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The Genetic Improvement of Ponderosa Pine in Idaho

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The Forest Tree Improvement Program in Idaho is conducted as a cooperative effort of the University of Idaho, the U. S. Forest Service, State Forestry Department, Bureau of Land Management, and private industry. Since its initiation, a decision was made by all cooperators that the tree improvement was to be concentrated first on ponderosa pine. In Idaho this species is very abundant naturally and is the one most extensively planted for artificial regeneration. The greatly expanded reforestation program of the last decade increased the demand for genetically improved seed and facilitated the establishment of experimental plantations necessary for progeny tests and seed orchards.

Ponderosa pine is well known for its hereditary variations (Weidman 1939, Munger 1947, Mirov et al 1952, Callahan et al 1961, Squillance et al 1962.) Preliminary results from a ponderosa pine local variation experiment including seed sources from Idaho and adjacent regions (Wang 1966) revealed a considerable range of clinal variation which strengthens the conviction that appreciable genetic improvement can be expected by selective breeding from a local population. It is hoped that knowledge and experience gained in this project will be useful to the improvement of other tree species.

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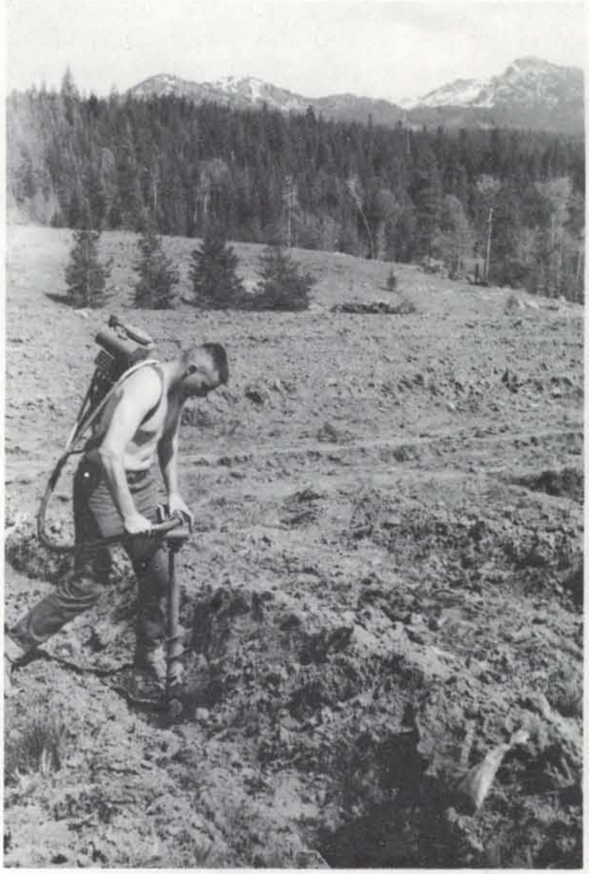

Fig. 1. Establishment of progent-test seed orchard near McCall. Selected trees were tested at four plantations in southern Idaho. Each plantation included 11,360 trees in 10 replicates. (Courtesy Idaho State Forestry Department, R. A. Miller).

I. Objectives and Approach

The objectives of the project are: (1) to produce genetically better seed in commercial quantity for local use; and (2) to gather genetic information and breeding materials to be used as a basis for further improvement. Genetic information essential for further improvement includes: inheritance data on the selected characters; sources and distribution of the selected characters in the local population; and performance of the selected progenies on different sites at different elevations.

The general approach is a form of half-sib family selection. In essence, the present project consists of three parts: (1) selection and testing of the one-parent progenies from natural stands in southern Idaho in four ten-replicate plantations under different site conditions (Fig. 1);/(2) natural stands of superior parent trees, as recognized by the performance of their progenies in the above test, will be developed into seed production areas for immediate seed production for local use; and (3) conversion of test plantations into seed orchards by selective thinning of the poorer progenies and the poorer individuals of better progenies. Genetically better seed will be produced from cross pollination between the selected progenies.

Initial selection was made in 1961 from natural stands of ponderosa pine in the Boise and Payette valleys (Fig. 2). Experimental plantations were established in 1966 for evaluation of the selected parental materials. Steps for further genetic improvement were presented in Wang (1963).

