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SLASH *and* LOBLOLLY PINE PLANTATIONS *in* ALABAMA'S PIEDMONT REGION

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SLASH *and* LOBLOLLY PINE PLANTATIONS *in* ALABAMA'S PIEDMONT REGION

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A STUDY OF THE EXISTING forest tree plantations in Alabama is now being conducted by the Alabama Agricultural Experiment Station. One of the main objectives of this study is to gain knowledge of the plantations that would be useful in the present-day tree planting programs in the State. Particular attention is being given to the effects that various soil characteristics have on the growth of young trees.

The study of plantations in the Piedmont Region of the State was recently completed. During the years 1935 through 1941, most of the various counties in the region had Civilian Conservation Corps camps. Although many farmers have established pine plantations on their own initiative, the majority of plantations in the Piedmont were planted by the CCC. In general, this work was fairly well conducted, and most of the plantations were successful. This study included plantations that were established by individuals and by several types of relief labor, such as the CCC and WPA.

Loblolly pine, *Pinus taeda*, L., is native to the region. Originally this species grew in small bottoms and in more moist spots, where it occurred quite commonly in mixture with hardwoods. Gradually, loblolly pine has moved up the slopes and has taken over former longleaf pine sites. Today, it is commonly found in pure stands on old abandoned fields; hence, it is known to many in the region as "old field" pine.

Slash pine, *Pinus caribaea*, Morelet, on the other hand, is not native to the Piedmont Region. Originally, it occurred in the lowlands and moist areas in only the most southern counties of the State. During the period of emergency labor (CCC, WPA), slash pine was introduced to the Piedmont region. It was planted mainly in alternate-row mixtures with loblolly pine. Occasionally it was planted in pure stands.

The Region — Its Climate and Soils

Compared with the mountainous and coastal plain regions, the Piedmont Region of Alabama is small. It comprises an area of approximately eight counties[1] in the east-central portion of the State.

This region is characterized by an average annual rainfall of 50.1 to 55.6 inches *(9)*. Rain is usually plentiful during the winter and early spring. Rainfall during May and June is somewhat less ample, and local drought conditions are likely to prevail. July usually is a month of plentiful rain, which revives crops suffering from the preceding drought and sustains those crops already in good growing condition. After July, the rainfall gradually decreases until a low is reached in the fall, which is the driest season of the year. The average date of the last killing frost varies from March 22 in the southern part of the region to March 30 in the northern part. The average growing season varies from 219 to 237 days.

Alabama's Piedmont Region is the southwestern tip of the Piedmont Plateau, which extends from Alabama across Georgia and northeastward to New Jersey. The topography of this section of Alabama is generally rolling. Slopes are gentle in the southern portion, but they become more severe in the northern part. While the land is well drained, most of the streams and bottoms are small.

Geologically, the soils of this region are the oldest in the State and they have been subjected to the most severe erosion. The predominant soil series are Cecil, Appling, Lloyd, Louisa, Madison, and Coosa. With the exception of Louisa, which is poorly developed, all of these soils have similar characteristics. They are well-drained, residual soils with highly differentiated profiles. Most of them originally had a sandy loam topsoil 12 to 14 inches deep. However, because of early cultivation and misuse, most of the old field areas now have a very thin topsoil, varying from a grey or light brown sandy loam to a red, yellow, or dark brown clay loam. In many old fields there is no topsoil left.

Review of Literature

Although numerous studies concerning the correlation of soils and site with tree growth have been reported, little work has been

[1] Practically the entire area of the following counties: Cleburne, Clay, Randolph, Coosa, Tallapoosa, and Chambers. A portion of the following counties: Lee, Elmore, Chilton, and Talladega.

done with young trees (5 to 20 years old). Very little work has been reported concerning slash pine in the Piedmont Region.

Coile *(3)* recently made an investigation of correlating site index of loblolly and shortleaf pine with soil factors in the lower Piedmont Region of North Carolina. The variables that he found to contribute significantly to the site index of each species were: (a) thickness of the A horizon, or surface soil, in inches; (b) ratio of silt plus clay to moisture equivalent of the B horizon; (c) second power of that ratio; (d) imbibitional water value[2] of the B horizon. Coile states that the imbibitional water value was fairly characteristic of the conventional soil series as mapped, and was better correlated with site index than the ratio of silt plus clay to moisture equivalent. While topographic position and total depth to C horizon were tested, they were not found to be significantly correlated with site index. He concluded that site index for loblolly and shortleaf pine in the Piedmont of North Carolina can be estimated from the thickness of the A horizon and the imbibitional water value of the B horizon. His study did not include stands less than 30 years old.

In the South Carolina Piedmont, Cooper *(4)* found that loblolly pine site indexes were uniform (within 5 to 6 feet) on soils of the same series, type, and Soil Conservation Service standard erosion class. His data show that there was a drop of 5 to 10 feet in site index for each drop of one erosion class.

