INCREASING SEED YIELD THROUGH CULTURAL PRACTICES - TODAY AND TOMORROW

C. B. Davey [1]

Abstract.-- Proper management of tree nutrition and moisture regime as well as the maintenance of good soil physical factors will result in increased seed yields from seed orchards. If careful site selection and preparation are conducted prior to orchard establishment, they will also pay dividends in seed yield obtained and in ease of orchard management.

Additional keywords: Seed orchard, site selection, soil, fertilization, irrigation, subsoiling.

Over the past decade and a half considerable progress has been made in increasing seed yield in Southern pine seed orchards through the development of improved and intensified cultural practices. These practices are important during orchard establishment and early vegetative growth as well as during the reproductive growth phase of the trees. These cultural practices have included improved tree nutrition through the use of fertilizers, improved tree moisture regime through seed orchard irrigation, and improved soil physical conditions and tree rooting habit through proper subsoiling of the orchard soil. Each of these practices has resulted in improved tree vigor and seed production. Also, they are compatable and their effects are partly additive. Much remains to be done in the area of delineating optimum utilization of each.

This paper includes a very brief summary of the development of these practices up to 1975 and includes some thoughts and speculation on further increasing seed orchard seed yields over the next few years. Throughout this paper megasporangiate and microsporangiate strobili are referred to as female and male flowers, respectively. Hardwood seed orchards are not included in this discussion in part because they currently represent only a small acreage in comparison to the pines and secondly, because research on increasing seed production in them is only now gaining momentum.

TREE NUTRITION

It had been intermittantly reported in the literature for about four decades that well-nurished trees in natural stands and seed production areas produced more seed than did trees on a more stringent diet (Demmer 1932). Beginning in the early 1960's, however, the question was being asked whether this same concept would also apply to grafted "superior" trees in seed orchards. The answer was not immediately obvious.

The history of seed orchard fertilization has progressed in a step-wise manner. The early trials simply tested whether fertilization (sometimes in

---

[1] Professor of Forestry, Soil Science, and Plant Pathology, North Carolina State University, Raleigh, N. C.

combination with irrigation) would stimulate flowering and seed production. The answer was usually in the affirmative. The second generation of tests involved the determination of which nutrients were usually the most critical in terms of stimulating flowering and seed production. These tests provided information suggesting that on most soils in the South, phosphorus and, on essentially all soils, nitrogen were needed. The third generation of tests then included studies of different rates of application of nitrogen and phosphorus.

Each of these sets of tests have had to span five or more years since it is the third year before the harvested cones have been under the influence of the imposed treatment throughout their development. Then at least two more years are required to account for year-to-year climatic variation.

It was learned early that there is always tree-to-tree variation within the ramets of the same clone. This led to the general conclusion that a minimum of five ramets of each of five clones was necessary per treatment plot. Then a minimum of three replications per treatment resulted in the inescapable conclusion that few if any existing seed orchards are large enough to provide for complete factorial designs which cover more than a very few treatments. This has led to the utilization of incomplete rotatable factorial designs with replication restricted to the central treatment and similar statistical shortcuts.

At this point in time, it is safe to say that proper fertilization is worthwhile and is probably essential in nearly all seed orchards, if their seed-producing potential is to be even closely realized. Nitrogen has been repeatedly shown to be the key element in stimulating flowering and seed production.

The effect of fertilization has been the production of more branches on a tree, more flowers per branch, and increasing the portion of the tree crown which bears flowers (Webster 1974). The biggest single effect of fertilization appears to be the stimulation of a large number of bud primordia to differentiate into either flower or branch buds rather than needle fascicles (Webster 1974).

To date fertilization has not been shown to greatly reduce the time required to bring an orchard into meaningful production or to markedly reduce the number of unproductive clones. In every test known to this author, there has been a greater range in seed production among clones than there has been among treatments.

The next areas of interest in fertilization research should shed light on the matters of the impact of nutrient form and time of application on tree flowering and seed production. We expect to hear about current research on both of these topics today. Eventually we will need to study nutrient balance within the tree. This information will lead to a more efficient fertilization program than is now possible.

SOIL FERTILITY

Knowing that trees can respond to fertilization is only a portion of the solution to the problem. Of equal importance is being able to determine nutrient needs. This can theoretically be approached through either or both soil testing or tissue analysis. To date, neither system is fool-proof but more progress has been made in utilizing soil testing than tissue analysis to predict nutrient needs. The following standards are currently used for determining nutrient needs where the dilute double acid soil extractant is used. This includes the majority of the states in the South.

