POTENTIAL FOR FOREIGN PRODUCTION OF PINE SEED FOR THE UNITED STATES

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Abstract.-- An attractive possibility exists for contract production in a foreign country of pine seed for use in the United States. Because domestic first-generation orchards have usually been established, the greatest opportunity exists with advanced-generation genetic material. The primary advantages of foreign seed production are:

1. Large quantities of extremely valuable seed could be available more quickly and cheaply than is possible in the United States.

2. The certainty of the magnitude of annual seed yield is greatly improved due to reduced yearly production variance.

INTRODUCTION

The breeding of pine trees for improved growth, form and disease resistance is a routine practice in the southern United States. Over 6,000 acres of production orchards are established (Knight & McClure 1974), with the oldest being approximately 20 years of age. The seed currently produced are sufficient to plant at least 400,000 acres annually, and within five years enough improved seed will be available to plant well over one-half million acres each year (Anon. 1974a, Anon. 1974b). At maturity, 6,000 acres of pine seed orchards should produce annually enough seed to plant over 4 million acres, a quantity probably sufficient to satisfy the annual planting needs of the South. Even so, there is a need to establish more pine orchards-- new, more genetically improved orchards that will make the current 6,000 acres of "first-generation" orchards obsolete.

Matziris (1974) has calculated the current superiority of 8-year-old first-generation trees over wild stock to be 15 to 19 percent in volume, 18 percent in disease resistance, and over 11 percent in straightness. But the predicted additional gains possible from second-generation breeding efforts are even greater (Table 3). With rapidly rising land and timber values in the southern United States, it is certain that the first-generation orchards should be replaced with superior second-generation material at the earliest opportunity. Only 28 acres of second-generation orchards are now established (Anon. 1974a), and none are old enough to bear commercial quantities of seed.

The southern pines, especially loblolly (P. taeda) and slash (P. elliottii), are grown in a number of foreign countries, such as Australia, Brazil, South Africa, and New Zealand. For reasons not entirely understood, these species yield larger and earlier seed crops in some countries than in the United States, and an example is shown in Table I. There are three major reasons to consider

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second-generation tree seed production in foreign countries. (1) The cost of seed production may be lower. (2) It can be possible to obtain larger volumes of highly improved seed sooner than in the United States, and with more consistency. (3) Due to faster tree growth the possibility exists of accelerated generation turnover.

Establishment Procedures for First- and Second-Generation Orchards in the U.S. and a Foreign Country

The breeding method most used to create superior first-generation populations of southern pines is mass selection plus progeny testing. The degree of improvement possible from this procedure depends on the variance of the population, the phenotypic superiority of selected individuals, and the degree to which individual traits are inherited.

Phenotypic selection is inefficient in that phenotypes do not always accurately indicate genotypes, i.e., a phenotypically superior individual sometimes produces inferior progeny. Progeny testing is a refinement of the initial selection process, and accurately reflects the performance of certain matings when the offspring are grown in a particular locality. Parent trees that are inferior based upon progeny tests for a locality are rogued -- removed-- from the orchard. Therefore, the total improvement derived from a first-generation orchard is from the initial gain from mass selection plus the refinement of the initial choices through progeny testing.

Second-generation orchards will provide additional gain over that obtained in the first-generation. The elite population derived from mass selection and progeny testing is used as a breeding base to provide control-pollinated "families" in which both first-generation parents are known. The most outstanding individuals within the best families are vegetatively propagated to be used as parents in second-generation seed orchards. Good precision is possible in choosing superior individuals and predicting the performance of the progeny in the second-generation because of knowledge about the genetics of families and of individuals as well as from the greater uniformity of site and spacing in planting. Once a pedigree has been established for each individual and a better environment created for selection, efficiency and gains are rapidly improved.

If second-generation seed for the U.S. were to be produced in a foreign country, one of two procedures would have to be used: (1) Vegetative material (scions) from the appropriate individuals would be sent to the foreign country where it would be used to form vegetative orchards similar to many in the U. S. Only the location of the orchard would be different, and the seeds produced for return to this country would be genetically identical to those produced domestically from the same parent trees. Currently, however, the governments of most countries, including the U. S., will not allow free importation of vegetative tree material for fear of disease introduction. Sterilized seed is usually permitted to enter a foreign country. (2) In lieu of scion introduction, seed of the same genetic crosses that produced the superior control-pollinated families in the U. S. could be sent to the foreign country. There it would be grown as in the U.S., but it is not certain that selection of the best individuals within the best families would always be valid. Geneticists use the term "genotype-by-environment interaction" to describe the situation where individuals behave distinctly differently-- perhaps change rank within a group-- depending on the environment in which they are grown. Where this problem exists for certain characteristics, especially growth or disease resistance, individuals selected for superiority in a foreign country may not be superior when grown in the U.S. Thus a portion of second-generation gain due to selection of individuals within the best families may be lost.

