OPTIMUM FERTILIZER RATES FOR LOBLOLLY PINE SEED ORCHARDS

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Abstract.-- Fertilizers were applied annually for 7 years to individual ramets in a loblolly pine *(Pinus taeda* L.) seed orchard at rates ranging from 0 to 400 lbs N/acre. Treatments also included splitting the applications into spring and summer segments, and fertilizing every other year. The optimum fertilizer rate for flowering and seed production was 200 lbs N/acre/year, applied every year in mid- to late summer. Including phosphorous in the fertilizer regime appears to be desirable, whether it is applied separately in the spring or with a summer N application. The benefit of using foliar analysis to make fertilizer recommendations depends on the accuracy of the analysis used. Using heavy fertilizer rates had little effect on the concentration of foliar micronutrients.

Keywords: *Pinus taeda* L., seed orchard, cone production.

INTRODUCTION

There are many reports in the literature indicating that fertilization enhances flowering and seed production in southern pines (Schmidtling 1974). Nitrogen (N) *is* the acknowledged critical nutrient in flower stimulation (Sprague et al. 1978) and is the element most often used in routine seed orchard management. Fertilizers have been applied to many orchards at high rates for a number of years, but long-term effects of high fertilizer rates on cone and seed production are not known.

Shoulders (1968) reported on a long-term fertilizer rate experiment in slash *(Pinus elliottii* Engelm. var. *elliottii)* and longleaf *(P. palustris* Mill.) pine stands. He found the best flowering and cone production response with his highest rate of 150 lbs N/acre. Orchard fertilization rates have ranged from 100 to 400 lbs N/acre/year, so Shoulders' high rate of 150 lbs *is* on the low side compared to current orchard practice.

At moderate rates, fertilizers can improve cone and seed yields per flower as well as increase flowering (Sprague et al. 1978). Studies with longleaf pine, however, indicate that high nutrient levels may cause an increase in conelet abortion (McCall and Kellison 1981). There is other evidence that longleaf pine cannot tolerate nutrient rates as high as those that are optimum for slash and loblolly *(P. taeda* L.) pines (Schmidtling 1987).

Fertilization rates and formulations are sometimes based on soil analysis (Sprague et al. 1978), which is marginally satisfactory for nutrients other than

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nitrogen. The availability of nutrients in soils depends on more than their concentration; soil analysis is usually not done for nitrogen because there is no reliable test for available nitrogen.

Webster (1974) recommended 180 to 200 lbs N/acre/year for loblolly pine seed orchards, although the results of his nitrogen-phosphorous rate study were inconclusive. Current fertilizer rate recommendations are based on these limited research results, some preliminary results of the present study, and intuition (Jett 1986).

Foliar analysis is the logical choice for diagnosing mineral requirements for pine seed orchards (Jett 1987). Minimum standards for foliar nutrient for some nutrients have been established for forest stands of some southern pines (Leaf 1968, Pritchett 1968, Wells 1968), but little has been published on foliar standards for seed production in orchards. Webster (1974) noted an increase in foliar N and a decrease in foliar P with increasing N fertilizer rates but did not explore the use of foliar analysis for determining optimum rates.

The following are the objectives of this experiment:

(1) To determine the long-term effects of varying rates of fertilizers on cone production,
(2) To examine the relationship between foliar levels of macro- and micro-nutrients to explore the feasibility of foliar analysis for prescribing fertilizer treatments,
(3) To quantify the clone X treatment interactions in (1) and (2) above. Beers (1974) proposed fertilization on a clonal "prescription" basis to maximize fertilizer efficiency. One important objective of this experiment will be to determine the magnitude of interactions in both the short and long term,
(4) To examine the feasibility of alternative methods of application; specifically, single versus split application and annual versus biennial application.

MATERIALS AND METHODS

The study was established in the Alabama seed source at the Erambert Seed Orchard in south Mississippi. As in most production seed orchards, the makeup of orchard blocks varies considerably in age of ramets and clonal composition. Because the broad-sense heritability of flowering traits is so high, it is very important that the clonal composition of any flowering experiment be carefully balanced (Schmidtling 1974). Experiments in which whole orchard blocks are treated are often difficult to interpret because of high error rates; in this experiment, individual ramets were treated.

