RESPONSE TO NITRATE AND AMMONIUM FERTILIZERS - FLOWERS, CONES AND SEED IN A LOBLOLLY PINE SEED ORCHARD

John F. Robinson[1/]

Abstract.--Fertilizer was applied at different rates to two young loblolly pine seed orchards in Louisiana and Texas in the form of nitrate or ammonium nitrogen.

The only response in the Louisiana orchard was to the third year's application when clone x treatment interaction was significant for male and female strobili.

Higher rates were then applied to the Texas orchard. Response to the first year's applications (April and July) showed no difference between the control and the nitrate treatment. The ammonium treatment was greater but significant only at the 10 percent level of probability. Response to the second year's applications showed the nitrogen treatments to be significantly (05 percent) greater than the control but not different from each other. Response was strongly affected by clone.

Seed production was observed and rate of return on investment in dollar value from increased seed crops due to fertilization was calculated at 104 percent and 245 percent respectively for the two years.

Additional keywords: Pinus taeda, rate of return

The value of pine seed orchard seed has been estimated at from $100-$1000/pound (Zobel 1974). Whether one assumes the higher or lower figure, such values accentuate the need to manage seed orchards for optimum production.

One widely used and effective technique for stimulating pine seed orchard production is the application of agricultural fertilizer. Nitrogen specifically has been shown to result in yield increases (Anonymous 1971; Schmidtling 1971). Nitrogen usually has been applied in combinations of ammonium and nitrate ions in the form of ammonium nitrate. Some research has indicated that the nitrogen form - ammonium ion or nitrate ion may have an effect on the response of the plant (Pharis et. al. 1964; Ebell 1972; Schmidtling 1975). Two experiments were carried out by the Western Gulf Forest Tree Improvement Program (WGFTIP) in cooperation with the Louisiana Forestry Commission and Champion International in their respective seed orchards. The tests were intended to show: (1) if orchards in the western range of southern pines would respond to nitrogen and (2) if there would

1/ Associate Geneticist, Texas Forest Service, College Station, Texas.
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be a different response to different forms of nitrogen.

In a preliminary study in one of the Louisiana Forestry Commission's loblolly orchards, 48 pounds per acre of nitrogen was tested over a three year period. Nitrogen was supplied as either sodium nitrate or ammonium phosphate. A complete randomized block design included five replications with five clones each and four treatments. Fertilizer was applied in July and trees were from five to seven-years-old at the time of application. Both phosphorus and potassium were included in the fertilized treatments. Two controls were used, one with and one without P_2O_5 and K_2O amendments.

No female flowering response was observed the first two years. However, flower crops were generally light with large variation among ramets. A significant clone x fertilizer interaction was observed the third year. Some clones responded more to the ammonium form of nitrogen (NH4) while others responded more to the nitrate form of nitrogen (NO_3). Although the response to NH_4 was greatest, differences among treatment means were not statistically significant. Male flowering was generally very poor. However, one clone responded strongly to the NH_4SO_4 treatment.

With this preliminary information a similar study was initiated in 1974 in Champion International's drought-hardy orchard in southeastern Texas at much higher application rates.

METHODS

A randomized complete block design was used with four replications, six clones, two ramets per clone and three treatments for a total of 144 trees. The same six clones were used in all treatments and replications. Trees to be treated were chosen according to their location in the orchard so that different fertilizer treatments were separated by at least one untreated orchard spot. Trees are spaced 30' x 30' and were four-years-old at time of test initiation. The treatments were:

1. The equivalent of 963 lbs/a of nitrogen and 69 lbs/a of P_2O_5 as $CaNO_3$ and superphosphate broadcast to individual trees in April plus 250 lbs/a of nitrogen applied in July.
2. Same as above except nitrogen applied as NH_4SO_4.
3. Control, no fertilizer applied.

The spring application proved to be too concentrated. Four trees were killed and several showed toxic effects. The nitrate treatments were the most severely damaged. The summer application showed no apparent damage.

In the spring of 1974, before fertilizer application, pollen strobili clusters and female strobili were counted on all sample trees. Flower counts were again taken in 1975. The 1975 flowers were monitored to maturity and in 1976 actual cone and seed yields were observed.

