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A SIMPLE, PROGRESSIVE, TREE IMPROVEMENT PROGRAM FOR DOUGLAS-FIR

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Present Douglas-fir tree improvement programs appeal primarily to the very large forest ownerships. There is need for a simple, low-cost program which appeals to medium and smaller forest-land owners if tree improvement is to become generally practiced in the Northwest. There is need also for a ready alternative to programs based upon clonal Douglas-fir seed orchards because technical problems, though probably solvable, are becoming serious. This paper proposes and describes such a program in which substantial improvement in steady increments appears assured from known performance patterns of tree families in the half-century-old Douglas-fir heredity study.[1]

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[1] Munger, Thornton T., and Morris, William G. Growth of Douglas fir trees of known seed source. U.S. Dep. Agr. Tech. Bull. 537, 40 pp., illus. 1936.

Silen, Roy R. Regeneration aspects of the 50-year-old Douglas-fir heredity study. In Western Reforestation. West. Forest. & Conserv. Ass. Reforest. Coordinating Com. Proc. 1964: 35-39. 1965.

Silen, Roy R. A 50-year racial study of Douglas-fir in western Oregon and Washington. (Abstr.) West. Forest Genetics Ass. Proc. 1965: 6-7. 1966.

U.S. Forest Service. The 1912 Douglas-fir heredity study. In Annual Report 1963, the Fifty and Fiftieth Year(s). Pacific Northwest Forest & Range Exp. Sta., pp. 4-7, illus. 1964.

It departs from previous programs in that it (1) provides immediate and ample supplies of seed from cone-producing trees along roadsides rather than from seed orchards, (2) emphasizes testing of parent trees by the hundreds through performance of their offspring instead of stressing rigorous initial selection, (3) leaves decisions on details of parent tree selection to foresters of future generations, and (4) leads directly and logically into a long-term breeding program covering many tree generations.

THE PROGRAM IN BRIEF

The program can be briefly described as follows. Enough cone-producing trees would be chosen along the road system of a forest ownership to provide adequate seed supplies for all planting needs of a sustained yield program. This group of trees will henceforward be referred to as the seed source group. At the same time, a group--two or three times larger and referred to henceforward as the reserve tree group--would also be chosen for the program. The degree of selection could range from random to rigorous, as decided by the landowner. Some improvement would be expected in the initial seed collections if we assume some positive correlation between selected parent and their offspring.

The basis for steady and progressive improvement of the seed source group of parents over the years would be a test of every parent in both groups by performance of their wind-pollinated offspring in several test sites on the forest ownership. Each evaluation of this progeny test, possibly at 5-year intervals, would provide opportunities to eliminate poor parents in the seed source group and to substitute better parents from the reserve tree group. All parents would be carefully preserved. Genetic improvement becomes progressively more assured from the earliest to the final evaluation of the progeny test, although half a century or more may elapse before the final results of growth and survival are available.

As test results accumulate, numerous opportunities are provided to phase into sound breeding programs, based on tested parents or families, or into various seed orchard programs. Steps in the program are outlined in more detail on pages 12 and 13.

RESEARCH BACKGROUND

Many of the details of this proposed program are based on unpublished results from the Douglas-fir heredity study. Some of the most important findings from this study are:

1. Some parents in every race tested could have provided appreciable genetic gains, even though their progeny have only one known parent. Within a race, best families from wind-pollinated parents outproduce poorest families in timber volume per acre at 50 years by

ratios of 2:1 and sometimes over 3:1. Even from randomly selected parents within a race, the one best parent in four would have provided more than 10 percent increased volume over the average of unselected parents. However, the data provide no satisfactory substitute for a long-term progeny test to determine which parents actually produce best families for a particular site. Hence, the study provides a major simplification--a sound tree improvement program can be based upon seed collections from progeny-tested mature parent trees located in the forest.

2. Progeny tests employing wind-pollinated seed are practical. Although tests using controlled-pollinated seed would provide more information for the plant breeder, a test using wind-pollinated seed will separate poor and good parents. Using wind-pollinated seed for a progeny test facilitates testing hundreds of parents of the same crop year with minimum of time, initial effort, expense, and highly trained personnel.

3. A long progeny test is required because early results are often reversed in later years. Survival differences, although generally unimportant for the first quarter century, account for more and more differences as stands approach the half century mark. At the family level, inherent survival differences already account for one-quarter or more of the volume-per-acre differences. At the racial level, the local races now are surviving best. Thus, the study furnishes evidence that improvement should be based upon a long-term test of parents well distributed among the local race to assure that they are well adapted to the site.

