SEED ORCHARD FERTILIZATION: OPTIMIZING TIME AND RATE OF AMMONIUM NITRATE APPLICATION FOR GRAFTED LOBLOLLY PINE (PINUS TAEDA L.)

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Abstract.--Ammonium nitrate has substantially increased female flower production in two successive years, even when applied in addition to a high level of complete fertilizer. The response was highly variable by clone. There were no significant differences between times of application throughout the summer, and cone survival and production of viable seed were not affected. Therefore, the increase in female flower production due to fertilizer should be reflected in an overall increase in seed yield.

Key words: Pinus taeda, seed production, ammonium nitrate, seed orchards, female cones.

INTRODUCTION

Fertilization with nitrogen generally promotes flowering in conifers (see review by Puritch, 1972) and appears to be more effective on loblolly pine than either potassium or phosphorus (Schmidtling 1974 and 1975, and Webster, 1974). Loblolly pine responds well to nitrogen in the form of ammonium nitrate, ammonium sulfate, or sodium or potassium nitrate (John Robinson, personal communication, Western Gulf Tree Improvement Cooperative, 1977; Schmidtling, 1975). All three types of fertilizer had a significant promotive effect on female flowering by loblolly pine, but did not differ significantly from one another (Schmidtling, 1975). Whether nitrogen in the form of nitrate, ammonium, a combination of both, or some other form is most effective on loblolly pine requires further experimentation. In Douglas fir, the nitrate form is more effective than ammonium in promoting flowering (Ebell, 1972).

Most past demonstrations of the effectiveness of summer nitrogen were carried out on seed orchards or stands that had received little or no prior fertilization (Puritch, 1972; Schmidtling, 1974). In addition, Schmidtling (1974) found that response to ammonium nitrate varied greatly with the time during the summer when it was applied.

Since increases in flowering due to ammonium nitrate fertilization can be spectacular (a 300% increase for grafted loblolly pine has been reported by Schmidtling, 1974), this fertilizer has been used operationally in seed orchards for several years. At present, ammonium nitrate is applied to Weyerhaeuser's loblolly orchards at a rate of 75-112 kg N/ha (67-100 lb N/A) sometime

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in July, in addition to complete fertilizer applied in the spring and/or fall. The summer nitrogen is always applied, while the need for complete fertilizer is determined by analysis of soil samples.

Therefore, since complete fertilization in seed orchards is now routine, further information is needed to answer the following questions:

1) Is supplemental nitrogen effective even when applied in addition to a high level of complete fertilizer?

2) What is the optimum rate of application?

3) What is the optimum time of application?

METHODS

Ammonium nitrate was applied in the first half of May, July, and August at a rate of 224 and 448 kg N/ha (200 and 400 lb/A) and split applications of either 112 or 224 kg N/ha (100 or 200 lb/A) were applied in both May and August. The first treatments began in the spring of 1975 and have been applied yearly since then. Each treatment, including a control receiving no fertilizer, was applied to 5 ramets each of 5 clones for a total of 25 trees per treatment. All treatments were applied to the 11 year old (in 1975) North Coastal Long Fiber Orchard in Washington, North Carolina, while the July treatment was omitted from the five year old (in 1975) Flatwoods Orchard at Aliceville, Alabama. Both orchards have received 561 kg/ha (500 lb/A) of 10-10-10 complete fertilizer in late November every year since 1974.

Complete flower counts were made on all study trees each spring. Counts were made by two persons in a lift bucket, and were recorded if both counts were within 10% of each other. The first counts, made in 1975 prior to any fertilizer application, did not show any significant difference in the number of female flowers between the treatment groups used in the experiment.

In the fall, all the mature cones were harvested by clone and treatment, and if 50 cones per clone and treatment were collected, they were sent to the Eastern Tree Seed Laboratory in Macon, GA, for SOSET analysis. Data was obtained by clone and treatment on percent filled seed, seed germination, and total number of seed. produced.

Results were analyzed by analysis of variance of the raw data and after a $\sqrt{n+1}$ transformation as used by Schmidtling, 1975. Treatment means were compared using both Duncan's multiple range test and Dunnett's statistic (Steele and Torrie, 1960).

RESULTS

The overall response of female flower production to different rates and times of ammonium nitrate application is summarized in Table 1. In both seed orchards, there has been an overall positive response to fertilizer in both 1976 and 1977. Although all treatments increased female flowering in 1976, analysis of variance did not reveal any significant overall treatment effects,

Table 1. Effect of rate and time of NH_4HO_3 application on ♀ flower production. Response as percent of untreated control. The actual number of flowers per tree for the control is given in the center column.

