EFFECT OF NITROGEN AND PHOSPHORUS FERTILIZATION ON GROWTH OF A SWEETGUM PLANTATION DAMAGED BY AN ICE STORM

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Abstract—In 1994, an ice storm impacted a 19-year-old sweetgum plantation (*Liquidambar styraciflua* L.) fertilized with nitrogen (N) and phosphorus (P) at age 4. Thirty-nine percent of the stems were broken, 55 percent were not damaged, and 6 percent were leaning. After the ice storm, differences in height and dbh among the fertilization treatments disappeared. To test if fertilization can increase growth of both damaged and undamaged trees, we applied N and P fertilizers in early 1999. Two fertilizers, ammonia nitrate and superphosphate, were used in four combinations of treatments: N only (205 lb. N/ac), P only (123 lb. P/ac), N+P (205 lb. N/ac + 123 lb. P/ac), and a control. The treatments were on the same plots that were treated at age 4. After one growing season, N increased overall dbh growth, and P increased height growth. The effect of P was mostly on the damaged trees with height growths of 5.8 feet for P only, and 6.5 feet for the N+P treatment, compared to 4.8 and 5.1 feet for N only and the control, respectively. P had been shown to increase height growth with N at age 11.

INTRODUCTION

Sweetgum (*Liquidambar styraciflua* L.) was one of the hardwood species that was used to meet demand for fiber in the 1970s. Fertilization was used to increase sweetgum productivity on less fertile sites, such as Coastal Plain soils. This study was established in 1975 to test the effect of nitrogen (N) and phosphorus (P) fertilization on growth of sweetgum seedlings. After one growing season, N fertilization increased both total height and diameter of the 4-year-old plantation (Ku and others 1981). The gain in height and diameter was maintained for many years. When last reported (Guo and others 1998), the 15-year-old trees treated with N fertilization averaged about 5.5 inches in dbh, which was significantly greater than those without N fertilization. Height was also greater for the trees treated with N only, but N+P fertilization further increased height growth at age 14. The effect of N on sweetgum growth has been previously studied in the southern United States (Berry 1987, Broadfoot 1966, Buckner and Maki 1977, Ku and others 1981, Nelson and Switzer 1990, Nelson and others 1995a). These studies revealed that fertilization, especially with N, improved sweetgum growth on soils ranging from fertile alluvial soils to less fertile Coastal Plain soils. Significant growth improvement with fertilization even occurred in a 20-year-old sweetgum stand (Broadfoot 1966). As for P fertilization, Nelson and Switzer (1990) found in a preliminary greenhouse study that sweetgum responded to P fertilization, but that P did not increase growth in a field study. Broadfoot (1966) reported greater height growth of a 20-year-old sweetgum following a N+P+potassium (K) application.

On February 10, 1994, an ice storm struck southeastern Arkansas and caused considerable damage to the sweetgum plantation. Overall, trees with stem breakage averaged 39 percent, compared to 55 percent with no damage, and 6 percent leaning. Percentage of breakage did not differ statistically among fertilization treatments (Guo 1999). After the ice storm, differences in height and dbh among the fertilization treatments disappeared. To test whether fertilization can increase growth of both damaged and undamaged trees, we applied fertilizers to the plantation. The objective was to determine the effect of N and P fertilization on height and dbh growth of damaged and undamaged 25-year-old sweetgum trees.

METHODS AND PROCEDURES

The study was located in Drew County, AR (91° 46' W and 33° 37' 31" N) in the West Gulf Coastal Plain physiographic province. The soil is a poorly-drained Henry silt loam (Typic Fragiaqualf) and was formed from wind-blown silt. The native vegetation is mixed pines and hardwoods. A representative soil profile includes a surface 28-in. thick, light-gray to gray mottled silt loam, a 25-in. thick subsoil of firm, brittle fragipan (light-brownish gray, mottled silt clay loam), and mottled silt loam beneath to a depth of 72 inches. The natural fertility is moderate and the site index for sweetgum is 80 feet at age 50 (Larance and others 1976). The climate is subtropical humid with an average annual rainfall of 53 inches per year. Rainfall is somewhat greater in the winter and early spring, and summers may include drought periods.

