ESTABLISHMENT, CULTURE, AND PROTECTION OF SLASH AND LOBLOLLY PINE SEED ORCHARDS: SOME TENTATIVE RECOMMENDATIONS

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Many forest nurserymen in recent years have been called upon to assume new responsibilities involving management of seed orchards. It seems that forest administrators have concluded--and we think rightly so--that professional nurserymen, by nature of interest, training, and experience are exceptionally well suited for this demanding assignment.

To form a framework for discussion, let's briefly review what is required of a seed orchard manager (Zobel et al., 1958; Hoekstra et al., 1961; Matthews, 1963).

Assuming that you are called to help in the establishment phase of the orchard's development, your start will be with a map showing the location of perhaps a hundred select trees, scattered over several hundred square miles. You are expected, within a few years, to vegetatively propagate these trees, to establish the delicate propagules in the face of drought, diseases, and insects on a site determined to be favorable from the standpoints of accessibility, tree growth, and freedom from pollen contamination. Then, you must culture and protect the young trees in appropriate ways to assure their early, abundant, and sustained production of seed through natural cross-pollination among the various clones.

One not familiar with the problems involved might ask, "Why should this be so difficult; can't you simply apply the technology used in the culture of, for example, pecans or citrus?" To a certain extent, seed orchard managers can and do borrow from these related horticultural specialties. A major source of difficulty in forest tree seed orchard culture, however, is the fact that the plant material being propagated and nurtured is fresh from the wild. The trees, selected with primary emphasis on traits related to wood growth potential, are not necessarily good pollen and seed producers. In addition, they are not genetically alike, except within clones, so it is difficult to devise systems of propagation and culture which can be expected to produce uniformly favorable responses in all individuals.

Despite the uncertainties involved, nurserymen have helped establish some 85 successful and increasingly productive pine seed orchards on

2,700 acres in the South during the past 10 years./ These orchards are a tribute to the ingenuity and perserverance of the foresters and nurserymen involved. However, many acres of seed orchards remain to be established, and there is good reason to believe (Otterbach, 1963) that some existing orchards are receiving less care--and some more--than experience indicates is justified. It is entirely appropriate, then, that we attempt, periodically, to update our knowledge and improve our practices by reviewing recent research progress in this field.

Unfortunately for the seed orchard manager, and especially for a beginner in this field, it is difficult to assemble all the pertinent information. Even more difficult is the evaluation and assimilation of information and defining a course of action from it. We have attempted to do this for you. Recommendations 2/ are developed in the chronological order in which seed orchard managers usually would have need for them. In the interest of brevity, only the barest details are given on topics for which published information is available. The references cited should be consulted for more complete information. We have gone into more detail on cultural practices because this is an area where published information is currently very meager.

RECOMMENDATIONS

Old fields make good orchard sites

Abandoned cropland in the Lower and Middle Coastal Plain often offers desirable sites for pine tree seed orchards. Such land requires little clearing and is generally well-drained, accessible, and relatively fertile. Homesites should be excluded, however, because they frequently include areas of soil affected *by* former livestock concentrations or by incorporated concrete or mortar which can cause extreme variation in rate of tree growth within the orchard. Such variation unnecessarily complicates cultural practices.

Sites near oaks of the evergreen species, which are alternate hosts for cone rust (Cronartium strobilinum), should be avoided unless the cost of alternatives exceeds that of the necessary control measures (Matthews and Maloy, 1960; Matthews, 1964).

1/ Personal communication from *J.* D. Strange, Southeastern Area, State and Private Forestry, Atlanta, Georgia (data through June 30, 1965).

2/ The recommendations made here--especially those for cultural practices--are tentative, being based largely on preliminary data and informal observations. Most of the experience described and cited here was gained in orchards of slash and loblolly pine in the Coastal Plain of the southeast, hence the recommendations will best suit conditions in this area. However, many of the principles and some of the practices discussed will be applicable in adjacent areas and for related pine species. Hardwood seed orchards, on the other hand, are not within the scope of this review.