4. There is no assurance that a family that displays a clear superiority on one site will do well on another. A small percentage of families are above average on several sites, but the great majority that do well on one site are average or poor on others. The only way to determine such behavior is to test families on several sites.

ASSUMPTIONS

The proposed tree improvement program is based also upon these assumptions:

1. That the most important consideration at the start of a breeding program is to screen a large number of parent trees by progeny test. This provides a large genetic base as a major safeguard against production of a poorly adapted or otherwise undesirable strain from subsequent selections and reselections after investing years of effort.

2. That substantial improvement of any race is possible with wind-pollinated seed provided the best quarter of the parents are used as ascertained by long-term progeny test.

3. That a progeny test must, as a minimum, evaluate survival differences, at least up to age 30 and perhaps to age 60.

4. That a seed source unit, within which movement of planting stock should be limited, should have generally the same local climate and probably normally correspond to some management unit of about 75,000 to 150,000 acres. The data for this assumption is fragmentary for Douglas-fir. The effect on program cost per pound of seed from using larger or smaller areas is very large.

5. That 75 to 100 parent trees of climbable size in the seed source group will furnish enough seed for the sustained yield planting program on a seed source unit.

6. That 300 trees, well dispersed over the seed source unit, constitute a large enough genetic base for a long-term breeding program. This number still limits first-generation selection of parents at end of the test to the best 25 percent of the 300 parents in order to have a genetic base of at least 75 parent trees.

7. That, in choosing parents for the seed source group, trees will not be selected very rigorously from the population because of their roadside location and cone-bearing requirements. Detailed discussion of pros and cons of this assumption are given later.

8. That any practical program must provide seed in ample quantities within as few years as possible. Economic analysis has shown all tree improvement programs where ample seed supplies are long delayed to be costly and often uneconomical.

9. That there is a positive parent-progeny correlation which will result in some improvement in the progeny of the seed source group of trees even if the parental selection is not very rigorous. No data as to the strength of this correlation is yet available for traits in mature trees.

10. That a practical progeny test involving 300 parents can be made under conditions found in the region. Difficulties in finding homogeneous test sites in the rugged terrain of the Douglas-fir region and expense of installing such a test on heterogeneous sites may make this assumption one deserving much analysis. However, this problem is one which will eventually face any selection or breeding program.

DETAILS OF THE PROGRAM

Based upon the above background and research, the following steps are the minimum required to implement the program: (1) selection of seed source and reserve groups of trees, (2) repeated collection of seed from the seed source group, (3) establishment of a progeny test, (4) periodic evaluation of the progeny test with reselection of the seed source group, (5) initiation of a program for long-term breeding. Alternative steps are also discussed.

Selection

The selection of about 300 parent trees divided between a seed source group (75 to 100) and a reserve group (200 to 225) would be made among easily climbed trees 30 to 60 years old, well distributed along forest roads, each capable of bearing a bushel or more of cones. There is no reason why a high intensity of selection could not be used if conditions permit. However, the population of trees that meet these requirements is usually restricted on most Northwest forest units. Selection beyond the best 1 in 20 would probably not usually be practical for the combination of traits ordinarily included in selection programs when this large a number of parent trees is desired. The practicing forester should be aware that arguments do exist for low intensity of selection just as they do for high selection intensity in an initial program. Otherwise, he may place more weight on the disadvantages of low selection intensity than present knowledge would justify. The next three paragraphs, therefore, discuss some of the arguments for a low selection intensity.

Simply from the standpoint of costs and returns, there is no data at present upon which to base the decision of whether a dollar spent in more intensive selection is better than the same dollar spent in progeny testing a greater number of trees selected less rigorously. Present figures on heritability of traits and the expertise with which foresters can assess the environmental component expressed for a trait in a single tree raise many questions about the effectiveness of any level of present-day selection. Intensive selection procedures require concentrating at the outset on a very few traits, a somewhat dangerous limitation in view of changes in market demands even in the last decade. The preference of some families for a single site, as displayed in the 50-year-old study, raises additional problems.

The only kind of selection in Douglas-fir on which there is long-term data is random selection. In the Douglas-fir heredity study the items for which selection was made (age, stand condition, or soil type) amounted to no conscious selection for growth, form, or survival. With volume differences at age 50 of 2:1 or larger between families within every race, there seems little question that adequate gains could be expected even from random selection to justify the proposed program.