II. Field Selection of Parent Trees

Selected trees included in the progeny test plantations were mainly from six counties in southern Idaho, viz: Adams, Boise, Elmore, Gem, Idaho, and Valley. They were selected from the Boise and Payette National Forests and holdings of Idaho State Forestry Department, U. S. Bureau of Land Management and Boise-Cascade Corporation. This is a mountainous country. Sagebrush-grass vegetation occupies the lower slopes and basins. Extensive forests of ponderosa pine mostly in pure stands exist generally between 3000 and 7000 feet. They are replaced by spruce-fir types at higher elevations.

The plan was to subdivide the ponderosa pine region of southern Idaho into twenty subdivisions. Each subdivision corresponded to approximately a Ranger District. The two best stands in each subdivision were to be located one from higher elevations (above 4500 feet) and one from lower elevations. Open pollinated seeds were to be collected from the ten best trees in each stand. Seeds were to be kept separate by parent. A total of 400 trees were to be included in the progeny test plantations.

This method of selecting parent trees was devised primarily in consideration of the groupwise population structure of ponderosa pine. As was observed by Curtis and Lynch (1957) and Hallin (1959), the characteristic ponderosa pine type is composed of many small even-aged stands

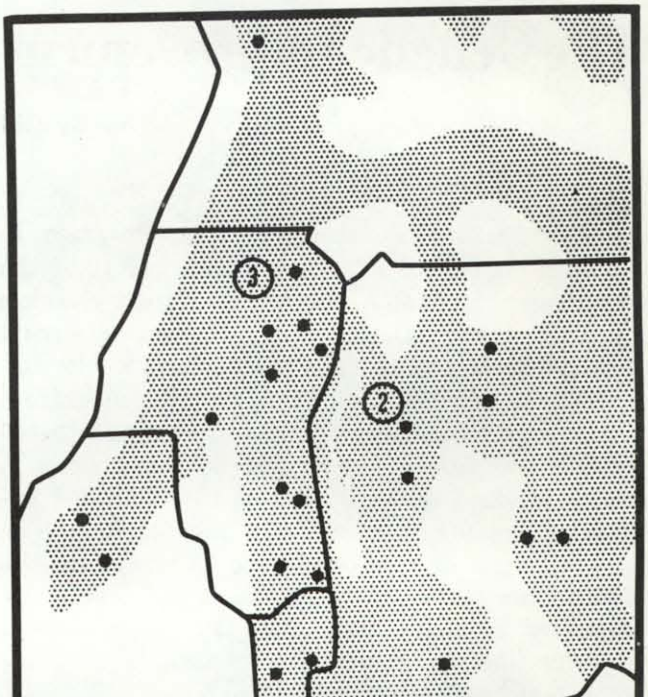

Fig. 2. Natural range of ponderosa pine in southern Idaho (shaded areas), and locations of stands of selected trees included in the progeny-test. The progeny-test plantations are located at (1) Idaho City, (2) Jack's Creek, McCall, (3) Boulder Creek, New Meadows, and (4) Holcomb Guard Station.

which form a mosaic of homogenous units. The natural stands were established in a fortuitous combination of abundant moisture, cleared ground and viable seed. Seed production of ponderosa pine in general is sporadic. It was observed that very little seed is carried more than 100 feet from the edge of timber (Curtis et al 1957.) The effective range of pollen dispersal also is limited. Furthermore, the difference in age class, time and year of flowering, and the physical handicap of local topography are all effective breeding barriers conducive to the development of a heterogenous population as evidenced by obvious phenotypic differences between adjacent stands.

These mosaics of even-aged stands are in reality "progeny-test" stands of local population. Each stand possibly represents the progeny of only a few local trees that happened to be close to a newly created forest opening and produced seed in a wet year. The even-aged stands are the ideal units for initial field selection.

The general guides for selection were as follows: (1) Selection was to be made on the general phenotypic characters of the even-aged stands. Stand differences serve as a more reliable basis of selection than individual tree characters.

(2) In this region of great topographical diversities there are inevitable site differences even within an area of a few acres. In comparison with volume growth, tree form characters are less readily influenced by site differences, but are important factors that directly affect the value and quality of timber.

The parent trees were selected and cones collected by foresters of cooperating agencies who had intimate knowledge of their respective areas. As a rule, cones were collected from the "best looking" stands within their jurisdiction. But not all selections are equally rigorous. The major limitation was cone crop. 1962 was a moderately good seed year. Seeds were available from 284 trees in 35 selected stands. However, even with this limitation, the parent trees selected are all good specimens of timber trees. They are all straight and tall, vigorous and without visible defects. The stands as a whole appear obviously superior phenotypically in comparison with those of adjacent areas. They vary from average to slightly above average in growth for the site class. Trees from higher elevations (above 4500 feet to 6500 feet) and lower elevations (4500 feet to 3200 feet) and from the "basaltic" and "granitic" areas were about equally represented.

