EFFECTS OF FERTILIZATION ON SEED ORCHARDS

Jack T. May[1]

Abstract.--The effects of fertilization on five Forest Service seed orchards in the southern region were variable between and within orchards. Fertilization stimulated the establishment and growth of the vegetative ground cover and the trees. Cone production was significantly correlated with clones, size of trees, cycles, and fertilizer treatments. Moderately high levels of N (224 to 364 kg/ha) and P (97 to 158 kg/ha) generally gave the best yield of cones. High levels of P (195 kg/ha) and K (373 kg/ha) tended to reduce cone production. Low levels of N (84 kg/ha), P (37 kg/ha) and K (70 kg/ha) did not stimulate production.

Additional keywords: Fertilization, cone production, *Pinus taeda*, *P. echinata*.

Many treatments and techniques have been tried and used to stimulate flower and seed production in southern pine seed orchards, [Barnes and Bengtson (1968), Green and Taylor (1974); Fuentes (1969); Long et. al. (1974); Pritchett (1967); Schmidtling (1969, 1971, 1975); Schultz (1971); Schultz et. al. (1975); Van Buijtenen (1965); Varnell (1976)]; but results have been extremely variable and indicate that special treatments may be needed for specific species, areas and situations.

This paper discusses the effects of fertilization on grass cover, tree growth and cone production on five U. S. Forest Service seed orchards established in 1961 on diverse sites with low inherent fertility in North and South Carolina, Mississippi, Louisiana and Arkansas. Most of the planting and/or grafting was complete by 1975.

DESCRIPTION OF ORCHARDS

Francis Marion Seed Orchard

This Orchard is located in the coastal flatwoods on the Witherbee Ranger District, Francis Marion National Forest in South Carolina. The site had been stocked with a second growth stand of predominately loblolly pine (*Pinus taeda* L.) and longleaf pine (*P. palustris* Mill.) which was clear-cut. The landscape consist of broad, nearly level ridges with very gentle slopes and depressions with the maximum slope < 2 percent. The drainage classes range

[1] Professor of silviculture and forest soils, School of Forest Resources, University of Georgia, Athens. Fertilizer treatments and cone collection were handled by seed orchard personnel. Statistical analyses were made at the Computer Center, University of Georgia.

from very poorly drained to well drained. Soils include Bayboro and Caroline fine sandy loam, Duplin and Dunbar sandy loam, Goldsboro loamy sand and Coxville loam. The sub-soil ranges from sandy clay loam to clay with mottling at 48 to 64 cms. Drainage was a major problem affecting orchard management as the water table was within 1.2 m for all series except the Caroline fine sandy loam. Due to the nearly level soil surface and depressional areas, natural drainageways could not remove excess rainfall within a reasonable time and water percolation through the soil was very slow due to the soil texture and structure.

Twenty-one soil samples taken in 1965 from 10 to 15 cm depth showed a mean and range as follows: pH - 5.0 (4.4 to 5.2); P - 1.5 ppm (0 to 8); K - 21 ppm (10 to 31); Ca -907 ppm (220 to 1230) **an**y Mg - 13 ppm (4 to 30).

Beech Creek Seed Orchard

The orchard is located on the Tusquitee Ranger District, Nantahala National Forest in the Blue Ridge Mountain Province of North Carolina. Much of the area was cleared during the early nineteenth century and converted to fruit orchards and pasture. Late in the 19th century the land reverted back to a mixed forest. The landscape consists of ridgetops, gentle to steep slopes and floodplains. Soils developed in materials of the Great Smoky conglomerate geologic formation consisting of graywacke sandstone and conglomerate with interbeds of slate. The upland soils are well drained fine sandy loamy to stony fine sandy loam, in the Hayesville series. Slopes range from 2 to 45 percent. The subsoil is a clay loam to clay. Soils are highly erodible. Soils of the coves, toeslopes and bottomland floodplains are in the Brevard, Cartecay, Colfax and Wehadkee series. Eighteen soil samples from the uplands taken in 1963 showed a pH of 5.1; P - Very low to low; K - Low to medium; Ca - Low and Mg - Very low. In 1967, after liming and fertilization 17 soil samples show a mean and range as follows: pH - 5.7 (5.5 to 6.0); P - 14 ppm (5 to 36); K - 32 ppm (20-48); Ca - 248 ppm (151-343); Mg - 41 ppm (27 to 61).

