# TREE SURVIVAL AND GROWTH ON TWO 45-YEAR-OLD REFORESTATION PROJECTS IN EASTERN OHIO[1]

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**Abstract**. Reclamation of coal-mined lands before 1977, the date of the federal Surface Mining Control and Reclamation Act, was variable depending on the current state laws and regulations. Early attempts at revegetation, particularly those before 1960, emphasized reforestation since most of the mined areas were originally forest communities. This study evaluated two sites mined in 1941 and 1943 which were reclaimed a few years later using several tree species. The trees that were common to both sites were yellow-poplar (Liriodendron tulipifera), eastern white pine (Pinus strobus) and white ash (Fraxinus americana). Data collected in 1975 by researchers at the Ohio State University indicated that yellow-poplar had the poorest survival of the three species averaging 18.4% between the two sites. White ash had the highest survival at 58.4%. White pine was intermediate at 25.0%. Preliminary results from a 1992 study indicate this trend continued among species: yellow-poplar 16.1%, white pine 21.1%, and white ash 42.1%. The lower survival values for 1992 are indicative of normal stand development. A closed canopy of the planted species occurred at both sites. Ten minesoil samples were collected and two soil composites were formed from each study plot at both sites. Soils were analyzed for particle-size distribution and pH. Correlations between rock fragments and pH did not predict tree survival and growth on these two sites.

**ADDITIONAL KEYWORDS:** Reclamation, revegetation, white pine, white ash, yellow-poplar, abandoned mine lands.

## Introduction

Approximately 1.4 million acres of land were disturbed by coal mining in the Appalachian Region before 1977. The Surface Mining Control and Reclamation Act, passed in 1977, provided nationwide performance standards for reclamation in the U.S. Reclamation of surface-mined areas is necessary primarily for controlling runoff, sedimentation, and erosion. The establishment of vegetation improves the aesthetics of the site and contributes directly to restoring mined lands to productive uses (Vogel, 1981). The landowners' goals and objectives should be taken into consideration when designing a reclamation project. The land-use goal may be cropland, pasture, wildlife habitat, and/or timber production.

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Modern reclamation practices emphasize the planting of grasses and legumes rather than trees. These faster-growing plants help stabilize slopes quickly and decrease erosion. Also, the site can provide rapid economic returns in terms of grazing by livestock or hay production. Trees may take many years, even decades, to produce economic returns. However, trees and herbaceous species can be interplanted with forage plants and used for grazing and wildlife habitat.

In Ohio, legislation requiring reclamation after mining activities was enacted in 1948. Reclamation was practiced by few individuals before then (Davidson, 1981). Many of the early reclamation projects were directed towards reforestation of the site (Davidson and Graves, 1987; Larson and Vimmerstedt, 1983). The USDA Soil Conservation Service (SCS) initiated and conducted many of the early tree plantings. However, replication and randomization were often not employed in the planting scheme due to space and financial constraints. Although records of these older plantings are sometimes inaccurate or simply non-existent, there are cases where documentation exists, and plantation development can be determined (Davidson, 1981). For non-replicated sites, data may not be conducive to certain statistical analyses. However, gross differences in minesoils and micro-climate may be found among sites or within sites (Little, 1981).

Evaluation of old tree plantings is needed to determine tree species to use under certain minesoil conditions. In some cases, minesoils may be constructed during the mining and reclamation process to enhance tree survival and growth. Tree species that may survive 10 years after planting may not continue after 20 or 30 years (Wade et al., 1985).

The objectives of this study were to evaluate the survival of three planted tree species on two 45-year-old surface mines in Ohio. Soil samples were analyzed to see if soil properties could be used to predict tree survival, diameter, or height.

## Materials and Methods

### Site Description.

In 1946 and 1947, the U.S. Forest Service established several experimental plantations in eastern and southeastern Ohio. There were 13 of these plantations still in existence in 1975 and two of these were re-evaluated in this study. The sites chosen were: Georgetown, located in Harrison County; and Dundee, located in Holmes/Tuscarawas Counties.

