and Rowe 1971, Wang and Patee 1974); *P. resinosa* Ait. (Lester 1963, Yao and others 1971); *P. strobus* L. (Kuo and others 1971); *P. taeda* L. (Barber 1966, Brown and Goddard 1959, van Buijtenen 1966); and *P. virginiana* Mill. (Evans and Thor 1971).

[2] Jenkinson, James L. 1975. *Edaphic interactions in first-year growth of California ponderosa pine.* (Manuscript in preparation.)

Table 1—*Paired ponderosa pine stands used as seed sources, represent fertile (F) and infertile (I) soils in four geographic areas in the northern Sierra Nevada*

Area, tree seed zone,[1] and stand no.	Locality	Soil parent material	Average seed-parent elevation	
			Feet	*Meters*
El Dorado, 526:				
48 F	Garden Valley	Marine	1940	591
137 I	Johntown Creek	Serpentinite	1925	587
Yuba, 525:				
7 F	Kennedy Ranch	Granitic	2975	907
6 I	Woodleaf	Serpentinite	3100	945
Sierra, 525:				
2 F	Gleason Spring	Volcanic	4680	1426
3 I	Brush Creek	Slickentite	4600	1402
Plumas, 523:				
3 F	Spring Garden	Marine	4910	1496
4 I	Rocky Point	Peridotite	4975	1516

[1] Buck and others 1970.

design consisted of four randomized blocks, with families grouped by geographic area and a 12-seedling row plot for each family in each block. The seedlings were watered twice weekly the first growing season and monthly during the second. To eliminate nitrogen deficiency in the otherwise fertile Aiken soil, a slow-release ammonium phosphate-sulfate fertilizer was added once during bed preparation and again in midseason at the rate of 100 pounds of nitrogen per acre (112 kg/ha).

Germination speed, expressed as maximum value of the quotient cumulative germination percent/days (Czabator 1962), was determined at 20° to 25° C. Shoot heights from cotyledon scar to shoot apex were recorded in late October after the first growing season. Height and stem diameter at bed surface were recorded following the second season.

Data for each area were subjected to analysis of variance. Heritabilities of family means were calculated from estimates of variance components, and means were compared by least significant difference procedures and Duncan's multiple-range test (Falconer 1960, Steel and Torrie 1960). Regression analyses were run to determine the relation between family growth and seed weight, and between family growth and seed-parent stem volume. To remove the effect of area, family means and seed-parent stem volumes were expressed as percents of the means for native area and stand.

RESULTS

The relation of family growth to family seed weight was found to be poor. The correlation between 1-year shoot height and seed weight was low, with only 19 percent of the variation in family mean heights associated with variation in family mean seed weights (*fig. 2*). Family mean height was not correlated with germination speed (r^2 = 0.00). After the second season, only 10 percent of the variation in height and 6 percent of that in stem volume were associated with seed weight. Significance of r^2 at the 5 (*) and 1 (**) percent levels was as follows:

Growth trait	*Seed weight*	*Height, 1-year*
Height		
1 year	0.19**	–
2 years	.10*	.82**
Stem volume, 2 years	.06	.70**

As expected, significant differences in growth were found between offspring from different areas (*table 2*). Average seedling growth decreased as the elevation and latitude of the area of seed origin increased. After two seasons, mean heights, diameters, and stem volumes for offspring from west-side areas were greater than those for the east-side Plumas area.

Inherent variation in seedling growth was also found among families native to the same area. For each area, variation in family growth traits was significant at the 5 (*) and 1 (**) percent levels or was not

Table 2—*Average nursery growth of twelve ponderosa pine families from each of four geographic areas in the northern Sierra Nevada*[1]

Area	Seedling height		Seedling diameter, 2 years	Stem volume, 2 years
	1 year	2 years		
	Cm			*Cc*
El Dorado	13.2 a	43.7 a	1.13 a	21.7 a
Yuba	10.8 bc	40.0 ab	1.15 a	19.3 a
Sierra	11.5 b	39.2 b	1.12 a	17.6 a
Plumas	9.5 c	34.4 c	1.02 b	12.5 b

[1] Means followed by unlike letters differ significantly at the 5 percent level.