Carefully evaluate soil properties on prospective orchard sites

A soil survey should be conducted on each prospective orchard site to map soil types and areas of uniform potential for tree growth. Soil samples should be taken and the soil profile examined in depth to permit evaluation of the nutrient-supplying and water-holding capacity of the soil. Such data will also provide a point of reference for future analyses aimed at assessment of treatment effects on soil and trees. As a precautionary measure, soil samples should also be examined for presence of heavy concentrations of pine-parasitic nematodes.

Reduce competition and pest hazards through site preparation

Vegetation on the site should be removed and/or incorporated into the soil to the extent possible without creating an erosion hazard or plowing subsoil to the surface. If pines are present on the area, prompt removal of their roots or proper stump treatment (Driver, 1963) is advisable to minimize subsequent risk of Fomes root rot infection. If heavy populations of parasitic nematodes are present, broadcast applications or treatment of planting spots with nematocides may be desirable to assure vigorous growth of the trees (Ruehle and Sasser, 1962).

Successful vegetative propagation requires skill and care

If the orchard is to be of the clonal type, i.e., composed of vegetative propagules, cleft grafting or side veneer grafting (Mergen and Rossoll, 1954) on field-grown stock with techniques adapted to local conditions and the available labor force is the most generally effective means of propagation. Since grafting is as much an art as a science, a proven "green thumb" grafter is worth more than a dozen unskilled workers at this task.

When grafting fails because of stock-scion incompatibility, air layering (Mergen and Rossoll, 1954° Zak, 1956; Hoekstra, 1957) may prove a suitable alternative procedure, provided the trees to be propagated are not more than 20 years old. Rooted air layers have grown as fast as seedling stock and have proven to be windfirm (Bengtson, 1965).

Care should be taken to prevent infection of grafting stock with fusiform rust (Campbell et al., 1962) and to cull all suspected galled stock. Graft unions should be protected against bark beetles (Smith and Mergen, 1954) and the elongating shoots against tipmoth. Some of the new systemic insecticides show real promise in preventing tipmoth damage (Cade and Heikkenen, 1965)

Choice of initial spacing must recognize the need to sustain high seed yield per acre

Trees should be planted to allow a spacing of about 25 feet by 25 feet following roguing. Closer spacing (15 x 15 feet) in a slash pine breeding orchard near Gainesville, Florida, has through age 9 yielded

more cones per acre than wider spacings, but crowns are interlocking, natural pruning is accelerating, and flowering per tree is low (Goddard, 1966).

In Australia, Florence and McWilliam (1956) examined cone production in southern pine plantations over a range of stockings and suggested 24- x 24-foot spacing as a compromise between that giving maximum cone production per acre and minimum cone production per tree.

Working with loblolly pine in Texas, van Buijtenen (1965) found that both male and female flowering were heavier on trees spaced 30 x 30 feet than spaced 20 x 30 feet. The difference in flower production on an individual tree basis was significantly great to cause a greater per acre production of pollen clusters and conelets in the 30- x 30-foot plots.

Irrigation not beneficial in young orchards

If the trees are to be widely spaced and the orchard is to be located where growing season rainfall is generally high (as in southern Georgia and northern Florida), irrigation during the first 5 years after orchard establishment is of doubtful value for increasing growth rate and cone production of the southern pines.

Slash pine air layers at Olustee, Florida, grown under seed orchard conditions showed no statistically significant effects of irrigation on growth after 4 years of treatment (Bengtson, 1965). Production of female flowers was reduced, while clusters of male flowers were slightly increased by irrigation.

In older plantations and in areas and circumstances where soil moisture is more likely to be limiting (i.e., in peninsular Florida or the west Gulf States), irrigation may prove beneficial. We will have to await further developments in current irrigation experiments before final conclusions and recommendations can be drawn. Of course, during the first year following out planting, irrigation will likely improve tree survival, but this can be effectively accomplished using a mobile watering tank.