The Georgetown site was mined in 1943-44 for the No. 8 Pittsburgh coal seam. Stratigraphic descriptions of the overburden are provided in Table 1 (Limstrom, 1946a and 1946b). Overburden materials were simply dumped adjacent to the pit from which the coal was extracted. The next cut removed the overburden and placed it into the previously mined out area. Overburden materials, removed by mechanized shovels, were placed in ridges averaging 8 m in height and left without regrading or revegetation.

The Georgetown study was established to investigate the effects of spoil leveling on survival and growth of four species: black locust (Robinia pseudoacacia), yellow-poplar, white pine, and white ash. Twelve plots of approximately 250 $m^2$ were established on each of three leveling treatments: completely leveled, partially leveled, and unleveled. These twelve plots were planted with one of the four tree species, with three replications per species per treatment for a total of 36 plots. The partially leveled areas were constructed by bulldozing crude "roadways" on top of the ridges of the spoil banks, pushing some of the material into the "valleys". The "leveled" areas were gently sloped to allow surface runoff.

The Dundee site was mined for the No. 5 Lower Kittanning coal seam in 1941 and 1942. The overburden was composed mainly of acid shales and sandstone. The Dundee study was established to investigate several aspects of reclamation. A total of 78 plots were established to study 1) species and age class of planting stock, 2) tree species planted in mixtures, and 3) comparison of cost and effectiveness of planting methods. Only those plots planted with white pine, white ash, and yellow-poplar were evaluated. The plots planted in black locust had very good initial survival, but were decimated by the locust borer (Megacyllene robiniae) in later years.

Methods.

A study plot measuring about 200 $m^2$ (1/20th-acre) was established within the boundaries of the original 250 $m^2$ plot. The location of the study plot was determined by randomly selecting either the plot center or one of the corners.

All trees greater than 7.6 cm diameter at breast height (dbh, at 1.4 m from the ground) were identified as planted or volunteer. Dbh was measured for each tree using a diameter tape. The height of each fifth planted or volunteer tree was measured using an Abney level.

Ten soil samples were taken to a depth of 15 cm at evenly spaced intervals within the study plot. The first five samples were combined into one composite and the last five were combined into a second composite. In the field, the composites were tested for rock fragment contents including greater than 7.6 cm (>3 in) and between 1.9 and 7.6 cm (.75 to 3 in). Surface soil cores were also taken at these points to determine bulk density of the soil.

In the lab, the samples were sieved into the following size fractions: between .63 and 1.9 cm (.25 to .75 in); between 2 mm and .63 cm; and less than 2 mm. The pH of each sample (composite) was also determined using a pH electrode in a 1:1 mixture of soil and water.

The data were analyzed by ANOVA to determine differences among species, sites, and leveling treatments. Other laboratory soil analyses are being performed but will not be reported in this paper.

## Results and Discussion

Survival and Diameter.

The analysis of variance on the Georgetown site showed survival was significantly different among species (Table 2). White ash had the highest survival on all leveling treatments at the Georgetown site averaging 93.3% in 1948, 91.3% in 1950, 91.0% in 1955[3]; 63.0% in 1975 and 45.7% in 1992 (Figures 1-3). White ash also showed the highest percent survival at the Dundee site (Figure 4) with 32.6% in 1992. Overall, yellow-poplar had the poorest survival with 16.1% in 1992 and white pine was intermediate at 21.1% in 1992.

Leveling of the plots had no significant effect on survival among the three species (Table 2). This suggests that grading a site may not influence the survival of these three tree species.

The ANOVA table for tree diameter looks very similar to the ANOVA table for survival with the only significant factor determining tree diameter being species (table not shown). White ash had the smallest average diameter at each site (20.7 cm in 1992) and yellow-poplar had the largest (29.5 cm in 1992). Again, leveling had no significant effect on diameter of any species.

Height.

There was no significant difference among species for tree height (Table 3). However, leveling had a significant effect on tree height at the Georgetown site. The trees on the unleveled plots were significantly taller

[3] The partially leveled plots were not measured in 1955.

Table 1. Stratigraphic description of overburden materials on the Georgetown and Dundee sites.