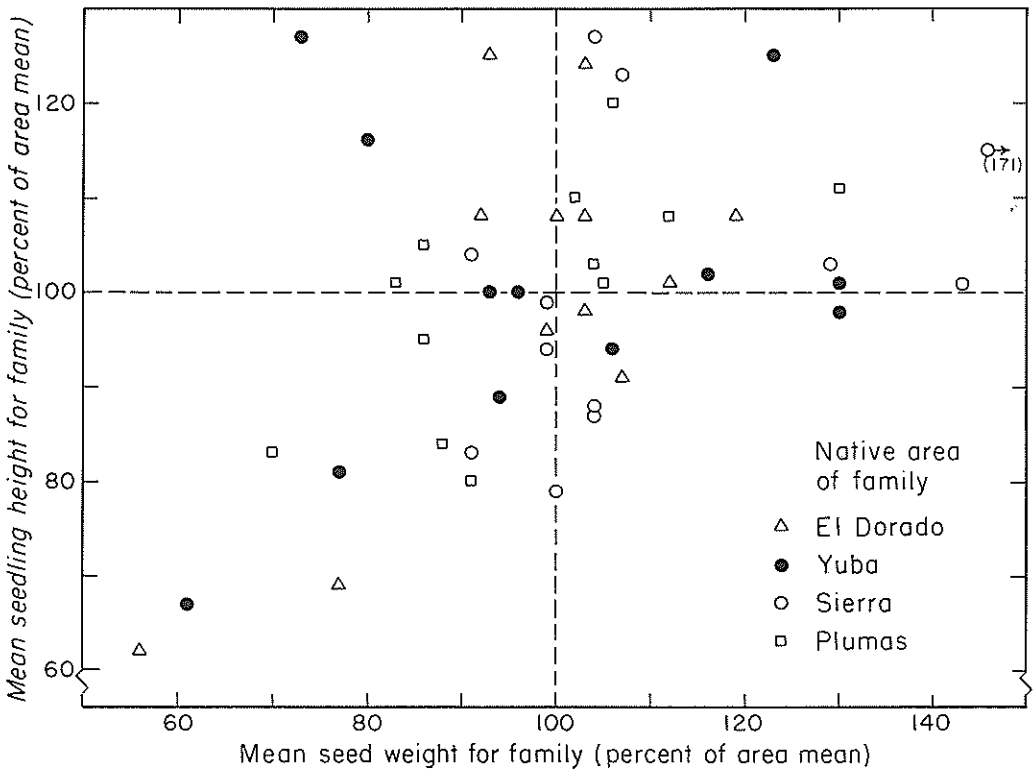

Figure 2—Relation between 1-year seedling height and seed weight of ponderosa pine families grown in the nursery was poor. Family means were expressed as percents of native area means to eliminate effect of area.

significant (n.s.). as follows:

Growth trait:	*El Dorado*	*Yuba*	*Sierra*	*Plumas*
Height				
1 year	**	**	**	**
2 years	*	**	**	n.s.
Diameter, 2 years	*	**	n.s.	n.s.
Stem volume, 2 years	n.s.	*	n.s.	n.s.

Heritability, the estimated proportion of additive genetic variance in the total variance, was between 0.22 and 0.55 for all traits of the El Dorado and Yuba families, and for height growth of the Sierra families (*table 3*). Heritability was 0.36 for 1-year height of families from stands east of the Sierra crest (Plumas area), and dropped to low levels for 2-year diameter and stem volume. The 2-year bud growth of the Plumas families was very different from that of west-side families. With a growing season three times longer than the native season, Plumas seedlings showed abnormally large and variable extension of the terminal and lateral buds after leader elongation was completed.