Auten *(1)* made a study of 77 natural second-growth stands of yellow poplar, which varied in age from 12 to 61 years. Depth to tight subsoil was the most important and valuable measurement he found for evaluating site. He stated that topography must be taken into account on rolling and steep areas. His data indicate a difference of 33 site index points between a sheltered cove and an exposed ridge.

Roberts *(8)* found the height growth of 5-year-old planted black locust in Mississippi to be closely correlated with the depth of surface soil.

In addition to the foregoing, there are many studies that emphasize the importance of topsoil measurements in evaluating sites for tree growth. Most of these studies only concern trees older than 20 years of age. However, because of the limited development of the root systems of young trees, it seems that

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[2] Imbibitional water value is the difference between moisture equivalent and xylene equivalent.

topsoil alone might have a relatively greater effect on early growth than on later growth.

In many of the previous studies, site was evaluated according to some system of site index. One criticism of site index is that the growth of trees during early life sometimes shows little or no relation to their later growth. Therefore, the height-over-age curves for determining site index are valueless when applied to young stands. It is generally recognized that the site index curves for slash and loblolly pine *(10)* are of little value when applied to young, old field plantations.

Methods of Investigation

Approximately 400 plantations were located and examined to determine the type of planting and the type of site. The general condition of each plantation was observed at this time. One hundred and thirteen plantations, ranging in age from 5 to 12 years, were selected for study. These were well distributed over the various types of sites, and comprised those plantations on which the best records had been kept.

Field observations were made on tenth-acre plots, each of which represented a particular set of site conditions. Twenty-five plots of pure slash pine, 34 plots of pure loblolly pine, and 54 plots of slash and loblolly pine in alternate-row mixtures were studied. While most of the plots were established in old field plantations on the predominant soil series, a few were in small bottoms where there was colluvial material.

The soil on each plot was described and identified. Average depth of the topsoil, or A horizon, was recorded. If a transition horizon was present between the A and B horizons, it was counted as part of the A horizon. Therefore, the depth of A horizon in this study represents the depth to compact B horizon. Composite soil samples were collected from both the A and B horizons.

In order that volume might be calculated, the diameter at breast height of each tree was measured and the total height was estimated. Heights of approximately ten dominant and co-dominant trees on each plot were measured, and their average height was used as a criterion of site quality.

Past history, present condition, and present usage of the land were recorded. Percentage survival of the trees was determined. Insect damage, disease, and such other injuries as wind and ice damage were recorded. Infections of southern fusiform rust, *Cronartium fusiforme* (A. & K.), Hedgc. and Hunt, were recorded for each tree.

Correlation of Soil Characteristics with Height Growth[3]

Regression analysis was used to try to determine the relationship between soil factors, which were measured, and height growth of slash and loblolly pine.

Height was the dependent variable in all the regressions. Its correlation with the following independent variables was investigated: (1) per cent of sand in A horizon, (2) per cent of clay in A horizon, (3) moisture equivalent of A horizon, (4) imbibitional water value of A horizon, (5) depth of A horizon, (6) moisture equivalent of B horizon, (7) imbibitional water value of B horizon, and (8) age of plantation. All of these independent variables were not used in every equation, but they were used at various times in equations of different form. Some form of both age and depth of A horizon was used in each equation.

Straight line equations were used in the preliminary analysis, whereas curvilinear equations were used in the final analysis.

Age and depth of A horizon were highly significant in all of the equations used. However, none of the other independent variables named were significant in any of the equations.

The equation finally adopted for slash pine in pure plantations was: Logarithm of Height =

$$1.981 - 0.452 \left(\frac{10}{\text{Age}}\right) - 0.028 \left(\frac{10}{\text{Depth A horizon}} - \frac{10}{\text{Depth A horizon} \times \text{age}}\right)$$

The equation finally adopted for loblolly pine in both pure and mixed plantations was: Logarithm of Height =

$$1.907 - 0.371 \left(\frac{10}{\text{Age}}\right) - 0.032 \left(\frac{10}{\text{Depth A horizon}} - \frac{10}{\text{Depth A horizon} \times \text{age}}\right)$$

Figures 1 and 2 represent the foregoing equations and are intended for use in classifying planting sites in terms of early height growth. Based on depth of topsoil only, the classes of planting sites recognized on the graphs are:

(a) Class No. 1., less than 2 inches topsoil; poor site (Figure 3)
(b) Class No. 2., 2 to 4 inches topsoil; fair site (Figure 4)
(c) Class No. 3., 4 to 8 inches topsoil; good site
(d) Class No. 4., more than 8 inches topsoil; excellent site (Figures 5, 6)

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[3] Refer to the Appendix for a more detailed explanation.

