

RESIDUAL SOIL FERTILITY AND GROWTH OF PLANTED COTTONWOOD ON UPLAND SOILS IN SOUTHERN ILLINOIS

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ABSTRACT.—Cottonwood was planted on a recently abandoned agronomic experimental field that had been used for 50 years to test crop rotations with soil and fertilizer practices. After four growing seasons, tree survival was not affected by past soil treatments. Cottonwood growth was best on plots that had received lime, but the addition of rock phosphate to limed plots depressed height growth. The effects of past fertilizer practices upon the chemical composition of the soil are given.

Each year in southern Illinois numerous upland areas that contain soils with dense subsoils are retired from agronomic production. With a greater demand for cottonwood (*Populus deltoides* Bartr.) as a pulp species, there is a need to know the productive capacity of these poorly drained upland soils for this species. An opportunity was afforded on the Raleigh Soil Experiment Field located in Saline County to test the effect of such soil conditions as well as the effect of residual soil fertility on the survival and growth of cottonwood. This experimental field was established by the Department of Agronomy in 1910 as part of their statewide program of research in crops and soils. Agronomic work was discontinued on the tract in 1962 and cottonwood was planted in 1964.

SOIL DESCRIPTION

The field ranges from nearly level to slopes up to 4 percent, with the soil types being Hoyleton and Chauncey silt loams. Where the slope is greater than 2 percent, the soil has eroded.

Hoyleton is a moderately dark-colored, imperfectly drained Brunizem soil, intergrading toward a Planosol that occurs on the slopes. It developed in 20 to 30 inches of loess over weathered glacial drift, with the native vegetation being prairie grasses. Permeability is slow because of its somewhat dense, fine-textured subsoil. Available moisture capacity is high, but the natural fertility is low. The B horizon is at a depth of less than 20 inches.

The Chauncey soil occurs on the level areas and is a moderately deep, dark-colored Planosol. Except for these features, it is similar to the Hoyleton soil in other respects.

ROTATION AND SOIL TREATMENTS

The field arrangement in 1910 included 10 plots, each one-fifth acre in size. Three plots were operated as a livestock system, making use of barnyard manure. The other seven plots represented a grain system of farming. They received no manure, but crop residues were returned to the land except on the check plots. A four-year rotation of corn, oats, mixed hay, and wheat with catch crops was used during the entire time agronomic research was in progress.

In 1924, the plots were divided and additional phosphorus was added to the east halves. A second division was made in 1952 when potassium was applied to the north halves of all plots.

The following treatments were applied singly and in combination to the west

20 plots, each one-twentieth acre in size, that were used in the cottonwood study:

- O = no treatment
 M = manure—1 ton of manure applied, preceding the corn crop, for each ton of crops grown during the rotation
 R = crop residues—stalks, chaff, and straw produced in rotation
 L = limestone—a total of 16 tons per acre applied in seven applications from 1910 to 1924
 P = rock phosphate—a total of 16 tons per acre applied in five applications from 1910 to 1924
 K = muriate of potash (0-0-60)—332 pounds per acre each rotation, 166 pounds on wheat, 166 pounds on oats
 K (plus) = muriate of potash (0-0-60)—167 pounds per acre applied biannually ahead of wheat and oats from 1952 to 1962

These basic treatments were systematically assigned in the following combinations to 10 plots: O, M, ML, MLP, O, R, RL, RLP, RLPK, and O. The other 10 plots were assigned the same treatments as the first 10 plots except for the addition of K (plus) to each plot. Treatments were applied through the 1962 growing season, when agronomic research was discontinued.

METHODS

One-year-old cottonwood seedlings from a local seed source were used in the study. Seedlings were planted in the spring of 1964 in 6-inch auger holes, 20 inches deep at a 11 x 11-foot spacing. Before being planted, all lateral roots were clipped to within one-half inch of the seedlings' tap root. After planting, the seedlings were cut off at ground level. Three annual diskings for weed and grass control were required during the four growing seasons.

A composite soil sample from the 0-12 inch layer from each plot was taken from six locations per plot. Chemical analyses of the soil included readily available (.002 N sulfuric acid) P as described by Troug (1930); exchangeable K with a flame photometer after leaching with ammonium acetate; calcium and magnesium by EDTA on the evaporated ammonium acetate leachate

(Malmstadt and Hadjiioannou, 1959); total N by the semi-micro Kjeldahl method (Bremner, 1960); and pH with a glass electrode.

Differences in heights between those plots receiving additional potassium and those not receiving the added potassium were analyzed by the "t" test, while all other treatments were analyzed by Duncan's multiple-range test (Steel and Torrie, 1960). Simple and multiple correlations between fertility levels and heights were determined by regression analyses. Survival was not statistically tested.