Erambert Seed Orchard

The orchard is on the Black Creek District, Desota National Forest in the Middle Coastal Plain of Mississippi. Most of the area was forested with pole-size loblolly and longleaf pine. Soils developed in materials of the Citronelle formation consisting of white clay and red sand containing gravel. Upland series are well drained Iuka, Lucy, Ruston, Vaucluse, Norfolk and Orangeburg loamy sands, and Orangeburg and Vaucluse stony loamy sand. Subsoil ranges sandy clay loam to clay loam. Soils are highly erodible.

The landscape varies from gently rolling to hilly and steep, with slopes from 2 to 17+ percent. Seven soil samples collected in 1963 show a mean and range as follows: pH - 5.3 (5.1 to 5.5); P - 1 ppm (0 to 4); K - 35 ppm (20 to 64); Ca - 152 ppm (74 to 260); Mg - 38 ppm (27 to 53).

Stuart Seed Orchard

The orchard is on the Catahoula Ranger District, Kisatchie National Forest in the Coastal Plain Province of the Gulf Coast in Louisiana. Most of the site was covered with sedges (*Carex* spp) and bluestems (*Andropogon* spp) with scattered pulpwood and post size loblolly and longleaf pine at the time the orchard was established.

Soils developed from undifferentiated clays, sands, sandstone and volcanic ash. The landscape ranges from nearly level to rolling with slopes up to about 12 percent. Soil series of ridgetops, upland flats and slopes are Bowie, Beauregard, Muskogee and Acadia silt loams to fine sandy loams. The subsoils are silt loam to clay with mottles starting between 38 and 76 cm. Drainage varies from well to somewhat poorly drained. Soils are highly erodible. Soil analysis prior to 1973-74 are not available. Samples collected in 1973 from areas that received a light fertilization showed a mean as follows: pH - 5.5; P - < 3 ppm; K - < 24 ppm; Ca - 384 ppm; Mg - 36 ppm.

Ouachita Seed Orchard

The orchard is located on the Womble Ranger District, Ouachita National Forest in Arkansas. The site was stocked with a mixture of shortleaf pine (*P. echinata* Mill.) and mixed hardwoods. Soils formed in weathered material from shale. Hard shale bedrock is within 0.6 to 1.5 m of the surface in most locations. Limestone, calcite and quartzite occurs in 0.5 to 5 cm stratified layers. The landscape varies from undulating with shallow depressions to hilly. The slope gradient averages about 10 to 12 percent with extremes of 30+ percent. Soils of the upper slopes and ridges are Goldstonshaly silt loam, and Herndon gravelly silt loam. Altavista, Wickham, Lindside and Foley series have developed on low stream terraces and alluvial bottoms. Goldston and Herndon series are well drained with medium to rapid run-off. A 1965 soil analysis of two samples showed: pH - 4.6 to 4.8; P - 2 to 5 ppm; K - 42 to 51 ppm; Ca - 280 to 320 ppm; and Mg - 45 to 55 ppm.

EARLY MANAGEMENT OF ORCHARDS

Site preparation, i.e. clearing, grading, disking, fertilization and seeding of a ground cover was completed for a major portion of the Orchards between 1962 and 1965. Species used for ground cover included: bahiagrass (*Paspalum notatum*), bermudagrass (*Cynodon dactylon* (L.) Pers.), fescuegrass (*Festuca arundinaceae* Schrab.), lovegrass (*Eragrostis curvula* (Schrad.) Nees), browntop millet (*Panicum pamosum*), sudax (*sorghum* spp.), and some clovers (*Trifolium* spp.) and lespedezas (*Lespedeza* spp.)