Fertilizer was again applied in April and August 1975 at the rate of 250 lbs/acre of nitrogen either as NH_4SO_4 or $NaNO_3$. One hundred lbs/acre

of phosphate was applied in the spring. The 1976 flower crops were observed and followed to cone collection in 1977.

Analyses were made using the Statistical Analysis System (SAS) developed by Barr, Goodnight, Sall and Helwig (1976).

RESULTS

1974 Male and Female

As expected, no significant differences, due to treatment, in male or female flower counts were observed in 1974. These observations were made before fertilizer was applied.

Female Strobili

Figure 1 shows female flowering, with all clones combined, for all three treatments for all three years. Values having different letters are significantly different from each other at the five percent level. in 1975, female flowering in the nitrate treatment was no greater than in the control. The ammonium treated trees showed an increase in flowering which, although not significant at the .05 percent level, indicated a response may be there. In 1976 a large and significant increase in flowering was observed for both fertilized treatments.

Response was strongly affected by clone in both years. In 1976 the two clones which inherently flowered most showed a large increase of flowering in the ammonium treatments. In 1976 with exception of one clone a favorable response was observed in both fertilizer treatments.

It must be noted that the same ramets of the same clones were treated each year, yet response was not the same in 1976 as in 1975. What could account for the difference? Some possibilities are:

a. Fertilizer was applied at a much heavier rate in the spring of 1974 than in later applications.
b. In 1974 nitrate was supplied as calcium nitrate and in 1975 as sodium nitrate (due to unavailability of calcium nitrate in 1975).
c. Rainfall pattern was different. In 1974 spring rainfall was below average through July with exception of one heavy rain in June. In 1975 spring rainfall was well above average through July.
d. There could have been a delayed effect from the initial application.
e. Increased orchard maturity and natural variation of flower crops from year to year. Loblolly pine flowering was heavy throughout the region in 1976.

Male Strobili - 1975 and 1976

Fertilizer treatments also affected male strobili production. In 1975 only two of the six clones had significant numbers of male strobili. Of these, one clone responded slightly favorably to both ammonium and nitrate nitrogen treatments while the other responded negatively to nitrate and very favorably