RESULTS AND DISCUSSION

Growth of cottonwood in this study is less than that reported for this area (Minckler and Woerheide, 1968), but it must be noted that in this study we are dealing with areas of low fertility. Even the high fertility areas cannot be considered high when compared to most cottonwood sites.

The additional potassium applied after 1952 produced no significant effects on seedling height, nor did it appear to influence survival. These results were not surprising, as this soil is inherently well supplied with this element. But if the other elements were raised to a higher level, a response could be expected from added potassium. Therefore, data from plots receiving additional potassium in 1952 and plots that had received none in 1952 were combined.

Survival averaged 95 percent, with a range from 91 to 99 percent and appeared to be independent of past agricultural practices (Table 1). These results were expected, as soil moisture is the factor most often associated with plant survival, and the similarity in the moisture-holding capacity within the experimental area precludes any difference in survival of the cottonwood seedlings.

The effect of past fertilization practices on the top 12 inches of the soil

TABLE 1.—Survival and Height of Cottonwood Seedlings after Four Growing Seasons.

Treatment	Survival Percent	Average height Feet ¹
O.....	91	10.8
M.....	94	12.8
ML.....	97	18.5
MLP.....	97	17.2
R.....	97	15.2
RL.....	97	18.2
RLP.....	99	16.5
RLPK.....	92	16.9

¹ O, M, and R are significantly different (5 percent level) from all other treatments; MLP, RLP, and RLPK are significantly different (5 percent level) from ML and RL.

is shown in Table 2. Plots receiving phosphorus contained nearly 20 times as much available phosphorus as those plots to which none had been added. Differences in exchangeable potassium between treatments were small, and no trend could be detected, but exchangeable calcium and magnesium were more than twice as great on plots that were limed as on unlimed plots. Total nitrogen was

slightly higher on limed as on unlimed plots, but not as great as expected. The largest quantities of nitrogen were found on the plots that had received both lime and phosphorus. The pH of unlimed areas averaged 5.1 and limed areas, 6.3. But a striking feature of Table 2 is the low available phosphorus in the nonphosphorous-treated plots. Twenty pounds per acre in the top 12 inches of soil is only a fraction of that which is needed for good tree growth. On the other hand, 400 pounds per acre at a pH of 6.5 must be influencing the availability of some of the minor elements, notably iron and zinc.

Height growth after four years was greater on limed plots than on unlimed plots, but the addition of phosphorus to limed plots depressed height growth (Table 1).

A highly significant relationship (1 percent level) was found between height growth and each soil variable except phosphorus and potassium in the simple regression analyses. The best single correlation was between

TABLE 2.—Soil Nutrients and pH in Top Twelve Inches of Soil when Cottonwoods Were Planted.

Treatment	Available P	Exchangeable			Total N	pH
		K	Ca	Mg		
	Pounds per acre					
O.....	20	260	2,500	2,100	4,100	5.1
M.....	16	320	2,300	2,000	4,200	5.1
ML.....	28	250	4,900	4,300	4,200	6.1
MLP.....	424	240	7,200	5,600	4,900	6.4
R.....	40	300	2,500	2,200	4,500	5.1
RL.....	12	120	4,700	3,600	4,300	6.0
RLP.....	428	170	7,400	1,700	5,000	6.5
RLPK.....	312	290	5,300	4,200	5,000	6.3

height and pH, but the combination of nitrogen and calcium was the most potent combination in a multiple regression analysis. This combination explained 64 percent of the variation in tree growth during these first four years.

This study substantiates the results of Lunt (1947), who found that growth of hybrid poplar was increased by nitrogen and lime fertilization. But the effect of lime (calcium) on the growth of cottonwood was more than likely an indirect one in this study. Lime not only raised the pH so that a more favorable environment existed for micro-organisms, but also contributed to soil nitrogen through better alfalfa cover. Even though there are small differences in the quantity of total nitrogen between plots (Table 2), undoubtedly there must be differences between the limed and unlimed plots in the quantities of nitrogen readily available for cottonwood growth.

The depressing effects that phosphorus has in combination with lime on tree growth have been reported in other studies. For example, Bogges and Gilmore (1960) found that rock phosphate in combination with lime depressed pine growth, and Gilmore and Bogges (1963) found this to be true for hardwoods. Their studies were on an old soil experiment field in southern Illinois with similar soil treatments but different soil types. A possible explanation for this depressing effect is that phosphorus at this high pH (on limed plots) resulted in a large percentage of the iron and

zinc becoming unavailable for tree growth.

Results derived from this study show that acceptable early cottonwood growth can be obtained on these shallow upland soils if an adequate soil fertility level is maintained. The best growth in this study was about 4.5 feet per year, but there is no reason to believe that growth cannot be increased with higher soil fertility levels.

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