Without corresponding data on the outcome of intensive selection, increasing departure from random selection introduces an additional risk. The 50-year-old study shows that (1) adapted races and families survive best, (2) ability to survive becomes increasingly important in influencing volume differences after 30 years, and (3) unexpected extremes of climate, which occur at infrequent intervals, are very important in this survival. Exact traits that permit one genotype to survive and another to perish over a rotation in the wild may be rather difficult to ascertain at present stage of knowledge. A sobering thought is that natural selection is generally against almost every trait that deviates far from the average, including unusual growth. The low selection intensity built into the plan would appear to be a safeguard against including an overly high proportion of any trait that deviates far from the average.

With these uncertainties and risks, a rather low selection intensity for the 300 trees is certainly acceptable, if not prudent. However, foresters would not be human if they did not wish to exercise their skill and experience in initially selecting good phenotypes for inclusion in the program. Hence, inclusion of as intensively selected a seed source group of trees as roadside selection will permit is probably inevitable. The advisability of including a randomly selected group of trees among the reserve parent group is discussed under alternative steps.

Seed Collection

Initially, wind-pollinated seed would be collected from all 300 trees in the small amount adequate for the progeny test. Such collection would best be made during a good crop year to maximize cross-pollination and minimize possible bias toward inherently prolific cone producers. One of the advantages of using wind-pollinated seed is that collections from all the parents can be made in a single crop year.

From the 75 to 100 trees of the seed source group, all the cones would be collected any year they produce appreciable seed to provide the supply of seed for the planting program. Higher seed costs than commercial collection should be expected because commercial seed collections are usually confined to heavily bearing trees with large cones to reduce costs. The seed source group of trees would have greater variation in range of cone size and crop, and smaller cone lots would be handled. However, costs would be no higher than normal for any collection from specified trees.

Whether enough seed can be obtained from 75 to 100 roadside trees is a debatable assumption. An estimate of seed yields in British

Columbia[2] indicates that rather large trees might be required--perhaps 20- to 30-inch diameters--for even the 25 to 50 pounds of seed needed yearly. This amount of seed is based upon needs of a 100,000-acre forest, assuming a planting program of 1,250 acres a year and an 80-year rotation. There are several alternatives if seed quantities prove insufficient. The total number of parent trees can be increased, or cones can be collected from more than the 75 to 100 trees of the seed source group. It is fairly certain that if provided ample growing space for several decades, 75 original parent trees of the seed source group, representing a 1:4 selection among the 300 trees, would develop enough crown to produce seed in required quantities. As another alternative, an auxiliary group of selected, but untested, trees could be used while the seed source group of trees gained crown size.

Progeny Testing

The proposed program emphasizes the progeny test rather than intensive initial selection.

Any design of test might be employed that adequately ranks parent trees in terms of progeny performance on the forest ownership.

Because the testing phase is the most important cost of the proposed program, as well as the major informational requirement, the reader needs some idea of what minimal effort may be involved in a progeny test. Hence, a few remarks are ventured concerning problems, size, and evaluation.

The Douglas-fir region has some complications associated with progeny testing that are common to rugged topography and high rainfall forests. It is difficult to find uniform testing areas of 10 acres and larger in most of the forested areas of this region. Intensive cultivation or scarification of the plots, though desirable, is often impossible because of stumps and the heavy accumulation of slash. Problems with drought and animal damage to seedlings are often severe. Initial growth of Douglas-fir seedlings is slow, and brush invasion sometimes becomes a serious problem providing highly variable competition to various parts of the plot. Any progeny test design must cope with these complications.

A standard progeny test for the wind-pollinated seed needs to be designed; possibly, by some genetics group like the Western Forest Genetics Association. It should provide a sensitive test for families

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2/ Kozak, A., Sziklai, O., Griffith, B. G., and Smith, J. H. G. Variation in cone and seed yield from young, open-grown Douglas firs on the U.B.C. Res. Forest. Univ. Brit. Columbia Fac. Forest. Res. Paper 57, 8 pp. 1963.

that perform well at several sites and a less sensitive test for families that perform outstandingly at a single site. Preference in early selection would probably be toward families that perform well on a variety of sites. The 50-year-old-study results suggest that, as a bare minimum, a test could be based upon as few as 40 seedlings per parent if survival is excellent, or about 12,000 trees at each site, possibly planted with complete randomization. At least three sites would be needed to sample the seed source unit. A test with 36,000 tagged seedlings would entail a workload comparable to that of the Douglas-fir heredity study, which is not excessive for a small company. A more sensitive, larger test would be justified if suitable outplanting sites are available.