Georgetown

| Stratum | Thickness (feet) |
|---|---|
| Soil, brown, acidic, silty clay loam, single-grained | 1 |
| Clay, partly shaly, acidic, brown, blocky structure | 3 |
| Shale, clayey, gray-brown, acidic | 15 |
| Shale, carbonaceous | 1 |
| Limestone, reddish yellow, massive | 27 |
| Shale, gray, hard, acidic, clayey, greasy | 3 |
| Coal, Redstone, shaley | 1 |
| Limestone, massive, reddish gray | 20 |
| Shale, gray, mixed with limestone boulders, calcareous | 6 |
| Coal, No. 8, Pittsburgh | |

Dundee

| Stratum | Thickness (feet) |
|---|---|
| Soil, brown, acidic, loam | 0.5 |
| Sand, somewhat loamy, acidic, reddish-yellow, intermixed with sandstone fragments | 5 |
| Sandstone, fragmental, intermixed with reddish-yellow sand, and slightly ferruginous | 11 |
| Shale, grayish black, mottled red, carbonaceous, thin-bedded | 26 |
| Shale, grayish black with red mottling, carbonaceous, intermixed with red kidney ores, concretion, and some marcasite, acidic | 11 |
| Coal, No. 5, Lower Kittaning | |

Table 2. Analysis of variance with tree survival as the dependent variable, Georgetown.

| Source | df | SS | MS | F Ratio | Prob>F |
|---|---|---|---|---|---|
| Model | 8 | 4458.1 | 557.3 | 9.127 | 0.0003 |
| Leveling | 2 | 155.7 | 77.9 | 1.275 | 0.3121 |
| Species | 2 | 3446.5 | 1723.3 | 28.223 | 0.0000 |
| Lev*Spp | 4 | 712.9 | 178.2 | 2.919 | 0.0632 |
| Error | 13 | 793.8 | 61.1 | | |
| Total | 21 | 5251.9 | | | |

Figure 1. Percent survival of three tree species from 1945 to 1992 on leveled, basic minesoils in Ohio.

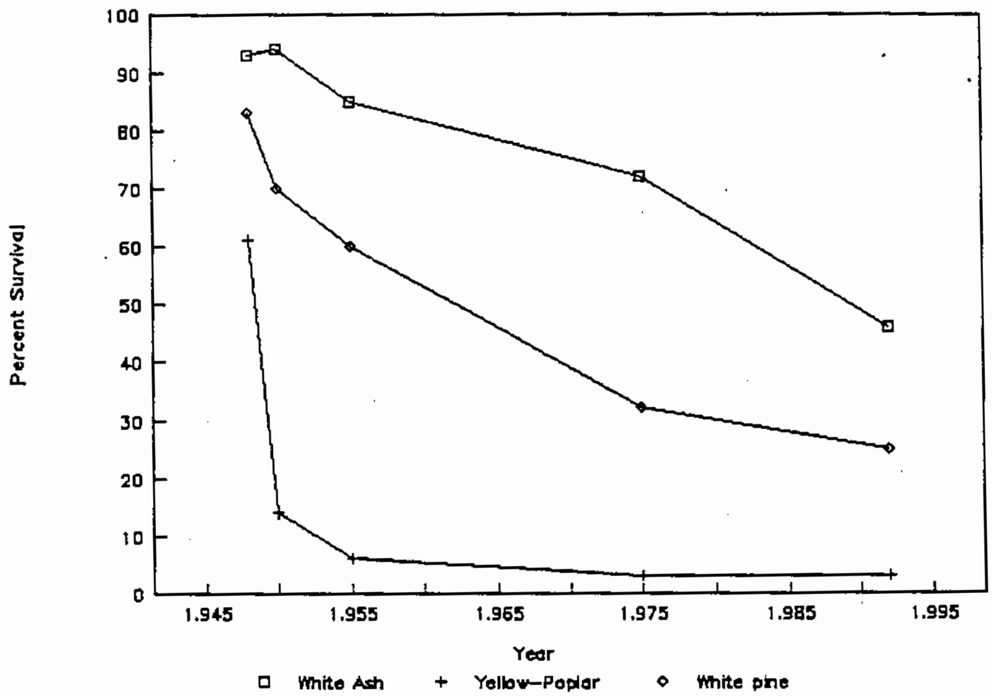



Figure 2. Percent survival of three tree species from 1945 to 1992 on partially leveled, basic minesoils in Ohio.