The variation among families originating within the same stand or area was large. After one season, mean seedling height for individual families ranged from 38 percent below to 27 percent above the means for their native areas, and the tallest family exceeded the shortest by a factor of from 1.5 to 2 (*table 4*).

After two seasons, the absolute height differences between families were double those at 1 year (*table 4*). Stem volume varied from 56 percent below to 61 percent above the native area averages, and the best family surpassed the poorest by factors of 3.7, 2.9, 2.4, and 1.8 for the El Dorado, Yuba, Sierra, and Plumas areas respectively.

Table 3—*Heritabilities of nursery growth traits of wind-pollinated families of ponderosa pine from four geographic areas in the northern Sierra Nevada*[1]

Growth trait	El Dorado	Yuba	Sierra	Plumas
Height				
1 year	0.50	0.47	0.35	0.36
2 years	.34	.55	.30	.14
Diameter, 2 years	.29	.35	.17	.07
Stem volume, 2 years	.22	.37	.14	.03

[1] Heritability estimated by

$$\frac{4\sigma^2_{\text{families}}}{\sigma^2_{\text{families}} + \sigma^2_{\text{families x blocks}} + \sigma^2_{\text{within plots}}}$$

Table 4—*One- and two-year nursery growth of ponderosa pine families from four areas in the northern Sierra Nevada*

Area and Family	1-year growth: Seedling height[1]	1-year growth: Relative height (percent of area mean)	1-year growth: Small-grade seedlings (under 7.5 cm; percent of total)	Area and Family	2-year growth: Seedling stem volume[1,2]	2-year growth: Relative stem volume (percent of area mean)	2-year growth: Seedling height[3]	2-year growth: Seedling diameter[3]
	Cm				*Cc*		*Cm*	
El Dorado:				El Dorado:				
48-2	16.5	125	8.3	48-2	35.7	161	49.1 a	1.35 a
137-6	16.3	124	0.0	137-6	30.9	139	49.2 a	1.26 ab
48-12	14.2	108	6.1	137-4	29.2	132	47.3 ab	1.27 ab
137-1	14.2	108	4.3	137-9	25.0	113	48.0 a	1.19 bc
137-9	14.1	107	4.3	137-1	21.3	96	41.1 c	1.19 bc
48-11	14.1	107	0.0	48-12	20.2	91	45.1 abc	1.15 bcd
48-8	13.3	101	6.2	48-11	20.2	91	45.7 abc	1.14 bcd
48-4	13.0	99	4.4	48-8	19.5	88	44.6 bc	1.11 cd
137-4	12.9	98	2.1	137-5	18.0	81	41.7 bc	1.06 cde
137-5	12.0	91	29.4	48-4	17.1	77	44.9 abc	1.04 de
137-3	9.1	69	39.4	137-3	13.7	62	35.3 d	.93 ef
48-7	8.1	62	46.7	48-7	9.7	44	31.8 d	.88 f
Yuba:				Yuba:				
6-7	13.8	127	4.3	6-7	30.9	160	46.0 a	1.36 a
7-7	13.5	125	0.0	6-2	28.0	145	49.2 ab	1.28 ab
6-2	12.6	116	2.1	7-7	22.8	118	45.0 b	1.21 bc
7-12	11.0	102	2.1	7-3	22.6	117	43.6 bc	1.23 bc
7-3	11.0	102	4.2	7-6	20.1	104	38.6 d	1.21 bc
7-8	10.8	100	11.6	7-4	19.7	102	38.4 d	1.14 c
7-4	10.8	100	23.3	7-8	19.0	98	41.0 cd	1.15 c
7-6	10.6	98	16.2	6-3	17.2	89	39.4 d	1.14 c
6-3	10.2	94	6.5	7-12	16.8	87	38.5 d	1.13 cd
6-10	9.7	89	23.3	6-10	12.8	66	34.1 e	1.02 de
6-8	8.7	81	27.7	6-8	11.5	60	33.4 e	1.01 e
6-9	7.2	67	62.5	6-9	10.6	55	32.7 e	.95 e
Sierra:				Sierra:				
3-3	14.6	127	4.3	2-7	27.5	157	46.5 a	1.33 a
3-7	14.2	123	2.2	3-3	20.6	117	44.1 ab	1.15 bc
2-10	13.2	115	8.7	2-10	19.7	112	41.0 bc	1.15 bc
2-7	12.0	104	2.3	3-7	19.2	109	42.9 ab	1.13 bc
2-11	11.8	103	2.2	3-4	18.6	106	38.7 cd	1.14 bc
2-9	11.6	101	0.0	2-11	17.9	102	37.5 cde	1.17 b
2-8	11.1	96	22.9	2-8	17.7	101	40.0 cd	1.12 bc
3-4	10.8	94	18.2	2-9	16.7	95	38.9 cd	1.14 bc
3-12	10.1	88	25.5	2-1	15.2	87	36.2 de	1.05 cd
2-1	10.0	87	26.1	3-12	13.9	79	35.6 de	1.01 d
3-2	9.5	83	17.4	3-11	12.6	72	34.0 e	1.05 cd
3-11	9.0	79	17.8	3-2	11.5	66	36.0 de	.97 d
Plumas:				Plumas:				
3-11	11.4	120	2.2	3-8	16.7	133	35.6 ab	1.13 a
3-4	10.5	111	8.5	3-4	15.2	121	37.0 a	1.07 ab
4-2	10.4	110	9.3	3-11	15.1	120	37.3 a	1.08 a
4-12	10.2	108	4.3	4-2	13.8	110	37.7 a	1.04 bc
4-3	9.9	105	9.1	4-12	13.4	107	36.5 ab	1.02 bc
3-7	9.7	103	10.6	3-7	13.1	105	33.8 bcd	1.06 ab
3-5	9.6	102	22.9	3-5	11.6	93	33.1 cde	.99 bcd
3-8	9.5	101	20.8	4-7	11.2	89	31.9 de	1.00 bcd
4-10	9.0	95	20.8	4-10	10.6	85	33.2 cd	.98 cd
4-7	8.0	84	34.8	4-3	10.6	84	33.7 bcd	.96 cd
3-12	7.8	83	41.7	4-11	9.8	78	30.2 e	.92 d
4-11	7.6	80	45.5	3-12	9.5	76	32.2 de	.94 d