Early fertilization of the ground cover was based on recommendations of state soil testing labs--with some variations within orchards. Fertilizer rates were: Francis Marion: 2240 kg of lime, 1344 kg of 4-12-12 and 112 kg of 21-53-0 per ha; Beech Creek: 84 kg/ha of 8-8-8; Erambert: 336 kg/ha of 10-20-10 or 13-13-13; Stuart: 2240 kg of lime and 258 kg of 10-10-10 per ha; Ouachita: 2240 kg of dolomitic limestone and approximately 560 kg of 13-13-13 per ha.

Planting of root stock and/or transplanting of ramets began in 1963 and continued until 1975. When ramets were moved from the nursery or greenhouse to the orchard, 227 to 453 g of 10-10-10 or 12-12-12 were applied in the hole. Maintenance fertilization at rates of approximately 224 to 336 kg/ha of 10-10-10 was: applied at 1 to 4 year intervals between rows of trees. In either 1968 or 1969 individual trees were fertilized at a rate of 453 g of 13-13-13 per 2.54 cm of dbh.

Problems that appeared in the various orchards during the early years were: 1) injury to ramets due to excessive fertilization; 2) poor drainage and soil compaction on the Francis Marion Orchard; 3) erosion on the Erambert and Stuart Orchards; 4) poor drainage and very slow tree growth **on the Stuart**; 5) an invasion of native grasses and weeds.

Because of problems in the orchards the U. S. Forest Service, the University of Georgia and the Georgia Forest Research Council entered into an agreement in 1967 which provided that the University and the Council provide on-the-site consultation for soil related management problems in the seed orchards. Immediate actions included: 1) a intensive soil map of each orchard by The U. S. Forest Service soil scientists; 2) chemical analysis of soil samples that were collected from selected areas in each orchard; 3) correction of drainage problems in the Francis Marion and Stuart Orchards; 4) control of erosion in the Erambert and Stuart Orchards; and 5) improvement of the ground cover by an increase in fertilization and control of pest plants.

FERTILIZATION TO STIMULATE CONE PRODUCTION

In 1971 a fertilization study to stimulate cone production was initiated in each orchard as many of the clones were producing female flowers and stems diameters of the larger trees were 10 cm dbh or larger.

Procedure

A statistical response surface design was used because it was easier to fit than a complete factorial; and it tends to locate the combination of values for the controllable factors (N, P and K) that optimize the response (Cochran and Cox, 1957; Clutter, 1968). A central composite second order design in three incomplete blocks with 3 x-variables provides 20 treatment combinations.

Treatment levels per ha were: N - 0, 84, 224 and 364; P205 - 0, 84, 224, 364 and 448; K20 - 0, 84, 224, 364, and 448. The 448 kg/ha rate of N was inadvertently omitted.

In each orchard, there were 50 clones in each row. Spacing of ramets was 4.5 m within rows and 9.14 m between rows. One set of three incomplete blocks contained 20 rows of trees. Fertilizer treatments were applied in bands approximately 1.8 m wide on each side of a row of trees. Treatments were scheduled for February or March of each year. Cones were collected and counted in the fall of each year. Number of trees for each orchard were as follows: Francis Marion, Beech Creek and Stuart - 1000 each; Erambert - 2000; and Ouachita - 5000.

RESULTS

Ground Cover and Tree Growth

The ground cover, especially seeded grasses, responded readily to fertilization. Visual observations indicated that the density and height of grasses increased with increasing rates of nitrogen and phosphorus. Erosion was controlled as the grass cover was stabilized.

All levels of fertilization increased diameter growth of trees. D.B.H. measurements were obtained for all trees in the Beech Creek Orchard Study. Trees in the Erambert, Stuart and Ouachita Orchards were grouped into two size classes in 1974-75, **i.e. <** 9 cm and > 9 cm; but in 1976, trees in the Ouachita orchards were grouped into three size classes, i.e. < 9 cm; 9 to 14 cm and > 14 cm.

The mean dbh's of the Beech Creek Orchard ranged from 8.4 cm for treatment 6 (84-84-364 kg/ha of N, P205 and K20) to 12.4 cm for treatment 12 (364-364-84 kg/ha of N, P205 and K20). Mean dbh for the control plots was 7.4 cm. Percent of larger trees (sizes 2 and 3) was almost consistently higher for treated plots as compared with controls (Table 1).