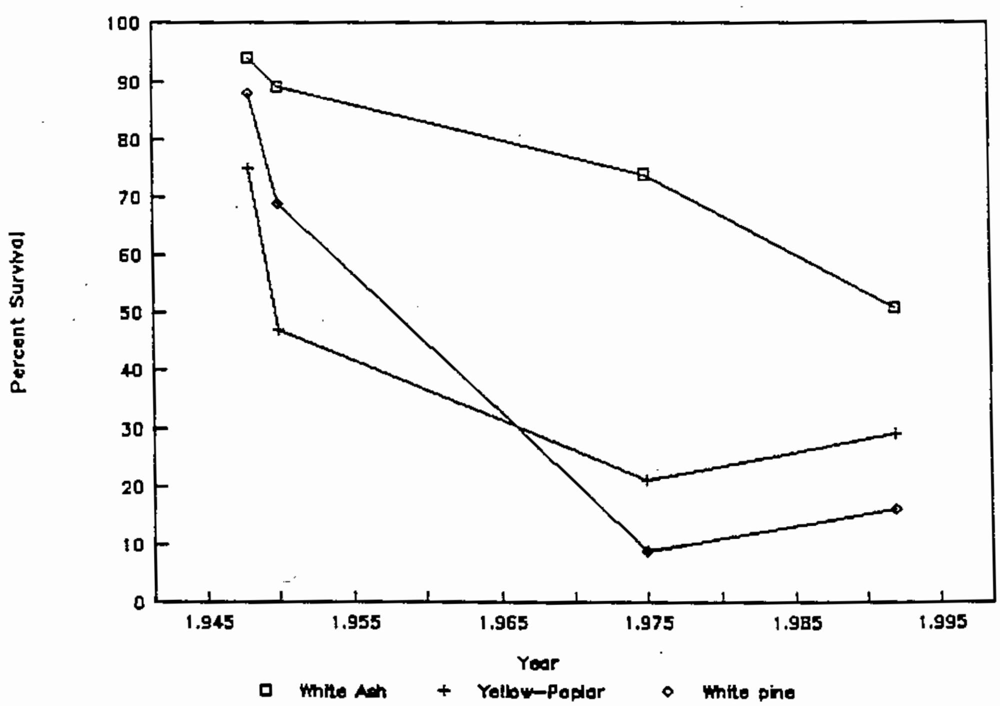


Figure 3. Percent survival of three tree species from 1945 to 1992 on unleveled, basic minesoils in Ohio.