If an irrigation system is to be installed, expert advice should be sought to ensure that the system is adapted to the soil type, available water, and to the intensity of irrigation to be practiced (Scott, 1956; Viehmeyer and Hendrickson, 1960).

Choice of water source is very important. High soil pH, leading to nutritional problems, may be encountered if well water fran limestone aquifers is used for irrigation (Bengtson, 1965). Accumulation of soluble salts may also trouble users of well water (Wander and Reitz, 1951). Most important, of course, is the dependability of the water supply in terms of quantity and quality in time of severe drought.

Procedures for timing of irrigation in orchards are numerous. Methods we have tried include gravimetric soil moisture determinations, Tensiometers (Veihmeyer and Hendrickson, 1960), and various systems based on differences between recorded rainfall and estimated evapotranspiration. Tensiometers have great potential utility, but more experience in calibration of the instruments to give an accurate picture of soil moisture stress in sandy pine orchard soils is needed. Gravimetric procedures are too time consuming, and estimated water needs can never be more than crude approximations of tree irrigation needs. Perhaps a method based on needle moisture deficits (Harms and McGregor, 1962) or tree trunk growth (Verner et al., 1962) will eventually provide the most effective means of estimating irrigation needs in seed orchards.

Periodic fertilizing in early years assures good growth

Widely spaced trees on non-eroded abandoned agricultural land in the Lower and Middle Coastal Plain are unlikely to develop nutrient deficiencies in the first 2 to 5 years (Bengtson, 1965). However, as the stand closes and competition intensifies, incipient N deficiency will probably appear (Walker and Youngberg, 1962).

On virgin flatwoods soils in this area, young trees sometimes show a significant growth response to P fertilizers and a more pronounced response to P + N (Pritchett, 1960, 1963: Hughes and Jackson, 1962). Recently, slash, sand, and loblolly pines on deep sands of penisular Florida have shown growth response to Sulpomag (a source of K, Mg, and 3) applied with N-P fertilizers. 3/

Forest seed orchards require a tremendous establishment investment. Since the product is so valuable and fertilizer relatively cheap, it is probably not worth debating whether a complete fertilizer is actually needed in all orchards. Until the science of fertilizer prescription for forest trees based on soil and foliage analyses is more advanced, an "insurance" application of a complete fertilizer is the safest course. Broadcasting 300-500 pounds per acre of a fairly high-analysis complete fertilizer (e.g., 13-13-13) plus perhaps 100 pounds of Sulpomag or 25 pounds of $MgSO_4$ at the time of orchard establishment and again at 3, 5, and 7 years will eliminate the possibility of nutrient deficiency in the young orchard. The temptation to apply higher rates of fertilization should be suppressed because the most likely effect is increased weed competition. Tests in a number of seed orchards indicate that micronutrients are not likely to limit growth of pine orchards in the Coastal Plain (Pritchett, 1960, 1963).

Gradual shift from clean cultivation to mowed cover advised

In experiments in Texas (van Buijtenen, 1965) and Florida (Bengtson, 1965), trees grown in clean-cultivated plots produced more male and

3/ Unpublished TVA data.

female flowers than those grown with grass or summer legume cover. It is not known whether the response to cultivation is due to root pruning, more rapid mineralization of soil nitrogen, or elimination of competition from other vegetation. Perhaps all are involved.

Since continuous clean cultivation will eventually lead to impoverishment of the soil's important organic matter fraction, it does not appear wise to continue disking indefinitely. Light disking during the growing season for the 2 or 3 years following establishment of the trees is recommended to reduce competition for soil moisture and light. (Disking during the cooler months at temperatures near 70°F. should be avoided because of higher hazard of Fomes infection (Driver and Ginns, 1964).