Soil attribute	Units	Desired level
P	lbs/acre [1]	40
K	"	150
Ca	"	400
Mg	"	50
Mn	"	10
Acidity	pH	5.5
Organic Matter	%	2.0

[1] Also approximately kg/ha

In all soils the amount of a nutrient needed to raise its test value from that determined to that desired exceeds the difference in the two values. The finer the soil texture, the greater the application needed. Also, seed orchards in the Piedmont require larger applications of phosphorus than do those of the Coastal Plain.

The major element nitrogen is not included in the above chart since there is no test for available soil nitrogen. It has been generally established that within reason, nitrogen needs can be determined from the percent organic matter in the soil, the soil type, and the age of the trees to be fertilized. Additional research in this area is needed, however.

Nitrogen is important at all stages of seed orchard management. An adequate supply of nitrogen will increase grafting success during orchard establishment. This can be obtained from about one ounce (30 gm) of elemental nitrogen per tree applied once in the month or two immediately before grafting as well as during the preceeding year.

During vegetative growth, trees should receive increasing amounts of nitrogen per tree up to about five ounces (150 gm) of elemental nitrogen per tree at three or four years of age of the graft. Beyond that age the root system is sufficiently expanded to make broadcast application of nitrogen over the entire orchard more feasible. This also stimulates the sod cover which is necessary to reduce traffic damage to the soil. In fact, broadcast application of fertilizer maybe started at grafting if the sod is not thrifty at that time.

During vegetative growth, after broadcast application of nitrogen has been started, amounts of elemental nitrogen up to 100 lbs. per acre (about 100 kgN/ha) per year are needed. Once reproductive growth has started, the amount of nitrogen applied can be increased considerably and still result in increased seed yield. The upper limit of nitrogen application has not yet been determined but rates of up to 400 lbs. of elemental nitrogen per acre (about 400 kgN/ha) per year have been tested.

IRRIGATION

Irrigation of seed orchards has been studied far less than their fertilization. However, it has been found beneficial in nearly every test. Irrigation improves grafting success, sod establishment, early vegetative growth, and flowering and seed production. Whereas fertilization primarily tends to stimulate female flower production, irrigation has increased pollen production in Southern pine seed orchards. The need for, and response to, irrigation is highly dependent upon the amount and distribution of rainfall.

Both the need for irrigation and the amount of irrigation needed can be determined through the use of soil tensiometers installed in the seed orchard soil at depths of 12 and 24 inches, (30 and 60 cm). Irrigation is utilized to keep the soil moisture stress between 0.5 and 0.1 atmospheres of tension.

Irrigation in the first year of the reproductive cycle results in more male and female flowers in the second year. Irrigation in the second year reduces conelet abortion and in the third year it results in somewhat longer cones and heavier seeds.

A long-running study of fertilization and irrigation, conducted by the Catawba Timber Co. in Catawba, South Carolina, will be used to illustrate the value of both practices (Table 1). The treatments have been imposed since the orchard was grafted in 1964. Irrigation has been supplied as indicated above and fertilization has included 350 lbs./acre (about 350 kg/ha) of NH_4NO_1 applied in the spring and again in July and 500 lbs./acre (about 500 kg/ha) of 10-10-10 fertilizer in November of each year. This total application of 300 lbs.N/acre (about 300 kgN/ha/yr) was originally intended to be excessive but to date has not been detrimental although it may not represent the optimum rate of application.

Table 1.--Yield of cones per tree in a loblolly pine seed orchard [a/] as affected by irrigation and fertilization

Year	Treatment: Control	Irrigation (I)	Fertilization (F)	F + I	$\bar{x}$
	cones/tree				
1971	45	81	60	102	72
1972	72	99	134	145	112
1973	70	88	88	100	86
1974	55	98	117	144	104
$\bar{x}$	61	92	100	123	
Difference		(I-C) 31	(F-C) 39	[(F+I)-C] 62	

a/Catawba Timber Co., Catawba, S. C. Tests initiated in 1964.

The effects of both irrigation and fertilization can be seen to be positive in each of the four years although their magnitude changes from year to year. It is instructive to note that where the treatments are applied individually the response totals 70 cones. That is, the response was 31 cones for irrigation and 39 for fertilization. When both treatments were applied to the same trees, the combined response was 62 cones. Thus it may be concluded that the effects of fertilization and irrigation are additive at best. Definitely, their combined effect is not synergistic.

A conservative economic assessment of these data by H. D. Smith (personal communication) using 1974 cost figures indicates a benefit/cost ratio for value of additional seed obtained versus cost of treatments imposed of approximately 27 to 1. That is favorable even if you choose to discount Dr. Smith's assessment by a whole order of magnitude.