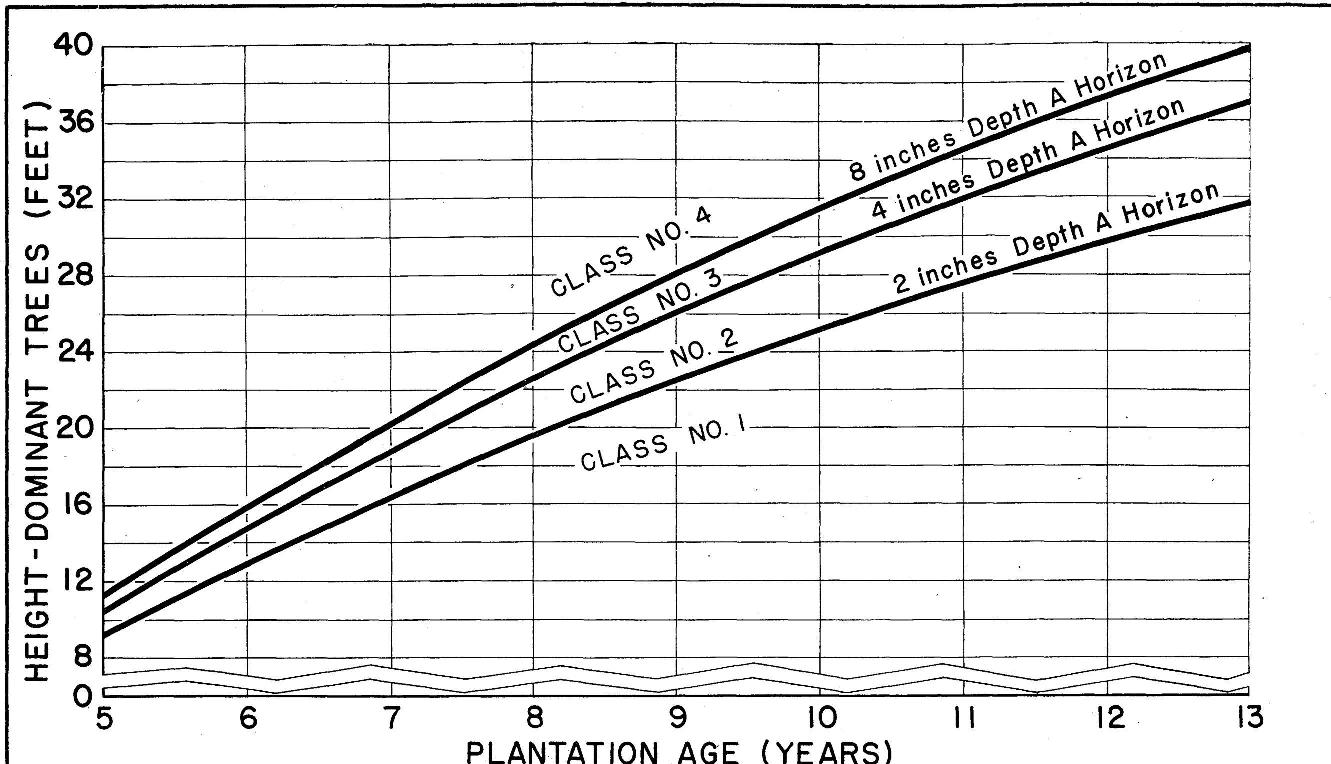

FIGURE 1. Estimated heights of young slash pine in pure plantations.