Comparative Foreign and Domestic Seed Yields

Southern pines sometimes yield more seed, and with less annual variance, in foreign countries. For example, Tables 1 and 2 illustrate typical orchard yields for both South Africa and the U.S. It is clear that in these typical U.S. orchards there is extreme year-to-year variation, and there is also considerable variation between orchards. Reports from S.A. and some other countries indicate their yields are very stable from year to year, and with proper selection of orchard location, yields are predictable and consistent between orchards.

Table 1. -- Comparison of South African and U. S. orchard yields of loblolly pine seed[a/]

	SA	C_1	C_2	C_3	P_1	P_2
Age	Pounds/Acre					
3	---	.07	2.30	---	.50	---
4	1.70	.02	3.00	---	.80	---
5	7.20	5.30	4.00	---	1.40	---
6	36.00	8.30	12.70	---	5.30	---
7	42.80	10.30	16.80	---	7.00	---
8	99.40	14.20	22.00	---	---	---
9	106.30	13.40	---	9.28	---	16.67
10	111.40	21.50	---	13.93	---	24.11
11	---	---	---	14.86	---	40.89
12	---	---	---	50.86	---	30.67

SA = South African Orchard -- loblolly pine.

C_i = Coastal sources of U. S. loblolly, representing various orchards.

P_i = Piedmont sources of U. S. loblolly, representing various orchards.

[a/] Sources: S.A. yields were furnished by Mr. Neville Denison of S. A. Investments Ltd., and represent actual loblolly seed yields from orchards in that country. Other yield figures are production records from typical orchards in the southeastern U. S.

For purposes of comparison, a composite profile of typical yields of U.S. loblolly orchards was prepared (Table 2). Harvest costs are based on a recent survey of members of the N. C. State Tree Improvement Cooperative.

The Question of Genotype-x-Environment Interaction

Without knowledge of the effect of GE interaction on selection it would not be safe to do within-family selection in a foreign country. Unless GE interaction is shown not to be a serious problem, about 40 percent of the possible gains from second-generation breeding might be lost by producing seed in a foreign country because of the inability to choose the best individuals within families (Table 3). Some information is now available to help determine the magnitude of the GE interaction.

In 1970, seed from selected clones of loblolly and slash pines grown in South Africa were sent to the U.S. for testing. At the end of one year, of the top 50 percent in height growth, four of six families were listed in the top 50 percent in both the U.S. and in S. A. Four-year measurements will soon be available and more definite comparison of family rank between countries can be made. It is evident by observation that nearly all these families selected for superiority in S.A. have grown extremely well in the U.S. Three-year measurements are available for progeny grown in Rhodesia from seed sent from the U.S., and a number of the best-performing families in Rhodesia are also top performers in the U.S.

Table 2. -- Composite profile of seed yield per acre in a typical U. S. loblolly seed orchard and the associated harvesting cost per acre

Age	Yield/Acre (Lbs.)	Harvesting Cost/Acre
5	7	$158
6	10	192
7	13	226
8	19	295
9	27	387
10	33	456
11	37	501
12+	40	536

All available data offer little more than a general indication about the GE interaction question. The most comprehensive answer will come from a unique test now being established through the N. C. State Cooperative Programs. Seed have been selected from over sixty clones known to perform well when mated with nearly any other parent (Good General Combiners). These are being used in test plantings across the South by 28 companies, and in six foreign countries. In a few years these tests will give solid indication of the extent of the GE interaction problem across the South and among areas of four continents.

Based upon data available, this writer must assume that intelligent location of southern pine family tests in foreign countries where the species grows well will allow reasonably accurate within-family selection for second-generation material that is to be repatriated to the U.S.

Predicted Genetic Gains From Second-Generation Selections

Matziris (1974) has estimated the genetic variance components and correlations at age eight from first-generation loblolly pine progeny tests in nine separate locations across the South. The values are reasonably consistent across locations, though sometimes statistically different. Within a location the statistical significance of estimates is good.

These numbers were used to estimate the values in Table 3, which are predicted gains that could be obtained by selecting for each trait individually under normal U.S. breeding practices.

Table 3. -- Predicted additional gains (%) in single traits under different breeding procedures from second-generation orchards in the U. S.

	A	B
Height (Ft.)	5.3	8.7
Straightness (Score)	8.2	14.7
Volume (Cu. Ft.)	9.0	25.0
Fusiform (Score)	21.5	35.0

A = Selection of top 25% of families.

B = Selection of top 25% of families plus additional selection of top 3 percent of individuals within families.