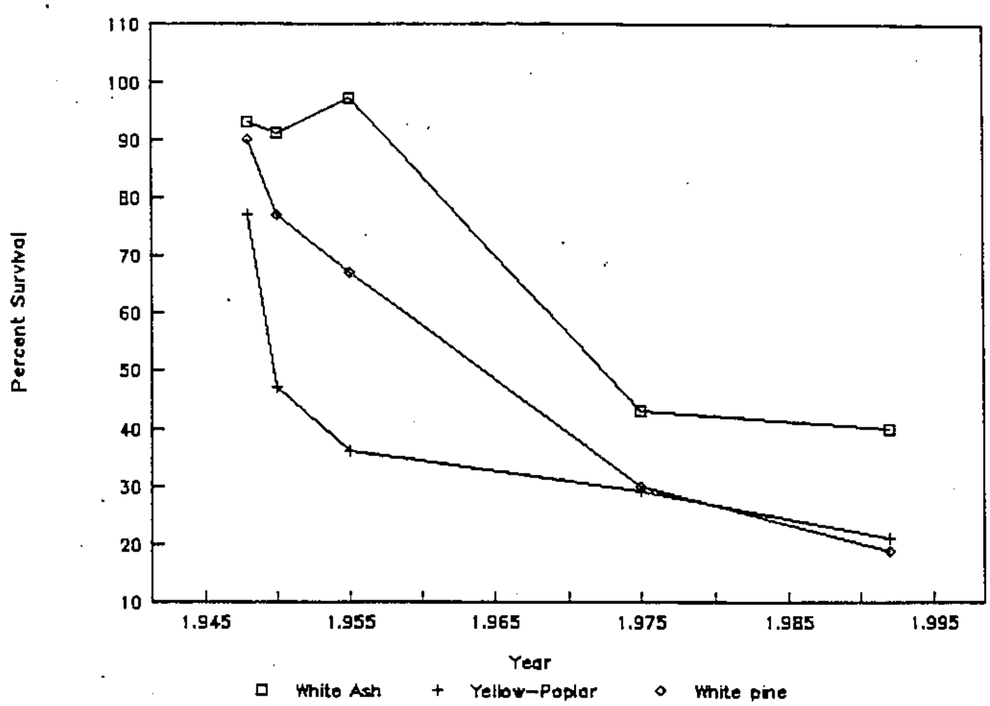
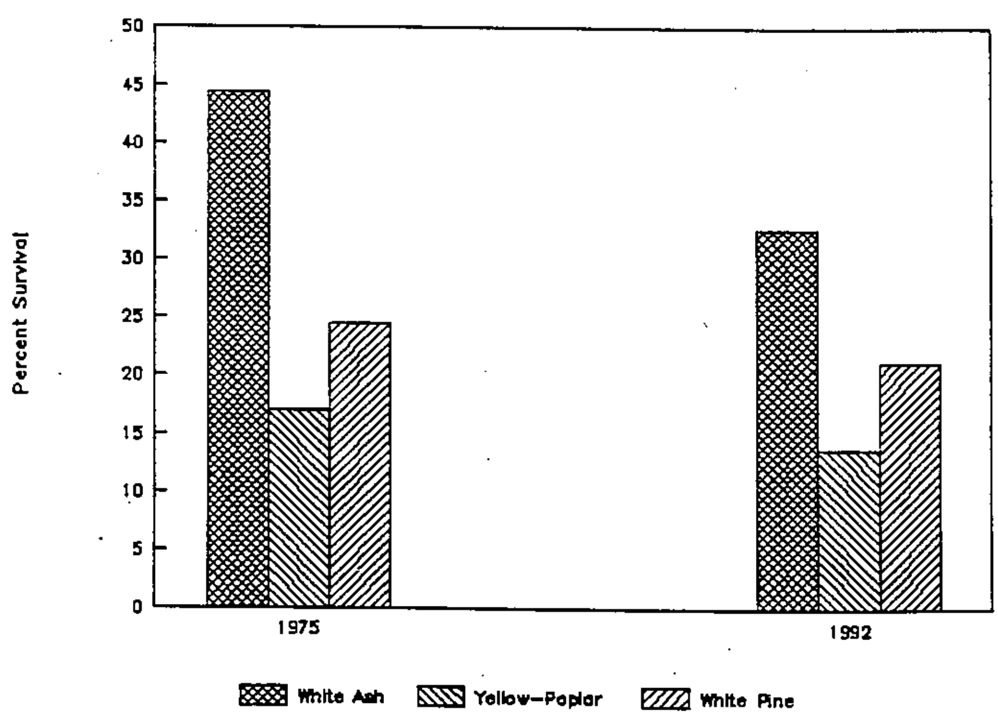



Figure 4. Percent survival of three tree species at 29 and 46 years after planting on unleveled acid minesoils in Ohio.



than those on either of the other treatments (Figure 5). This has been demonstrated many times through the years (Chapman, 1949; Foresman, 1952; Torbert and Burger, 1990). Also, trees growing on unleveled minesoils tend to grow as well as, or faster than, those on adjacent undisturbed land (Carpenter, 1944; Foresman, 1947; Deitschman and Lane, 1951). While grading may not affect survival, grading does affect tree growth. This probably is due to increased compaction on leveled and partially leveled plots which may have caused higher bulk densities, less water infiltration, and less rooting depth and volume.

Basal Area and Site Index.

Basal area (BA) is the amount of area (in square centimeters) covered by the stem of a tree, taken at dbh. Summed over an area, this is used to determine the stocking of a stand.

Between the two sites, there was no significant difference in BA due to species or site (Figure 6). However, species was significant at the Georgetown site and there was a significant interaction between species and treatment (Table 4). This interaction is primarily due to yellow-poplar, which had extremely poor survival, and thus low basal area on the leveled plots, averaging 3.3% in 1992.