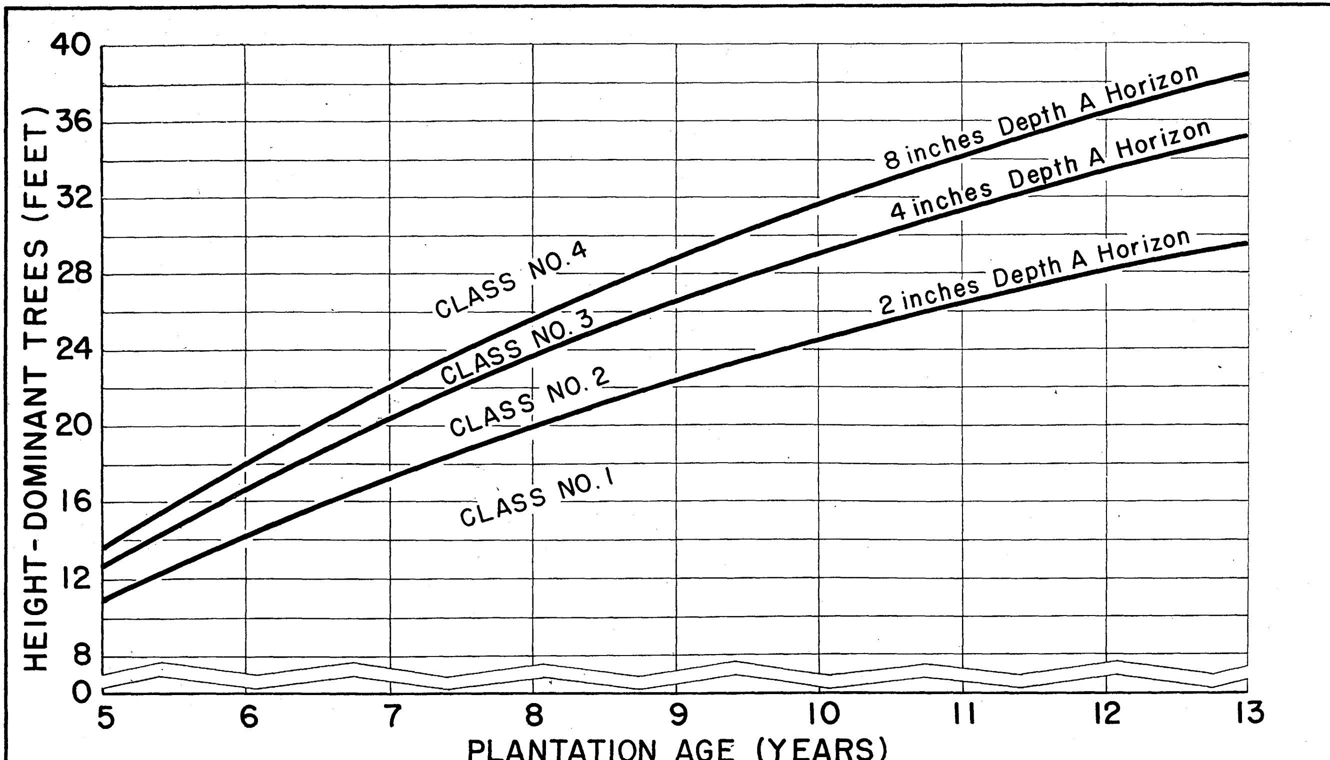

FIGURE 2. Estimated heights of young loblolly pine in pure and mixed plantations.

FIGURE 3. Slash and loblolly pine on a site on which erosion continues 7 years after the trees were planted. Highest trees averaged 11 feet. This is a Class No. 1 site with practically no topsoil. No precautions were taken to prevent erosion, and the original spacing was 6 by 6 feet, which was too wide for this site.

The equations themselves may be used to calculate the predicted heights of the average dominant trees (or average of the highest trees if no dominance is shown) in a plantation where the depth of topsoil is greater or less than that shown in Figures 1 and 2. Values above zero depth of A horizon should always be used in the equations. These equations are more reliable for ages of more than 7 years, since growth during the first 7 years does not follow a definite trend.

It is important that the foregoing equations and graphs be applied only to trees planted on soils of the Cecil, Appling, Madison, Lloyd, Coosa, and Louisa series. Several sites in small bottoms were studied. Included in these bottom lands were plots on soils of the Senneca and Starr series. These soils were of deep, well-drained colluvial materials, and were well supplied with moisture. All such bottom lands were Class No. 4 planting sites.

In most other investigations of the relationship between soil and site, it has been found that tree growth cannot be predicted from any single soil variable. There are several factors that might explain why depth of topsoil alone is sufficient for reasonably reliable predictions of early growth of slash and loblolly pine within the limits of this investigation. Principal among these is the absence of large variations in subsoil characteristics that influence water relations among the soils of the Alabama Pied-