Thirteen clones were chosen from among the 50 available based on an inventory by clone and year of grafting. The ramets were 15 or 16 years from grafting when the experiment was initiated (age was confounded with clone, i.e., all ramets of a given clone were the same age). The ramets averaged 10 inches d.b.h. Original spacing in the orchard was 15 X 30 feet. Soils in the orchard are primarily well-drained sandy loams.

Table 1. Fertilizer rates per acre for the seven treatments of the study.

Treatment	Nitrogen	P205 (P)[a]	K20 (K)[a]	Timing
	- - - - Pounds/acre[b] - -			
1 (Control)	0	0	0	
2	100	28 (12)	28 (23)	July
3	200	56 (24)	56 (46)	July
4	300	84 (37)	84 (70)	July
5	400	112 (49)	112 (93)	July
6	400	112 (49)	112 (93)	July - Alternate years
7	56 144 200	56 (24) 0	56 (46) 0	April _ Split July Applications

[a] Elemental rates for phosphorous and potassium shown in parenthesis.
[b] Spacing in the orchard is 15 X 30 ft. Fertilizer rates per acre are calculated based on 450 ft^2 growing space per ramet. 100 lbs/acre = 92 kg/ha.

Beginning in summer of 1982, seven treatments were applied yearly to three ramets each of the 13 clones in a factorial design (table 1). The first five treatments consist of increasing rates of N from 0 to 400 lbs/acre. The sixth treatment was included to determine whether 400 lbs/acre every other year is as effective as 200 lbs/acre every year. The seventh treatment tested the efficacy of the common practice of splitting the applications,i.e., applying a balanced fertilizer in early spring to stimulate growth and nitrogen in the summer to stimulate flowering. The overall rate is the same as the 200 lb/acre rate. A total of 273 ramets were included in the experiment.

Experience has shown that N is most often the important nutrient for flowering response (Schmidtling 1974). Severe P or potassium (K) deficiency may inhibit flowering, however, so fertilizers for most of the treatments consisted of a 50/50 mix of ammonium nitrate and 13-13-13 NPK. Fertilizers were broadcast within the "drip line" of the individual ramets at times determined to be optimum for flowering response (Schmidtling 1983) (Table 1).

From 1983 through 1986, male and female strobili were counted in the spring and cones in the fall. Foliar analysis was done on a subset of the experiment in September of 1983, 1984, 1985, 1986, and 1989. Two ramets each from the first five treatments for 10 of the 13 clones (a total of 100 trees) were analyzed for nitrogen, phosphorous, potassium, calcium (Ca), magnesium (Mg), iron (Fe), boron (B), manganese (Mn), and copper (Cu). Foliar samples consisted of most recently-formed needles from at least three branch tips from the upper crown. The foliar samples were collected in late September, just after probable formation of female strobili initials (Schmidtling 1975). Five cones per tree were collected from this subsample in the fall of 1983 and 1984 to assess the effects of fertilization on seed yields.

SAS (1985) General Linear Model (GLM) procedure was used to test differences among treatment means in the analysis of variance for the completely random, single-tree plot design. Regression was used to test relationships between flowering (dependent variables) and foliar nutrients (independent variables). Probabilities of less than 0.05 for no difference were considered significant.

RESULTS AND DISCUSSION

As expected, the clonal effects for both male and female flowering in the analysis of the results of the experiment were always large and significant. Treatment effects were also significant for female flowering over the duration of the experiment and for male flowering the first two years (Figure 1). Clone X treatment interactions were not significant.

Fertilizer Rate

In the first 2 years after the study began, 1983 and 1984, it was obvious that the 200 lb rate was optimum for both male and female flowering (Figure 1). In 1983, controls averaged just over 160 strobili per ramet. Fertilizing with 100 lbs/acre N increased flowering to just over 180 strobili; fertilizing with 200 lbs/acre increased flowering to over 200 strobili per ramet. Higher rates did not further increase flowering. The response in number of male strobili per ramet followed a pattern similar to that of female strobili.