[1]Family means not common to a bar differ significantly at the 5 percent level.
[2]Estimated by $0.1\ \pi D^2H$.
[3]Family means followed by unlike letters differ significantly at the 5 percent level.

One-year height was a good indicator of 2-year height and stem volume. For each area, five of the six tallest families after 1 year ranked among the top six in height and stem volume after 2 years (*table 4*). Two families (El Dorado 137-4 and Plumas 3-8) moved into top volume rankings partly on the strength of increased height growth in the second season, but primarily because of their superior diameter growth.

Seedling stem volume was not correlated with stem volume of the seed parent ($r^2 = 0.01$). Seven of the eight largest seed trees produced only average-to-poor families.

DISCUSSION

Improving Planting Stock

In this study the inherent early growth differences among wind-pollinated families of ponderosa pine from a single stand or geographic area were pronounced. Such family differences offer the opportunity to improve the size of nursery stock and the efficiency of nursery production.

For the El Dorado, Yuba, Sierra, and Plumas areas, selecting the three tallest families in twelve would increase average shoot height of planting stock by 18.9, 23.1, 21.7, and 13.7 percent (*table 5*). If nursery grading were normally practiced and small-grade seedlings were discarded (*table 4*), selecting the three tallest families could still increase height by 14.0, 16.5, 18.0, and 7.8 percent. Small-grade loss would simultaneously be reduced by 62, 85, 58, and 65 percent.