	224 kg N/ha (200 lb N/acre) Application Date					448 kg N/ha (400 lb N/acre) Application Date			
	May	July	August	May-August	# ♀/tree Control	May	July	August	May-August
Aliceville 1976	138%	-	145%	145%	40	113%	-	123%	140%
Aliceville 1977	189%	-	180%	206%*	54	144%	-	165%	217%*
Washington 1976	151%	153%	122%	147%	259	139%	125%	131%	136%
Washington 1977	224%*	237%*	218%*	240%*	280	194%*	170%	209%*	189%*
Overall $\bar{X}$, %:	176%	-	166%	185%	158	148%	-	157%	171%

*Significantly greater than control at 5% level (Dunnett's statistic).

although the response of some individual clones was significant (Figure 1). Variation between clones was highly significant. In 1977, all clones showed a much greater response to ammonium nitrate, and although differences between clones were again highly significant, ammonium nitrate had a significant (at the 1% level) effect on female flower production in both orchards.

Response at both orchards to different times of treatment did not significantly differ from each other either in 1976 or 1977. However, only the response to May-August treatment was significantly greater than the control in the Flatwoods Orchard in 1977 (see Table 1). In the North Coastal Long Fiber Orchard several treatments, including the split May-August treatment, were significantly greater than the control at the 5% level. While the split May-August treatment has given the best overall results, we cannot as yet conclude that the split application is the best method of application.

Trees at both orchards receiving 224 kg N/ha (200 lb N/A) flowered better than those receiving 448 kg N/ha (400 lb N/A). Comparing the response at each date for both sites in both 1976 and 1977, the 224 kg N/ha (200 lb N/A) rate performed best 12 of 14 times (χ^2 = 7.14, which is significant at the 1% level) so that the lower rate of application appears to be significantly better.

The effect of the treatments on seed production by cones harvested from Washington, N.C. in 1976 is shown in Table 2. Although the flowers that gave rise to these cones were initiated prior to the first application of fertilizer, they completed most of their development after the first fertilizer treatments were applied. As yet, there are no significant differences in cone survival (expressed as a percent of the 1975 flower count) between the treat-