The pattern of flowering response in 1984 was similar to 1983, although flowering was greater in 1984 (Figure 1). The flowering response pattern changed somewhat in 1985 and 1986, when it appeared that the rates higher than 200 lbs/acre, especially the 400-lb rate, produced better results. Rather than indicating a fundamental change in the flowering response, this change is probably a result of the field design. Most of the feeder roots of the trees occur under the drip line of the crown. The fertilizers were applied with this in mind. Some roots invariably extend beyond this area and root growth occurs in response to a nutrient gradient. The most striking effect of nitrogen fertilization in agronomic crops is increased growth of roots, which brings the plant into contact with a greater quantity of nutrients (Grunes 1959). In slash pines, nitrogen fertilization has increased root growth (Schultz 1969). In this experiment, roots from adjacent, unfertilized trees probably have extended and proliferated into the area beneath the fertilized trees, absorbing nutrients and giving the appearance of a drop in rate effectiveness for the study trees.

The original study plan called for subsoiling between the ramets to minimize this effect, but the orchard manager was reluctant to do so because of the risk of increased root diseases (Webb and Alexander 1982, 1983). Such risks appear to be exaggerated (Schmidtling 1986), and subsoiling has become a common practice in seed orchards (Jett 1987).

Application Method

Applying 400 lbs/acre every other year appears to be much less effective than applying 200 lbs/acre every year. In 1983 (Figure 1), when the biennial 400-lb rate was applied, response was the same as with the regular 400 lb rate