Selecting the six tallest families would increase average height by 12.9, 12.0, 12.2, and 9.5 percent for the four areas. With grading, the six tallest families would still increase height by 7.7, 7.8, 8.2, and 3.9 percent and would decrease small grades by 70, 74, 73, and 62 percent.

Eliminating the three shortest families (in twelve) could increase average height by 8.3, 7.4, 5.2, and 5.3 percent. Compared to growing all families and not grading, growing the tallest three-fourths and practicing grading would increase the average height of planting stock by 12.9, 11.1, 10.4, and 10.5 percent for the El Dorado, Yuba, Sierra, and Plumas areas.

Seedlings were not graded by diameter in these examples. Spacing in the nursery beds was 10 seedlings per square foot, and diameter growth of first-year ponderosa pine in production nurseries is acceptable even at 30 seedlings per square foot (Baron and Schubert 1963). Though closer spacing reduces diameter growth, the effect on height growth is minimal (Baron and Schubert 1963, Shoulders 1961). Thus height remains a valid index to family performance and seedling quality.

Table 5—*Effect of family selection on size of planting stock and efficiency of nursery production calculated from growth of ponderosa pine families from four geographic areas in the northern Sierra Nevada*

Area and family selection method	Mean height		Small-grade seedlings (under 7.5 cm)
	All seedlings	Seedlings over 7.5 cm	
	Cm		*Percent*
El Dorado:			
12 random	13.2	14.3	12.6
9 tallest	14.3	14.9	4.0
6 tallest	14.9	15.4	3.8
3 tallest	15.7	16.3	4.8
Yuba:			
12 random	10.8	11.5	15.3
9 tallest	11.6	12.0	7.8
6 tallest	12.1	12.4	4.0
3 tallest	13.3	13.4	2.1
Sierra:			
12 random	11.5	12.2	12.3
9 tallest	12.1	12.7	9.6
6 tallest	12.9	13.2	3.3
3 tallest	14.0	14.4	5.1
Plumas:			
12 random	9.5	10.3	19.2
9 tallest	10.0	10.5	12.0
6 tallest	10.4	10.7	7.3
3 tallest	10.8	11.1	6.7

Predicting Growth of Families

The literature is replete with investigations reporting positive influence of seed size on seedling growth. But most of these investigations graded seed—by screening, volume, or weight—from mass collections for a single source. The few studies that have examined the dependence of family growth on family seed weight found little or no relationship at the close of one growing season (Brown and Goddard 1959, Hanover and Barnes 1963, Morgenstern 1969a, Righter 1945, Stonecypher and others 1966).

In ponderosa pine, I found family seed weights to be consistent from year to year: the correlation between mean seed weights of 17 Yuba families collected in 1967 and again in 1970 was 0.80. Although seed weight varies widely among families from a single stand or area (*fig. 2*), the nursery trial shows that the influence of family seed weight on height and volume growth is weak and quickly lost. Neither selection of large-seed families within an area nor elimination of small-seed families will increase the size of seedlings produced in the nursery (*fig. 2*).

Nursery growth of families is not predicted by family germination speeds determined at 20 to 25° C. In a highly favorable nursery environment with a long growing season, inherent growth potential obscures any initial advantage expected for either large-seed or fast-germinating families. The contrasts between these results and those in a 1937 ponderosa pine study (Callaham and Hasel 1961) are attributable to spring sowing of unstratified (dormant) seed for the 1937 study.

Seed parent stem volume does not forecast family growth performance in the nursery. In these natural stands, microsite variability was immense and growth of the seed parents may simply reflect the influence of microsite. Within natural stands, trees that show fair-to-good cone production display a wide range in the 1-year growth of their wind-pollinated families whether the stand is unimproved or improved for seed production. The mean 1-year height and the range of means of families from the Plumas stands were the same as those of 44 families from a nearby seed production area (Lees Summit) in which most intermediate, suppressed, and other poor-phenotype trees had been removed. In both instances, heritability of 1-year height was 0.36.