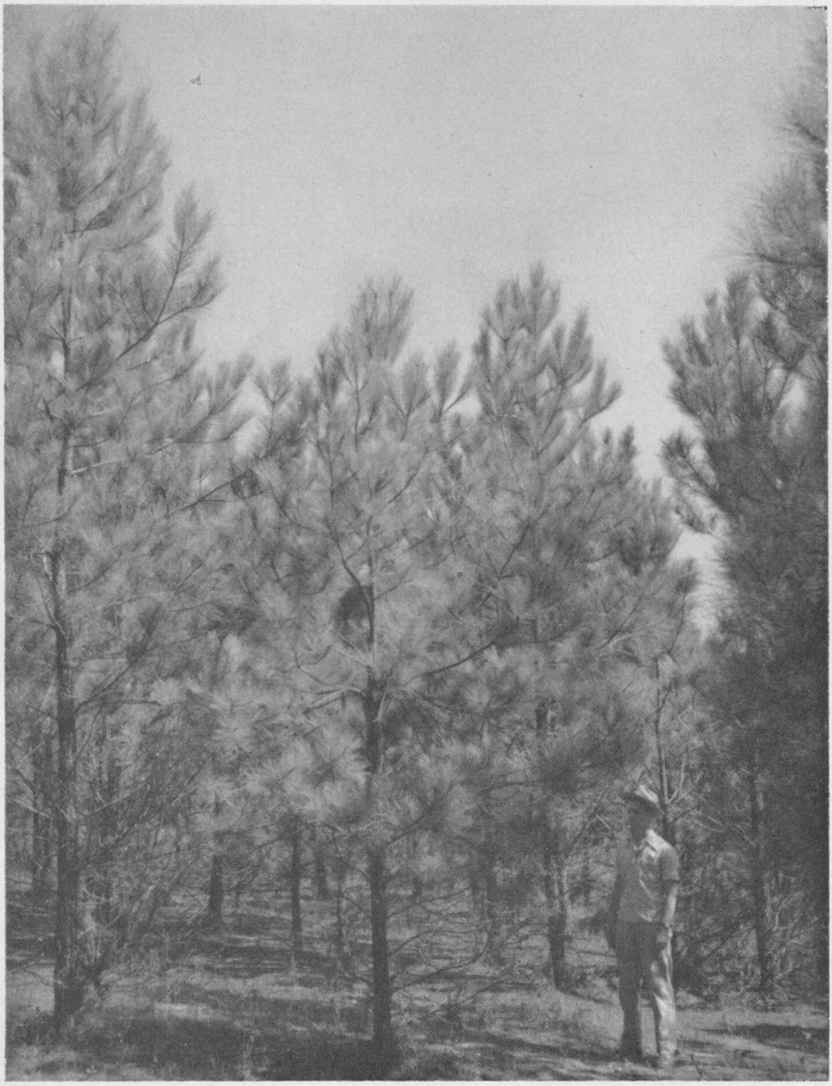

FIGURE 4. Loblolly pine, 8 years old, average height of highest trees is 21 feet. This is a Class No. 2 site, with 3 inches of topsoil.

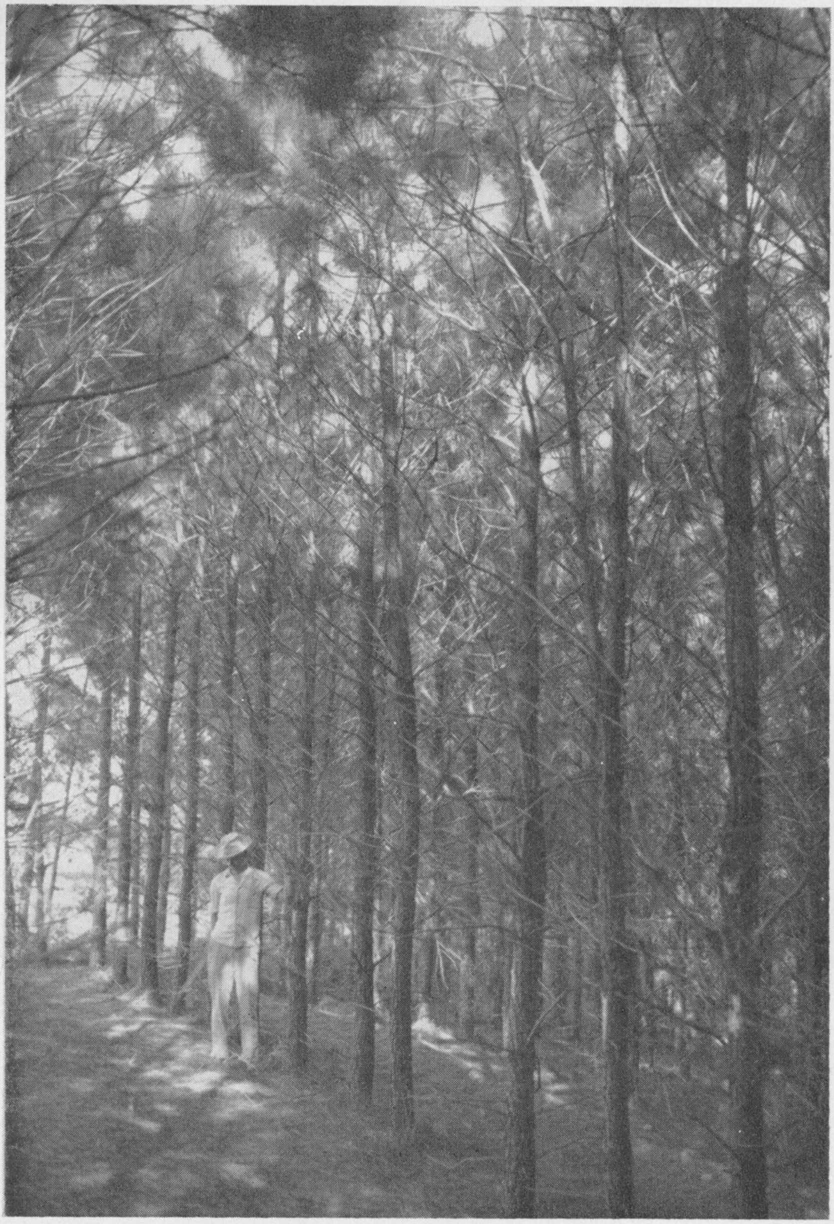

FIGURE 5. Loblolly pine, 8 years old, average height of highest trees is 32 feet. This is a Class No. 4 site with 9 inches of topsoil.

FIGURE 6. Alternate row loblolly and slash pine plantation showing a row of oppressed slash pine between two rows of loblolly pine. The stand is 9 years old; site is excellent.

mont on which slash and loblolly pine plantations were studied. The plantations investigated had all been established in old fields on closely related, well-drained soils. For all plots, the average imbibitional water value of the B horizon was 6.97. A very large majority of the values were between 5 and 9.