All the selected trees bore a moderate to good crop of cones. Because seed production is the major objective of a seed orchard, and inherent fecundity of individual trees is known to be the dominant factor in cone production (Grano 1951, Wenger 1964), fruitfulness is an important consideration in parental selection.

III. Establishment and Care of Progeny-Test Plantations

Seeds were sown in regular seed beds of the U. S. Forest Service Lucky Peak Nursery according to a four-replicate randomized complete block design. The plots are in four-foot, single rows across the seed bed, and the rows are 12 inches apart. Seed weight and seed size measurements were made before sowing. Regular nursery care, such as watering and weeding, was given. No fertilizer was applied. Seedlings were raised to 2-0 stage for outplanting. Prior to lifting they were labeled with numbered sticker tape and root-pruned. The seedlings were then sorted according to seed sources into four-seedling bundles. The seedling bundles were kept separate in individual polyethelene tubes with the tips of the seedlings exposed and the roots wrapped in moist sphagnum moss. Each four-seedling bundle included at least one labeled seedling. The four-seedling bundles were then divided into replicate bundles. Each replicate bundle included one four-seedling bundle from each of the 284 progenies. The bundles were kept in cold storage until planting.

The progenies were to be field-tested at four plantations in southern Idaho. The planting sites were selected to represent the altitudinal range in which ponderosa pine was to be planted. They were located at 3700 feet (Holcomb, Boise National Forest plantation); 4400 feet (Idaho City, Bureau of Land Management plantation); 4750 feet (Boulder Creek, New Meadows, Payette National Forest plantation); and 5350 feet (Jack's Creek, McCall, Idaho State Forestry Department plantation.) The planting sites were on ponderosa pine land with approximately ten percent slopes of average or slightly above average site quality in the granitic region. Other conditions considered in site selection included proximity to existing roads, and the nature of surrounding terrain suitable for establishment of pollen barriers.

The plantations were established according to a randomized complete block design. Each plantation included 10 replicates of 284 progenies in four-tree plots, or a total of 11,360 trees. In addition to the above, each replicate included four 4-tree plots of ordinary local 2-0 seedlings to serve as control. The planting sites were cleared of stumps and brush, and plowed the year before planting. They were disked and furrowed in the spring just before planting. Seedlings were planted by hand with planting bar or "little beaver" power planter at the bottom of furrows which ran in parallel lines ten feet apart along the contour (Fig. 1). The four seedlings in each plot were planted at five-foot intervals in a single row. The 5x10-foot spacing was used in order to include more trees for the observation of juvenile characters, and to maintain the plantation at a uniform 10x10-foot spacing after the first thinning.

The first plantation was completed in mid-April near Idaho City. The two plantations in the Payette area were planted from the last week of May (Jack's Creek plantation) to the first week of June (Boulder Creek plantation) when the ground was clear of snow. The fourth plantation (Holcomb) was postponed to 1967 for further ground preparation. With the exception of a few marginal plots in extremely severe sites, initial survival of 85 to 90 percent was expected.

Barbed wire fences were installed to protect the plantations from grazing. Plot corners were marked with large permanent markers. Progenies were mapped and tagged to maintain their identity. In the first few years after planting, necessary measures will be taken for the suppression of gophers which are particularly destructive to young plantations. Early thinning will only be made when release from crown competition becomes necessary. Fertilizer will not be applied to the plantations before significant between-progeny differences are obtained. Thereafter, the plantations will be transformed from progeny testing to seed production purposes.

IV. Evaluation of Progenies

The progenies in the experimental plantations are observed for evidence of probable genetic variations. Measurements will be taken at regular intervals and the data will be analyzed primarily for between-progeny differences.

The initial survival will be recorded a year after the establishment of plantations. The twelve-month survival count is more reliable and practical than year end count, especially for the high altitude sites which were not plantable until the early part of June and will be snowbound in November. The inherent ability to withstand transplanting shock was reported in southern pine (Beineke et al 1965.) Finding of between-progeny differences in the transplantability of ponderosa pines is an important step in developing better strains for less favorable sites.

