Fertilization Increases Longleaf And Slash Pine Flower and Cone Crops In Louisiana

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ABSTRACT.—Annually fertilizing heavily thinned, cultivated stands with 1,000 pounds per acre of 15-25-10 markedly increased female flower and cone production. Flowering was also related to March-through-July rainfall in the previous year and to the size of the flower crop two years earlier. Annual fertilization of seed production areas appears practical if mortality of female strobili can be minimized.

COMMERCIAL fertilizers increase flower and cone production of southern pines, as has been shown by Gemmer (*6*), Allen (*2*), Wenger (*12*), and Hoekstra and Mergen (*8*). This paper tells how six successive female flower and cone crops of longleaf (*Pinus palustris* Mill.) and slash pine (*P. elliottii* Engelm.) were influenced by annual fertilization at various rates and times with nitrogen, phosphate, and potash in a 3:5:2 ratio.

Methods

The study was established in central Louisiana in a 45-year-old natural longleaf stand, which averaged about 100 square feet of basal area per acre, and in a 22-year-old slash pine plantation, which averaged 115 square feet. Soils were fine and very fine sandy loams of the Beauregard, Bowie, and Ruston series—soils that require complete fertilization for production of agricultural crops. Site index averaged 80 feet at 50 years in the longleaf stand and 95 feet in the slash stand.

In each stand, square 0.1-acre plots, surrounded by ½-chain isolations, were thinned to 90 and 50 square feet of basal area per acre at five-year intervals. Longleaf plots were thinned during the dormant seasons of 1957-1958 and 1962-1963. Slash plots were thinned between March and June of 1958 and 1963 because winter logging was impractical.

In 1958, lightly thinned longleaf plots were cut back to 110 trees per acre and heavily thinned plots to 52 trees. Slash plots averaged 210 and 98 trees per acre after cutting. The 1963 longleaf stocking was reduced further to 90 and 40 trees per acre for light and heavy thinning, and slash stocking to 150 and 67 trees. Vigorous, well-formed dominants and codominants that were potentially good seed producers were retained.

Some heavily thinned plots received additional treatments: (1) annual disking in June with a heavy-duty offset farm disk that cut about 4 inches deep, and (2) annual disking plus annual fertilization.

Seven fertilizer treatments were tried; they comprised three rates and three times of application. The medium rate supplied 75 pounds N, 125 pounds P_2O_5, and 50 pounds K_2O per acre, and was equal to 500 pounds per acre of a 15-25-10 fertilizer. It represented an estimate of pine requirements, as computed from the literature (*8*) and with allowance for the nutrients naturally present. The high rate was double this amount, and the low rate half of it. The seven treatments are listed in Table 1. Two were split applications—i.e., half the total amount was applied in March and half in May. The fertilizer was broadcast prior to the annual disking. Treatments were replicated three times with each species.

Total female flower production was estimated by climbing two randomly selected sample trees on each plot and counting the number of female strobili that could be seen. New sample trees were selected as needed to replace those that died or were removed in thinning. These counts were averaged and multiplied by the number of living trees on the plot. This procedure was adopted because covariance analysis of sample-tree counts in 1959 and 1962 showed that basal area per tree influenced flowering in only one of four analyses. Binocular ground counts of female strobili were totally unsatisfactory estimators of flowering.

Mature cones on all trees on the plots were first estimated by binocular ground counts from a single position per tree. Beginning in 1962, ground counts were supplemented by climbing the sample trees and counting the ripe cones. Simple linear regressions were developed for each species in each year to estimate total cones per tree from ground counts. An overall regression based on 1962, 1963, and 1964 data was computed to convert earlier binocular counts to total production. It gave a better estimate of total produc-

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Table 1.—Female Flowering of Longleaf Pine Sample Trees as Affected by Thinning, Cultivation, and Fertilization

Treatment	Female flowers 1959	1960	1961	1962	1963	1964	Average	Mature cones 1962	1963	1964	Average
	Number										
Light thinning	104	110	60	106	60	28	78	13	16	11	13
Heavy thinning	136	143	62	124	83	77	104	10	55	17	27
Heavy thinning and cultivation	174	176	188	256	132	97	170	108	81	31	73
Heavy thinning, cultivation, and:											
Low NPK, March	227	139	112	264	185	113	173	57	101	61	73
Low NPK, split	224	226	180	306	190	143	212	97	139	57	98
Low NPK, May	337	346	208	292	205	155	257	60	87	77	75
Medium NPK, May	169	144	126	250	186	103	163	25	53	23	34
High NPK, March	447	316	320	594	324	130	355	115	206	64	128
High NPK, split	301	169	154	372	331	182	252	26	107	52	62
High NPK, May	468	388	335	503	329	160	364	71	89	47	69
Average	259	216	174	307	202	119	213	58	93	44	65

tion than binocular ground counts, but was less reliable than the individual regressions.