The trees on these sites are categorized as pole-sized (10-30 cm dbh) and small sawtimber (30-40 cm dbh). The stands are at a stage in their development where management may be used. According to Ginrich (1967), a fully-stocked stand contains between 58 and 100 percent of the basal area that the site can support. Of those stands measured in our study, 21 stands were overstocked, 12 stands were fully-stocked, and 7 stands were understocked. Overstocked stands may be in line for a silvicultural treatment like thinning.

Foresters commonly use Site Index (SI) as a measure of productivity of a site. Site index is the height in meters of dominant or codominant trees of a given species at a specified age. In the eastern U.S., this is usually specified at the age of 50 years. White pine plantations, on the other hand, commonly use a site index at 30 years. These sites were found to generally have average SI for all species based on the SI tables developed by Carmean et al. (1989).

Prediction.

In preliminary analysis, five soil factors were used to predict survival, diameter, height, and BA (Table 5). Different soil-sized fractions and soil pH did not predict any of the tree variables that we considered. A more detailed study of soil factors and their effect on tree parameters is being conducted. Other soil factors such as texture, bulk density, sulfur, macro- and micronutrients, and organic matter will be used to estimate tree survival and growth.

## Summary

While there were significant differences using a standard ANOVA, only one variable (namely species) was significant in describing the results. Species was significant in describing survival and diameter at both sites. Rock fragment content of the soil and soil pH were not helpful in predicting any of the tree survival and growth parameters.

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Figure 5. Tree height of three species on leveled, partially leveled, and unleveled plots at Georgetown and on unleveled plots at Dundee.

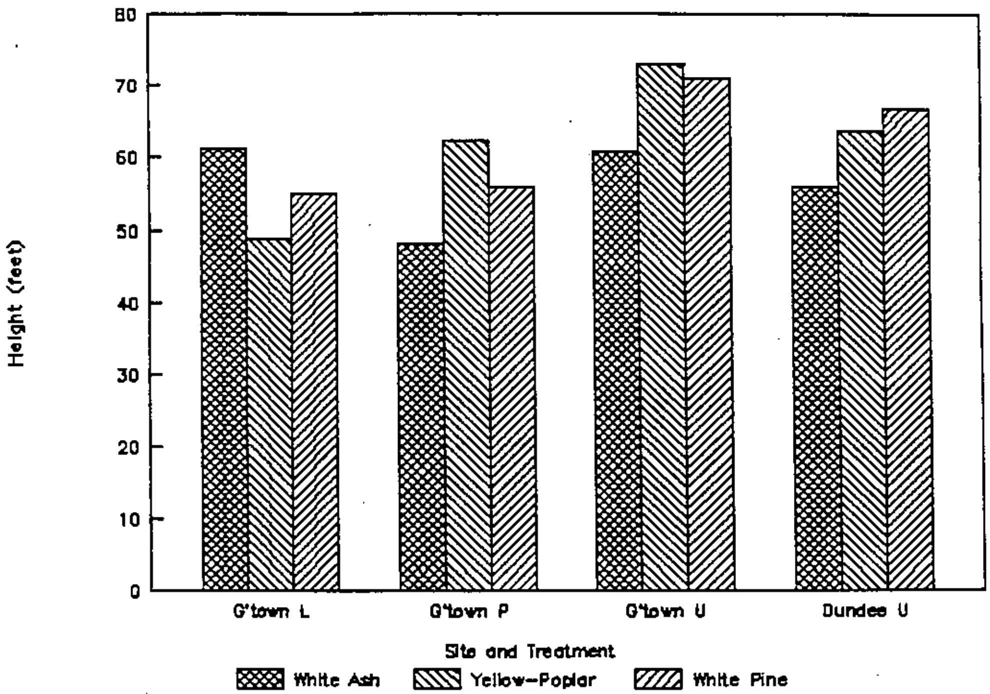


Figure 6. Basal area of three species on unleveled, acid minesoils at Dundee and on unleveled, basic minesoils at Georgetown.