After the trees have reached 6 to 8 feet in height, disking should be discontinued and a cover crop suited to the local area should be established. This will provide a more gradual release of applied fertilizers to the trees and will permit small rootlets of the trees to develop near the soil surface. During the summer months the open area between trees should be mowed as required to keep down weeds. Aggressive summer cover crops, such as hairy indigo, are not recommended unless irrigation and supplemental N fertilization are provided for the trees (Bengtson, 1965).

Top pruning not encouraged

The practice of top pruning to facilitate cone collection is not to be encouraged in southern pine seed orchards. With loblolly pine, van Buijtenen and Brown (1962) concluded that, although pruning held down the size of the tree effectively, even rather light treatments seriously reduced the number of flowers produced. Also, Fowler (1965) has suggested that top pruning may increase natural self—pollination in pines. This may lead to reduced seed yields and decreased growth rate of the progeny (Peters and Goddard, 1961; Squillace and Kraus, 1962).

Broken live limbs should be removed promptly. Top forks should be reduced to a single terminal to prevent subsequent breakage.

Nitrogen boosts conelet production in maturing trees

As trees begin to attain sexual maturity, or ripeness to flower", as it has been called, the availability of nitrogen apparently exerts a strong effect on the number of female flowers the trees produce. This has been observed as a direct promoting effect of fertilizing with nitrogenous materials (Goddard, 1965: Bengtson, 1965) and as an indirect effect of ground cover competing with the trees for available nitrogen (Bengtson, 1965).

In a few cases in the southeast, female flowering has been increased by potassium when applied in conjunction with high levels of nitrogen (Goddard, 1966). Van Buijtenen (1965) has found phosphorus essential to stimulation of early flowering in Texas pine orchards, but in orchards in the southeast, phosphate fertilization has shown no benefit. This is probably because most seed orchards in this area were established on former agricultural land where residual phosphate fertilizer is present or on better forest sites where soil phosphate content is above the limiting range.

Since little has been published as yet on flowering response to nitrogen applications in southern pine seed orchards, two examples are presented here.

In May 1962, a rate of nitrogen study was set up in the Rayonier orchard in Nassau County, Florida. Rates were 4, 8, 12, and 16 ounces of nitrogen as ammonium nitrate per tree annually. Since 1964, rather striking results have been obtained, but because the trees were just beginning to flower, even the highest rate of nitrogen did not result in large numbers of flowers. In 1965, all rates of ammonium nitrate application were doubled. This, together with a general increase in flowering potential of the trees, induced a really remarkable response in flower production in the spring of 1966 *(fig.* 1). On the average, trees receiving 2 pounds of nitrogen as ammonium nitrate bore almost 2-1/2 times as many female flowers as the untreated controls.

Response of individual trees and clones to nitrogen fertilizers is apparently strongly conditioned by genetic factors. However, nitrogen fertilization generally elicits similar responses in trees of various innate fecundities. This is demonstrated in an experiment conducted in the orchard at Gainesville. Records of past flowering history were examined and trees were grouped into four flowering classes--high, medium, low, and no past flowering. Ammonium nitrate was applied at annual rates of 0, 8, and 32 ounces of nitrogen to trees in each class.

Each year and in each flowering class the greatest difference has usually been between the zero and moderate fertilization level, with some additional increase with heavy fertilization *(fig.* 2). Although the 1966 season was one of general abundant flowering, the response can still be seen. There is some indication this year that accumulation of nitrogen under the heavy rate may have resulted in levels above optimum. This may be explained by the tendency of very heavy flowerers to occasionally produce a bumper crop even without fertilization, since the response of trees with lower flowering capability to the highest rate was still quite strong. However, it may be that some other factor is beginning to limit flower production in this group.