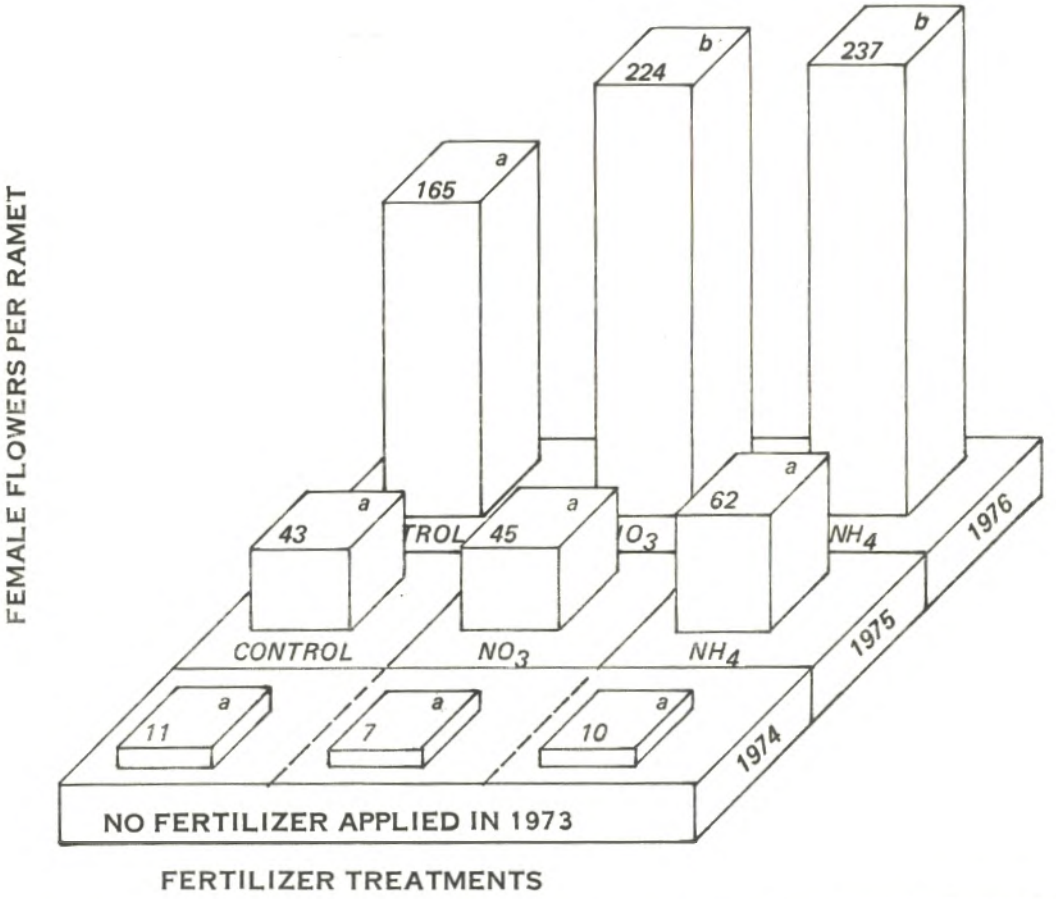

Figure 1. Female flowers per tree by year and fertilizer treatment in young loblolly pine orchard. Values with different letters are significantly different at the 05 percent level of probability.

to ammonium nitrogen. Clone x treatment interaction was highly significant.

In 1976, however, male strobili occurred on five of six clones. Pollen response was generally increased by either source of nitrogen. The exceptions were one clone which showed no response and another which did not produce pollen in any treatment. Male flowering was greatest in the ammonium treatment. Both ammonium and nitrate treatments stimulated catkin production significantly above the control. Clone x treatment interaction was highly significant, however, this was probably due to slope as the response appeared linear with the nitrate treatment intermediate between control and the NH_4 treatment.

Cones and Seed

To determine the economic value of increased seed yield due to fertilization, cone counts and sample seed yields per cone were taken from all trees in this study. The 1976 and 1977 cone and seed crops were measured as these were the crops expected to be affected by the fertilizer applications in 1974 and 1975. As would be expected cone counts per clone were closely correlated with corresponding flower counts 18 months earlier and will not be presented here.

Of more practical interest is the difference in over-all seed yield due to fertilizer treatments. Several variables were observed:

1. Sound cones/tree - The actual number of seed bearing cones collected from each tree. Insect destroyed and empty cones were not included.
2. Sound seed/cone - Up to 20 cones per tree were collected for seed extraction. All seed was extracted by hand. Empty seed were kept separate from sound seed.
3. Sound seed/tree - Sound cones/tree x sound seed/cone.
4. Extractable sound seed/cone - In 1977 commercial extraction was simulated by merely shaking cones for seed extraction before removing all seed. Only filled seed removed in this manner is included in this variable.
5. Extractable sound seed/tree - Extractable sound seed/cone x sound cones/tree.

From Table 1 it can be seen that cone production was greatest in the fertilized treatments for both years. Differences were highly significant in 1977 and very nearly significant in 1976. No significant difference between sources of nitrogen was shown. Ammonium treated trees produced the most cones in 1976 and nitrate treated trees produced most in 1977.

Seed per cone values for both fertilized treatments in both years were consistently higher than for the non-fertilized trees. Significant differences were shown in extractable sound seed per cone in 1977. The greater seed yields from the fertilized trees are shown to result primarily from more cones per tree; however, seed per cone counts on fertilized trees were consistently higher than on unfertilized trees.

Extractable sound seed is used to show the realizable gain in yield that an organization can expect merely from fertilizer application. Total sound seed more nearly reflects the effect of fertilizer application on seed pro-

duction, even though this total is not all harvested as usable seed.

Table 1.--Cone and seed yields for nitrate, ammonium and non-fertilized loblolly pine in a 6-7 year old orchard. Phosphate was included for fertilized plots.

