IRRIGATION AND FERTILIZATION OF SEED ORCHARDS

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Widespread interest in tree improvement has brought about the establishment of many pine seed orchards in the South within the past 10 years. The high cost of establishment and the demand for early and abundant seed production have made it desirable to manage these orchards intensively. Some aspects of seed orchard management need more investigation, among them irrigation and fertilization (20, 36). Matthews (17), in reviewing research on factors affecting the production of forest trees, found that much more experimentation has been done with fertilization than with irrigation. This paper will review the research in irrigation and fertilization and report what, according to a recent survey made by me, seed orchard managers are now doing in these areas.

IRRIGATION

Probably the earliest work showing the relationship of irrigation to southern pine cone production was done by Paul and Marts (21). In their research on controlling the proportion of summerwood in longleaf, they found that both fertilizer and irrigation, but especially fertilizer, stimulated cone production.

In 1932, Gemmer (8) fertilized and irrigated longleaf pine trees for 5 years. Treated trees averaged 62 cones; check trees averaged only 2 cones. Croker (5) reported a 5-year study of a 60-year-old stand of longleaf pine which was treated with 1,900 pounds of 8-13-5 fertilizer per acre per year plus an average of 13 inches of water from April to October. The average increase of cones, from 33 to 43 per tree, was not significant.

Bengtson (2) reported irrigation of slash pine orchards in north central Florida for 4 years after the orchards had been established 1 year. He supplemented rainfall with enough irrigation water to assure 1 inch per week during the second and third years. After the third year, 2 inches per week were applied during the growing season (March - November) and 1 inch per week during the winter months. Bengtson concluded that irrigation during the first 5 years after orchard establishment is of doubtful value for increasing growth rate and cone production of slash pine in his area, which averages 50 inches of rainfall annually. Approximately half of the rainfall in this area occurs from June through September. Irrigation had a significant depressing effect on the production of female flowers, but promoted pollen production.

Veihmeyer and Hendrickson (22) found that irrigation increased yields in fruit and nut orchards in California, where the winter storage of water is usually exhausted before the end of the growing season. But response to irrigation appeared slowly and was sometimes apparent only after several years. They made the following statements about water use by trees:

> Large trees need no more water than small ones as long as the area shaded by the leaves is the same.
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> Withholding irrigation does not make trees send their roots more deeply into the soil.
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> The presence or absence of fruit does not materially influence the amount of water used by trees.
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> Evergreen trees use water throughout the year, but the amount used in winter is usually much less than in summer.
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> Beneficial results of good irrigation practices, such as increased yields, are cumulative and require many years to appear.
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> Cover crops in orchards do not conserve soil moisture.

There are two principal methods of irrigation: furrows and sprinklers. Furrows can be used if the slope of the land and the volume of water are together not great enough to cause erosion. Furrows should be spaced so that the wetted areas meet, and water should be kept in the furrows until it has penetrated to the desired depth. The length of a furrow on a slope should be regulated so that the difference in penetration between the upper and lower ends is not great. Irrigation water should be applied no faster than the soil can absorb it. Straight furrows are adapted to relatively flat lands. On sandy soils a good length of furrow is about 300 feet, on medium textured soils about 600 feet, and on clay soils it may be longer. Graded contour furrows are sometimes used on slopes up to 25 percent. If contour furrows are contemplated, the trees should be planted on contours. The grades of the furrows should range from 0.5 percent in clay soil to 1.5 percent in sandy soil. Zigzag or check back furrows may be used to reduce the grade of furrows or to ensure wetting the soil in tree rows.

Sprinklers can be used under a variety of conditions, and are suitable for rolling or steep lands (33). Sprinkling can spread small volumes of water widely, and usually results in fairly uniform wetting of the soil. The disadvantages of sprinkling are the high capital investment and maintenance costs: interference of growing trees with the spray, causing uneven distribution of water: and, after the original design of the system is adopted, the inflexibility in operation of sprinklers. Bengtson (2) installed tall risers to cope with the spray interference problem, but this could hardly be used successfully on trees older than 5 years.

A 1966 survey of approximately 25 seed orchard managers in the South showed that all of them irrigated during the first 1 or 2 years after orchard establishment, chiefly to ensure survival. Otterbach (20) reported in 1963 that 17 of 34 orchards he obtained data on were watered the first year of establishment. The water in most cases was hauled to the orchard in portable tanks. Five gallons were used per tree at weekly or longer intervals during dry periods, as judged necessary. An evapotranspiration chart was used at one orchard. Some of the water was taken from ponds and streams, but most from wells.

For measuring irrigation need, the nuclear moisture meter (16) is probably best. It is accurate, and has the added advantage of not disturbing the sampling point. Another way of accurately measuring soil moisture is by gravimetric sampling (16) in which a soil sample is weighed, oven-dried, and reweighed. The original moisture content is expressed in percent of oven-dry weight of soil.