It is now generally accepted that irrigation as well as fertilization can have both biologically and economically positive effects on flowering and seed production. Much remains to be determined, however, on the effects of minor moisture stress at critical stages of the reproductive cycle. It is quite obvious from the data at hand that severe moisture stress is not profitable but it has been suggested by several workers (e.g. Shoulders 1967) that minor stress in late summer may trigger flower bud differentiation. Verification and quantification of this phenomenon (if real) should be undertaken soon. Finally, there are interactions that need to be studied among nutrition, moisture stress, and applied active compounds such as the gibberellins. The whole area of chemical regulation of flowering, seed formation, and cone abscission remain to be studied.

SUBSOILING

The practice of subsoiling in seed orchards was born out of desperation. In the early 60's trees in certain orchards were losing apical dominance, patches of cambium on the bole were dying, and roots were appearing on the soil surface. At first it was suggested that fertilization was to blame. When fertilization was stopped the situation got worse. Finally, it was noted that soil compaction was becoming severe and deep subsoiling was attempted (in 1964) in order to "loosen up the soil." Dire consequences were predicted because of all the root cutting involved. The response, however, was favorable and dramatic both above and below ground. Thus, the practice of subsoiling on an operational basis was started. It has continued to the present purely on the basis of visual results.

In 1973, research was finally started in two seed orchards to determine whether it was possible to improve the effectiveness of the subsoiling process. Variables under investigation include shallow (approximately 6 inches or 15 cm) and deep (approximately 18 inches or 45 cm) soil disturbance, early (June) and late (August) summer subsoiling, number of sides of the tree subsoiled (1 or 2) simultaneously, and frequency of repeated subsoiling (every 2 to 5 years).

To date, the 1974 and 1975 female flower counts appear to indicate that subsoiling is of immediate value in stimulating flowering but that we must delay judgment on the relative value of the two depths employed (table 2). Also, late appears better than early subsoiling, although this effect may not persist beyond the first year. No conclusions can be drawn on the other variables under study at this time.

Table 2.--Effect of subsoiling in two seed orchards [a] on female flower production for two years following treatment

Subsoil treatment	Subsoiled June 1973 Females/tree		Subsoiled August 1973 Females/tree	
	1974	1975	1974	1975
Control	13.4	19.7	14.4	43.8
Shallow	11.9	24.0	23.8	50.2
Deep	11.1	23.5	30.0	48.3

a/Orchards of the Virginia Division of Forestry, Buckingham, VA (June subsoiling) and Union Camp Corp., Murfreesboro, NC (August subsoiling). The data include 6 clones in each orchard.

Root excavations have revealed rapid proliferation of new roots near the cut ends of severed roots. The new roots are abundant, soon bridge the subsoil slit and proliferate beyond it, and in the case of the deep subsoiling, grow down the slit and proliferate in the deeper soil layers. The apparent effect of this new rooting habit is to give the tree improved stability and moisture supply from the action of the new deep roots. Nearly all of the new roots are mycorrhizal. Obviously, more time will have to elapse before these tests can be fully evaluated but these first results appear encouraging. Operational subsoiling will continue as before.

SITE SELECTION AND PREPARATION

Perhaps as much gain in seed yield can be realized by careful selection of new seed orchard sites and their proper preparation as through any of the above discussed techniques. At the moment a large study is underway to delineate critical factors of soil and climate in selecting optimum sites. Thus, we may expect some refinements in our present thinking. However, at this time we do suggest that soils which range from fine sandy loams, through silt loams, to some clay loams (those with good structure and internal drainage) will offer the best opportunities for high seed yield. Primarily these soils have better nutrient- and water-holding properties than the sandier soils and fewer trafficability, compaction, aeration, and drainage problems than the heavier soils. Also the site should not be eroded and a topsoil of at least 8 inches (20 cm) is preferred.

The newest piece of equipment in the arsenal of the loblolly pine seed orchard manager will soon be the vacuum seed harvester. A smooth soil surface will increase seed yield when this machine is used. The best time to prepare for this is during seed orchard site preparation. It is now possible, through use of a computer program, to solve the earth moving required to provide the surface shape desired while maintaining a stated minimum topsoil thickness. If significant earth movement is required it will be necessary to subsoil the site before the root stock is planted.

Careful site selection and preparation offer long-term benefits in increased potential for high seed yields. Also they have the advantage of being non-recurring expenses in the life of the orchard. Further refinements in our knowledge in these areas will pay large dividends both in ease of seed orchard management and in seed yield obtained.

LITERATURE CITED

Genmer, E. W. 1932. Well-fed pines produce more cones. Forest Worker 8:15.

Shoulders, E. 1967. Fertilizer applications, inherent fruitfulness, and rainfall affect flowering of longleaf pine. For. Sci. 13:376-383.

Webster, S. R. 1974. Nutrition of seed orchard pine in Virginia. Ph.D. thesis, N. C. State Univ., Raleigh, NC 180 pp. Univ. Microfilms, Ann Arbor, Mich.