Variable	Year	Treatment		
		Control	NO_3 + P	NH_4 + P
Sound cones/tree	1976	78	102	122
	1977	203aa**	323bb**	302bb**
Sound seed/cone	1976	67	74	75
	1977	68	78	80
Sound seed/tree	1976	5,628	7,897	9,187
	1977	16,419aa	26,022bb	23,726bb
Extractable sound seed/cone	1977	54a*	67b*	68b*
Extractable sound seed/tree	1977	13,124aa	22,621bb	20,804bb

*Values having a pair of different letters are significantly different from each other at the 01 percent level.
*Values having different letters are significantly different from each other at the 05 percent level.

DISCUSSION

How much is this increased yield worth, and will an investment in fertilizer application in a seed orchard pay off? In order to answer these questions some calculations and assumptions were made. Assumptions to assign values to a pound of seed orchard seed above ordinary seed were:

One pound of seed contained 18,000 seed (based on actual samples from this orchard) and is expected to produce 9,000 plantable seedlings. At a planting rate of 750/acre it will plant 12 acres.
Stumpage value = $12/cord and $100/MBF Scribner.
Interest = 8 percent.
Rotation = 30 years (or 31 years from seed).
Base growth = 19.2 cords and 7.55 MBF at rotation (Schumacher and Coile 1960).
Genetic gain = 10 percent.

The value of a pound of seed orchard seed above ordinary seed is:

$$\text{Value} = \text{Gain Stumpage value at age 30})(1 + i)^{-31} \times \text{acres planted.}$$
$$= .10 (\$12 \times 19.2) + (\$100 \times 7.55)1(1 + .08)^{-31} \times 12.$$
$$= \$109 \text{ pound.}$$

To calculate the increase in value per seed orchard acre achieved from fertilization and the rate of return on investment as shown in Table 2, the following assumptions were made:

A. Number of trees/orchard acre = 40 (30 x 30 foot spacing with 83 percent of positions filled).

B. Cost of fertilizer and application = $125/orchard acre.

Table 2.--Value of increased seed production from application of ammonium or nitrate plus phosphorus in a 6-7 year old loblolly pine orchard.

Variable	Unfertilized 1976	Fertilized[a] 1976	Unfertilized 1977	Fertilized[a] 1977
Sound seed/tree	5,628	8,542	16,419	24,874
lbs sd/tree @ 18,000/lb	0.313	0.474	0.912	1.382
lbs sd/orchard acre @ 40 trees/acre	12.5	19.0	36.5	55.3
Value @ $109 lb[b]	$1438	$2185	$4198	$6360
Value difference/ orchard acre		$747		$2,162
Estimated cost per acre of fertilizing		$125		$ 125
Value increase/acre		$622		$2,036
Rate of Return[c]		104 percent		245 percent

[a] Fertilized = mean of ammonium and nitrate treatments.

[b] At stumpage value of $12/cd and $100 MBF Scribner, 08% interest, 10% genetic gain, base growth of 7.55 mbf and 19.2 cds/acre at age 30 (S.I. 85).

[c] Rate of return = $\sqrt[2.25]{\text{Return/Cost}} - 1$ (from Davis 1966).

In order to compare fertilized versus unfertilized trees, the means of the ammonium and nitrate treatments were used." Rate of return was calculated by solving the formula, Cost = Return/(1 + i) for i (Davis 1966). As fertilizer was applied in July to affect the seed crop 27 months later, n = 2.25 years.

From table 2 it is readily seen that in both 1976 and 1977, value increases of fertilized over unfertilized trees were substantial. Rates of return on investment were 104 and 245 percent. In 1976 the unfertilized cone crop was average, followed by an excellent crop in 1977. This paralleled the general pattern of cone production throughout the region. Differences in yield attributed to fertilization between 1976 and 1977 probably reflect this yearly variation in cone and seed production. In 1978 cone and seed produc-

tion was very low and it is doubtful that an application of commercial fertilizer in 1976 would have changed the yield to any appreciable extent. However, even with some years of poor production, the magnitude of gain as illustrated in this six to seven year old orchard indicates how much in dollar value fertilization can mean to an orchard manager.

Results of this study support the use of ammonium nitrate as a source of nitrogen in soil amendments.

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