FERTILIZER TIMING AND FORMULATION AFFECT FLOWERING IN A LOBLOLLY PINE SEED ORCHARD

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Abstract.--Fertilizer trials in a Mississippi seed orchard showed that N stimulated flowering, P did not, and N + P was no better than N alone. Of three nitrogen sources tested, NH4NO3 proved most effective in one experiment; but response to NH4NO3 and to $NaNO_3$ was about the same in another experiment. Fertilizing in mid to late summer produced the greatest increase in flowering (as much as 300 percent); the best treatment (fertilized July 26) tripled cone yield and quadrupled yield of sound seed. Fertilized ramets were no taller than controls, but diameter growth was improved by treatments. Clone x treatment interactions were always significant.

Additional keywords: Pinus taeda, nitrogen source, seed production.

Soil fertility, one of the chief environmental factors affecting fruitfulness in conifers, is usually controlled with fertilizers. The effectiveness of the treatment depends on the formulation, rate, application method, timing, and their interactions with soil type and water relations. This paper reports the effects of different times of application and different fertilizer formulations on loblolly pine *(Pinus taeda* L.).

MATERIALS AND METHODS

In 1970 a series of six fertilizer experiments was initiated in the U. S. Forest Service's Erambert Seed Orchard near Brooklyn, Mississippi. Three experiments tested time of fertilizer application; two evaluated responses to different nitrogen sources; and one was an N-P factorial, testing effects of nitrogen, phosphorous, and the N-P combination.

The orchard is composed of loblolly ramets from south Mississippi that had been grafted to nursery-run seedling rootstocks of local source. Nearly all the ramets used in these experiments are on three soil types: Ruston, Norfolk, and Luka loamy sands. N and P in soil analyses averaged 280 p/m and 5.7 p/m at a 6- to 8-inch depth.

Many aspects of experiment design were the same for all six experiments (table 1). Randomized complete blocks with single-tree plots were used throughout. All experiments were designed so that clonal and clone x treatment effects could be evaluated. No ramet was used in more than one experiment, nor was any ramet treated more than once in any experiment. Different clones were used for each experiment with the exception of

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Table 1.--Details of six fertilizer experiments

Experiment	Time of establishment		Clones	Blocks	Treatments	Fertilizer			Graft age	Trees in study
						N	P_2O_5	K_2O		
	Year	Month	-------------	No.	--------------	Gms./tree			Yrs.	No.
Timing I	1970	*	7	7	7	57	11	11	5	343
Timing II	1971	*	6	6	6	91	18	18	5	216
Timing III	1972	*	6	5	4	272	--	--	6	120
N-P factorial	1972	July	7	8	4	272	272	--	6	224
N-source I	1971	May	3	5	4	113	--	--	6	60
N-source II	1972	July	8	8	3	272	--	--	6	192

*See figure 1.

N-source II, which had some clones in common with the N-P factorial. Fertilizers were applied in four equally spaced holes under the dripline of the crowns and followed by about 1/2 liter of water before the holes were closed.

Strobili were counted for 2 or 3 years before and for 2 years after treatment. Heights were measured before and for 2 years after treatment. Diameter measurements were made before and after treatment in the N-P factorial and timing II experiments, and after treatment in the timing I experiment. In the fall of 1973, cones from all trees in the timing II experiment were harvested. Seed were extracted, counted, and weighed.

All count data were transformed to $\sqrt{\text{count} + 1}$ for analyses of variance. All statistical tests were at the 0.05 level of probability. Treatments are assumed to be fixed effects, clones random.

RESULTS AND DISCUSSION

Flowering in the seed orchard varied considerably from year to year. Female strobili production was below average in 1970, slightly above average in 1972, and above average in 1973. However, proportional increases in flower production caused by fertilizer treatments were about the same in all three years.

Timing

Fertilization in March increased flowering by 50 percent over controls (fig. 1). Flowering increased with progressively later fertilizer applications until it peaked with the August treatment at about 300 percent over controls. Response dropped sharply after August, but flowering was still about 30 percent over controls in ramets fertilized in the first week of

