SOUTHERN FOREST EXPERIMENT STATION

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NITROGEN FERTILIZATION INCREASES COTTONWOOD GROWTH ON OLD-FIELD SOIL

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SOUTHERN FOREST EXPERIMENT STATION

Nitrogen (150 lb./acre as NH_4NO_3) applied to a 6-year-old eastern cottonwood plantation in an old field on Commerce silt loam soil increased diameter, basal area, and volume growth by 200 percent over untreated controls. The plantation did not respond to 100 pounds P per acre from concentrated superphosphate.

Eastern cottonwood grows very rapidly when planted on fertile alluvial soils of the Mississippi River Floodplain and given proper care *(9)*. However, with increased flood control and exhaustive agriculture, mainly cotton farming, the fertility of many sites has declined to the point where fertilization, particularly with nitrogen, is necessary for the production of agronomic crops. Although field fertilizer trials have not previously been conducted in cottonwood plantations on old fields in the Mississippi River Floodplain, it is well known that the species is sensitive to soil fertility *(1, 2, 3, 4, 5, 10, 14)*. This paper reports the first-year results of nitrogen and phosphorus fertilization of a young cottonwood plantation on a site that had been cropped for many years.

METHODS

Site and stand condition.—The study site is in western Mississippi in the floodplain of the Mississippi River. The soil is a Commerce silt loam, overlaid by a thin layer ($<$ 6 inches) of clay.

Commerce soils are members of the fine-silty, mixed, nonacid, thermic family of Aeric Fluventic Haplaquepts. They are somewhat poorly drained and have developed in alluvial deposits from the Mississippi River. Slopes range from 0 to 5 percent. Analysis of soils from the study area indicated a high phosphorus level (130 p.p.m. with Bray No. 2 extractant) and a very low level of total nitrogen (0.038 percent or 760 pounds per acre). Understory vegetation on the test site was predominantly Johnson grass *(Sorghum halepense*

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[L.] Pers.), typical of most old fields in the area. Average rainfall is 50 to 60 inches annually.

When treated, the study plantation was 6 years old and contained approximately 32 square feet per acre basal area and 590 cubic feet per acre total volume. Tree diameters averaged 3.7 inches, and mean height was 39 feet. On Commerce soils recently cleared of natural timber, planted cottonwood can be expected to attain heights of 50 to 60 feet in 6 years. Krinard *(7)* reported heights up to 67 feet in 6 years on Commerce soil.

When fertilizers were applied, the trees had classic symptoms of nitrogen deficiency—very sparse crowns, small yellowish-green leaves, and generally poor vigor. Understory vegetation was sparse and also appeared nutrient-deficient.

Treatment and experimental design.—The study design was a randomized block with three replications of four treatments: (1) control (no fertilizer), (2) 100 pounds of P per acre, (3) 150 pounds of N per acre, and (4) 150 pounds of N plus 100 pounds of P per acre. Fertilizer source materials were ammonium nitrate (33 percent N) and granular concentrated superphosphate (20 percent P). Fertilizers were broadcast on May 8, 1970, by hand and incorporated by light disking over a 0.17-acre plot containing approximately 100 trees spaced 8 by 10 feet. Control plots were also disked at the time of treatment. The center six rows by four rows were used for measurement. Growth response to treatment was assessed in terms of height, diameter, basal area, and total volume.

An identical study was installed in an adjacent area from which 50 percent of the stems (every other diagonal row) had been removed before fertilization.

Foliage analyses.—Foliage samples were collected from upper and lower crowns of trees on each plot in mid-August 1970. Each sample was a composite of 60 fully developed leaves, 20 leaves from each of three dominant trees per measurement plot. Samples were dried at 65°C., weighed, and ground to pass through a 40-mesh screen. Subsamples of ground foliage were analyzed for total N by a macro-Kjeldahl procedure. Other subsamples were dry-ashed for 5 hours at 550°C., the ash dissolved in dilute HC1, and solutions analyzed for total P by the molybdophosphoric blue method.

