SEED ORCHARD MANAGEMENT

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Papers pertaining to seed orchard establishment and management have been presented to this group for the past several years, e. g., Marler (1969), Vande Linde (1969), and Goddard (1967). These authors have discussed vegetative propagation, spacing, number, position, and isolation of clones within the orchard, and various cultural measures necessary to achieve acceptable tree growth and cone and seed production. Nothing would be gained by rehashing their conclusions, of which we are all in general agreement. Therefore, I shall restrict the contents of this paper to the most recent and most pertinent measures for increasing the production of seed orchards and to the colossal job of harvesting the seed. Thoughts are also presented on establishing and managing second-generation and two-clone seed orchards which are integral parts of present-day tree improvement programs.

MAXIMUM PRODUCTION FROM EXISTING ORCHARDS

The immediate need for genetically improved seed of the southern pines for the South's 600,000-acre annual regeneration program was a major consideration in favoring clonal seed orchards over other breeding approaches. A minimum of ten years was to be saved in obtaining the seed, but the savings in time was to be bought at the expense of less genetic gain than could be obtained from seedling seed orchards. From an economic standpoint, however, the time saved was considered more important than the genetic gain lost. Results to date from thousands of acres regenerated with genetically improved seed from clonal seed orchards verify the logic of that decision.

The advantages of clonal seed orchards are lost if there is not maximum seed production. Various methods have been used to increase production, including mutilation of both above- and below-ground parts of the tree, fertilization, irrigation, subsoiling and control of insects. Mutilation has not been successful; the most common result is loss of vigor or outright death of the tree. But for loblolly pine particularly there have been positive, sometimes dramatic, responses in tree vigor and in seed production from fertilization, irrigation, and subsoiling. Fertilization alone gives a twofold increase in seed production over nonfertilized treatments; and when combined with irrigation, a still greater increase is obtained (Gregory, 1968). Irrigation alone increases seed production only slightly except in droughty years when it means the difference between no seed crop and a heavy crop. It is concluded that an irrigation system will pay for itself every year in which droughty conditions prevail.

Subsoiling has become standard practice in many seed orchards of the South. It is considered essential to subsoil new orchards, particularly if the orchard site is abandoned agricultural or grazing land. It is equally essential to subsoil established orchards every four or five years to alleviate soil compaction caused by equipment traffic and to force the large, often exposed roots

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of the orchard trees to develop at deeper levels where they will be less subject to invasion by insects and diseases. Without question, the practice enhances development of the orchard trees, and there is good reason to expect that seed production is also increased. Some reasons for the positive responses are better soil aeration, interception of surface water runoff, and a proliferation of roots into the trench.

Insect control in seed orchards is mandatory if seed production is to be maximized. Results from studies of mature loblolly and shortleaf pines in the N. C. State Cooperative Tree Improvement Program show a 30 percent loss of ovulate strobili to tip moths during one growing season when no control was applied. Indirect and direct destruction of strobili, cones, and seed by tip moths and other insects is even more severe on young seed orchard trees, often resulting in complete failure of seed crops.

Many of the commercial insecticides, particularlty the systemics, have been effective in controlling the majority of destructive insects. But the effect they are reported to have on environmental pollution has already resulted in the banning of certain insecticides and others are in danger of being banned. It does not take great foresight to visualize the absence of pesticides in future seed orchard management. Since the pests will still be with us, perhaps in even greater numbers than are now present, what recourse will we have to producing genetically improved seed for the accelerated regeneration programs? Breeding for genetic resistance is one way; another is biological control of the pests; and still another is seed orchard expansion. The first two alternatives are long-term goals, whereas the latter can be made operational on short notice. It will not be surprising to see additional acres of seed orchard established to offset seed lost to insects and other pests.

HARVESTING SEED ORCHARD SEED

The N. C. State Cooperative Tree Improvement Program has been working for fifteen years and other organizations in the South have been working even longer to bring the 5500 acres of established seed orchards into commercial production. That day has arrived for the majority of those acres; but with it is a tremendous logistic problem in harvesting the seed.

The problem is a minor one for slash and longleaf pines whose mature cones, intact with seed, can be shaken from the tree by the high-frequency tree shakers. However, the tree shakers are ineffective for harvesting the cones of loblolly, Virginia, shortleaf and other southern pines because of the absence of an abscission layer in the cone's peduncle. The cones continue to cling to the tree or to broken limbs long after the crown has been completely denuded by the shakers. Abbreviated attempts to induce formation of abscission layers by the use of chemicals have met with failure.

If persistent cones, intact with seed, are to be collected, the only alternative is to collect them individually by cutting, twisting, or knocking them from their base of attachment. This is a slow and expensive task and one that loses its feasibility for orchards exceeding fifty acres. Owners of large orchards simply cannot marshal equipment and manpower in sufficient quantities to complete the harvest of cones in the ten to fourteen days between cone maturity and the start of natural dispersion of the seed. The season of harvest can be extended up to two weeks by artificially ripening the cones, but even this extension does not materially expand the area from which individual cones can be collected. The logical alternative to harvesting individual cones is to collect the seed after they shed from the tree-ripened cones. Methods investigated to accomplish this task include encasing the tree in tobacco cloth, lining the orchard floor with polyethylene or canvas, and erecting back-drops and funnels to catch the seed. For one reason or another, each method has proven unsatisfactory.