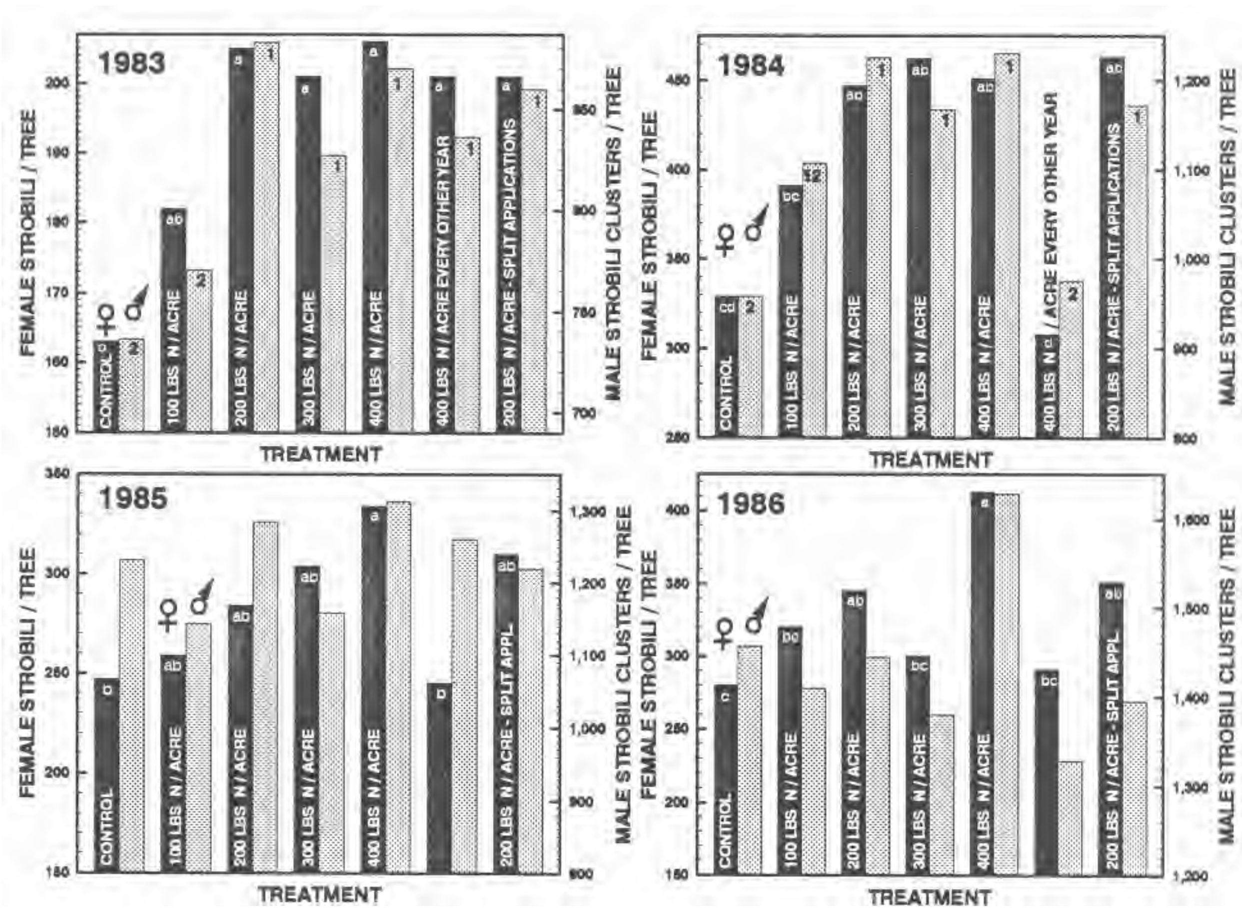

Figure 1. Male and female flowering in response to several rates and application methods of fertilizers. Bars topped by the same letter (female flowering) or number (male flowering) do not differ significantly from one another according to Duncan's multiple range test (0.05 level of significance).

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and did not differ from the response with the 200 lb rate. In 1984 there appeared to be no carryover at all, and the flowering rate in the biennial treatment dropped to that of the controls. This treatment was dropped after 1984, and these trees responded similarly to the controls thereafter.

There also appeared to be no advantage to splitting the application, i.e, applying a balanced fertilizer in early spring to stimulate overall vigor, followed by applying nitrogen in summer to stimulate flowering. In all 4 years applying all the fertilizer in summer (the 200-lb treatment) was equivalent to splitting the applications (Figure 1).

Cone and Seed Yields

The treatments had no significant effect on the proportion of female strobili which were harvested as cones in any year. There were, however, small but significant effects of treatment on the yield of total numbers of seed per cone (Figure 2). In 1983, the highest rate of fertilizer appeared to reduce the total number of seed per cone from 110 in the controls to 90 seed per cone at the 400-

lb treatment. Differences among treatments in full seed per cone were not statistically significant.

The differences in total seed per cone in 1984, although statistically significant, did not agree with the pattern of differences in 1983 (Figure 2). Seed yield from trees fertilized with 200 lbs/acre was best, while yield from the trees receiving the 100-lb and 400-lb rate was poorest. Considering the results in total seed for both years and the number of full seed per cone, the 200 lb/acre rate appears to be best both for flowering and seed yield.