RESULTS

Four weeks after treatment, all trees on N and NP plots had larger, darker green leaves and fuller crowns than trees on check and P-treated plots. This visible response was confirmed by mensurational and foliage composition data collected at the end of the first season after treatment.

Growth.—Four months after fertilization, average stem d.b.h. had increased by 0.63 inch on plots treated with nitrogen and only 0.21 inch on check plots (table 1). A combination of N and P resulted in slightly less diameter growth than N alone. Growth on plots treated

Table 1.—*Influence of fertilizer on growth of a 6-year-old cottonwood plantation*

Fertilizer [1]	Growth (1970) [2]			
	Diameter	Basal area	Height (5 largest trees)	Volume
	– – Inch – –	*Sq. ft./acre*	*– – Ft. – –*	*Cu.ft./acre*
O	0.21 a [3] (–) [4]	3.99 a (–)	4.1 a (–)	76.2 a (–)
P	.23 a (10)	4.39 a (10)	4.4 a (7)	79.3 a (4)
N	.63 b (200)	11.77 b (195)	8.4 b (105)	231.7 b (204)
N-P	.57 b (171)	11.13 b (179)	7.7 b (88)	211.4 b (178)

[1] O = check, no fertilizer; P = 100 pounds P per acre from concentrated superphosphate; N = 150 pounds N per acre from ammonium nitrate; N-P = combination of the above.
[2] Mean based on approximately 60 trees except for height.
[3] Means followed by the same letter (vertically) are not significantly different at the 0.05 level.
[4] Numbers in parentheses indicate percentage increase over control.

with phosphorus alone was not different from that on the control plots.

Basal area growth (table 1) followed a pattern similar to that of diameter growth. Controls increased in basal area by about 4 square feet per acre while nitrogen alone produced almost 12 square feet. Phosphorus alone had very little effect, while N plus P resulted in slightly less basal area growth than N alone.

Average height (table 1) of the five largest trees per plot ranged from 35 to 47 feet. Mean height increases for the one season were approximately 4 feet for check plots, compared to about 8 feet for N- and NP-treated plots.

Likewise, the greatest volume response (table 1) resulted from the application of 150 pounds of N per acre. Statistical tests revealed that the N and NP treatments did not produce significantly different results; both were superior to the control and P treatment. Nitrogen alone produced 156 cubic feet per acre, three times as much stemwood volume as the control. Phosphorus in combination with N was slightly but not significantly less effective than N alone.

In the plantation from which 50 percent of the stems had been removed, the pattern of growth response was very similar to that of the unthinned stand.

Foliar N and P concentrations.—Foliage levels of nitrogen (table 2) were increased by nitrogen fertilization from about 1.6 to 2.3 percent in the upper crown and from about 1.3 to 1.7 percent in the lower crown.

Table 2.—*Effect of fertilizer on foliar N and P levels in 6-year-old cottonwood trees*

Fertilizer [1]	Concentration			
	Upper crown		Lower crown	
	N	P	N	P
	Percent			
O	1.61 a [2]	0.18 a	1.32 a	0.18 a
P	1.57 a	.16 a	1.25 a	.19 a
N	2.24 b	.17 a	1.74 b	.15 b
N-P	2.39 b	.18 a	1.75 b	.17 b

[1] O = check, no fertilizer; P = 100 pounds P per acre from concentrated superphosphate; N = 150 pounds N per acre from ammonium nitrate; N-P = combination of the above.

[2] Means followed by the same letter (vertically) are not significantly different at the 0.05 level.

Phosphorus levels in foliage (table 2) were affected only slightly by fertilization. The significantly lower P levels in the lower crown with added nitrogen probably reflect a "dilution effect." Nitrogen levels were well correlated with growth parameters, with slightly better correlations in the upper crown (table 3). Phosphorus concentrations, on the other hand, were poorly correlated with growth.