Periodic Evaluation

Gradually, as confidence is gained in progeny test results, choice of parents for the seed source group will change from phenotypic to genotypic selection. An evaluation of the progeny test is contemplated at 2 years in the nursery, to remove parents with low germination or weak seedlings from the seed source group. At 5 years in the field, a further evaluation of the progeny will probably reveal a small percentage of very outstanding or weak families on which to base further replacement of parents in this group. The first major reliance upon the progeny test would come with the 10-year examination, when reasonable seedling-to-mature tree correlations appear obtainable. Subsequent examinations at 5-year intervals, up to the half century mark, can be expected to substantially improve the genotypic selection. The first generation goal is a completely tested group of parents from which the landowner can select any combination of traits displayed in the best families.

Future Breeding

At least for the first 20 years, the main seed supply would come from parent trees. Eventually, seed from seed orchards and breeding programs would replace this supply. Hand-pollinated-progeny tests could be started early in the program to explore specific combining ability of some parental combinations, pinpoint gene-environment interactions, and to interpret wind-pollination results. When outstanding families are identified, future breeding programs could be planned to achieve specific objectives such as early volume production, desirable form, or custom-grown wood. Whether best gains would come from parental combinations or from crosses of best individuals of the offspring is a question that can be decided only by the outcome of such tests. The plan itself permits complete flexibility since all parent trees are preserved.

Alternative Steps

Alternative pathways are available from initial selection onward. For example, there are good reasons to consider inclusion of a portion of parents selected at random. As a group, their progeny furnish a yardstick for comparing all future progress in breeding. For example, the genetic gain would be computed at each evaluation of the progeny test. Inclusion of a substantial portion of randomly selected parents, for example 100 trees, assures inclusion of the complete gene pool of a race at the beginning of the program. This is a safeguard against unknowingly limiting genetic variability and is a hedge against future technological changes which may demand tree traits now in little demand. Because a fair proportion of excellent families did show up in the random selection used in the 50-year-old study, the inclusion of a randomly selected group of parents involves little risk and would provide a sporting challenge to the forester's selection system. Are his selections better or worse than random selection?

The development of a seedling or clonal seed orchard is an alternative that presents itself early in the progeny test. One of the plots on good topography could be successively thinned of poorest performing families starting soon after the first decade. Once the best parents are identified, a grafted seed orchard could be established if larger supplies of seed are needed.

Another alternative is open to a landowner who might wish to incorporate existing grafted seed orchards into this type of tree improvement program. Selections already made for the seed orchard form a nucleus of parents that could be included as part of the 300 trees to be tested. Conversely, number of clones in some orchards might be increased by adding the best phenotypes from the reserve group of trees when losses in the orchard are replaced. Seed collected from the orchard might be preferred early in the program to seed collected from parent trees along the road system. Including seed orchard trees in the progeny test would be complicated by the need to hand-pollinate the orchard clones with a pollen mix comparable with wind-pollinated seed in the parent locality. Since many seed orchards now have too few clones for a long-range breeding program, some elements of this plan may provide a way to make the necessary transition to a more adequate breeding program.

DISCUSSION

The main theme of the proposal is an attempt to simplify procedures and reduce risks through using seed from wind-pollinated parent trees already producing cones in abundance. Fifty-year results of the Douglas-fir heredity study indicate a clear, safe pathway to virtually certain substantial improvement. We would be remiss if the information were not synthesized into a proposal for those desiring a simple, low-cost, low-risk program that fits Northwest conditions. We would also be remiss if we left the impression that other plans involving cross-pollination between highly selected parents may not turn out to be superior in the long run. This is quite possible. As a rule, such programs do involve greater investments of effort and facilities, and rely more heavily on genetic theory. The simple program outlined here extends the range of programs available, with the hope that the low-investment, low-risk features will broaden the tree improvement efforts in Douglas-fir to the smaller ownerships or to applicable portions of larger ownerships. Furthermore, the program can easily be split up so that several landowners in the same area can each choose and test a portion of the 300 trees in a cooperative effort.

The fact that it has also some important side benefits makes for easy acceptance of such disadvantages as wind pollination from forest trees and low selection intensities. The proposal is highly flexible. At the outset, selection intensity can be varied to fit local desires. Progeny testing can be done to any intensity and by any well-conceived plan. More sophisticated breeding can begin on the trees at any time.

What might easily be overlooked is the flexibility of the end product. If families differ appreciably in such traits as growth, survival, taper, and straightness, future stands can be tailor made through choosing a mixture of parents for seed source. For example, a parent tree whose family survives poorly or grows slowly may be added to the seed mix to accomplish the same purpose as a precommercial thinning. Families that produce Christmas tree types might be added for an early cash crop. Families that produce high proportions of trees suited for poles and pilings may be included, as well as those that produce maximum volume at end of rotation. Thus, the forester can produce many different products on the same acre instead of a single product as is the usual goal of tree breeding. He can choose and collect seed from all these types displayed in the progeny as long as all the parent trees are carefully preserved. All these decisions are made by the forester of the future based upon the markets of the future rather than now.

