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RELATION OF SOME PHYSICAL AND CHEMICAL SOIL PROPERTIES TO THE GROWTH OF SYCAMORE, SWEETGUM, AND GREEN ASH ¹

R. Larry Willett and M. Victor Bilan ²

Abstract. Soil properties were related to height growth of three small plantations on a second terrace in East Texas: 1.5 acres of 5-year-old sycamore (*Platanus occidentalis* L.), 1.5 acres of (i-year-old sweetgum (*Liquidambar styraciflua* L.), and 3.0 acres of 6-year-old green ash (*Fraxinus pennsylvanica* Marx.). Five soil sample pits in each stand represented variation in height classes. Stepwise regression analysis was used to determine significant height growth predictors. Height of the sycamores ranged from 3.1 to 16.4 feet. Height at age 5 was negatively correlated with percent clay at a depth of 1.0 foot and positively correlated with pH at 0.5 foot. Clay slowed drainage on this generally low, wet site, while pH of the best sites favored optimum nutrient availability. Sweetgum heights ranged from 3.2 to 15.5 feet. Height at age 6 increased with increasing fine material at a depth of 2.5 feet, which improved moisture retention on this high, well-drained plantation. Green ash heights ranged from 4.5 to 18.1 feet. Height at age 6 increased directly with pH of the A1 horizon and decreased with increasing potassium in the A1. The pH levels of the better sites favored optimum nutrient availability, but the effect of potassium could only be explained as sample variation.

Introduction

The first commercial planting of hardwood in the South took place in 1960 when the Crown Zellerbach Corporation established a 15,000-acre cottonwood plantation in the Mississippi Delta (Johnson 1983). Within five years, at least six other companies had established large-scale commercial plantations of cottonwood.

Interest in planting hardwoods began to develop in East Texas in the early 1960's. One timber company established a series of small test plantings on a terrace of the Neches River in southeastern Texas. Subsequently, large variations in height growth were apparent within a 5-year-old plantation of sycamore and within 6-year-old plantations of sweetgum and of green ash. This study was begun in the fall of 1968 to determine whether the height growth differences might be correlated with specific quantifiable site characteristics as a first step in development of a soil/site evaluation system.

Methods

The Study Area

The 1.5 acre sycamore plantation, 1.5 acre sweetgum plantation, and 3.0 acre green ash

plantation were growing on a terrace or former floodplain of the Neches River in Tyler County, Texas. The site had previously supported a mixed hardwood and pine forest. Following harvest, the site had been prepared by piling and burning the slash. The sweetgum had been planted at an 8 feet by 8 feet spacing and the sycamore and green ash at 12 feet by 12 feet. Following plantation establishment, competing vegetation was controlled by mowing.

The sweetgum plantation was located at the highest elevation, but elevations within the plantation differed by as much as 6 feet. The green ash site was generally lower than the sweetgum plantation but it was upslope from the sycamore plantation which it adjoined. The sycamore plantation was lowest in elevation.

Field Procedure

Heights of trees in each plantation were measured and mapped. Five soil sample pits were located in each plantation to represent variation in height classes. The average height of the two closest trees to each soil pit was used as an estimate of site quality. A soil profile description was prepared for each pit, including such information as thickness of

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the horizons, color, texture, structure, consistence, and pH. Soil samples were taken from each horizon.

Laboratory Procedure

Soil samples were oven-dried. Standard methods were used to determine soil texture; separate soil particle sizes; determine percent organic matter; and determine exchangeable phosphorus, potassium, sodium, manganese, zinc and magnesium. Data were compiled by soil horizon and also by depths of 0.2, 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 feet.

Statistical Analysis

For each species, average heights were plotted over soil values at each soil horizon or depth to discern trends. Simple linear correlation analysis were used to quantify the trends. **Stepwise** regression analyses were then used to determine significant predictors of average tree height.

Results

Sycamore

Average height for the sycamore plantation was 7.56 feet and heights ranged from 3.1 to 16.4 feet. Simple linear correlation analysis showed highly significant (0.01 level) negative correlations between tree height and percent clay at a depth of one foot and also between height and percent clay in the **B1** horizon. Significant (.05 level) positive correlations were found between tree height and Ph at 0.5 foot and in the **A1** horizon, parts per million calcium at 0.5 foot, and percent organic matter at 0.5 foot. Significant negative correlations were found to exist between tree height and percent clay at 0.5 foot; clay plus silt at 1.5 feet, 2.0 feet, and 3.0 feet; and parts per million sodium at a depth of 2.5 feet.

When the data were analyzed using **stepwise** regression techniques, percent clay content of the soil at a depth of 1 foot -- within a range of 17 to 52 percent clay -- was found to be negatively correlated to tree height and significant at the 1% level (Table 1). Soil pH at a depth of 0.5 foot -- with a range of pH 3.9 to 5.9 -- was also highly significant but positively correlated. The equation to predict average height for sycamore, where percent clay at one foot

accounts for 92.21% of the statistical variation in tree height and pH at 0.5 foot for 7.78% is:

$$Y = 6.3779 - 0.1889 X_1 + 2.0347 X_2$$

$$R^2 = 99.99\%^3$$

$$sy.x = 0.0715,$$
 and

where Y = tree height in feet
 x_1 = % clay at a depth of 1 foot, and

X_2 = pH at a depth of 0.5 foot

Table 1. Analysis of variance for the regression equation to predict average sycamore height.

| Source | df | ss | MS | F |
|-----------------|----------|---------------|---------|-----------|
| Clay at 1.0 ft. | 1 | 92.91 | 92.9126 | 18218.2** |
| pH at 0.5 ft. | 1 | 7.85 | 7.8451 | 1531.6** |
| Residual | 2 | 0.01 | 0.0051 | |
| Total | 4 | 100.77 | | |

** $F_{.01} = 98.49$

Sweetgum

In the **sweetgum** plantation, tree heights ranged from 3.2 to 15.5 feet and averaged 7.17 feet. Simple linear correlation analysis showed a highly significant positive correlation between tree height and the percent fine material (less than 60 mesh) at a depth of 2.5 feet and a significant positive correlation between tree height and percent fine material at a depth of 2.0 feet. There was a significant negative correlation between tree height and parts per million of manganese in the **B1** horizon.