Table 3.—*Coefficients of determination (r^2) for linear regressions relating foliar nutrient levels and growth of young cottonwood trees*

Element and crown position	Diameter growth	Basal area growth	Height growth	Volume growth
Percent N				
Upper crown	0.82	0.87	0.52	0.88
Lower crown	.78	.75	.56	.77
Percent P				
Upper crown	.00	.04	.00	.04
Lower crown	.40	.39	.47	.43

DISCUSSION

Results show that nitrogen is the primary nutrient limiting growth on the site. Since phosphorus alone did not stimulate growth, soil phosphorus apparently is at an adequate level. In fact, analyses revealed that the level of extractable-P was slightly higher than is often observed on highly productive sites. Total soil nitrogen in the present study was 760 pounds per acre, as compared to about 2,000 pounds per acre on productive sites. Adding phosphorus alone probably enlarged the difference between soil N and P, resulting in an even greater imbalance of the two elements.

Few workers have demonstrated large growth responses in cottonwood stands. However, Martin and Carter *(10)* demonstrated large responses from nitrogen applied to cottonwood in the nursery. Blackmon and Broadfoot *(1)*, working with Commerce soil in the greenhouse, reported a slight growth response from nitrogen. Likewise, some European research *(6, 11)* has shown that nitrogen often limits the growth of poplars.

Foliar analyses also bear out the conclusion that nitrogen is limiting growth. First, foliar

N in both upper and lower crown positions was increased by N fertilization, while P levels were relatively unchanged. The generally high correlations of foliar N and growth also lend support to this position.

White and Carter *(14)* recommended sampling both upper and lower crown positions for foliar N and P determinations. Our data suggest that, for N, either position is satisfactory since r^2 values are essentially the same for both positions.

Other researchers *(12, 13, 14)* have suggested a nitrogen foliage level of 2 percent to be minimum for several species of poplars. Our results seem to support this proposed critical value. All treatments which included nitrogen boosted foliar N levels to over 2 percent in the upper crown (fig. 1). This foliage N/growth relationship is probably strongest on sites that are deficient in nitrogen and where growth is not severely limited by some other factor. According to Leyton *(8)*, growth and nutrient concentration are linearly and positively related only within the deficiency range. Nitrogen rate studies should yield additional information on this point.

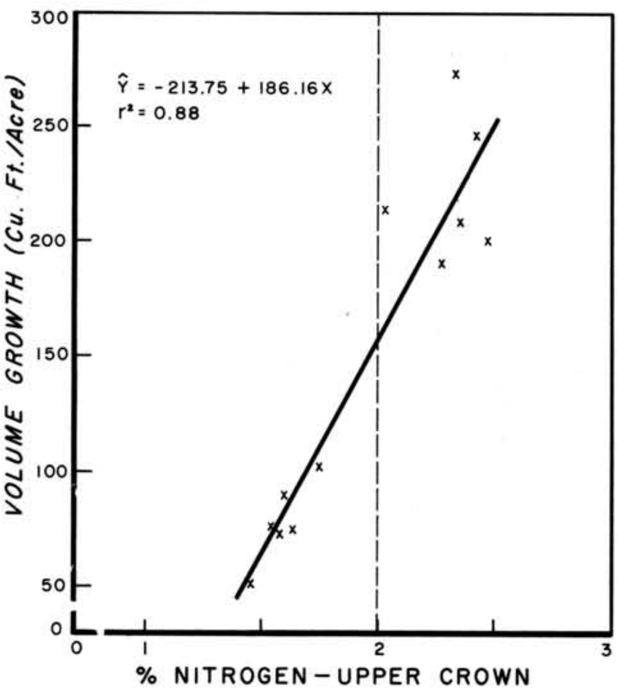

Figure 1.—*Total volume growth and nitrogen content of foliage in upper crowns of cottonwoods.*

The large growth increases in this pioneer investigation are the first field fertilizer responses reported for cottonwood on Misssissippi River Floodplain soils. Important questions about rates, sources, and frequency of application remain unanswered. For industrial firms requiring cottonwood fiber, the response obtained during the first year of the study is probably practical. If this response is of several years' duration, fertilizer application will become attractive for increasing growth of cottonwood on old-field sites in the Mississippi Delta.

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