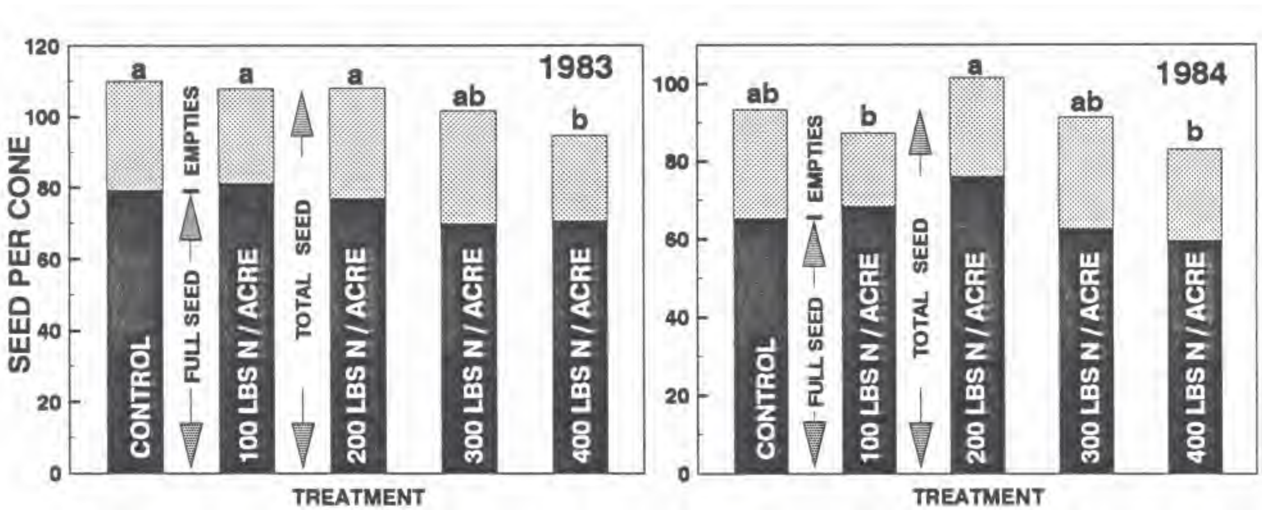

Figure 2. Seed yield in response to several rates of fertilizers. Bars topped by the same letter do not differ significantly from one another in total numbers of seed per cone according to Duncan's multiple range test (0.05 level of significance).

<u>Foliar Nutrients</u>

Analysis of foliar nutrients showed that clonal effects for most nutrients were significant most years. There was no relationship between flowering and foliar nutrients on a clonal basis, however. The strength of the clonal component underscores the need to consider this source of variation when sampling.

The only consistent treatment differences in foliar nutrients was for nitrogen (Figure 3a). The concentration of N generally followed the order of treatment rates, i.e., N concentration was highest in foliage from trees given the highest rates of fertilizer and lowest in foliage from the controls. There was a large overall drop in N concentration between the 1985 and the 1989 samplings (fertilizer treatments were continued during this time, although no measurements were taken). Even so, treatment effects were statistically significant and in the correct order. This may represent a change in the way the analyses were done at the commercial laboratory, since sampling methods and timing were identical to previous years.

In the earlier samplings, there appeared to be a decrease in phosphorus concentration with higher fertilizer rates, even though P was included in the