Analyses of variance were made of annual flower and cone production of sample trees. Differences between degrees of release, between release with and without fertilization, and between times and levels of fertilization were tested by orthogonal individual-degree-of-freedom comparisons. Additional analyses were made to determine if flower production varied significantly among years and if treatments and years interacted.

Flowers and cones per acre were computed to appraise the practicality of fertilizing but were not evaluated statistically.

Longleaf Flowers and Cones

Female flowering of individual longleaf trees usually increased with intensity of management. The number of flowers per tree averaged 78 for light thinning; 104 for heavy thinning; 170 for heavy thinning and cultivation; 214 for heavy thinning, cultivation, and fertilization at the low rate (combining three times of application); and 324 with heavy thinning, cultivation, and fertilization at the high rate (Table 1).

Treatments and years both influenced flowering and the interaction of these two factors was significant (significance was tested at the 0.05 level.) Orthogonal single-degree-of-freedom comparisons of groups of

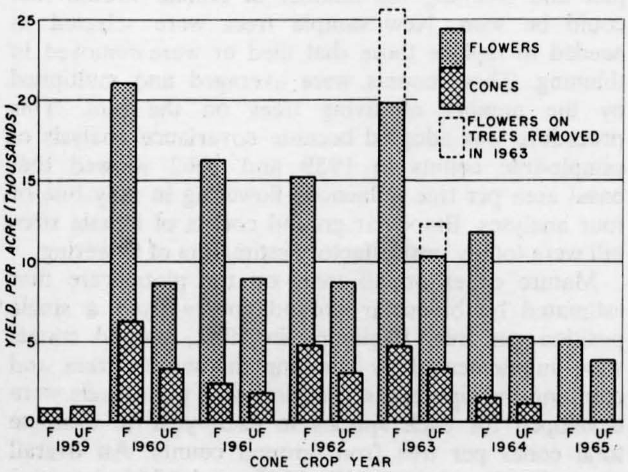

Fig. 1.—Longleaf pine flowers and cones on cultivated and heavily thinned plots that were unfertilized (UF) or fertilized (F) annually with 1,000 pounds per acre in one application.

treatments were made for each year; the most consistent and important differences were:

> March and split fertilization with 250 and 1,000 pounds per acre increased female flowering over light and heavy thinning in five of six years, including the first year after fertilization was started.
>
> One thousand pounds of fertilizer improved flowering more than 250 pounds in four of 12 comparisons. Increases occurred with all dates of application.
>
> At the high rate, March fertilization was superior to split application in two of six years.

In summary, heavy fertilization of cultivated and released trees was clearly superior to release alone.

Thinning intensity did not significantly affect flowering, but numerous workers (*1, 2, 4, 7, 10, 11, 13*) have shown that release promotes cone and seed production. Only heavy thinning released the trees substantially. Perhaps differences existed but sampling was too light to identify them.

March and May applications were not compared in the formal analyses, but they induced similar responses from the high rate of fertilization in most years.

For reasons not discernible, medium fertilization in May produced fewer flowers than any other fertilizer treatment. It was inferior to low and high fertilization in May in three of six years.

Sample-tree cone production in 1962, 1963, and 1964 was greater with March and split fertilization at high and low levels than with light and heavy thinning. Moreover, the superiority of March over split fertilization that existed in the 1961 and 1962 flower crops persisted in the cone crops that they produced.

Differences in cone yields between low and high rates of fertilization were not significant. This discrepancy between flower and cone production arose because losses of female strobili to insects and other agents averaged nearly 70 percent, with no consistent pattern between years of treatments. Exact reasons for the losses were not established, but *Dioryctria* and *Ernobius* larvae were collected from dead conelets. The former cause considerable injury to twigs and cones of longleaf and slash pine; the latter are reputed to attack only dead or dying conelets (*5*).

Yield per tree varied from 10 cones for heavy thinning in 1962 to 206 cones for March fertilization at the high rate in 1963 (Table 1). The 1963 crop, which was largest of the three, was markedly influenced by intensity of management. It ranged from 16 cones per tree for light thinning to 55 for heavy

Table 2.—Female Flowering and Cone Production of Slash Pine as Affected by Thinning, Cultivation, and Fertilization