The most promising system to date is the vacuum sweeper which collects the seed from the ground after they have been shaken from the tree-ripened cone by the high-frequency shaker. A seed harvest committee operating within the N. C. State Cooperative Tree Improvement Program has devoted considerable time, effort and money over the past several years to the development of such a system. Tests conducted in the seed orchards of Union Camp Corporation in 1970 2/ a part of the action of that committee showed that the shaker removed 87 percent of the seed from the tree-ripened cones; and of those seed, nearly 100 percent were recovered by the vacuum harvester.

The vacuum harvester, as presently constructed, is not operational. Structural changes are needed to speed the operation, to make the unit more functional, and to engineer it for the rough terrain encountered in seed orchards. But the important point is that the principle of the system is sound; only structural modifications are needed to make the system operational.

Conditions necessary for the successful operation of the harvester in the seed orchards are a relatively smooth ground surface and a continuous grass cover that is free of coarse debris. Developing an orchard floor without excessive humps and depressions can be accomplished with a minimum of difficulty; the sweeper can recover seed from four- to six-inch-deep depressions. Maintaining a continuous grass cover is critical because without the grass the harvester picks up soil and rock particles in large quantities, creating maintenance and seed cleaning problems. A single-stem grass is desirable for complete recovery of the seed but is not essential if the sweeper follows closely behind the shaking operation. A side-delivery rake and a hay baler are satisfactory for removing the coarse debris from the orchard floor. The baled straw is ideal for mulching material, helping to offset the cost of cleaning the orchard.

The relatively slow speed at which the sweeper has to operate to assure complete seed pickup dictates the path of least resistance to cover the maximum area in a given time. In the seed orchards of the N. C. State Cooperative where initial spacing of the grafts is 15 feet in rows and 30 feet between rows and final spacing will be 30 by 30 feet, the path of travel is with the

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2/ Progress Report, Vacuum Seed Harvesting Test, 1971--Barry F. Malac and Marvin H. Zoerb, Jr., Woodlands Research Department, Union Camp Corporation, Savannah, Georgia. 28 pp.

rows for one sweeping and across the rows for the next sweeping; the interval between the two sweepings will be from seven to ten days. This procedure allows about 85 percent of the orchard area to be covered at each sweeping, resulting in some seed loss. However, this loss is more than offset by the time and effort encountered in double sweeping or in weaving among the trees. Since harvesting of cones and seed is the most demanding problem of seed orchard establishment and management, it is essential that this be considered in the design of future seed orchards.

SPECIALTY ORCHARDS

Tree improvement programs in the South have now progressed to the point that specialty and second-generation orchards are being established. Various of the specialty orchards such as improved first-generation 1/ disease resistant, and wet site orchards have a design similar to the present commercial production orchards and need not be discussed further here. They differ from rogued first-generation orchards in that the proven clones of the organization establishing the orchard plus the best of his neighbors' are included; rogued orchards are restricted to the base from which they were started. The conditions surrounding two-clone orchards and second-generation orchards are so unique, however, that some thoughts are given on methodology and design of establishment.

Two-Clone Orchards

Control-pollinated progeny tests of first-generation seed orchard trees reveal that specific combining ability of certain two-clone combinations is outstanding for certain characteristics. The most notable responses have been in volume production, tree form, and disease resistance. There is considerable interest in taking advantage of these specific combinations by establishing two-clone seed orchards, the progeny from which will be planted locally or on specific problem areas.

Problems encountered in establishing two-clone orchards are numerous. The ideal would be for progeny from specific combinations to be outstanding in all characteristics evaluated but this is rarely the case. Those that are outstanding in volume production may be less desirable in disease resistance, tree form, or wood properties; and those which are highly resistant to disease may be questionable for one or more of the other desired characteristics. The result is that sacrifices may have to be made for traits of least economic importance in order to favor those of greatest importance.

In addition to producing outstanding progeny, the two clones must be good strobili producers, they must be phenologically synchronized, and they must be relatively or completely self-sterile. Exceptions to the need for self-sterile clones would be when selfed progeny is equally good in all ways to

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3/ Locally referred to as 1.5-generation seed orchards the outcrossed progeny of the two clones and when an exceptionally good progeny for specialty use is produced from a two-clone combination, one of which produces inferior selfed progeny. In the latter case it would be advantageous to forego collection of seed from the selfing clone, at the expense of seed orchard efficiency, in order to obtain the special value seed from the second clone. Other essential attributes of the clones are graft compatibility, relative freedom from attack by insects and diseases, and responsiveness to the cultural measures used to increase seed production.