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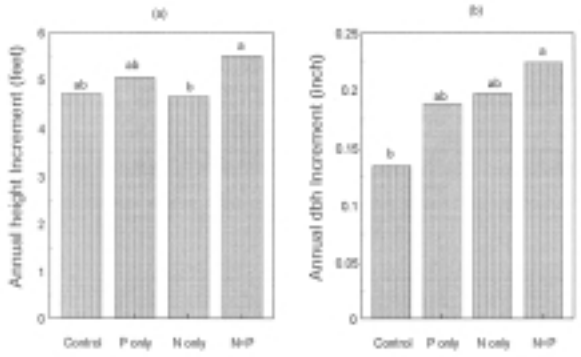

Figure 1—Effect of nitrogen and phosphorus fertilization on overall height (a) and dbh (b) increments one growing season after fertilization. Bars with the same letter are not significantly different at $\alpha = 0.05$.

The study was established in 1975 with 1-year-old seedlings (1-0 stock) planted at a spacing of 9 x 9 feet. Two fertilizers, ammonium nitrate and superphosphate, were applied in 1979 with an experimental design of 2 x 2 factorial in a completely randomized block layout with six blocks. The four combinations of treatments were N only at a rate of 205 lb. N/ac of ammonium nitrate (N only), P only at 123 lb. P/ac of superphosphate (P only), N and P at 205 lb. N/ac + 123 lb. P/ac (N+P), and no N or P [control (C)]. Each plot contained 50 trees (537 trees/ac), with 10 trees in each of five rows. The first and last row and the first tree and last tree of each row served as border trees to isolate the effects of adjacent plots. Measurements were obtained from the interior 24 trees. The survival rate was from 62 to 73 percent at age 15, but did not differ significantly among treatments. The ice storm did not affect the survival. In the spring of 1999, five growing seasons after the ice storm, plots were treated with the same rates of N and P that were used in 1979. Granular fertilizers were applied on the soil surface by hand. Height and dbh were measured just before the fertilization. Total height and dbh did not differ significantly prior to the treatments. After one growing season of fertilization, height and dbh were measured in January 2000.

Annual increments in height and dbh were analyzed by General Linear Models of SAS (SAS Institute, Inc., 1990). The data analysis was based on a split plot model with fertilization as the major plot and ice damage as the subplot. The subplot had two levels: damaged and undamaged. Leaning trees were considered undamaged trees. A small number of damaged trees (< 4percent on average per plot) did not show any growth, so these trees were not included in the data analysis. Means were separated by the Ryan-Einot-Gabriel-Welsch multiple range test at $\alpha = 0.05$.

RESULTS

Overall, P influenced height increments at p = 0.09, and N affected dbh increments at p = 0.08. There was no interaction between N and P (p = 0.81 for height and p = 0.56 for dbh). Height increments averaged 5.5 feet for the N+P treatment and 5.1 feet for the P only treatment, which were significantly greater than the 4.7 feet for the N only treatment. However, height increments for the N+P and P only treatments did not differ statistically from the control, while height increments among the P only, N only, and the control were not significantly different (figure 1a). For the dbh increment, N+P fertilization resulted in a growth of 0.22 inches, which was not statistically different from 0.20 inches for the N only and 0.19 inches for the P only treatments but significantly greater than the 0.14 inches for the control. (figure 1b).

Height growth of the damaged trees was significantly greater than the undamaged trees. Damaged trees

Table 1—Mean annual height and diameter increments of damaged and undamaged trees and their associated standard errors of an ice-storm damaged sweetgum plantation one growing season after fertilization with nitrogen and phosphorus

	Damaged		Undamaged	
Treatment	Mean	Standard Error	Mean	Standard Error
	Height Increment (feet)			
Control	5.07	0.37	4.35	0.40
P only	5.81	0.32	4.31	0.49
N only	4.76	0.42	4.55	0.38
N+P	6.47	0.44	4.55	0.37
	Dbh Increment (inch)			
Control	0.08	0.08	0.20	0.08
P only	0.14	0.12	0.23	0.13
N only	0.16	0.11	0.23	0.15
N+P	0.18	0.09	0.27	0.15

averaged 5.5 feet during the growing season after the fertilization while undamaged trees averaged 4.4 feet. Dbh growth was opposite. Dbh growth was 0.23 inches for the undamaged trees, which was significantly greater than the 0.14 inches growth for the damaged trees.