The above methods of measuring soil moisture, while accurate, require equipment not normally available. Other less accurate methods may be more practical. The tensiometer, which measures soil moisture tension at high moisture contents (16), consists essentially of a porous ceramic cup connected to a vacuum gauge or mercury manometer. In use, the cup is buried, usually 12 - 18 inches, and water in the cup comes into equilibrium with that in the surrounding soil. As the soil dries or wets, water flows from or into the cup. These changes activate a pressure-measuring device. Tensiometers function with tensions as low as 0.8 - 0.9 atmospheres. For the most meaningful readings, samples of the soil from the depth the tensiometer is placed should be saturated and subjected to various pressures to relate the amount of available water and its tension to water content of the soil. An average silt loam at a tension of 0.9 atmosphere will contain about 50 percent of the available water it is capable of storing.

The electrical resistance method (16) depends upon differing resistance to the passage of an electrical current between two electrodes buried in the soil as moisture content of the soil changes. The fabric or plaster of paris material of the unit wets and dries along with the soil around it, and change in moisture content affects the electrical resistance of the unit. Wires lead from the unit to the surface of the ground, where resistance is read with a meter. To convert resistance to soil moisture values requires calibration of the units in the soil being studied.

An evapotranspiration chart (15, 30) is not as accurate as other methods, but is more reliable than a guess. A table gives daily water losses due to evaporation from the soil and transpiration of any vegetation. To use this chart most effectively, the moisture content of the soil at the beginning of the growing season, the soil texture, and water—holding capacity should be known. By subtracting the daily moisture loss from the starting moisture figure, and adding any moisture from precipitation, a record can be kept of water needs.

Irrigation water should be tested to make sure it is free of harmful components. It is especially important to test well water. The sodium—absorption—ratio (SAR), which measures the sodium (alkali), should not run higher than 10, and the conductivity, which indicates the salinity, should not be greater than 250 micromhos per centimeter (a).

Initially, we should realize that every orchard probably has a different soil type. Indeed, most orchards have more than one soil condition. All orchard soils si-ould be typed and tested before sites are chosen. Any soil amendments should be based on frequent analyses of the soil and the fertilizer requirements of the tree species.

Nutrient deficiency symptoms for some of the southern pines are described as follows by Walker and Beacher (21.) based on research of others:

Species	N	P	K
Shortleaf	Pale green short needles	Short necrotic needles beginning at base	Yellow tipped needles
Loblolly	Short yellow needles		Brown, purple, or yellow needles; necrotic spots
Longleaf	Pale green		Short bluish-green needles, dark brown tips

Walker and Beacher listed deficient nutrient levels for the foliage of loblolly pine as follows: nitrogen 1.2 percent, phosphorus 0.10 percent, potassium 0.26 percent, magnesium 0.07 percent, and calcium 0.033 percent.

Research showed benefits from fertilization of southern pines as early as 1931 and 1932 (8, 21), but little work was done until after 1950 when seed orchards came into existence. Early work with fruit and nut trees developed the theory that a high carbohydrate-nitrogen ratio aided flowering. Recent work (10, 14) suggests that the initiation of the flowering process may precede the accumulation of carbohydrates and that the variation in the C/N ratio is a consequence rather than a cause of flowering.

The use of fertilizer has generally increased seed production (1, 3, L, 2, 6, 8, 9, 11, 12, 13, 19, 21, 23, 24, 25, 26, 27, 28, 29, 32, 35). Mixed fertilizers have been most successful (1, 3, 6, 8, 11, 12, 19, 24, 28, 29, 35). In some cases the addition of one or two elements has increased seed yields (4, 9, 14, 23, 25, 26, 27).

Seed yields have increased with per acre applications of fertilizer ranging from 200 pounds for young trees to 14,000 pounds for older trees. Some of the heavier applications were:

1. Fifty pounds of 7-7-7 analysis to a 25-year-old loblolly pine (32).

2. One thousand nine hundred pounds of 8-13-5 per acre in a 60-year-old longleaf pine stand (2)

3. One thousand six hundred to four thousand eight hundred pounds per acre of equal parts of ammonium sulphate and sodium nitrate in 4-inch x 8-inch and larger beech and sugar maple (4).

4. The fertilization of a single, large white oak tree at the heavy rate of 14,000 pounds per acre of 10-4-6 (6).

The oak received its fertilization in the early spring. The large amount was applied in error. Sixteen-inch holes 18 inches apart were each filled with 3/4-pound of fertilizer. Although this fertilized area covered only 30 percent of the crown spread, the tree produced 8 bushels of acorns the following year. It has never before borne more than 2 bushels.