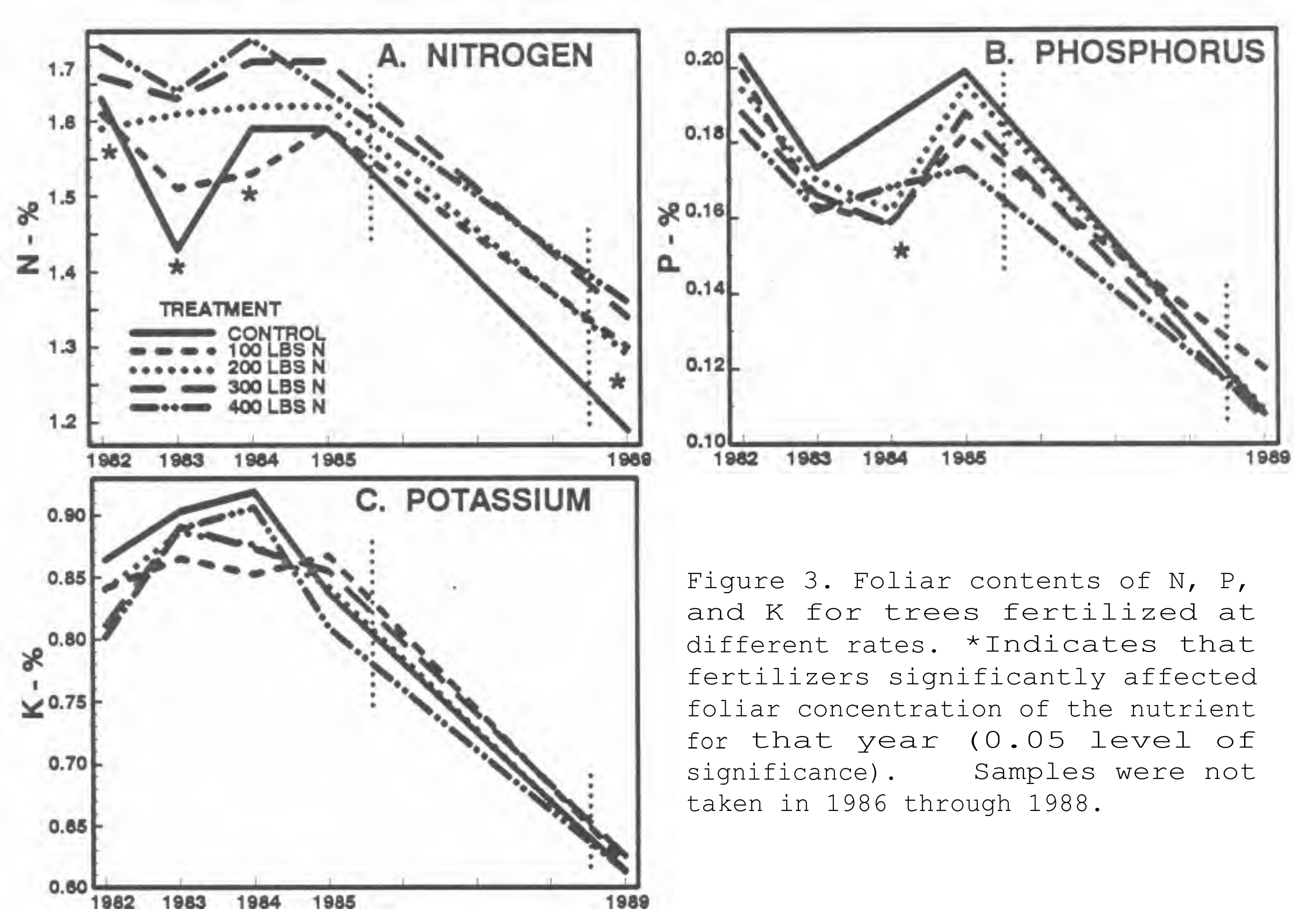

Figure 3. Foliar contents of N, P, and K for trees fertilized at different rates. *Indicates that fertilizers significantly affected foliar concentration of the nutrient for that year (0.05 level of significance). Samples were not taken in 1986 through 1988.

fertilizer mix (Table 1). A similar response was observed by Webster (1974). The difference was statistically significant in 1984 (Figure 3b). This difference was not evident in the final sampling in 1989.

There were no significant trends in the concentration of the other macro- and micronutrients over time. A decrease in micronutrients due to heavy nitrogen fertilization which was observed in *Pinus radiata* (D. Don) growing on deep sand (Woods 1983) did not occur in this experiment.

Flowering was not significantly related to concentrations of macro- or micronutrients in simple or multiple regressions. Ratios of nutrients, especially Ca/P and Ca/K were related to flowering in one report (Wilcox et al. 1991) but no significant relationship was found in the present study. The concentration of foliar N at the treatment level is related to flowering in a very general way (compare Figure 3a and Figure 1), but there was no relationship on an individual tree basis.

CONCLUSIONS AND RECOMMENDATIONS

The optimum fertilization rate for flowering and seed production in loblolly pine seed orchards appears to be 200 lbs N/acre/year, identical to the optimum rate determined for growth of loblolly pine in plantations (Ballard 1981). For best results, the fertilizer should be applied every year, in mid- to late summer. Although the experiment did not test the effects of phosphorous application separately, the foliar analysis indicates that including phosphorous with nitrogen in the fertilizer regime appears to be desirable.

The utility of using foliar analysis to make fertilizer recommendations may depend heavily on the accuracy of the analysis used. It does seem apparent, however, that heavy fertilizer rates had little effect on the concentration of foliar micronutrients in the soils of the Erambert Seed Orchard.

LITERATURE CITED

Ballard,R. 1981. Optimum nitrogen rates for fertilization of loblolly pine plantations. Southern Journal of Applied Forestry 5:212-216.

Beers,W.L.,Jr. 1974. Industry's analysis of operational problems and research in increasing cone and seed yields. P. 86-96 *in* Proc. Coll. Seed yield from southern pine seed orchards; Georgia Forest Research Council, Macon, GA.

Grunes,D.L. 1959. Effect of nitrogen on the availability of soil and fertilizer phosphorous to plants. Advances in Agronomy 11:369-396. Academic Press, NY.