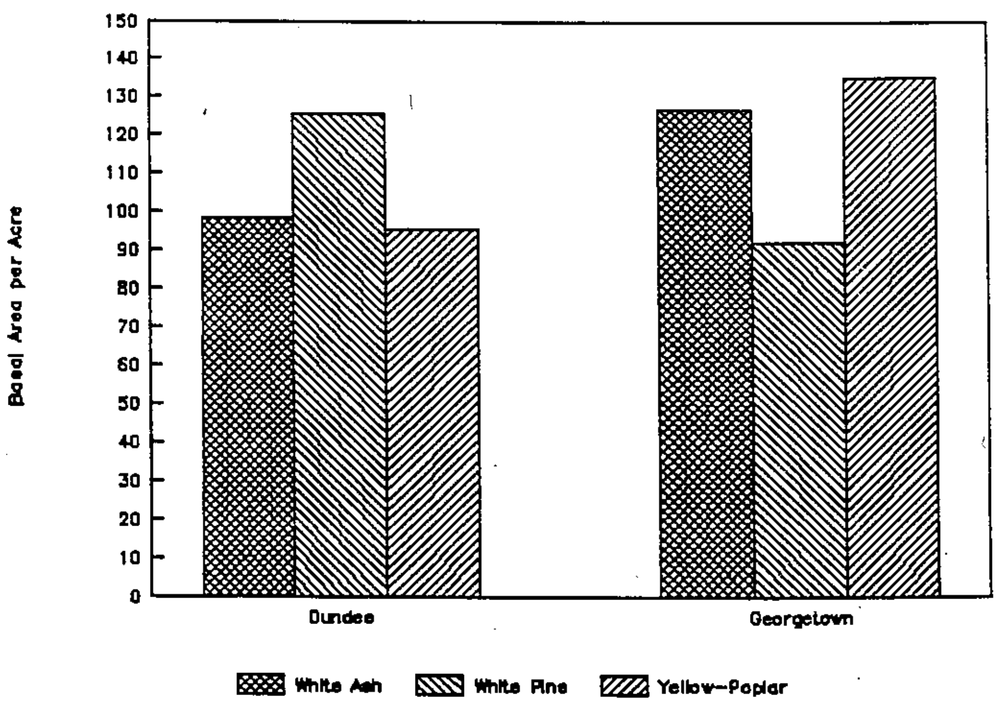

Table 3. Analysis of variance with tree height as the dependent variable, Georgetown.

| Source | df | SS | MS | F Ratio | Prob>F |
|---|---|---|---|---|---|
| Model | 8 | 1647.6 | 206.0 | 4.951 | 0.0056 |
| Leveling | 2 | 874.5 | 437.3 | 10.511 | 0.0019 |
| Species | 2 | 87.9 | 44.0 | 1.056 | 0.3758 |
| Lev*Spp | 4 | 488.9 | 122.2 | 2.938 | 0.0621 |
| Error | 13 | 540.8 | 41.6 | | |
| Total | 21 | 2188.4 | | | |

Table 4. Analysis of variance with basal area as the dependent variable, Georgetown.

| Source | df | SS | MS | F Ratio | Prob>F |
|---|---|---|---|---|---|
| Model | 8 | 37841 | 4730 | 4.902 | 0.0058 |
| Leveling | 2 | 2214.2 | 1107.1 | 1.147 | 0.3476 |
| Species | 2 | 19320 | 9660 | 10.012 | 0.0023 |
| Lev*Spp | 4 | 18984 | 4746 | 4.919 | 0.0123 |
| Error | 13 | 12544 | 964.9 | | |
| Total | 21 | 50384 | | | |

Table 5. Multiple linear regression results of soil and other variables in relation to survival, diameter, basal area, and height of trees on both sites.

| | Dependent Variable | | | |
|---|---|---|---|---|
| Source | Survival | Diameter | Basal Area | Height |
| | | Prob>F | | |
| Site | 0.1291 | 0.7966 | 0.1510 | 0.3870 |
| Species | 0.0000 | 0.0000 | 0.1442 | 0.0451 |
| % 1.9-7.6 cm | 0.7482 | 0.1860 | 0.6174 | 0.1368 |
| % 0.63-1.9 cm | 0.6276 | 0.1045 | 0.8930 | 0.4702 |
| % 2 mm-0.63 cm | 0.7977 | 0.7457 | 0.9625 | 0.7976 |
| % < 2mm | 0.7622 | 0.4516 | 0.8695 | 0.1248 |
| pH | 0.1596 | 0.9337 | 0.1597 | 0.3946 |

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