Another reason is that depth of topsoil is perhaps correlated with other factors that probably also influence growth. It has been the author's observation that such correlations do exist. Depth of A horizon, probably due to effects of erosion, is correlated with both topographic position and degree of slope. The texture of the topsoil also is closely correlated with its depth. This is due to the incorporation of subsoil clay into the plowed horizon as the topsoil becomes more shallow because of erosion. Most of the topsoils less than 3 inches deep were clay loams.

General Discussion

If the heights of the trees represented by the curves in Figure 1 (slash pine) are compared to those represented in Figure 2 (loblolly pine), it can be seen that slash pine grows slightly slower than loblolly pine up to an age of 9 to 10 years, depending upon the site class. After this age, slash pine grows slightly faster than loblolly pine up through the ages observed. While the differences in growth of the two species indicated by these data are not statistically significant, observations by the author and other investigators *(2, 5)* indicate that such a difference does exist in the southern Piedmont.

Many of the plantations observed in this study were slash and loblolly pine in alternate-row mixtures. On fair to excellent sites, the loblolly pine had grown faster than the slash pine during the first few years and the slash pine was being oppressed. As the age of the plantation and quality of the site increases, the oppression becomes more severe, Figure 6. Most of the slash pines in these plantations were in the intermediate and overtopped crown classes. Such oppression of the slash pine is not desirable from a general silvicultural standpoint. This may be overcome partially by planting three to five rows of one species and then three to five rows of the other.

For all plots studied in pure plantations, the average survival percentage of slash pine was 52.9, whereas the average survival percentage of loblolly pine was 83.2. It was generally observed throughout the study that slash pine had a much lower survival rate than loblolly pine. This lower survival of slash pine in the Piedmont has been mentioned by Claridge *(2)* and by Gibbs and Hendrickson *(5)*. Such anticipated loss might be overcome by using a closer original spacing than the one actually desired.

During this study, the growth of many plantations with various tree spacings was observed. On the basis of these general observations, the various spacings can be divided into two groups. Close spacings of 5 by 5, 6 by 6, or 7 by 7 feet have been best for landowners who were interested in such products of early thinnings as fuelwood, fence posts, and pulpwood. The wide spacings of 8 by 8 and 9 by 9 feet have been best for landowners who were interested mainly in sawlogs and who were not in a position to make early thinnings.[4]

Severely eroded sites and galled[5] areas are special problems, (Figure 3). Based on observations, the main problems on these areas were establishment of ground cover and reduction of erosion. Tree spacings have to be much closer on these sites. Spacings of 4 by 4 and 3 by 3 feet were observed to be very effective in stopping erosion quickly. Mulching with pine straw and pine boughs is effective in reducing erosion quickly on small areas of badly eroded gullies.

Causes of Injury

Most noticeably injurious to slash and loblolly pine plantations in the Piedmont Region are southern fusiform rust, grazing, and fire.

The incidence of southern fusiform rust, *Cronartium fusiforme,* has increased during the past 15 years to such an extent that it is now an important factor to be considered in planting and growing slash and loblolly pines. The resulting disease, hereafter referred to as Cronartium, shows itself in the form of elongated, cankerous swellings on the limbs and stems of the trees.

During this study of slash and loblolly pine, records were kept concerning Cronartium infection on each tree in all the plots. A complete report of the analysis of these data and a search for some factors correlated with infection has been made previously by Goggans *(6).* A partial summary of this report follows.

The average percentages of Cronartium infection by species and by location of infection are presented in Table 1.

In comparisons of these averages by standard t-tests, no significant differences were found between the incidence of Cro-

[4] These spacings have also been found the best of those tried in a planting experiment at the Main Station, Auburn, reported by Ware and Stahelin (*11*). It should be noted that the comparative growth of the slash and loblolly pine at Auburn is not the same as that in the Piedmont.

[5] Refers to a place where all the topsoil has been removed by erosion, leaving the subsoil exposed on a rather smooth area.

TABLE 1. INCIDENCE OF CRONARTIUM BY SPECIES AND LOCATION OF INFECTION ON SLASH AND LOBLOLLY PINE IN THE PIEDMONT REGION OF ALABAMA

Species	Type of planting	Number of plots	Per cent branch infection	Per cent stem infection	Per cent having both stem and branch infection	Total per cent of trees infected
Loblolly	Pure	29	12.19	14.02	3.04	23.18
Slash	Pure	21	9.10	17.55	1.75	24.90
Loblolly	Two species mixed	40	9.32	13.84	1.93	21.22
Slash	Two species mixed	40	2.54	6.84	0.14	9.24
Both slash and loblolly	Two species mixed	40	6.76	11.24	1.30	16.69

nartium on (1) slash pine in pure plantations and loblolly pine in pure plantations, and (2) loblolly pine in pure plantations and loblolly pine in mixed plantations. The incidence of Cronartium on slash pine in mixed plantations was comparatively low. Consequently, there was a highly significant difference between slash pine in mixed plantations and slash pine in pure plantations. Total infection (that on both slash and loblolly pine) in the mixed plantations was lower than that in either the pure slash or loblolly pine plantations. A highly significant difference was found between the infection on loblolly pine in pure plantations and total infection in mixed plantations, except for stem infection which was not significant. Branch infection, and stem and branch infection were not significantly different in the comparison of slash pine in pure plantations with total infection in mixed plantations. However, stem and total infection were significantly different.