There is a definite limit to the selection intensity that can be applied for second-generation selection, which is dependent on the number of families and individuals per family that are under test. Current procedure with the N. C. State Tree Improvement Program is to select about the top 25 percent of families, and the top 3 percent of individuals within families. With these selection intensities the average predicted gains to be expected in single traits from breeding within the U.S. are shown in Table 3. Column (A) shows predicted second-generation gains from family selection alone, and (B) the gain from selection of families plus within families. Roughly 60 percent of the total predicted second-generation gain from breeding within the U.S. comes from family selection; the rest is from within-family selection.

The predictions in column (A) would also be the minimum gain to expect from seed produced in a foreign country, since the family selection would occur in the U.S., and the seed would come from these same family groups in the foreign country. However, the predicted gains in column (B) could only be achieved in a foreign country if there is no genotype-by-environment interaction. To the degree that this interaction does exist, selection within families will be inefficient and the gain reduced for seed to be returned to the U.S. Selection within families for fusiform rust resistance would be very difficult to achieve in a foreign country because the pathogen exists only in the U. S. No natural infection could occur and the only way a selection differential could be obtained would be through screening individuals by artificial inoculation with fusiform spores. This is one current method of determining fusiform rust-resistant families in this country, but it is doubtful any foreign country would accept the procedure. Although fusiform rust requires a life-stage on red oak trees, and there are no natural oaks in many foreign countries, it is possible for a mutant spore to find another related hardwood species an acceptable alternate host. One feasible method of identifying the fusiform susceptibility of parent trees growing in a foreign country would be to send seed from individuals to the United States for testing. Facilities for laboratory testing for disease resistance are available now in the United States and the cost per test is insignificant. It does remain to be determined how well laboratory tests compare with field results, but early results are encouraging. The primary point to note is that the economic value of seed does depend on the level of fusiform intensity in the area for which the seed are intended, and the degree of genetic resistance carried by the seed. Furthermore, the degree of resistance is dependent on the ability of the tree breeder to accurately select disease resistant parent trees.

ECONOMIC ASSESSMENT

Seed Production Costs

Cost figures for an "average" orchard which were derived from a TAPPI (Technical Association of the Pulp and Paper Industry) survey of 19 industries in the Southern Pine Region are used to reflect the costs that will be involved with second-generation orchards. Costs of making new wild selections, controlled crossing, and progeny testing are ignored because these will be borne by the U.S. companies regardless of where the second-generation orchard is established. The relevant comparative seed production costs are shown in Table 4.

An inflation-free real rate of return (Mundell 1963) was used to calculate annualized average U.S. seed costs that could be compared with the real average annual cost of seeds from S. A. Based on the seed yields of U.S. loblolly orchards, the discounted annualized after-tax cost per pound of seed is $14.81 at a 10 percent real rate of return. Foreign companies have estimated that they could produce loblolly seed for about $13.50 per pound in constant 1974 dollars, or an after-tax cost of $7.02 in constant dollars for a large company who might purchase the seed.

In relative terms the cost of loblolly seed purchased from a foreign country could be about 50 percent cheaper than seed grown domestically. For a company that needs 2,000 pounds-of seed annually (the expected mean yield from a mature 50-acre U.S. loblolly orchard) the average saving in seed cost could be about $15,600 per year in current after-tax dollars. But cost of seed production is only one side of the coin-- the other is the benefit to be derived from seed produced in either the U. S. or a foreign country.

Seed Valuation

The value of a pound of improved seed is the discounted net present value of the additional wood produced by it in an on-going planting program. In Tables 5 and 6 these values are estimated for both domestic and foreign-produced seed when the seedlings are grown under various degrees of fusiform intensity.

Table 4. -- Seed production costs associated with a 50-acre second-generation loblolly seed orchard in the southern U. S. *

	Before Tax	After Tax
Orchard:		
Site preparation and establishment [a]	$13,150	$ 6,575
Management cost/year [b]		
1-5 years	7,650	3,825
6-10 years	12,850	6,425
11+ years	16,950	8,475
Land value, 50 acres	5,950	5,950
Annual property tax on orchard land	32	16
Harvesting: [c]		
age 5	7,900	3,950
6	9,600	4,800
7	11,300	5,650
8	14,750	7,373
9	19,350	9,675
10	22,800	11,400
11	25,050	12,525
12+	26,800	13,400

[a] Land clearing, burning grafting, planting stock trees.

[b] Fertilization, mowing, insecticides, supervision, etc.

[c] Cone collection, seed extraction, and cleaning.

* Adapted from TAPPI data shown in Porterfield (1973).