Table 1.--Percent of size 2 and 3 trees for treated plots and the control.

Orchard	Size 2 trees (> 9 cm)		Size 3 trees (> 14 cm)	
	Treatments range	Control	Treatments range	Control
	---------------percent---------------			
Erambert	31-79	26		
Stuart	37-54	39		
W. Ouachita	40-52[1]	35[1]	12-34	11
E. Ouachita	26-64[1]	31[1]	7-33	12

[1] 9 to 14 cm

Francis Marion - Piedmont loblolly pine

The orchard was fertilized in 1971, 1972, and 1973. Cones were collected in 1972, 1973, 1974, and 1975. Mean number of cones per tree were: 1972 - 1.0; 1973 - 9.8; 1974 - 15.6; 1975 - 5.9. Number of clones producing more than 10 cones per tree by years were: 1972 - 1; 1973 - 18; 1974 - 20; and 1975 - 6. Treatment affects on cone production were significant at the 5% level only in 1974. The Duncan range test showed that treatments with N and/or P205 levels of 224 to 364 kg/ha were significantly more effective than treatments with levels of 84 kg/ha or lower. Mean cone production per tree for N and P_20_5 at rates of 0, 84, 224 and 364 kg/ha were: 12, 13, 18, and 24 for N and 11, 11, 18 and 18 for P_20_5, respectively. Potassium fertilization did not affect cone production. The cyclic affect of cone, production was evident in 1975 when mean yield per tree decreased to levels lower than those in 1974 and 1973.

Beech Creek - Cherokee shortleaf pine

Plots were fertilized in the Spring of 1971, 1972, and 1973, and cones were collected in the Fall of 1972, 1973, and 1974. D,B,H, measurements were obtained for all trees; and grouped into three size classes < 9 cm; 9-14 cm, and > 14 cm. Analysis of the data for the 1974 cone crop showed that clones, tree size and treatments had significant effects on yield. Total cone production increased with time with yields of 690, 4941, and 9219 cones for 1972, 1973, and 1974 respectively. In 1974 one clone produced 27% of the total yield; 3 clones accounted for 54% of the yield; and 11 clones produced 84% of the yield.

Yield by tree sizes were highly significant, with mean yields per tree for all clones of 2.2, 14.7, and 25.8 for size classes 1, 2, and 3 respectively. Yields from the best clones were 13.9, 40.4, and 96.6 for size classes 1, 2, and 3 respectively. There was a direct relationship between cone production and rates of N. High rates (448 kg/ha) of P_2O_5 and K_2O had an adverse effect on production (Table 2).

Table 2.--Mean yield of cones per tree for different rates of nitrogen, phosphorus and potassium (Cherokee shortleaf

Rates kg/ha	Cones per tree: Nitrogen	P2°5	K20
0	3.3	5.3	5.7
84	9.8	10.2	12.2
224	10.2		
364	17.7	1761	14.9
448		6.5	13.2

Table 3.--Mean cone yields per tree from best and poorest treatments - Cherokee shortleaf pine - all sizes.

Best treatments: Rates N	!OL P20₅	K₂0	All Clones	Best Clones	Poorest treatments: Rates kg/ha N	P_2O_5	K_2O	All Clones	Best Clones
364	364	84	28.2	120.0	control			2,7	10.3
364	84	364	18.5	64.8	0	224	224	5.5	21.1
84	364	364	18.3	71.5	84	364	84	6.3	28.6
364	364	364	17.0	56.2	224	448	224	6.3	25.6

The high the low treatments were significantly different from one or more other treatments (Table 3). The cyclic effect of cone production did not develop during the three years of collection.

Stuart - Louisiana loblolly pine

Plots were fertilized in March or April of 1972, 1973, 1974, and 1975. Cones were collected in 1973, 1974, and 1975. Total cone production was fairly constant for the three years with yields of 16189, 12224, and 12511 cones for 1973, 1974, and 1975 respectively (clone number 6 excluded). Clones and tree size were the only factors correlated with cone production. Three clones produced 72.9 percent, 13 clones produced 95.7 percent, and 23 clones produced 98.9 percent of the yield in 1974, while 9 clones did not produce any cones.