Histories of the many plantations observed and studied revealed that grazing and fire had been extremely harmful to planted slash and loblolly pine in the Piedmont. Many landowners had planting failures merely because they made the mistake of planting trees in areas that were pastured regularly. Although most landowners know that fire will kill young trees, many plantations have been damaged or destroyed by carelessness in handling fire.

Even though fire and grazing do not always destroy plantations, they often decrease the number of trees to the extent that no early returns from pulpwood or poles can be realized. Many plantations were observed where the trees were so scattered that they will not grow into sawlog trees of good quality, but will become large, limby wolf-trees of little value.

Both grazing and fire are particularly injurious to plantations during the first 5 or 6 years after planting or while the trees are small. The importance of complete protection for plantations cannot be over-emphasized.

SUMMARY AND RECOMMENDATIONS

The Alabama Agricultural Experiment Station in 1950 completed a study of loblolly and slash pine plantations in the Piedmont Region of Alabama. Pure loblolly pine, pure slash pine, and mixed slash and loblolly pine plantations on old field sites were studied.

The main emphasis of this study was on the correlation of soil variables with early height growth. Regression analysis was used to investigate the correlation of the following soil variables with height growth: (1) per cent of sand in A horizon, (2) per cent of clay in A horizon, (3) moisture equivalent of A horizon, (4) imbibitional water value of A horizon, (5) depth of A horizon, (6) moisture equivalent of B horizon, and (7) imbibitional water value of B horizon. Depth of A horizon was the only soil variable found to be significantly correlated with height. This correlation was so high that it was possible to classify planting sites from the standpoint of early growth on the basis of this variable alone.

The regression equations used to classify the planting sites follow:

For Slash pine: Logarithm of Height =

$$1.981 - 0.452\left(\frac{10}{\text{Age}}\right) - 0.028\left(\frac{10}{\text{Depth A horizon}} - \frac{10}{\text{Depth A horizon} \times \text{age}}\right)$$

For loblolly pine: Logarithm of Height =

$$1.907 - 0.371\left(\frac{10}{\text{Age}}\right) - 0.032\left(\frac{10}{\text{Depth A horizon}} - \frac{10}{\text{Depth A horizon} \times \text{age}}\right)$$

A part of the study included an investigation of the incidence of Cronartium infection. The average of all infection in pure slash pine plantations was 23.18 per cent; whereas in pure loblolly plantations, it was 24.90 per cent. There was no significant difference between the incidence of Cronartium infection on slash and loblolly pines in pure stands.

Since it has been observed that slash pine grows slightly slower than loblolly pine up to 9 or 10 years of age, alternate-row mixtures are not advised. If a mixed plantation is desired, it is recommended that three to five rows of one species be planted alternately with three to five rows of the other.

The average survival of slash pine was 52.9 per cent; whereas the average survival of loblolly pine was 83.2 per cent. Since it is generally cheaper to offset anticipated losses by using a closer original spacing than by replanting, it is recommended that slash pine be planted closer in the rows than the final spacing desired.

Spacings of 5 by 5, 6 by 6, or 7 by 7 feet are recommended to landowners in the Alabama Piedmont who are interested in early thinnings. Spacings of 8 by 8 or 9 by 9 feet are recommended to landowners who are interested mainly in sawlogs. Those interested in the production of high quality poles and sawlogs should remember that trees planted at the closer spacings yield higher quality final products than do trees planted at the wide spacings.

Severely eroded sites need to be treated as special problems. An average spacing of 4 by 4 feet is recommended for planting on such sites. Mulching with pine straw, boughs, and brush is advisable on small areas of badly eroded gullies where it is necessary to reduce erosion to a minimum.

Grazing and fire have been extremely destructive to plantations in the Piedmont. It is recommended that plantations be completely protected from fire and grazing.

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Appendix

Correlation of Soil Characteristics with Height Growth

Regression analysis was used to try to determine the relationship between the soil factors that were measured and the height growth of slash and loblolly pine.

The following laboratory determinations were made for the collected soil samples: (1) mechanical analysis of A horizon, (2) moisture equivalent of A horizon, (3) xylene equivalent of A horizon, (4) moisture equivalent of B horizon, and (5) xylene equivalent of B horizon. The last four determinations allowed the calculation of the imbibitional water value of A and B horizons.