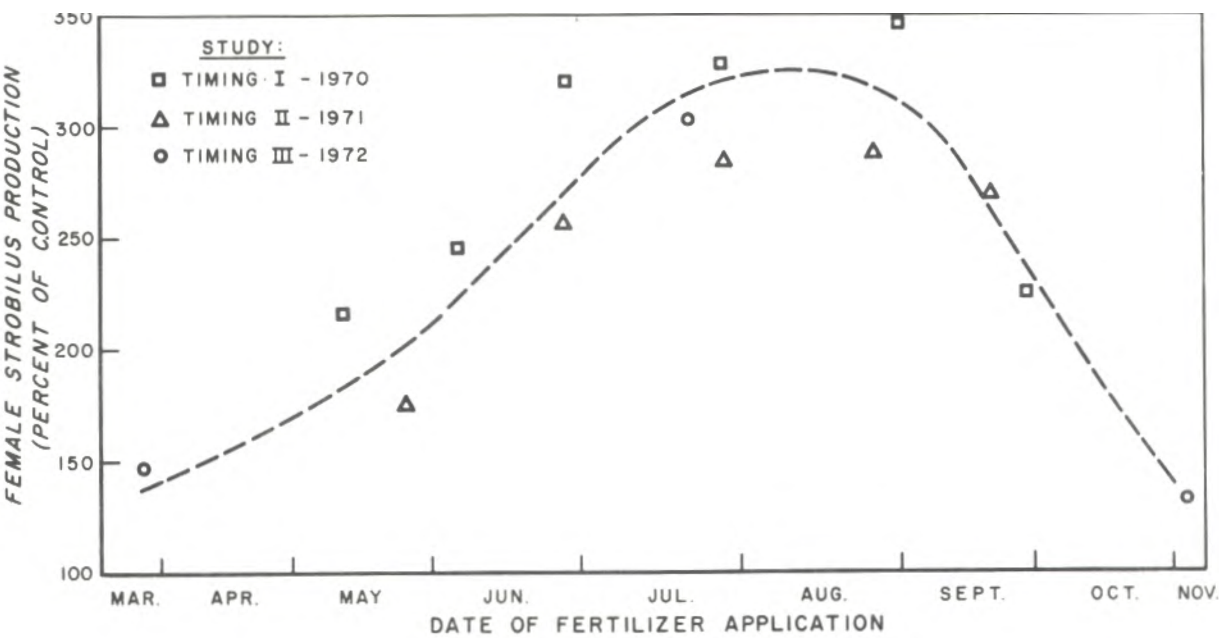

Figure 1.—Female strobili production in young loblolly pine grafts in response to timing of fertilizer application. Dashed line represents the generalized response for the three experiments.

November. Hence, fertilizing rather late in the year is best for inducing flower production in loblolly pines.

These results can he explained on the basis of growth and carbohydrate accumulation in relation to time of flower formation (Schmidtling 1974, Shoulders 1970). Fertilizers should be applied early enough to increase flower initiation (or perhaps prevent abortion of already formed primordia) but late enough to minimize uptake by competitors or diversion of nutrients to growth rather than flowering. Late summer application may also be beneficial to second-year cones since they accumulate most of their nitrogen at this time (Dickmann and Kozlowski 1969).

N-P factorial

The fertilizers (ammonium nitrate and triple super phosphate) were applied in late July, the optimum time as indicated by the timing experiments. Application of nitrogen increased female flowering threefold, P alone had little effect, and N + P was about the same as N alone (fig. 2).

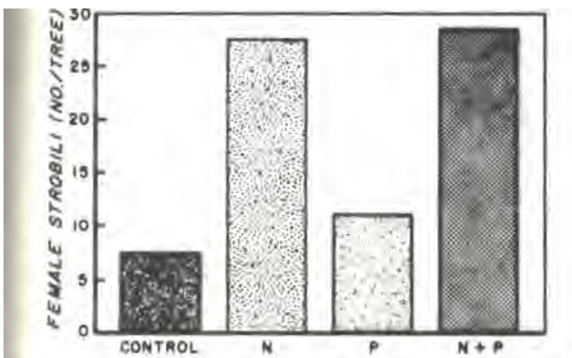

Figure 2.--Flowering of young loblolly pine grafts in an N-P factorial fertilizer experiment.

Nitrogen source

In both experiments, all nitrogen sources enhanced flowering over controls (fig. 3). In N-source I, tree fertilizers, nitrate of soda, (NaNO3) ammonium sulfate ((NH4)2SO4), and ammonium nitrate (NH4NO3), were applied in May, which is a little earlier than desired in view of results from the timing experiments. Differences between control and the fertilized ramets and differences among fertilizer treatments were all significant. Fertilizing with NaNO3 doubled flowering and fertilizing with $(NH_4)SO_4$ tripled female flowering, but the combined source $NH4NO_3$ was best.

In N-source II, $NaNO_3$ and $(NH_4)_2SO_4$ were applied in July, near the optimum time. The difference in timing between the two experiments may have some bearing on the results. As with N-source I, the difference between fertilized ramets and controls was statistically significant (table 2). However, differences between the two fertilizer treatments were not significant; both increased flowering fourfold over controls (fig. 3).