One of the most important properties of the progeny to be observed will be their "general adaptability" or "vigor." This will be measured in terms of height, diameter, and periodic growth. A number of other traits of economic importance also will be observed for evidence of genetic differences. They include stem straightness, stem taper, number of branches per whorl, prolepsis and lemma growth, size and angle of side branches, multiple forks, epicormic branch and other deformities, preferential browsing, and insect damage and disease susceptibility. When the progenies begin to bloom, the following traits will be observed: age of first flowering, time of flowering, abundance and ratio of male and female flowers, periodicity of flowering, and cone and seed characters.

The significance of differences between progenies will be delimited by variance analysis and multiple range tests. This information will be directly useful in seed orchards. It will serve as a basis for the isolation of superior progenies, the selective thinning of experimental plantations, and the recognition of superior seed tree stands for seed production purposes.

The second set of analyses involves the determination of progeny-environment interaction. This will indicate the development of genetic characters in response to environment. Some progenies will be found to be more adaptable than others over a wide range of tested conditions. However, in this region of diverse environments, it is also important to delimit the possible clinal or ecotypic differentiations in response to such factor as soil types and altitude gradients. Finally, the best adapted natural variants will be selected for the different site conditions.

The third set of analyses involves the delimitation of parent-progeny relationships and of juvenile-mature correlations. As early as in the nursery seed bed, obvious differences in seedling height are distinguishable between progenies. In the Idaho local seed sources experiment (Wang 1966), there were included six seed lots of mixed seeds from the same territory included in the present test. Striking differences were observed in height growth at the 5-year stage. In the present test, selection of the tested progeny will not be made until significent differences are observed at the mature stage. However, juvenile characters at various stages of development will be recorded to ascertain the juvenile-adult relations. Future selection of characters with high juvenile-adult correlation then can be made with confidence at an early stage.

V. Conversion to Seed Orchard

The progeny-test plantations will be converted to seed orchards in a series of selective thinnings. The purposes of thinnings are (1) to foster the full development of natural forms of the tested trees in an open grown condition; and (2) to improve genetic quality of the stand for the production of genetically better seed. A tentative schedule of thinning is presented in Table I.

Table 1. Selective thinnings of the progeny-test plantation at ten-year intervals.

	Year After Planting	No. of Progeny After Thinning	Approx. % of Progeny Removed	Plot Per Progeny	Trees Per Plot	Trees Per Plantation	Sq. Ft. Per Tree
Orignial Stocking		284	0	10	4	11,360	50
First Thinning	10	227	20	10	2	4,540	125
Second Thinning	20	85	70	10	2	1,700	334
Final Thinning	30	50	82	10	1	500	1,136

Thinning will be made by gradual removal of all trees of poorer progenies, and poorer trees of better progenies. Roguing of progenies will be made on the basis of between-progeny differences of full-grown trees. At the present, without definite knowledge of juvenile-mature correlations, the final judgment of the progenies shall not be made until 20 to 30 years after planting. The thinning of the poorer trees within each progeny, however, will be made in the first thinning ten years after planting. The reason for this is that, in ponderosa pine, clear expression of dominance generally develops at an early stage. The mortality in naturally regenerated young even-aged stands of ponderosa pine within a ten-year period was 40.33 per cent in densely stocked stands (6,000 trees per acre,) and 26.25 per cent in moderately stocked stands (4,000 trees per acre.) The mortality was mostly limited to death by suppression of trees in the smallest size clases (Myers et al 1961.) From the beginning, less vigorous seedlings are at a definite competitive disadvantage. They soon will be over-topped and eliminated by suppression.

In the first thinning at ten years after planting, two poorer trees will be removed from each of the four-tree plots. The spacing will be converted to a uniform 10x10 ft. area per tree. A light selective thinning also may be made at this stage by removing approximately 20 per cent of the tested progenies. This will include progenies with obvious defects and the least vigorous ones.

The second thinning shall be made 20 years after planting. The progeny-test plantation will be converted to seed orchard by removing approximately 70 per cent of the originally tested progenies that are less desirable according to the progeny test. Each plantation at this stage will include 1,700 trees of 85 progenies in two-tree plots. The orchard will be heavily fertilized, cultivated, and managed for seed production purposes. Before the second thinning, most of the trees will have bloomed and produced their first cone crop. Observation shall be made on their flowering habit. Under natural conditions most trees do not always bloom every year, and there are usually considerable differences in flowering time even between trees within the same stand. In progeny selection, special attention shall be paid to fecundity and overlapping flowering time.

The third thinning will reduce each plantation to 50 progenies in 500 one-tree plots at approximately 34x34 ft. spacing. This arrangement will provide the better individuals of the better progenies with ample spacing for seed production and full development to maturity. It will also provide them with opportunity conducive to maximum outcrossing and minimum inbreeding. The genetic superiority of seed produced in the seed orchard will be measured in the second generation progent test. The estimated genetic improvement was discussed in Wright and Bull (1963).