Phenological synchronization is more involved than the simultaneous maximum receptivity of the ovulate strobili of two clones. The staminate strobili of the two clones must also mature simultaneously and be in phase with female receptivity if there is to be a good seed set and if selfing is to be avoided. Results from a phenological study of Coastal Plain loblolly pine in Virginia (Wasser, 1967) showed maximum receptivity of the ovulate strobili among clones to differ by five days. Less variation was generally observed in time of staminate strobili maturity, but the pattern of maturity in relation to female receptivity indicated that problems could be encountered. Pollen of one clone was shed two days before maximum female receptivity, whereas it lagged behind female receptivity by three days on another clone. Choosing two such clones could spell disaster to a two-clone orchard.

The design of these specialty orchards will be dependent in large measure upon the flowering habit of the clones involved. If the two clones produce both male and female flowers in approximately equal proportions, the grafts of each should be alternated throughout the orchard. But if one parent produces pollen less profusely than the other it should be represented more frequently in the orchard to consummate cross-pollination. The ideal situation would be for one of the clones to be a good seed producer and a poor pollen producer and for the reverse to be true for the other clone. This would erase or minimize the possibility of selfing, and in addition it would allow the orchard to be operated for maximum seed production. To achieve this, the seed-bearing parent would be represented three to five times more frequently than the pollen parent.

The theoretical situation of selecting seed-producing and pollen-producing parents for the two-clone orchards is within reason. There are many clones in the seed orchards of the Cooperative Programs that possess one or the other of these extremes. The limiting factor to such a scheme would be the sacrifice of other factors essential to increased genetic improvement of such orchards.

Initial spacing of grafts in these specialty orchards is recommended for 20 by 20 feet, which would be increased to 40 by 40 feet after thinning. Results from production orchards of the Cooperative Programs indicate that cone and seed yields and seed germination is seriously impaired during the formative years of a seed orchard when pollen is at a premium. Spacing of grafts beyond 20 by 20 feet appears to aggravate the problem. Therefore, it seems economically sound to establish four times the number of grafts ultimately desired to assure a better supply of sound, germinable seed at a time when they are most needed. If seed- and pollen-bearing parents could be used in these orchards as suggested, an overabundance of the pollen-bearing grafts could be established with the knowledge that they would be thinned as pollen from the maturing grafts became more abundant. The grafts of the seed-bearing clone would remain as originally established.

Second-Generation Seed Orchards

Progeny tests of selected seed orchard parents of the southern pines are sufficiently progressed to allow initial selection of material for establishment of second-generation seed orchards. The procedure being followed is to select the best trees in the best families at age five. Criteria for selection are: volume production, insect and disease resistance, and crown and stem form. Those selections meeting the stringent requirements are then grafted into clonal banks where they will be observed for graft compatibility and reproductive fecundity, precociousness, and phenology. Reproductive behavior of the selections is deemed specifically important because of the fact that 80 percent of the seed obtained from the first-generation orchards is produced by only 20 percent of the clones. Those orchards are not only efficient seed producers but they also restrict recombination of some of the most productive genotypes.

During the-interim of clonal evaluation, the original selection occurring in the progeny test will be left to grow until year nine when it will again be evaluated for the characteristics mentioned previously and also for its wood properties. If it has maintained its superior phenotype and if it has passed the strict clone bank standards, it is ready for inclusion in the second-generation orchard.

We anticipate the need for 200 select trees as a base for any given orchard. These will be obtained not only from the progeny tests of the cooperator establishing the orchard but also from the progeny tests of other cooperators within the same general region and from other sources of undetermined genetic worth. Before the latter group is accepted for orchard use their genetic worth will have been determined. The 200 selections need not be completely unrelated because only the best fifty will be included in the seed orchard. Selection of the fifty clones will be based upon pedigree, upon the continued performance of the select tree in the progeny test, upon performance **of** the graft in the clone bank and in the seed orchard, and upon progeny tests of the select tree. Grafts of the second-generation orchard will be established at a 20 by 20-foot spacing, with final spacing of 40 by 40 feet for the same reasons given for two-clone orchards. An orderly progression of recurrent selection as explained above for a second-generation orchard is dependent upon complete pedigree records. Results from our own studies indicate that general combining ability is so strong among forest trees that selection of second-generation material from mother-tree tests could lead to severe inbreeding depression. For example, every seed orchard in the N. C. State Cooperative has one or more good general combiners. It is not uncommon for 80 percent or more of the best performing trees in control-pollinated progeny tests of these orchards to have one of these good general combiners as a parent. We are not sure how much inbreeding can be tolerated in forest trees but it is inevitable that problems will be encountered in future generations of breeding, if not in the present one, if the pedigree of the breeding stock is ignored.

Mass collections of scion material will be available from the clone bank material and also from the select tree for grafting. Evidence indicates that these second-generation selections which will be no more than twelve years old at time of establishment in the orchards will commence flowering profusely soon after grafting. Management of the second-generation orchard will be similar to that being practiced in the present commercial production orchards.