We, as yet, have no complete explanation for the basic factor involved in pine flowering responses to nitrogen fertilizers. We do know that there is a positive relationship between foliar nitrogen content in July and August and flowering in the spring following. Two

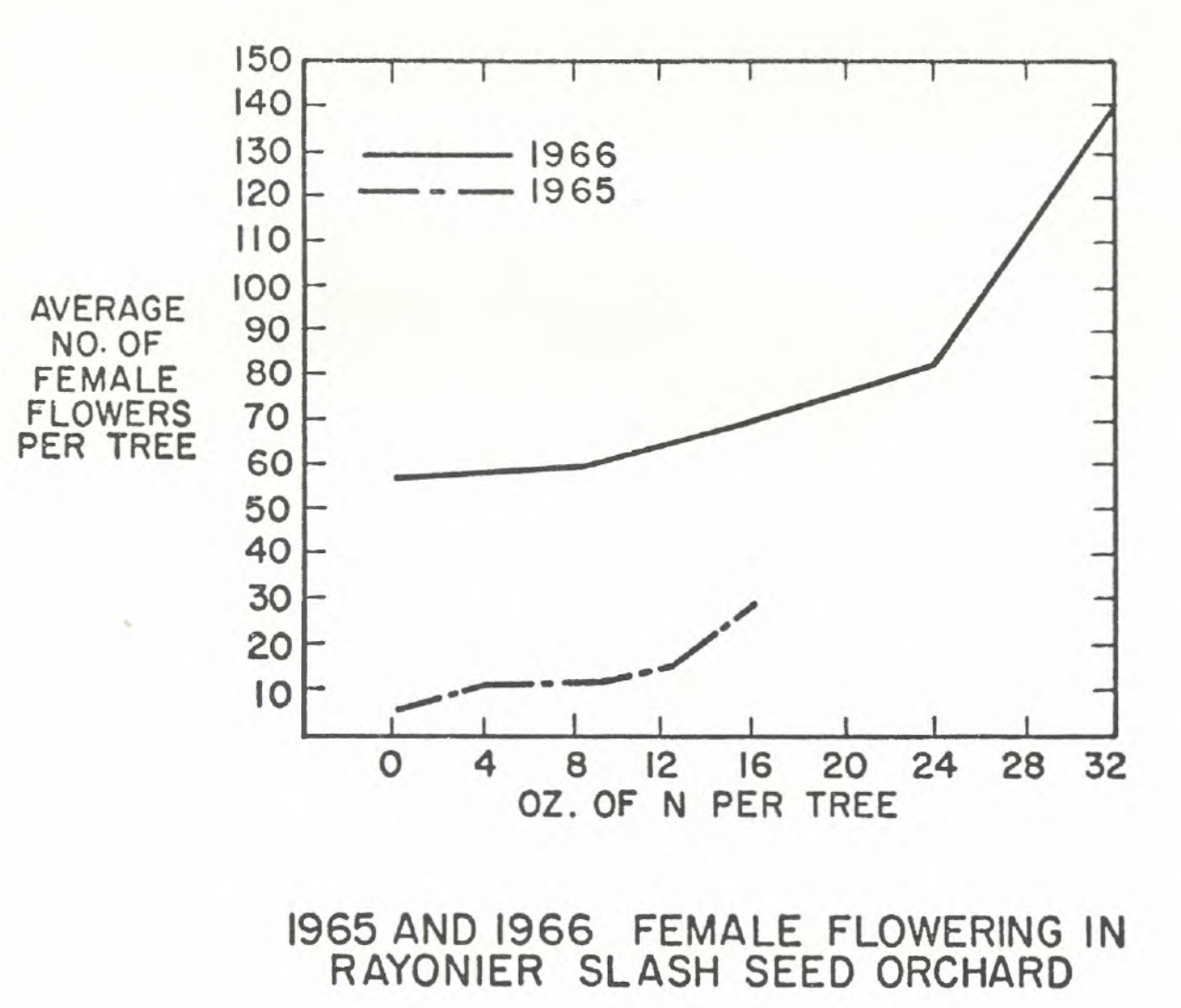

Figure 1.--Effects on female flower production of increasing rates of 1: as ammonium nitrate applied to slash pine ixi two successive years (Data from nayonier seed orchard).