Treatment	Female flowers 1959	1960	1961	1962	1963	1964	Average	Mature cones 1962	1963	1964	Average
	Number										
Light thinning	20	7	25	20	6	12	15	10	14	7	10
Heavy thinning	121	49	61	58	23	21	56	28	32	23	28
Heavy thinning and cultivation	94	34	37	51	24	52	49	24	52	21	32
Heavy thinning, cultivation, and:											
Low NPK, March	120	73	84	63	34	34	68	47	56	25	43
Low NPK, split	153	75	51	45	41	29	66	55	34	12	34
Low NPK, May	37	21	45	23	23	16	28	49	10	18	26
Medium NPK, May	160	126	114	106	75	75	109	140	36	74	83
High NPK, March	246	128	136	180	46	83	136	108	118	55	94
High NPK, split	117	76	98	103	99	42	89	77	82	113	91
High NPK, May	190	160	132	167	101	49	133	83	82	75	80
Average	126	75	78	84	47	41	75	62	52	42	52

thinning, to 81 for heavy thinning and cultivation, to 109 for low fertilization, and to 134 for high fertilization. Of course, fertilized trees were heavily released and cultivated. No such uniform response to treatments was evident in the 1962 and 1964 crops.

Plots fertilized at the high rate in a single application (i.e., average of March and May treatments) had twice as many flowers and 1½ times as many cones per acre as heavily thinned and cultivated plots (Fig. 1). The gain for 1960 through 1964 cone crops averaged 8,460 female flowers and 1,340 mature cones per acre annually. These values convert to a potential increase of 85 and an actual increase of 13 bushels of cones, if a factor of 100 cones per bushel is assumed. As expected, 1959 cone yields were unaffected by fertilization, which was started after the flower buds for that crop were formed. Thus, the differences in production between fertilized and unfertilized cultivated plots in later years were true responses to fertilization.

Slash Flowers and Cones

Fertilization at the high rate also increased female flowering of heavily thinned and cultivated slash pine stands. Flowering was not improved by cultivation or by low-level fertilization in May and, in contrast to results with longleaf pine, was not depressed by medium-level fertilization in May. Heavily fertilized trees (March, split, and May applications) averaged 119 female flowers per year, as contrasted with 54 for the low rate of fertilization, 49 for heavy thinning and cultivation, 56 for heavy thinning, and 15 for light thinning (Table 2).

Overall yields were significantly affected by treatments and years. Orthogonal single-degree-of-freedom comparisons showed two consistent and important differences between groups of treatments:

> March and split fertilization at low and high rates increased female flowering over light and heavy thinning in five of six years.
>
> One thousand pounds per acre of fertilizer improved flowering more than 250 pounds in eight of 12 comparisons, which included all times of application.

With the 1,000-pound rate, March was superior to split application in two years, and produced the greater number of flowers in five of six years. In 1963, however, split was better than March application. No difference between March and split application was found in the overall analysis.

As with longleaf, the difference between heavy and light thinning was not significant.

March and May fertilization at the high rate were about equally effective. They produced 136 and 133 female flowers per tree, respectively.

Slash pine sample trees bore about one-third as many female flowers as longleaf. Tree sizes undoubtedly contributed greatly to the difference.

Cone production of slash sample trees in 1962, 1963, and 1964 followed the trends established by the flower crops from which they originated:

> March and split fertilization at high and low rates increased cone yields over light and heavy thinning in two of three years.
>
> The high level of fertilization was superior to the low in two of six comparisons.
>
> March was poorer than split application at the high level in 1964.
>
> Other differences were not significant.

Average yield increased from 10 cones per tree for light thinning to 88 for high fertilization (Table 2). An average gain of 55 cones per tree was obtained by fertilizing heavily thinned and cultivated plots at the high rate in March or May.

Since more than one-third of the female flowers failed to develop into cones, gains from fertilization were below those indicated by flower counts. Actual

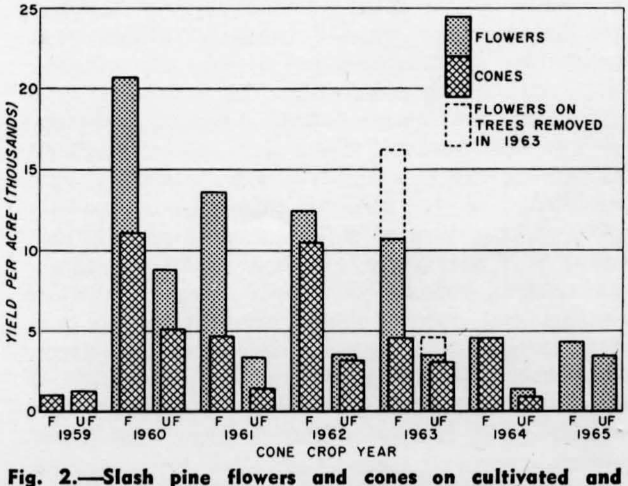

Fig. 2.—Slash pine flowers and cones on cultivated and heavily thinned plots that were unfertilized (UF) or fertilized (F) annually with 1,000 pounds per acre in one application.

annual production from 1960 to 1964 was increased 22 bushels (4,330 cones) per acre by fertilization in March or May at the high rate, as contrasted to a potential gain of 42 bushels (8,350 cones) if all female flowers had matured into cones (Fig. 2).