The proposal has a great many built-in safeguards against change, overcommitment, or failure. If all types of parents are tested and preserved, the heavy responsibility in other plans attendant with initial selection of which traits and which trees to include in the program is avoided. Early mistakes are of a transient importance since correct selections can be substituted later on the basis of progeny test results. Low selection intensity hedges against the possibility that intensive selection is associated with parents at such extreme positions in the population array that their types are naturally selected against. Testing of large numbers of trees safeguards against ending with too small a genetic base. Growth in crown size of parent trees hedges against the loss of trees through selection and accident so that seed for the planting program will continue to be produced in ample quantities. Having the entire program within the confines of the forest ownership, rather than geared to a complex, widely based cooperative program, guards against the impermanence of human organizations. The increasing certainty of identifying the truly superior parents for both growth and long-term survival, regardless of whether the right assumptions were made initially, is a hedge against the worst possibility of all--failure.

Accounting aspects also should not be overlooked. Parent trees and progeny test located on the seed source unit become a salable asset, increasing the land value each passing year far out of proportion to the parent tree values alone. What increased value, for example, would be attached to a 100,000-acre forest ownership today if a certain group of parent trees growing there were demonstrated as capable of enhancing future production of that piece of land by 10 percent? Increased land value would begin to develop almost at the outset of the program.

As a final comment, genetic improvement of most crop plants has required the testing of thousands of parents for their genetic traits. At present, only a few hundred parent trees are being tested in the Douglas-fir region in seed orchard or experimental programs. The future competitive position of the region will be enhanced when several thousand parent trees, distributed over a wide range of sites, are being tested. This goal is not likely to be attained until a highly profitable incentive is provided to the forest-land owner. It is hoped that the features of this proposal can provide a financial incentive to test large numbers of parent trees.

SUMMARY

The proposal for a simple, progressive, tree improvement program for a forest unit of 75,000 to 150,000 acres starts with selection of 300 trees along roads of a forest ownership and collection of seed needed for future planting from the best 75 to 100 of these trees. Initial improvement would be based upon phenotypic selection and assumed parent-progeny correlation. A progeny test of all 300 trees would provide information for progressive and certain improvement at 5-year intervals in choosing the genetically superior parents. All 300 selected trees would be saved for perhaps half a century so that any combination of tested parents could be used to produce whatever combination of products is desired in the stand. The proposal is an outgrowth of the findings of a 50-year study of Douglas-fir families of known parentage. Thus, estimates of gain and problems of implementation are, to a large extent, known.

OUTLINE OF PROPOSED PROGRESSIVE TREE IMPROVEMENT PROGRAM FOR A SEED SOURCE UNIT

Year	Activity	Options
1st	Choose 300 cone-producing parents at roadsides (75 to 100 in seed source group plus 200 to 225 in reserve group). Provide for permanent marking and excellent protection of all 300 trees.	Selection can range from random to high intensity. A randomly selected group of about 100 trees may form part of reserve group.
1st	Collect seed for progeny test from all 300 trees.	
1st	Collect and bulk all seed produced from seed source group. (Plan for subsequent collection every fair or good crop thereafter).	If seed requirements not met, use alternatives suggested in text.
2d	Sow bulked seed in nursery for planting program.	
2d	Sow 300 seed lots in nursery for progeny test.	Establish special nursery progeny test, carried to 3-0 or beyond for first evaluation of parents as possible alternative to 5-year examination of field test.
4th	Outplant seedlings from seed source trees as required for sustained yield program.	
4th	Measure progeny-test seedlings. Consider for elimination from seed source group parents showing very low seed yield, or whose progeny show poor germination or very poor growth.	Mild selection based on family performance may replace some phenologically selected parents.
4-5th	Outplant progeny test using some standard design.	Further selection on basis of 3-0 nursery progeny test.
7th	5-year measurement of progeny-test seedlings. Replace 10 to 20 percent of poorest parents from seed source group with better parents of reserve group.	Use any desired combination of phenotypic or progeny-test selection.

Year	Activity	Options
12th	10-year field measurement. Base primary selection of seed source group on progeny test.	Begin breeding program between best parents or families.
17th	15-year field measurement.	Begin seedling seed orchard by thinning out poorest families on one plot.
22d	20-year field measurement. Go entirely to selection based on progeny test.	
27th-52d	Replace parent trees of seed source group as changes occur in progeny test.	Continue breeding program.