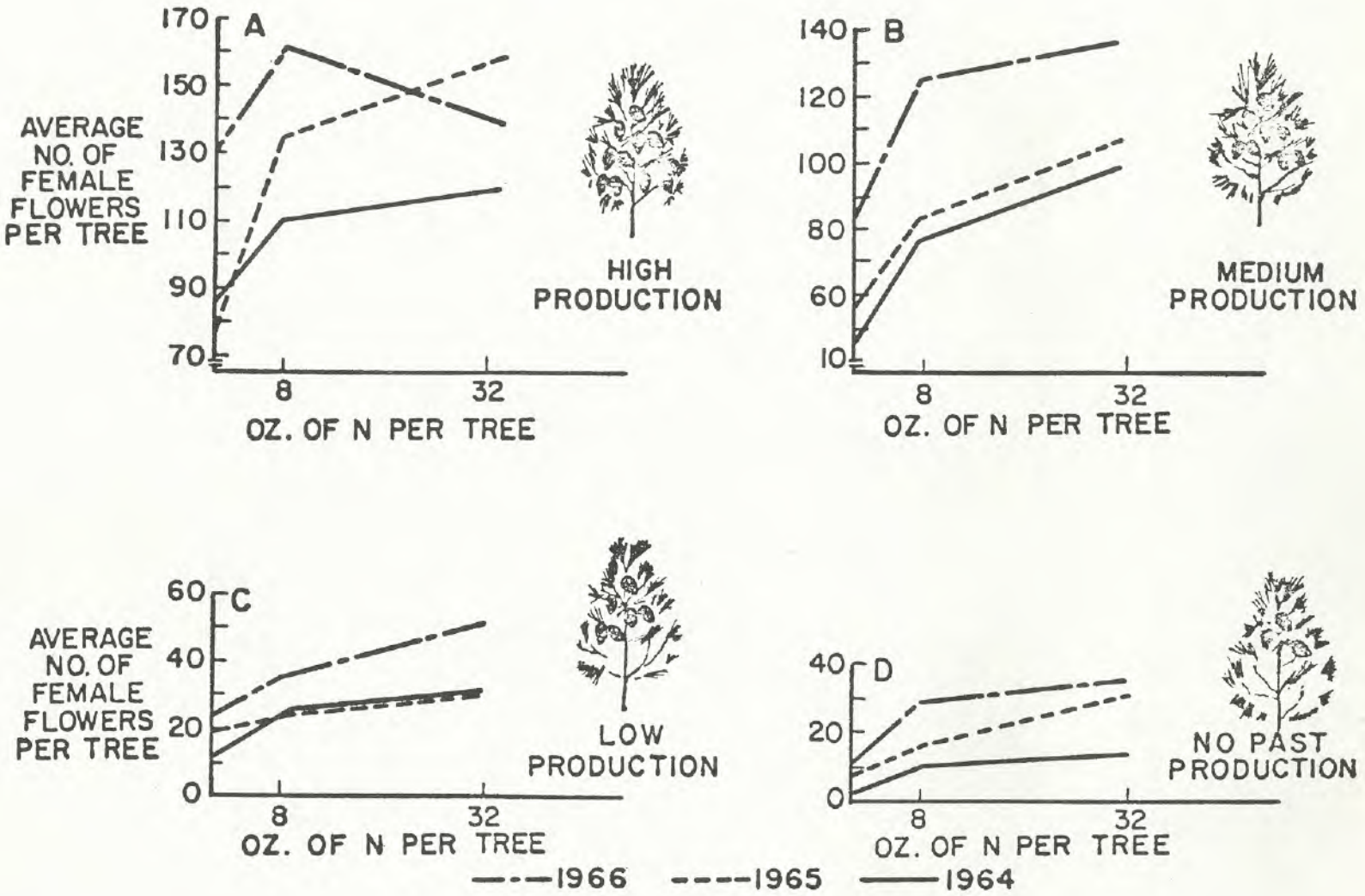

Figure 2.--Effects of N fertilization rates on female flower production by clones of four fecundity classes.