Jett,J.B. 1986. Reaching full production: a review of seed orchard management in the southeastern United States. P. 34-58 *in* Proc. IUFRO Conf. A joint meeting of working parties on breeding theory, progeny testing, and seed orchards. Williamsburg, Va.

Jett,J.B. 1987. Seed orchard management: something old and something new. P. 160-171 *in* Proc. 19th South. For. Tree Improv. Conf. College Station, TX.

Leaf,A.L. 1968. K, Mg, and S deficiencies in forest trees. Forest Fertilization: Theory and Practice. Tennessee Valley Authority 1968: 88-122.

McCall,E.Y. and R.C.Kellison. 1981. Pollination, pollen tube development and orchard nutrient status effects on conelet abortion in open-pollinated longleaf pine. P. 267-275 *in* Proc. 16th South. For. Tree Improv. Conf. Blacksburg, VA.

Pritchett,W.L. 1968. Progress in development of techniques and standards for soil and foliar diagnosis of phosphorus deficiency in slash pine. Forest Fertilization: Theory and Practice. Tennessee Valley Authority 1968:81-87.

SAS. 1985. SAS user's guide: statistics. Version 5 edition. SAS Institute, Cary, NC. 958 p.

Schmidtling,R.C. 1974. Fruitfulness in conifers: Nitrogen, carbohydrate, and genetic control. P. 148-164 *in* Proc. 3rd N. Amer. For. Biol. Workshop. Ft. Collins, CO.

Schmidtling,R.C. 1975. Fertilizer timing and formulation effect flowering in a loblolly pine seed orchard. P. 153-160 *in* Proc. 13th South. For. Tree Improv. Conf. Raleigh, NC.

Schmidtling,R.C. 1987. Relative performance of longleaf compared to loblolly and slash pines under different levels of intensive culture. P. 395-400 *in* Proc. 4th Biennial Southern Silvicultural Res. Conf. Atlanta, GA. USDA For. Serv. Gen. Tech. Rpt. SE-42.

Schmidtling,R.C. 1983. Timing of fertilizer application important for management of southern pine seed orchards. Southern Journal of Applied Forestry 7:76-81.

Schmidtling,R.C. 1986. Long-term effects of subsoiling and fertilization on growth and flowering in a Virginia pine seed orchard. P. 267-273 *in* Proc. 9th N. Amer. For. Biol. Workshop. Stillwater, OK.

Schultz,R.P. 1969. Effect of seed source and fertilization on slash pine seedling growth and development. USDA For. Serv. Res. Paper SE-49. Southeastern For. Exp. Sta., Asheville, NC 8 p.

Shoulders,E. 1968. Fertilization increases longleaf and slash pine flower and seed crops in Louisiana. *J.* Forestry 66:193-197.

Sprague,J., J.B.Jett, and B.Zobel. 1978. The management of southern pine seed orchards to increase seed production. P. 145-162 *in* Proc. Flowering and seed development in trees: A symposium. Starkville, MS.

Webb,R.S. and S.A.Alexander. 1982. Subsoiling and reduced radial growth in seed orchard loblolly pine established on sandy soils. Southern Journal of Applied Forestry 6:163-167.

Webb,R.S. and S.A.Alexander. 1983. Incidence of resin-soaked roots in subsoiled loblolly pine seed orchards in sandy soils. Southern Journal of Applied Forestry 7:104-107.

Webster,S.R. 1974. Nutrition of seed orchard pine in Virginia. Phd Diss. North Carolina State Univ. 185 p.

Wells, C.G. 1968. Techniques and standards for foliar analysis of N deficiency in loblolly pine. Forest fertilization: Theory and practice. Tennessee Valley Authority 1968:72-85.

Wilcox,P.L., R.L.Allen, and J.B.Jett. 1991. Foliar nutrient variation in loblolly pine seed orchards. P. 120-123 *in* Proc. 21st South. For. Tree Improv. Conf. Knoxville, TN.

Woods,R.V. 1983. Trace element problems induced by heavy nitrogen fertilization of *Pinus radiata* in South Australia. Communicationes Instituti Forestales Fenniae 116:178-182.