While working in Mississippi, I was told about two slash pine trees that regularly bore 7 - 12 bushels of cones each. Both, I found, were in cattle pens where there was abundant manure.

When should fertilizer be applied? Goddard 1/ fertilizes newly established

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1/ Dr. Ray E. Goddard. Personal communication, July 29, 1966.

slash pine orchards 1 year after planting. After orchards start bearing, which is usually in about 5 years (22), additional nitrogen is added in May in order that it will be available before flower primordia begin to form. (Mergen and Koerting (18) and Eggler (7) have shown that the southern pines initiate their flower primorida in late summer and early fall.) Stoate et al. (27) report that Douglas—fir produces visible flower buds which are carried on the tree for approximately a year before the flowers open in the spring. In two separate studies they found that a larger cone crop results from fall application of nitrogenous fertilizer after the buds are formed, and that spring application of nitrate, if applied at the time of vegetative bud flushing, causes a significant increase in the initiation of flower buds. Hocker (11) reported that there was a 3— to 4—year lag in eastern white pine after fertilization before cone production increased. If this is true with the southern pines, the time of the year that the general fertilizer application is made is probably not critical. Kellison, 2/ liaison geneticist for the North Carolina State University—Industry program, makes fertilizer applications in February or early—March and again in early—July in young orchards. His primary objectives are growth and vigor.

How should fertilizer be applied? Most workers fertilize orchard trees individually when they are small and begin making broadcast applications at 3 to 6 years. 3/ 4/

A survey of seed orchard managers in the South revealed that most of them fertilized sites before planting. Some, however, waited 1 to 2 years after planting. Almost all are using soil analyses as a basis for determining nutrient needs. The most common mixed fertilizers in use are 10-10-10 and 12-12-12. Applications are commonly 1 pound per inch of tree diameter applied within the drip line or broadcast applications up to 400 pounds per acre. Some orchards, when they begin to produce seed, are receiving additionally up to 300 pounds of ammonium nitrate. Lime is sometimes added to keep the pH at 5.0 — 5.5. If cover crops are used, more fertilizer per acre is added--in one case as much as 500 pounds more. The most common method of application is to broadcast around individual trees. Applications are being broadcast throughout older orchards. Weed growth stimulated by fertilization is eliminated by mowing or disking.

2/ Mr. R. C. Kellison. Personal communication, August 23, 1966.

3/ Dr. Charles B. Davey. Personal communication, August 19, 1966.

/ Dr. Ray E. Goddard, 22. cit.

SUMMARY

Irrigation of young trees with portable tanks for the first 1 or 2 years to ensure establishment and survival is practiced by many seed orchard managers. But irrigation to increase seed production has not been successful enough to warrant recommending its use in forest tree seed orchards in the South where there are 50 inches or more of fairly well distributed rainfall annually.

Many cases in the literature indicate that mixed fertilizers at the rate of 300 pounds or more per acre increase seed production. Extra nitrogen, when applied after trees begin to bear seed, gives additional yields when used at rates up to 300 pounds (33-1/3% N) per acre. As seed trees increase in size, their fertilizer requirements go up sharply.

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Discussion

Q. (Meade) What about the use of pelleted fertilizer?

A. (Grigsby) The fertilizer in coated pellets is generally more slowly available. This should aid in keeping nutrients available to the tree throughout the year.

Q. (Williams) How about use of chicken litter?

A. (Grigsby) I have found no reference in the literature to the use of chicken manure for seed production. It is known to have a very high analysis of the basic nutrients and should be a desirable seed orchard fertilizer.

Q. Do you know of any cases where fertilizer was pocketed into the ground--other than broadcast--such as put into holes?

A. (Grigsby) Although that is a common method of fertilizing ornamental trees, the only report I've seen on its effect on seed production was the case reported by Detwiler which I mentioned in the paper.

Q. (Bonner) I notice some horticulturists now talking about fall fertilization of fruit trees as opposed to late winter or spring. Is there any information on this for forest trees?

A. (Grigsby) Heinicke found that a later application of nitrogen caused leaves of apple trees to carry on photosynthesis later in the autumn, building up higher carbohydrate reserves and greater fruit yields. Goddard feels that fertilizer, especially nitrogen, should be available at the time the southern pines initiate their flower primordia, which is in the late summer and early fall. To make sure it is available at the proper time, he suggests applying the fertilizer in May.

Q. (Farmer) Have you run across, in the literature, a variable response of different genotypes to fertilization in the seed orchard situation?

A. (Grigsby) Absolutely. Some trees are inherently better seed producers than others. Croker and Shoulders found this to be so. It appears that the inherently good seed producers respond better to fertilization than genetically poor seed producers.

Q. (Farmer) What effect does cultivation have on the availability of soil moisture?

A. (Grigsby) Cultivation does not help preserve it, nor does it cause the soil to lose it, except from the pulverized layer.