variables, past flowering performance and foliar nitrogen content in late-July, explained 55 percent of the flowering variation in the University of Florida orchard in 1965 (Goddard, 1966). Similar results have been observed in the Olustee orchard (Bengtson, 1965). In addition, summer legumes in the Olustee orchard were associated with reduced nitrogen content of pine foliage during the summer months, higher nitrogen content of foliage during the winter, and reduced flowering the following spring.

Buds of slash pine strobili are initiated during late summer (Mergen and Koerting, 1957; Eggler, 1961) and it is at this time that the level of available nitrogen appears to exert an important effect on subsequent flowering. Researchers are now trying to determine how nitrogen nutrition affects basic physiological processes that lead to flower initiation in pine.

On the basis of what is known at present, we recommend that as trees begin to flower in the orchard, annual applications of ammonium nitrate be made in April or May to supply up to 100 pounds of nitrogen per acre (300 pounds of ammonium nitrate). Since the roots of the trees will have spread out well by the time the trees have reached this stage of development, broadcast applications on the soil surface should be satisfactory.

Effects of continued heavy nitrogen fertilization on the overall nutrition and physiology of slash pine are not yet known. Until such data are available, heavy annual application of nitrogen fertilizer (in excess of 100 pounds of nitrogen per acre, or 300 pounds of ammonium nitrate) is not recommended.

Although traumatic treatments, e.g., girdling or stem bending, may stimulate earlier or more abundant flowering (Hoekstra and Mergen, 1957; Goddard et al., 1963), they are not recommended because they weaken the trees and their benefits are short-lived.

Effects of culture on seed yields and seed quality appear favorable

Most evaluations of cultural treatments in seed orchards have been based on tree growth and flowering. One of our greatest needs at present is for data on pollen production and seed yields under various cultural regimes. Female flowers may not be successfully pollinated, conelets aborted, or seed yields reduced if the trees are subjected to severe stress for moisture or nutrients (Boynton, 1954; Veihmeyer and Hendrickson, 1960) at the time of pollination, fertilization, and cone maturation. Seed yields from orchards have been encouraging, however, (Goddard and Strickland, 1966) and no serious problems are anticipated if the cultural regime previously outlined is followed.

Keeping records of flowering, cone, and seed yields per ramet is a good practice because it permits evaluation of seed production trends and effectiveness of conelet protection.

Quality of seed as a function of environmental factors is also something of an unknown. However, we may derive some comfort from the report (Mergen and Voigt, 1960) that slash pine trees in a seed production area fertilized with a complete fertilizer produced heavier seed. This seed, in turn, when planted in an infertile sandy soil, produced larger, more vigorous seedlings with higher contents of nitrogen, phosphorus and potassium than did seeds produced on control trees.

Variability among clones in age of flowering calls for caution in use of seed from young orchards

Most of the pollen and female strobili produced in a young seed orchard will be borne by a few precocious-flowering clones (Goddard, 1964; Bentson, 1965). Considerable self-pollination is likely to occur under these circumstances. In addition, the seed resulting from outcrossing in young orchards will likely represent a small proportion of the clones in the orchard, hence may be dangerously uniform, genetically, for commercial plantings. At least 5, preferably 10, clones in the orchard should be flowering abundantly before open-pollinated seeds are used commercially.

Attention to pests a vital factor

Careful attention must be given to prevention and control of damage to flowers, cones, and trees by insect pests and diseases if full benefits of cultural practices are to be obtained.

As previously mentioned, preventive measures against the two Cronartium rusts are particularly important. Fusiform rust is a potential tree killer in young orchards (Campbell et al., 1962). The destructive effects of cone rust are restricted to first-year conelets (Hepting, 1958; Matthews and Maloy, 1960; Matthews, 1964), but this disease may reduce cone crops by as much as 90 percent in certain areas.