Tree size had a highly significant effect on cone production. Fertilizer treatments had no significant effect on cone yields, yet the fertilized plots produced twice the yield of control plots each year (table 4).

Table 4.--Mean number of cones per tree for Louisiana loblolly pine.

	1974	1975
D.B.H. < 9 cm - 54% of trees		
Treated plots	0.95	1.54
Control	0.77	1.27
D.B.H. > 9 cm - 46% of trees		
Treated plots	30.1	28.6
Control	17.4	12.2

Erambert - Alabama loblolly pine

Treatments were made on one set of plots in March 1972, 1973, and 1974 (Replication 1). A second set of plots were fertilized in 1973 and 1974 (Replication 2). Cones were collected from all trees in 1974, 1975, and 1976; and from Replication 1 (1972 plots) in 1973.

Only the 1974, 1975, and 1976 crops of replication 1 and the 1975 and 1976 crops of replication 2 were affected by treatments. Although trees from the two sets of plots contained the same clones and were comparable in age, the reactions to fertilizer treatments were different. Differences in cone production due to clones and tree sizes were significant at the 1% level for both sets of plots for all years. Treatment effects were significant at the 1% level for the 1975 cone crop - Replication l; and at the 5% level for the 197s6 cone crop, replication 1 and the 1975 cone crop, replication 2 (table 5).

Effects of nitrogen were significant at the l% level for 1974 and 1975 cone crops in replication 1 and the 1975 cone crop in replication 2. Other variables significant at the 1 or 5% level for one or more crops were treatment x tree size, P, K, N x P, P x size, and N2.

For trees smaller than 9 cm dbh, N and P significantly effected cone production in replication l. An application of 364 kg/ha of N produced the most cones for three consecutive years. Phosphorus at rates of 364 to 448 kg/ha of P_2O_5 gave the highest response. The best K rates were from 84 to 224 kg/ha of K_2O. For trees larger than 9 cm dbh, N had a significant effect on cone production for both replications and years, The optimum rate was 224 kg/ha of N each year except in replication 1, the 364 kg/ha rate was best for the 1976 crop.

Phosphorus and K apparently are not as critical as N in stimulating cone production in the Erambert Orchard. The highest yields per year sometimes obtained with the higher rates of P and K fertilization were not always significantly different from yields for other rates but they indicate the relatively wide range of rates that can be used. Potential optimum rates of P_2O_5 and K_2O are within the range of 84 to 224 kg/ha.

Table 5.---Rates of P_2O_5 and K_2O associated with the highest yields of cones - Alabama loblolly pine.

Variable	Years				
	1974	1975	1976	1975	1976
	P_2O_5				
All clones	Replication 1			Replication 2	
D.B.H. < 9 cm	448	448	224	0	0
D.B.H. > 9 cm	448	224	84	0	0
	Replications 1 & 2 Combined				
Best clones					
D.B.H. < 9 cm	448	364	364	--	--
D.B.H. > 9 cm	448	224	84	--	--
	K_2O				
All clones					
D.B.H. < 9 cm	224	84	84	224	84
D.B.H. > 9 cm	224	224	448	448	448
	Replications 1 & 2 Combined				
Best clones					
D.B.H. < 9 cm	448	84	84	--	--
D.B.H. > 9 cm	224	224	224	--	--

In 1975, the year of maximum cone production, only 18 clones produced an average of more than 40 cones per tree. Nineteen clones averaged less than 10 cones per tree. only 16 clones had produced cones consistently over a three year period. When yields from all trees and from best clones were compared for specific periods of time, mean maximum yields for four year (1973-1976) and two year (1975-1976) period were obtained at annual rates of 364 kg/ha of nitrogen and 224 kg/ha of P_2O_5 and K_2O.

Ouachita - West and East Ouachita shortleaf pine.

Three **sets** of blocks were established in West Ouachita shortleaf pine in the spring of 1972 and two sets of blocks in East Ouachita shortleaf pine in the spring of 1973. Treatments were continued through 1975. For reference purposes each set of blocks will be considered a replication. Cone collection began in 1973 and continued through 1976.