Table 2.--Analysis of variance for experiment N-source II

Effect	D.F.	Mean squares	Expected mean squares
Block (r)	7	6.171 *	$\sigma^2 + ct\,\sigma_r^2$
Clone (c)	6	44.935 *	$\sigma^2 + rt\,\sigma_c^2$
Treatment (t)	2	68.014 *	$\sigma^2{}_t \frac{t}{t-1} r\,\sigma^2_{ct} + rc\,\frac{\Sigma\,\tau^2}{t-1}$
Control vs. N	1	132.679 *	
within N	1	3.348	
Clone x treatment	12	2.624 *	$\sigma^2 + \frac{t}{t-1}\,r\,\sigma^2_{ct}$
C X (Control vs. N)	6	4.003 *	
C X (within N)	6	1.246	
Error	140	1.426	σ^2

*Significant at 0.05 level of probability.

$\sigma_r^2 = 0.226$ $\sigma_c^2 = 1.855$ $\sigma_{ct}^2 = 0.0916$ $\Sigma\,\tau^2/t-1 = 1.166$

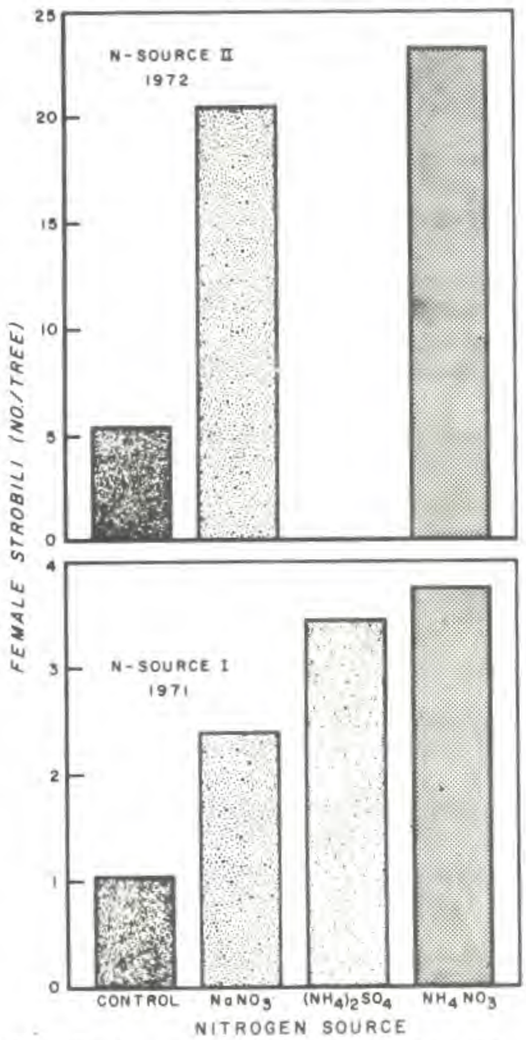

Figure 3.--Flowering response to different nitrogen fertilizers in young loblolly pine grafts.

Although this area of fertilizer research deserves more study, the practical implications are straightforward: ammonium nitrate was as good as or better than any other fertilizer tested. There is no indication in this study of a preference for nitrate source in eliciting flowering response in loblolly pines as has been found in Douglas-fir (Ebell and McMullan 1970).

Residual effects

In every experiment, fertilized trees produced more flowers than controls the second year after treatment. Generally, the differences were not as large as the first year, nor were they statistically significant in all cases, but they were always apparent. However, in the three timing experiments, fall applications had a greater effect on second-year flowering than on the first-year flowering; mid- to late-summer applications were most effective the first year.

Clonal differences

In every experiment, clonal differences were significant and constituted a major component of total variation. For example, in N-source II (table 2 and fig. 4), treatment effects accounted for 35 percent of the total variation. Clonal effects were much larger, however, accounting for 56 percent of the total variation. These figures are typical for all six experiments.