In order to obtain the possibly correct form of curve to use in trial regressions, the height and age data for each species were plotted. In many plots yearly growth intercepts had been measured down the stems of the same trees measured for height; therefore, heights of the trees at more than one age were available. The additional measurements aided considerably in selection of a form of curve to use in the final analysis. Since neither the slash nor the loblolly curve deviated appreciably from a straight line, a regression equation of straight line form was selected for the preliminary tests of correlation.

In all preliminary equations, height (average of approximately 10 dominant and codominant trees per plot) was the dependent variable. The first equations for each species had the following independent variables: (1) age, (2) depth of A horizon, (3) per cent of clay in A horizon, (4) per cent of sand in A horizon, and (5) imbibitional water value of B horizon. The equations for each species were highly significant. Age, as would be expected, was highly significant and contributed much to the significance of the equation. Depth of A horizon was also highly significant. The other variables were not significant.

A second equation for each species was solved. The equations were similar to those in the preceding paragraph, except that the independent variables per cent of clay in A horizon and per cent of sand in A horizon were omitted. The significance of the equations and remaining variables was not changed. The multiple correlation coefficient was not changed appreciably.

The reason that imbibitional water value of B horizon did not prove to be significantly correlated with height growth was probably due to the fact that the main soils studied had values that were close together. The average imbibitional water value for all the plots included in the above equations was 6.97. A very large majority of the values were between 5 and 9.

Moisture equivalent of B horizon was tested in a third equation for loblolly pine in which the other independent variables were age and depth of A horizon. Moisture equivalent was not significantly correlated with height.

Because it seemed desirable to have an equation that would fit the data better than a straight line, a new equation was used in the final analysis. The dependent variable of this new equation was the logarithm of the height, and the independent variables were as follows:

$$x_1 = \frac{10}{\text{Age}}$$

$$x_2 = \frac{10}{\text{Depth of A horizon}}$$

$$x_3 = \frac{10}{\text{Depth of A horizon}} \times \frac{10}{\text{Age}}$$

$$x_4 = \text{Imbibitional water value of B horizon}$$

$$x_5 = \frac{\text{Imbibitional water value of B horizon} \times 10}{\text{Age}}$$

This equation was solved for loblolly pine. The equation and variables x_1, x_2, and x_3 were highly significant. Variables x_4 and x_5 were not significant. These findings agree with those of the preliminary straight line equations. When plotted, the curves derived from this equation for the various depths of A horizon were found to cross each other at 6.33 years age. This was presumed to be caused by the nature of the equation itself; therefore, the equation was adjusted mathematically so that the curves would cross at age one year.

Since depth of A horizon was always highly correlated, it was thought that some other characteristic of A horizon might be important. Moisture equivalents and xylene equivalents of the topsoil samples were determined.

The basic data used to compute the previous equations did not include those plots on soils with a poorly developed B horizon (mainly Louisa). Due to the fact that neither the imbibitional water value nor the moisture equivalent of the B horizon was significantly correlated with height, it was thought that these plots might be safely included. Observation of all height, age, and soil data plotted on a chart indicated that the data for plots on poorly developed soils fitted in very well with data of the other plots.

The imbibitional water value of B horizon was eliminated as a variable, and the adjusted form of the previous equation was used to test the correlation of the imbibitional water value and the moisture equivalent of A horizon with height. The independent variables of the new equation were:

$$x_1 = \frac{10}{\text{Age}}$$

$$x_2 = \frac{10}{\text{Depth A horizon}} - \frac{10}{\text{Depth A horizon} \times \text{age}}$$

$$x_3 = \text{Imbibitional water value of A horizon}$$

$$x_4 = \frac{\text{Imbibitional water value of A horizon} \times 10}{\text{Age}}$$

Somewhat as before, the equations and variables x_1 and x_2 were found highly significant. Neither imbibitional water value nor moisture equivalent of the A horizon was significantly correlated.

Since variables x_3 and x_4 of the foregoing equations were not significant, these variables were dropped, and an equation of the following form was solved for both loblolly pine and slash pine:

Logarithm of Height =

$$b_0 + b_1 \left(\frac{10}{\text{Age}}\right) + b_2 \left(\frac{10}{\text{Depth A horizon}} - \frac{10}{\text{Depth A horizon} \times \text{age}}\right)$$

To test the soundness of the inclusion of the plots on soils with poorly developed subsoils, the above equation was solved both with and without the plots in question. For each species, the inclusion of these plots increased the significance of the equation and of both independent variables.

The final equation for slash pine in pure plantations (plotted in Figure 1) was:

Logarithm of Height =

$$1.981 - 0.452 \left(\frac{10}{\text{Age}}\right) - 0.028 \left(\frac{10}{\text{Depth A horizon}} - \frac{10}{\text{Depth A horizon} \times \text{age}}\right)$$

The final equation for loblolly pine in pure and mixed plantations (plotted in Figure 2) was:

Logarithm of Height =

$$1.907 - 0.371 \left(\frac{10}{\text{Age}}\right) - 0.032 \left(\frac{10}{\text{Depth A horizon}} - \frac{10}{\text{Depth A horizon} \times \text{age}}\right)$$