West Ouachita

Clones, tree size, treatment and years (cycle) significantly affected cone production.

The highest yields were from treatments that contained N and/or P_2O_5 at rates of 224 kg/ha or higher. Analysis of variance for nutrients indicated that P, NP, NK, N^2, P^2, K^2 and NPK effects on large trees were significant at the 1 or 5% levels. Effects on small trees were generally non-significant. There was a reduction of cone production the third year from the cyclic effect. However, size 3 trees (> 14 cm dbh) were less affected than trees in the 9 and 9-14 cm diameter classes.

In 1975, the year of highest yields, only two clones produced more than 100 cones per tree, 5 clones more than 50 cones, 15 clones more than 20 cones and 24 clones more than 11 cones per tree. Twelve clones were consistent cone producers over a three year period. The larger trees with high yields generally required lower rate of fertilization than other trees (Table 6).

Table 6.--Fertilization rates for maximum cone production of West Ouachita shortleaf pine - kg/ha.

Years and tree size (dbh)	Nitrogen	P_2O_5	K_2O
	All clones		
1974 - 9-14 cm	--	--	--
1975 - 9-14 cm	224	448	448
1975 - 9-14 cm	224	224	224
> 14 cm	364	448	448
	High-yield clones		
1974 - 9-14 cm	364	84	364
1975 - 9-14 cm	224	364	364
1976 - 9-14 cm	224	224	224
> 14 cm	364	84	84

The accumulative effects of annual fertilization probably accounts for higher yields with lower rates of fertilization.

East Ouachita

Treatment effects on East Ouachita shortleaf pine were more pronounced than on the West Ouachita trees. Nutrient rates and interactions were highly significant for trees above 9 cm dbh. There were no real significant effects on small trees. Best rates for two years are shown in Table 7.

Table 7.--Fertilizer rates for maximum production of cones from East Ouachita shortleaf pine - kg/ha.

Year and tree size (dbh)	Nitrogen	P_2O_5	K_2O
	All clones		
1975 - 9-14 cm	364	364	84
1976 - 9-14 cm	364	84	84
> 14 cm	364	84	84
	Best clones		
1975 - 9-14 cm	364	364	84
1976 - 9-14 cm	364	84	84
> 14 cm	364	364	84

In 1976, the treatments with the highest yields were significantly better than treatments with lowest yields (Table 8); but all are not significantly different for each other or some other treatments. Low yields were associated with 0 rates of N, P or K and with the highest rates of P and K. These treatments were significantly lower than all other treatments.

SUMMARY

i. Fertilization to stimulate and maintain a vegetative cover may not be sufficient to stimulate flower and subsequent cone production. Fertilization may stimulate tree growth without affecting flower production.

2. The variability among seed orchards precludes the use of a standard rate of fertilization for all orchards.

3. Species and provenance affect efficiency of nutrient use and fertilizer requirements.

4. Tree size influenced cone production. Trees less than 9 cm dbh were not heavy cone producers and cone production on these small trees was not affected by fertilization.

5. Non-cone producing trees did not respond to fertilization.

Table 8.--Yields for East Ouachita shortleaf pine - 1976.

N	Rates P_2O_5 kg/ha	K_2O	Mean number of cones per tree: All clones — All Sizes	All clones — 9-14 cm	All clones — > 14 cm	Best clones — All Sizes	Best clones — 9-14 cm	Best clones — > 14 cm
					Best treatments			
364	364	364	82.4	56.1	150.0	170.0	109.3	227.9
364	84	84	76.0	66.7	115.0	141.9	136.0	178.5
84	364	84	58.0	44.4	107.3	123.5	106.3	158.2
364	364	84	50.0	46.2	83.4	100.0	88.3	143.4
					Poorest treatments			
224	224	0	2.2	2.8	3.4	4.4	5.8	4.0
224	224	448	3.2	3.8	3.0	5.1	6.3	4.2
224	0	224	5.0	6.6	5.0	9.3	11.3	6.6
0	224	224	6.0	5.1	22.5	12.9	9.4	32.1
224	448	224	8.3	8.5	14.8	16.1	17.6	20.4