VI. Early Production of Genetically Better Seed

Twenty years will elapse before seed will be produced in any appreciable amount from the seed orchard. To meet the immediate need, seed in commercial quantity will be produced from the better parent trees and the natural stands of better parent trees as recognized in the progeny test. The latter will be done by developing the stands into seed production areas. The stands are mostly 10 to 25 acres in size. The trees are within the age classes of 50 to 150 years which are of prime seed production age for ponderosa pine.

The first series of seed production areas shall be developed on the basis of between-progeny differences observed during the first ten-year period of progeny testing. Ordinary 2-0 nursery seedlings of local origin planted in this area under similar conditions were three to six feet in height at five years after planting. At this age there will be ample indication of differences in inherent vigor and other characters between progenies in the four progeny-test plantations. Furthermore, several ordinary seed production areas have been developed in this general region at considerable expense, and additional ones are contemplated. They were converted from phenotypically selected stands without benefit of progeny-test. Under this circumstance the development of the first series of better parent tree stands into seed production areas on the basis of five-year progeny observation is fully justifiable.

Depending on the demand for seed, four or more stands of parent trees that produced the best progenies will be selected. Consideration shall be given both to the superior performance of the progeny in altitudes similar to the area where the seed will be used, and to the overall superior adaptability in all four tested conditions. Good overall adaptability is probably a more reliable clue to the inherent vigor at this juvenile stage, and a very important character for tree improvement in a region of great topographical diversities. The stands will be thinned to about 50 trees per acre, fertilized and cleared of undergrowth, and managed for quantity seed production. When the ten-year and twenty-year observations become available, the early selections will be verified and new or additional parent tree stands will be developed for seed production.

VII. The Long Range Approach

The practical purpose of the progeny test plantations is production of genetically better seed for immediate use. From the long range point of view, contributions of basic importance to further improvement are the collection of (1) inheritance data of local populations and (2) better trees selected in the one-parent progeny test to be used for future improvement by two-parent progeny test.

The inheritance data on parent-progeny relationships and juvenile-adult correlations will hasten the time at which future improvement can be accomplished. Other inheritance data of basic importance to genetic improvement include the knowledge of sources and distribution of desirable characters and the possible differentiation of altitudinal, edaphic or local ecotypes in this region. If the selected characters as revealed in the progeny test are concentrated in certain areas, then the effort of future selection shall be directed toward the most promising sources. Geologically, the region covered by the seed orchard is divided into granitic and basaltic formations. Trees from these two formations are about equally represented in the progeny test. In altitudinal range the tested trees were selected from 3200 feet (Rough Creek, New Meadows, Payette) to 6500 feet (Dutch Creek, Atlanta, Boise.) The genetic variation in the local population developed in response to the selective pressure of environmental conditions is further perpetuated by breeding barriers such as phenological differences in flowering time. In Boise Basin, for instance, some stands at the higher elevations bloomed as late as three to four weeks after the lower elevation trees. The evidence of ecotypic differences within this region will be indicative of the need for separate seed orchards for each area in future planning.

According to long range planning the one-parent progeny test represents Phase I (initial screening) of the work plan (Wang, 1963.) The local population will be screened in the field test for better breeding materials to be used for further improvement by a two-parent progeny test.

In the two-parent progeny test improvement will be gained from the additive and non-additive genes transmitted from both parents. More than twice the genetic improvement and inheritance information can be expected from control-pollinated progeny tests than from open-pollinated progeny tests in per parent tested. However, to produce control-pollinated progeny from 284 tall trees in their natural stands scattered over six counties all in one year will not be practical, and it will require much more commitment of our cooperative effort than to collect open-pollinated cones from the same number of trees. Under the present circumstances, a scheme involving thirty parent trees crossing with a few testers would be an optimistic estimate to produce enough control pollinated seed in a year for a progeny test of similar scale.

In comparison with the present one-parent progeny test and seed orchard approach the alternative thirty-tree, two-parent progeny test would not likely have included adequate superior progenies to provide a sound basis for future improvement. The one-parent progeny test, on the other hand, will have isolated the better individuals from the better progenies in a series of selection from the local population. The breeding materials selected will be all assembled in a plantation and ready to bloom. The plantation will be then used as a breeding arboretum for the production of two-parent F_2 progeny.

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