Where sanitation cuts or roguing of clones or individual trees are necessary, cutting should be confined to summer months (Driver and Ginns, 1964) and stumps should be promptly treated to prevent Fomes root rot infection (Driver, 1963).

Female strobili are subject to damage in the early stages of thrips (Gnophothrips piniphilus Cwfd). Control of these insects can be accomplished simultaneously with cone rust prevention through application of a mixed spray of certain insecticides and fungicides (Ebel, 1965).

Larvae of Dioryctria spp., which may attack both stems and cones (Hughes and Jackson, 1962; Lbel, 1963; Merkel et al., 1965), also present problems of serious potential in intensively cultivated slash pine plantations and may require direct control (Heikkenen, 1964; Merkel, 1964). Control of Cronartium rusts may indirectly check Dioryctria population buildup by reducing the availability of infected stem tissue, which is apparently favorable host material for Dioryctria larvae.

Pine seedworms (Laspeyresia spp.) are a more insidious pest than Dioryctria because their damage to individual seeds is generally unnoticed until the cones are extracted (Ebel, 1963). Direct chemical control measures are available for this destructive insect (Merkel, 1964) and, if all cones are removed from the orchard, the population will be further reduced because the mature larvae overwinter in the cones (Merkel, 1964).

It is important that the seed orchard manager recognize that the use of chemical pesticides, like fertilizers, can be overdone. Many of the pests have natural predators capable of holding damage within reasonable bounds. Indiscriminate use of insecticides can create problems by eliminating these predators. There is usually a need for insect control to protect young grafts and again when the trees begin to produce significant flower crops, but intensive broadcast insecticide applications in the intervening years are generally not justifiable.

Periodic tree-by-tree inspection of the orchard, at no less than bimonthly intervals throughout the year, is advisable to ensure early detection of insect, disease, and physiological problems. Alertness to peculiar symptoms among the trees, consultation with appropriate specialists and prompt action may mean the difference between trouble nipped in the bud and serious losses. Also, your reporting of personal observations on unusual phenomena to researchers can be a valuable contribution toward a more complete understanding of the basic aspects of forest tree seed production.

SUMMARY OF RECOMMENDATIONS

1. Choose an accessible, uniform, well-drained, relatively fertile site in an area of low insect and disease hazard.

2. Prepare a soil map and use it to lay out the planting areas. Take soil samples to evaluate soil moisture-holding capacity and mineral nutrient content.

3. Prepare the site to eliminate vegetative competition and to minimize hazards of pests, pathogens, and soil erosion.

4. Develop skillful vegetative propagation and after-care technique before making large-scale attempts at orchard establishment.

5. Space trees approximately 25 feet by 25 feet.

6. Do not irrigate young orchard trees except at time of planting and through the first summer, if needed.

7. Broadcast 300-500 pounds per acre of high-analysis complete fertilizer (e.g., 13-13-13), plus 100 pounds of Sulpomag per acre at the time of orchard establishment and semi-annually through age 7.

8. Maintain clean cultivation by disking during the growing season for 2-3 years after trees are outplanted. Establish low-growing cover when trees are well established and mow periodically.

9. Do not prune the trees except to remove broken limbs or to correct forked tops.

10. When trees begin to bear female flowers, broadcast up to 300 pounds of ammonium nitrate per acre annually to promote flowering. Do not apply girdling or stem bending treatments.

11. Maintain records of flowering, cone, and seed yields for evaluation of production trends and effectiveness of conelet protection.

12. Do not use seed from young seed orchards for commercial plantings until at least 5, preferably 10, clones (not individual trees) are flowering abundantly.

13. Keep up-to-date on recognition of pests and methods of control.

14. Take prompt action to control pests and to correct physiological problems. Report unusual phenomena to research specialists.

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Discussion

(Note: There was a discussion to this paper, but was not picked up on the tape.)