6. Trees with a high potential for cone production were significantly affected by fertilization.

7. There must be a reasonable balance between N-P-K for the stimulation of cone production.

8. Nitrogen is the most important element affecting flowering provided P and K are not limiting.

9. \Phosphorus and potassium are essential for cone production. High rates of fertilization may be used to increase levels of available and fixed P and K to optimum levels; after which heavy rates have an adverse effect on cone production. Optimum rates of fertilization after the first or second year are within the range of 84 to 364 kg/ha of P205 and K20. Rates of 448 kg/ha of P205 and K20 had an adverse effect on cone production.

10. Rates of fertilization up to 224 kg/ha of N, P_2O_5 and K_2O did not break the cyclic effect of cone production by loblolly and shortleaf pine.

11. By judicious fertilization, the seed orchard manager may be able to produce abundant cone crops in different parts of the orchard each year - thus concentrating harvest on 1/3 to 1/2 of the orchard.

LITERATURE CITED

Barnes, R. L. and G. W. Bengston. 1968. Effects of fertilization, irrigation and cover cropping on flowering and on nitrogen and soluble sugar composition of slash pine. Forest Sci. 14(2): 172-180.

Clutter, Jerome L. 1968. Design and analysis of forest fertilization experiments. In: Forest Fertilization - Theory and Practice. T.V.A. Muscle Shoals, Alabama, pp. 281-293.

Cochran, W. G. and Gertrude M. Cox. 1957. Experimental designs. 2nd ed. John Wiley & Sons, Inc. N. Y. 611 pp.

Fuentes, Juan M. 1969. The use of fertilizers to increase slash pine (Pinus elliottii) flower and seed production. Tech. Note No. 29. Southlands Experiment Forest, Bainbridge, Ga. 3pp.

Greene, James T. and John N. Taylor. 1974. Stimulation of flowering in loblolly, slash and shortleaf pines. In: Proc. of colloquium on "Seed yield from southern pine seed orchards." Edited by J. Kraus. Ga. Forest Research Council. Macon. pp. 61-72.

Long, Ernest M., J. P. van Buijtenen, and John F. Robinson. 1974. Cultural practices in southern seed orchard, In: Proc. of colloquium on "Seed yield from southern pine seed orchards." Edited by J. Kraus. Ga. Forest Research Council. Macon. pp. 73-85.

Pritchett W. L. 196/. Fertilizing slash pine seed orchards. Cooperative Forest Genetics Research Program - 9th Progress Report, pp. 15-19. School of Forestry, University of Fla, Gainesville.

Schmidtling, R. C. 1969. Influence of rootstock on flowering in shortleaf pine. In: Proceedings of the Tenth Southern Conference on Forest Tree Improvement." Sponsored Publication No. 30. S.F. T. I. C. Eastern Tree Seed Laboratory. Macon, Ga. pp. 229-230.

Schmidtling, R. C. 1971. Cultivating and fertilizing stimulate precocious flowering in loblolly pines. Silvae Genetica 20(5-6): 220-221.

Schmidtling, R. C. 1975. Influence of fertilizer timing and formulation on flowering of young loblolly pine grafts. Final Report FS-50-1401-1.38.

Schultz, Robert P. 1971. Stimulation of flower and seed production in a young slash pine orchard. Southeast. Forest Exp. Stn. USDA Forest Serv. Res. Pap. SE-91. lOpp.

Schultz, Robert P., Carol G. Wells, and George W. Bengtson. 1975. Soil and tree responses to intensive culture in a slash pine clonal orchard: 12th year results. Southeast. Forest Exp. Stn. USDA For. Serv. Res. Pap. SE-129. 8pp.

van Buijtenen, J. P. 1965. The effect of spacing, fertilization and cultivation on flowering and seed production in loblolly pine. In: Proc. of the "8th Southern Conference on Forest Tree Improvement." pp. 141-147.

Varnell, R. J. 1976. Cone and seed production in slash pine: Effects of tree dimensions and climatic factors. Southeast. Forest Exp. Stn. USDA For. Serv. Res. Pap. SE-145. lOpp.