Improving Field Performance

In the present study, both 2-year height and stem volume were strongly correlated with 1-year family height. But will tall families in the nursery continue to perform in a superior fashion in the field? The available evidence is encouraging. A plantation trial with ponderosa and Jeffrey pine in the northern Sierra Nevada (zone 523) demonstrated that spread in height between size classes of both 1-0 and 1-1 transplants increased through the ninth year after outplanting; large stock continued to grow faster than medium stock, which in turn grew faster than small stock (Fowells 1953). In California ponderosa pine plantations ranging in age from 16 to 50 years, the trees first reaching breast height continued as dominants and codominants in the developing stands (Oliver and Powers 1971). Such evidence suggests that the larger trees in a plantation develop from larger transplants. Besides growing faster, stock of medium and larger sizes often survives better than stock of smaller sizes (Bethune and Langdon 1966, Blair and Cech 1974, Burns and Brendemuehl 1971, Fowells 1953). Increasing the size of planting stock by eliminating the poorer families should improve both survival and early plantation growth.

Will the relative growth of consecutive wind-pollinated families from the same trees be consistent? In ponderosa pine I found that family heights in the nursery were consistent from one seed year to another. The correlation between mean heights of 14 Yuba families collected in 1967 and again in 1970 was 0.91 for 1-year height and 0.77 for 2-year height. Though limited, this evidence agrees with that reported for slash pine: For 3 crop years and plantings, the relative rankings of families were constant (based on 5- or 3-year growth) for four seed parents, and were variable for two others; and even for the latter parents three of the six families showed their expected growth (Green and others 1957).

Evaluating Variation for Tree Improvement

The inherent family differences in early growth of California ponderosa pine are sufficiently large to justify evaluation of family performance in the nursery to assist in identification of desirable (or undesirable) seed parents. Seed tree selection ought to depend not only on form and growth of the seed trees, but on progeny testing. That approach has been adopted for ponderosa pine in southern Idaho (Wang 1967).

In California ponderosa pine, seed production should also be a criterion for selection. Flower and cone production are strongly inherited in the southern pines (Barnes and Bengtson 1968, Cole 1963, Shoulders 1967, Varnell and others 1967) and undoubtedly are in ponderosa pine, too. Many phenotypically good trees bear small or no cone crops, even in the best seed years (Krugman 1965, Sundahl 1971).

Alternatives for obtaining improved seed for artificial reforestation in California forests until clonal (or other) orchards are producing include collection from seed trees selected in a wide variety of natural stands in each seed zone, collection of wind-pollinated seed from the Region's superior-phenotype trees, and collection of seed from trees chosen along

road systems (Silen 1966). Any of these alternatives easily lends itself to screening families in nursery tests.

For ponderosa pine, I favor delimitation of ecologically defined natural stands throughout California's tree seed zones, and selection among the average-to-good trees in these stands by screening their wind-pollinated families for nursery growth potential. This procedure would ensure that nursery stock is genetically adapted to local planting sites. Nursery production would not include offspring from trees whose families showed poor growth. In addition, future seed collections would include trees whose families showed average or better growth. The immediate returns would be an increase in size of planting stock and an improvement in nursery efficiency through the decrease in small-grade seedling production.

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1975. **Increasing planting stock size by family selection in California ponderosa pine.** USDA Forest Serv. Res. Paper PSW-108, 10 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

Wind-pollinated families from four geographic areas in the northern Sierra Nevada were tested in the nursery. For every area, the native families differed significantly from each other in 1-year seedling height, and in 2-year height, diameter, and stem volume. Family growth was poorly correlated with family seed weight; it was independent of germination speed and seed parent stem volume. The size of planting stock can be improved and small-grade seedling production decreased by eliminating from future collections seed trees whose families show poor growth in the nursery.

Oxford: 174.7 *Pinus ponderosa* (794)–232.41:265.5:181.25.
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