Let us assume that a company needs 2,000 pounds of loblolly seed annually which may be produced domestically in the usual fashion; alternatively, it can contract for enough acreage in a foreign country to yield an identical quantity of seed. The present value of the total amount of seed depends on:

I. Degree of genetic improvement over first-generation seed.

1. Life of the orchard, which will be set at 25 years.
2. Base productivity of the land on which the seed will be planted, assumed here to be 160 cubic feet per acre per year with first-generation material.
3. Degree of disease hazard. The present value of seed intended for a hazardous area is less than for a nonhazardous area.
4. Harvest age of the plantations, assumed to be 25 years.
5. Acres planted by each pound of seed; the number used is 16 acres.
6. Real alternative rate of return, which will be set at 10 percent.
7. Stumpage value of wood produced, taken to be constant at $.50 per cubic foot.

If GE interaction is a problem in a foreign country, then the appropriate comparison of alternatives is Method A in the foreign orchard with Method B in the U.S.; under conditions of no fusiform, the present value of the U. S.-produced seed exceeds that of the foreign-grown by $3,130,000. Under these circumstances it would not make economic sense to produce seed outside the U.S. But if little GE interaction is present, enabling foreign within-family selection for traits other than fusiform, then the present value of the foreign-produced seed exceeds that of U.S. seed by $557,000 under conditions where fusiform rust is of little importance.

Table 5.--Present value of the additional wood obtained from second-generation seed produced from a domestic orchard over a 25-year life

Method A (Family Selection Only)

Fusiform Intensity	None	Light	Medium	Heavy
After-tax net present value of 1 lb. of seed @ 10%	$213	$190	$140	$126
After-tax present value of all seed received for 25 years	$1,767,000	$1,576,000	$1,162,000	$1,045,000

Method B (Family Plus Within-Family Selection)

Fusiform Intensity	None	Light	Medium	Heavy
After-tax net present value of 1 lb. of seed @ 10%	$618	$560	$442	$378
After-tax present value of all seed received for 25 years	$5,128,000	$4,646,000	$3,667,000	$3,136,000

Table 6.--Present value of the additional wood obtained from second-generation seed produced from a foreign orchard over a 25-year life

Method A (Family Selection Only)

Fusiform Intensity	None	Light	Medium	Heavy
After-tax net present value of 1 lb. of seed @ 10%	$220	$197	$147	$133
After-tax present value of all seed received for 25 years	$1,998,000	$1,789,000	$1,335,000	$1,208,000

Method B (Family Plus Within-Family Selection)

Fusiform Intensity	None	Light	Medium	Heavy
After-tax net present value of 1 lb. of seed @ 10%	$626	$580	$473	$400
After-tax present value of all seed received for 25 years	$5,685,000	$5,267,000	$4,295,000	$3,633,000

The relative situation is little changed when seed are intended for areas of heavy fusiform infection. With severe GE interaction it would not make economic sense to contract for foreign seed production, but without GE problems it would be profitable. The situation seems to be that if foreign orchards can be established by vegetative means, in which case the GE problems are eliminated, there is a possibility of large gain by U. S. forestry corporations. If scion importation is forbidden, and foreign orchards must be produced from seed, then potential gains are directly related to the degree of GE interaction that occurs. Appropriate testing can eliminate much of this problem, but probably not all of it. Because of the amazingly large spread between seed production costs and the value of the seed to a wood-producing company, the issue of key importance becomes the rapidity by which improved seed can be obtained, not the cost of production.

The most satisfactory solution to the foreign seed production problem would be to develop mutually satisfactory scion exchange procedures with some foreign countries. In this way all question of GE interaction could be eliminated, and the financial gains from obtaining highly improved seed more quickly could be considerable. But even if scion exchange continues to be a problem, with the correct procedures, foreign seed production for use in the U.S. could be worthwhile.

SUMMARY

An attractive possibility exists for contract production in a foreign country of pine seed for use in the United States. Because domestic first-generation orchards have usually been established, the greatest opportunity exists with second-generation genetic material. The primary advantages of foreign seed production are:

1. Large quantities of extremely valuable seed would be available more quickly than is possible in the United States.
2. The certainty of the magnitude of annual seed yield is greatly improved due to reduced yearly variance.
3. The cost of seed production in a foreign country such as South Africa would be lower than in the United States if current cost differentials continue.
4. Acceptable scion export procedures would allow the greatest advantage to be made of foreign seed production possibilities.

The disadvantages to foreign seed production:

1. Selection of genotypes in a foreign country for use in the United States may not be efficient if large genotype-x-environmental interaction exists, although circumstantial evidence to date suggests that this will not be a serious problem.
2. Effective selection for fusiform rust resistance is more difficult outside the United States.

3. If a seed source is located outside the United States, supplies could be interrupted by political or social upheavals over which the United States company would have no control.

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