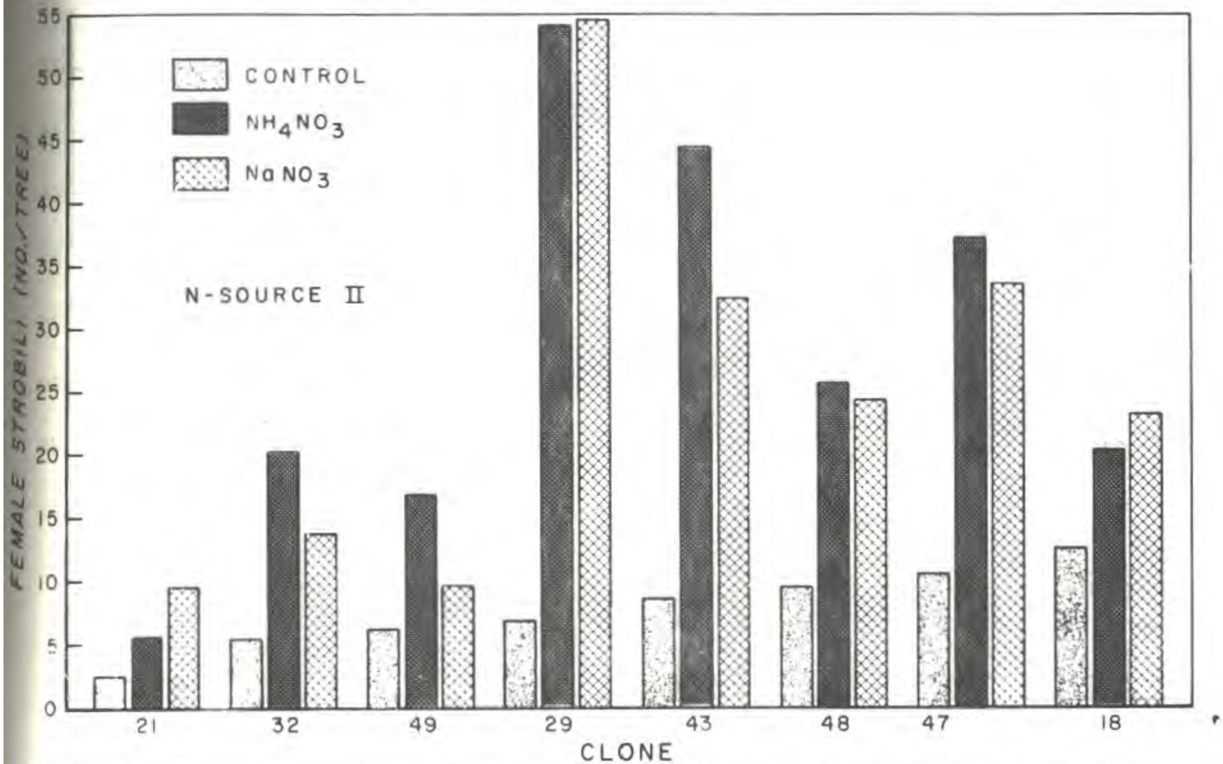

Figure 4.—Flowering response of eight loblolly pine clones to two sources of nitrogen fertilizer (N-source II).

In general, better flowering clones responded best to fertilization. However, there were some exceptions, especially in N-source II. Clone 29 (fig. 4) was less than average in flower production when not fertilized but was by far the best flowering clone when fertilized. In all but one experiment (N-source I), clone x treatment interactions were significant. The interaction in each case was made up primarily of the control vs. fertilized component. For example, clones did not respond differently to the various times of fertilization, but they did respond differently to the application of fertilizer itself. Similarly, in N-source II (table 2 and fig. 4), little of the interaction resulted from a differential clonal response to source of nitrogen.

Cone and seed yield

In the one experiment which included cone collection (timing II), only 21 percent of the female strobili produced harvestable cones. Nevertheless, the number of seed produced was always greater for fertilized trees than for controls (table 3). The July 26 application appeared best in terms of numbers of cones and sound seed produced. The variable nature of cone survival makes conclusions preliminary, but the larger number of flowers resulting from fertilization will most likely also increase seed production.

Table 3.--Cone and seed yields from timing II experiment

Treatment	Female strobili	Harvestable cones	Sound seed total	Sound seed /cone	Weight/ 100 seed
	No.				Gms.
Control	144	42	675	16	3.15
Fertilized					
May 27	247	72	1701	24	3.22
June 28	409	62	1295	21	2.94
July 26	400	156	2832	18	3.15
Aug. 23	445	48	1028	21	3.34
Sept. 20	364	26	862	33	3.39

Growth

In none of the experiments did treatment significantly affect height growth, though clonal effects were usually significant. Diameter, which was measured in only three experiments, was affected significantly by fertilization in all cases. In the N-P factorial, N stimulated diameter growth, P did not, and N + P was no better than P. Diameter growth in timing I and II was in line with what one would expect: fertilizing early in the year tended to affect growth in the same year fertilizer was applied; fertilizing later in the year affected the next year's growth.

CONCLUSIONS

Results of the six experiments indicate that fertilizers should be applied to loblolly pine seed orchards late in summer. Nitrogen seems to be the important component, though phosphorous may be beneficial on a P-deficient site, which the Erambert Seed Orchard apparently is not. Ammonium nitrate is as good as or better than either an ammonium source or nitrate source alone.

Clonal effects and interactions with clones are important in measuring flowering and should be accounted for in any experimental design.

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