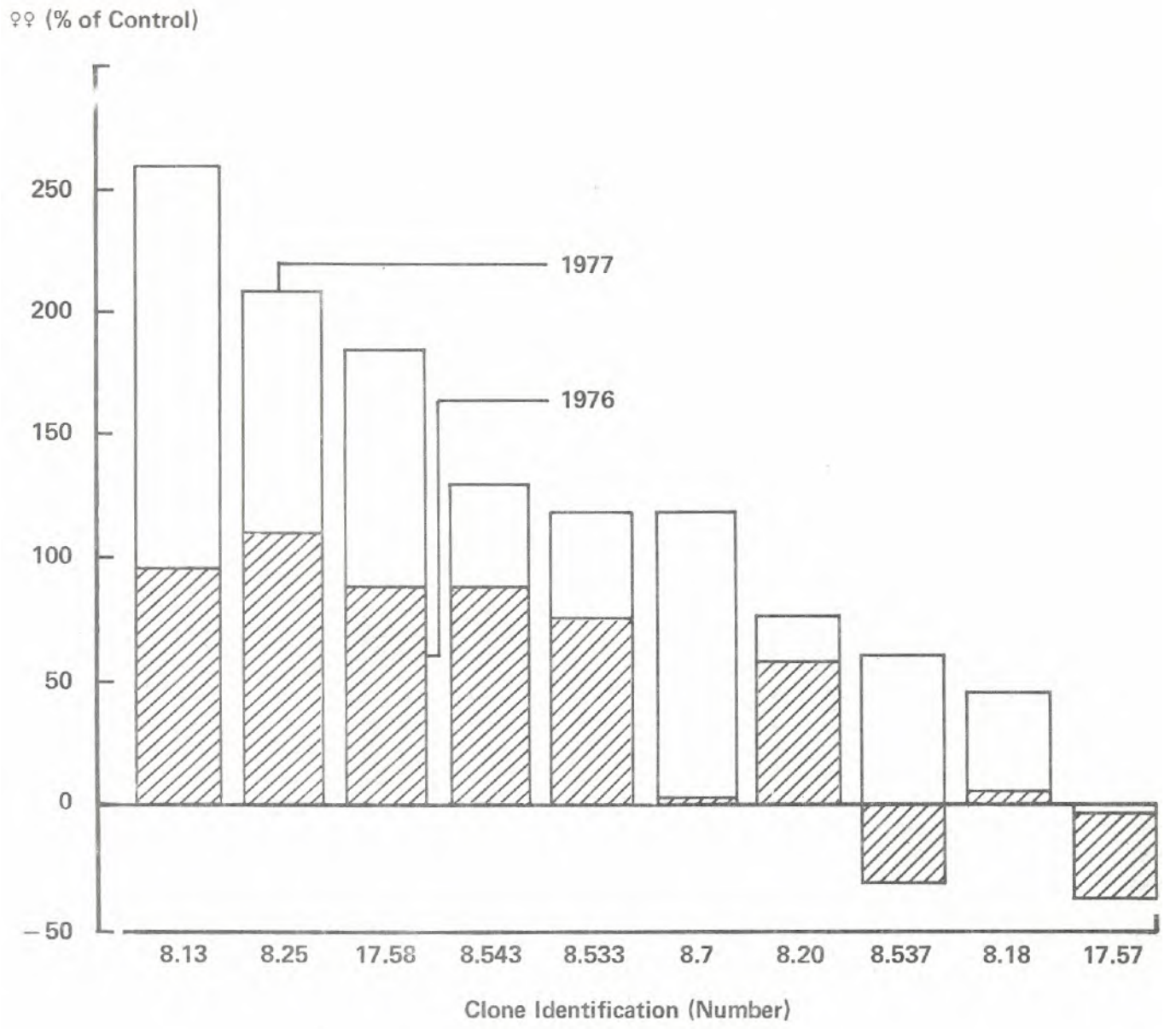

figure 1.--Response of all 10 clones to split May-August treatment of 224 kg N/ha. The 0 line represents control response. The shaded portion or the bars represents 1976 response.

ments. In addition, there were no significant differences in percent filled seed, seed per cone, or percent germination between the treatments. Overall, fertilization does not appear to increase the yield of viable seed per cone.

Table 2. Effects of NH_4HO_3 fertilization on cone survival, percent filled seed, number seed per cone, and percent germination for the 1976 cone crop at Washington, North Carolina.

	224 kg N/ha (200 lb N/acre)					448 kg N/ha (400 lb N/acre)			
	Application Date					Application Date			
	May	July	August	May-August	Control	May	July	August	May-August
% ♀ Survival	31	39	48	49	47	52	54	47	44
% Filled Seed	81	73	64	74	73	74	69	81	81
# Seed/Cone	112	110	93	98	115	93	97	102	95
% Germination	95	93	93	93	96	89	92	95	90
Yield Index*	2672	2912	2657	3305	3788	3185	3325	3689	3047

*Number seedlings per 100 ♀ flowers.

CONCLUSIONS

Ammonium nitrate appears to stimulate female flowering in grafted loblolly pine, even when applied in addition to high levels of complete fertilizer, but has little effect on cone survival or viable seeds per cone. Therefore, the increase in flowering due to ammonium nitrate fertilization should result in an overall increase in seed yield. 224 kg N/ha (200 lb N/A) appears to be more effective at both orchard sites, with 448 kg N/ha (400 lb N/A) yielding a lesser response 12 of 14 times. Although Schmidtling (1975) found that August was the best time to apply ammonium nitrate, we have not as yet found a significant difference in treatment time, although the split May-August application was most frequently the best application. Schmidtling (1975) made a single application of ammonium nitrate at only 74 kg N/ha (66 lb N/A) to a previously unfertilized orchard, so his trees may have been much more sensitive to timing of application than the heavily fertilized trees of this study. In addition, much more ammonium nitrate was applied in this study, so a "carryover" effect may have occurred with the early application dates.

The lowest level of N (224 kg N/ha; 200 lb N/A) applied in this study was still at least twice the rate of operational fertilization. Therefore, more information is needed to establish the optimum rate of N application. However, volume growth response by loblolly pine to different rates of N fertilization varies greatly with soil type (Wells et al., 1976) and the same could be true for the flowering response at different orchard sites.

Despite the fact that most of the clones used in this study were chosen as uniformly good cone producers, there was still a great deal of variation by clone in female flower production and response to fertilizer. However, the response by clone in 1976 was highly correlated with that for 1977 ($r = .84$, significant at the 1% level, for correlation between clonal ranks for response to the 224 kg N/ha (200 lb N/A) May-August treatment in 1976 and 1977). In addition, the clonal response to fertilizer was directly correlated with intensity of flowering of unfertilized trees of the same clone ($r = .66$, which is significant at the 5% level, for rank of response to fertilizer vs rank of flowering intensity by the control trees).

Therefore, the relative response of the 10 clones used in this study was similar in both years, and the best flowering clones appear to also respond the best to fertilizer. "Customized" treatment by clone is possible, with only the best responding clones receiving fertilizer. Since these will also be the heaviest flower producers, the proportion of seed produced by these clones will be even higher with fertilization.

This study will be continued for at least two more years, so that we can continue to monitor the effects of heavy fertilization on flowering and seed production.

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