The difference in height growth among the treatments was likely caused by the effect of the P fertilization on damaged trees (table 1). The height increments were 5.81 and 6.47 feet for the P only and N+P treatments, respectively, which were greater than those (5.07 and 4.76 feet) for the control and N only treatments. Height growth of the undamaged trees was similar among the treatments. The pattern of the dbh increments among the treatments for the damaged trees was similar to that of the overall increments, except that dbh increments were smaller for the damaged trees than the overall means (table 1).

DISCUSSION

N fertilization did not affect height growth of both damaged and undamaged trees, but P affected height growth in this study. Broadfoot (1966) found height increases for a 22-year-old sweetgum stand fertilized with N+P+K. However, it was not clear whether N alone increased the height growth in the study. P was not found to increase height growth in other studies for young stands (Berry 1987, Buckner and Maki 1977, Nelson and others 1995a), including the stand of this study in early ages. However, at age 14, P along with N was found to increase height growth significantly (Guo and others 1998). This phenomenon probably resulted from an increased demand of P by the faster-growing trees. P did not affect height growth of the young sweetgum stands because demand for P was relatively low. As demand of large trees increased, especially the trees with greater height, additional P in the soil promoted height growth. It seems that accelerated height growth of larger trees requires more P to maintain the increased height growth rates, this seems evident from the results of Broadfoot (1966), Guo and others (1998), and this current study.

The response of height growth to P in this study was complicated by the ice storm damage. Since the ice storm, height growth of the damaged trees has been significantly greater than that of the undamaged trees, although there have been no significant differences among the fertilization treatments. Increased height growth of ice storm damaged trees was also observed by Dunham and Bourgeois (1996). They attributed this phenomenon to the fact that most damaged trees were initially dominant or codominant trees, and rapid height growth was to recapture the lost crown position. The sweetgum trees in this study acted similarly to those of Dunham and Bourgeois (1996). Since larger sweetgum trees, compared to surrounding trees, have a greater probability to be broken (Guo 1999), most damaged trees were dominant and codominant trees. Compared to the damaged trees, undamaged trees had greater dbh growth but relatively slower height growth, although the height growth was also fairly fast (> 4 feet during the growing season of 1999, which was faster than a 3-foot average height growth for sweetgum). It seems that P further increased height growth of the damaged trees because they needed greater height growth to recapture their crown positions. This demand required additional P from the soils. Without the additional P, height growth potential was limited.

A related phenomenon to the greater height growth of the damaged trees was their reduced dbh growth compared to the undamaged trees. It seems that P does not affect dbh growth of sweetgum and N is more important than P for dbh growth. With accelerated height growth, the damaged trees had to allocate more resources for height growth. Dbh growth was then slowed.

Overall, the average heights of the undamaged and damaged trees were 57.8 and 50.2 feet, respectively, at age 25. The site index for the undamaged trees was slightly greater than the 80-foot site index at age 50, which is about 55 feet at age 25, based on the site index curves developed by Clatterbuck (1987) for central Mississippi minor bottoms. This site index of the undamaged trees is greater than that measured two years after the ice storm or three years before this measurement. The site index of the undamaged trees was below 80 feet at age 50 then. Three years later, site indexes have increased to about 85 feet. This phenomenon suggests that the undamaged trees have been growing faster after the ice storm than before it. The ice storm resulted in the undamaged trees switching from being less dominant to dominant or codominant trees, and they have been growing with a faster-than-average height growth rate in the last five years. On the other hand, although the damaged trees have been growing faster than the undamaged trees in height, they still have an additional 7-8 feet to grow before they catch up.

CONCLUSION

Phosphorus fertilization at age 24 increased overall height growth of the sweetgum plantation, but the effect was mostly on the damaged trees. Nitrogen fertilization helped dbh growth, but not the height growth. Damaged trees had greater height growth but smaller dbh growth than the undamaged trees.

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