Despite losses to insects and other causes cone counts sometimes exceeded flower counts, and the actual increase from fertilization exceeded the anticipated increase in 1964. These discrepancies arose partly because new sample trees were selected as they were needed to replace dead and cut trees, partly because different methods were used to estimate flower and cone production per acre, and partly because some female flowers were overlooked.

Other Factors Affecting Flowering

Wide variations existed in female flowering between individual trees fertilized at the high rate in March or May. Therefore, regression analyses were made to determine if number of flowers in a given year influenced a tree's flowering two years later, as has been reported for seed production of stands (*14*). Flowering two years earlier, rather than cone production in the previous year, was chosen as the independent variable because cone yields for individual trees were not available for all years. The later flower crop was expressed as a percentage of the earlier in these analyses, in order to reduce consistently good and consistently poor producers to a common base.

The regressions explained 42 percent of the variation in longleaf and 28 percent of the variation in slash flowering. Regressions had the form

$$\text{Log } Y = \text{Log } a - b \, (\text{Log } X),$$

where $Y =$ the later flower crop as a percentage of the earlier and $X =$ the earlier flower crop. They indicated that individual longleaf and slash trees are apt to have fewer female flowers in the second year following a good flower crop than in the second year following a poor one. Conversely, higher production may be expected in the second year following a poor crop than in the second year following a good one, other factors being equal. Age probably was responsible for the better correlation with longleaf than with slash pine.

Female flowering also fluctuated widely between years. Because there were no consistent relationships between time since release and average flowering of sample trees, other reasons for the variations were sought. With both species, average flowering of sample trees that were fertilized at the high rate in March or May was positively correlated with March-through-July rainfall in the previous year. The regressions explained 75 percent of the variation in longleaf and 80 percent of the variation in slash flowering. Interactions between rainfall, time since release, previous flowering, and current flower production were not tested. As more data are accumulated they may reveal that such exist, or that shorter periods of spring and early summer rainfall are reliably correlated with flowering (*14*). It seems clear, however, that heavy thinning at five-year intervals provided enough release for high fertilization to promote a good flower set when spring and early summer rainfall was adequate.

Discussion

Fertilization to increase cone crops will probably gain widest acceptance in seed production areas and seed orchards, where genetically superior seed is being grown. Market prices have not been established for such seed, but Perry and Wang (*9*) estimated that slash seed from selected trees in seed production areas was at least four times as valuable as wild seed of unknown geographic origin and parentage. Presumably, the ratio also applies to longleaf. Thus, prices of \$14 and \$9 per pound seem reasonable for improved slash and longleaf seed.

Collecting, extracting, and processing costs vary with size of the cone crop and the amount of seed extracted per bushel of cones. Cole (*3*) reported a contract price of \$3.12 per tree for climbing slash pines in seed production areas; this price may also apply to longleaf. Other collection and processing costs should not exceed \$1.75 per bushel of cones. Cultivation and fertilization at the high rate cost about \$60 per acre.

These prices and costs were applied to the data in Figures 1 and 2, after they had been converted to pounds of seed; and to the number of trees per acre that were present at each inventory on the plots. A factor of 1 pound of seed per bushel of cones was used. The appraisal showed that heavy thinning plus cultivation produced one slash and three longleaf cone crops that repaid the costs of cultivation, collection, and processing. Cultivation and fertilization at the high rate more than repaid the additional expense in three of five years with longleaf and in four of five years with slash; and in the other years net returns were greater with fertilization than without it.

Female flowering indicated a potential profit from high fertilization with both species in every year. Thinning and cultivation without fertilization produced potentially profitable flower crops in each year with longleaf and in two of six years with slash pine.

With costs and returns at the assumed levels, a yield of about 50 cones per tree was required to defray the cost of climbing. A second appraisal of actual yields, limited to trees that bore more than 50 cones, also indicated a profit from high fertilization in three years with longleaf and four years with slash. Thus, annual fertilization of select trees with 1,000 pounds of 15-25-10 in March or May appears practical—especialy if pollination can be assured, if large-scale abortions can be prevented, and it first- and second-year cones can be protected from insects.

Greatest returns accrued from fertilization in years of abundant spring and early summer rain. Perhaps irrigation would be helpful if rainfall is low.

So far as is known, cultivation is necessary to prevent competing grasses and other understory plants from utilizing the fertilizer before the pines can assimilate it. In another phase of this study fertilizer was applied without cultivation, and did not increase the cone crop.

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