Stepwise regression showed that after the effect of the percent fine material at 2.5 feet was eliminated, other measured criteria were not significant (Table 2). In these samples, the proportion of fine material at a depth of 2.5 feet ranged from 93.23 to 99.53 percent. The equation to predict tree height for **sweetgum** at age 6 where percent fine material is positively correlated at the 1% level and accounts for 92.67% of total variation is:

³ R^2 = percent of variation in height accounted for.

⁴ $Sy.x$ = standard error of the estimate.

$$Y = 148.3638 + 1.64578 X,$$

with $R^2 = 92.67\%$,

sy.x = 1.5602 feet, and

where Y = tree height in feet, and

x = % fine material at 2.5 feet.

Table 2. Analysis of variance for the regression equation to predict average *sweetgum* height.

| Source | df | SS | MS | F |
|------------------|----|-------|---------|---------|
| Fines at 2.5 ft. | 1 | 92.30 | 92.2954 | 37.916" |
| Residual | 3 | 7.30 | 2.4342 | |
| Total | 4 | 99.60 | | |

** $F_{.01} = 34.12$

Green Ash

Tree heights in the green ash plantation averaged 11.1 feet with a range of 4.5 to 18.1 feet. Simple linear correlation analysis showed a highly significant positive correlation between tree height and pH of the Al horizon. There was a significant positive correlation between height and the amount of potassium in the Al horizon. A correlation of 0.97 was found between pH and potassium in the Al horizon. In addition, there was a significant negative correlation between height and percent fine material (less than 60 mesh) at a depth of 2.5 feet and also between height and the amount of sodium present at a depth of two feet.

Stepwise regression showed that pH of the Al horizon, in the range of pH 4.15 to 6.35, accounted for 94.64% of the variation in tree height. The potassium content of the Al horizon, in the range of 52 to 260 parts per million potassium, accounted for 5.02% of the variation. Table 3 presents the analysis of variance, with pH of the Al horizon positively correlated to tree height and significant at the 1% level and exchangeable potassium of the A 1 negatively correlated and also significant at the 1% level. The equation to predict tree height for green ash at age 6 is:

$$Y = -39.9436 + 11.5165 X_1 - 0.0576 X_2,$$

with $R^2 = 99.66\%$)

sy.x = 0.4513 foot, and

where Y = tree height in feet,

X_1 = pH of the Al horizon, and

X_2 = ppm potassium in the Al horizon

Table 3. Analysis of variance for the regression equation to predict average green *ash* height.

| Source | df | ss | MS | F |
|-------------|----|--------|----------|--------|
| pH of the A | 1 | 114.01 | 114.0136 | 559.7" |
| K of the A | 1 | 6.05 | 6.0480 | 9.7 . |
| Residual | 2 | 0.41 | 0.2037 | |
| Total | 4 | 120.47 | | |

** $F_{.01} = 98.49$

. $F_{.05} = 18.51$

Conclusions

Height growth of sycamore to age five was found to decrease with increasing percent clay content at a depth of one foot within the range of 17 to 52 percent clay. This was apparently due to the effect of clay in slowing drainage and reducing soil aeration on this low-lying site. Sycamore usually grows best where the water table drops enough during the growing season to permit good soil aeration (Wells and Schmidting 1990). Tree height was found to increase with higher soil pH at a depth of one foot within the pH range of 3.9 to 5.9. The best sites in this plantation approach the pH range of 6.0 to 7.0 at which plant nutrients in the soil are most readily available (Buckman and Brady 1969) and the pH range of 6.0 to 7.5 which Spurway (1941) suggested as optimum for sycamore.

Sweetgum height at age six was positively correlated with percent fine material in the soil at a depth of 2.5 feet, within the range of 93.23 to 99.53 percent fines. This plantation was situated on a relatively high elevation so there would likely be a moisture deficiency during part of the growing season. A greater amount of fine material at a soil depth of 2.5 feet would allow good drainage of the upper soil horizons while still favoring water retention and increasing storage capacity in the subsoil of this generally well-drained site.

Height growth of green ash was found to increase with the pH of the Al horizon in the range of pH 4.15 to 6.35 and to decrease with an increasing potassium content of the Al horizon within the range of 52 to 260 parts per million of potassium. A soil pH range of about 6.0 to 7.0 is associated with optimum availability of plant nutrients (Buckman and Brady 1969). The best sites in this plantation were within that range of pH. The effect of potassium is

more difficult to explain. When used alone as a predictor, potassium content of the Al horizon was positively correlated with tree height, as would be expected where exchangeable potassium levels are relatively low. Sample variation may be the only explanation for the negative relationship of potassium in the equation when its effect is combined with the effect of **pH** of the Al horizon.

This study found strong correlations of soil microsite differences with large differences in early growth within small plantations of sycamore, sweetgum, and green ash. Obviously, however, the excellent fit of the regression equations to predict tree height must be viewed in the context of the very small sample size and the single study location.

This preliminary research was never expanded into the broader study which was envisioned initially. Interest in planting hardwoods quickly declined as it became feasible to use abundant, cheap, mixed upland hardwoods for pulp. In addition, we recognized the clear merits of the Baker and Broadfoot (1979) comprehensive approach to hardwood site evaluation.

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