Ten Years of Strip-Mine Forestation Research in Ohio

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Strip mining for coal began in Ohio in a modest way in 1915, but it was not until 1940 that it really came into its own. By 1948, more than half the coal mined in the State came from strip mines. Because strip mining leaves the land barren and temporarily nonproductive, this method of mining brought with it a unique problem in land rehabilitation. Unfortunately, such land does not reforest naturally very well, so many of the mining companies sought other ways to successfully establish forest cover on their mined land.

Some studies were undertaken by this station to solve this problem as early as 1937 (1)[1] but in 1945 increased financial support resulting from strong local interest in the rehabilitation problem made it possible to greatly increase the number and variety of forestation studies on strip-mined land in nearly all the states in the midwest (2, 3, 6, 11, 12, 13).

This paper summarizes the results of the following 10 years of planting studies on coal strip-mined land in Ohio. Some of the things studied were species adaptation, mixed plantings, direct seeding, as well as planting methods and the effect of grading strip-mined land on planted trees. Work was concentrated in southeastern Ohio (fig. 1). However, before discussing individual studies some mention should be made concerning the types of strip-mine banks on which the plantations were established.

1/ Numbers in parentheses refer to Literature Cited, p. 27

Figure 1.--Location of the Station's strip-mine reclamation studies in Ohio. Studies were conducted in counties shown in white.

GENERAL CLASSIFICATION OF STRIP-MINED LAND TESTED

The two most important characteristics of strip-mine banks that affect the survival and growth of planted trees are acidity and texture (6). If more than 50 percent of the surface material tested in a given mined area has a pH of 7 or higher the banks are classified as calcareous; if more than 50 percent of the material has a pH of 6.9 or lower they are classified as acid. Texture classes reported here are grouped according to the relative amounts of sand, silt, or clay that are present in mixture with the shales and stones found on the surface of banks (6).

Both acidity and texture of the eventual banks are in turn influenced by the kind of material that lies above the particular seam or seams of coal being mined. This overburden varies with each coal seam and depends upon the geologic time and conditions under which the seam was laid down. Coal seams are numbered according to their age, the lowest numbered seams being the oldest. Thus, within a given series and assuming level topography and strata, No. 8 coal would be nearer the surface than No. 7 but deeper than No. 9, and would have the same general characteristic overburden anywhere the seam was found. The strip-mine banks included in the forestation studies reported here resulted from mining coal seams 5, 6, 7, 8, and 9. They accounted for more than 80 percent of the total coal produced in Ohio in 1954 by strip mining (4).

DESCRIPTION OF STRIP-MINE BANKS TESTED

Detailed analyses of the overburden and strip-mine conditions in Ohio have been published (7, 8, 9, 10) but it seems appropriate to review this material here. Although the following descriptions are specific for the banks studied, they probably will also apply generally to other strip-mine banks resulting from mining the same coal seams.

NO. 5 BANKS

No. 5, or Lower Kittanning, coal seam is mined by stripping in Carroll, Columbiana, Holmes, Jackson, Jefferson, Lawrence, Mahoning, Muskingum, Perry, Stark, and Tuscarawas Counties (4). Forestation studies were established on typical banks located in Mahoning and Tuscarawas Counties. The overburden consists largely of silty shales and some sandstone. The resulting mine banks are usually dark in color and although they are generally silty or clayey in texture, they also contain some sand. Fine shales give some of these banks a loose texture making their tops and slopes susceptible to sheet erosion. These banks are usually very acid and sometimes have a pH as low as 3.0 resulting in conditions toxic to most plants. Occasional calcareous spots occur, but the general pH range is 4 to 6.5. Soil-sized particles (2 millimeters in diameter or smaller) found in the upper 12 inches of the banks a few years after stripping make up about 45 percent of the bank material volume. Some of the studies in Mahoning County are on banks that contain a small amount of glacial till usually not enough, however, to significantly affect the texture or reaction of these banks.

NO. 6 BANKS

No. 6, or Middle Kittanning, coal seam is strip mined in Athens, Carroll, Columbiana, Coshocton, Hocking, Jefferson, Mahoning, Muskingum, Perry, Stark, Tuscarawas, and Vinton Counties (4). Forestation studies were made on the banks in Tuscarawas, Muskingum, Carroll, Perry, and Hocking Counties. The overburden consists mostly of sandy shales and silty shales mixed with sandstones. Like the No. 5 banks, these banks are usually dark in color because of the dark shale that is present over most of the bank surfaces. The texture of the surface materials varies from clay to sand but is most frequently loamy. The reaction of the banks is generally acid; pH values seldom exceed 5.5 and in some spots the pH may be lower than 3.8. Consequently, toxic acid spots are frequently encountered on these banks. The amount of soil-sized material in the upper 12 inches of the banks a few years after stripping may range from 20 to 70 percent, but generally is about 45 percent.

Figure 2.--Graded (left) and ungraded (right) No. 7 banks before planting.

NO. 7 BANKS

No. 7, or Upper Freeport, coal seam is strip mined chiefly in Columbiana County, but also in Athens, Belmont, Carroll, Coshocton, Gallia, Harrison, Jackson, Jefferson, Muskingum, Noble, and Vinton Counties (fig. 2) (4). Forestation studies were made in Columbiana County. The overburden consists of various mixtures of sandstone, shale, and clay. The texture of the bank surface is usually loamy but sometimes clayey; color is medium dark to dark. Although these banks, like the No. 5 banks in Mahoning County, are in the glaciated region, only a small amount of glacial till is found on the surface of the banks. These are usually acid, but pH is seldom less than 5.0 and occasionally as high as 7.5. Soil-sized material in the upper 12 inches of the banks a few years after the banks are formed is usually about 35 percent by volume but may range from 20 to 50 percent.

NO. 8 BANKS

Most of the No. 8, or Pittsburgh, coal strip-mine banks are in Harrison and Jefferson Counties but some are found in Athens, Belmont, Gallia, Guernsey, Jefferson, Meigs, Noble, and Washington Counties (fig. 3) (4). The overburden generally consists of limestone and clays mixed with hard, sandy and silty shales. However, the overburden sometimes includes strata of Redstone and Fishpot limestone. These

Figure 3.--Ungraded No. 8 banks before planting. Note the large number of limestone rocks on the surface.

strata are thick and massive and weather to produce very fine textured material. Where these strata are lacking, the banks, although predominantly clayey, also contain relatively larger amounts of sand and sandy shales and these produce much coarser bank material. Except where the overburden on the coal was shallow, the resulting banks are very stony making planting difficult. These banks are calcareous, showing a pH of 7.0 to 7.5 except for an occasional spot where the pH may be a little lower. Soil-sized material in the upper 12 inches of fresh banks may be as low as 15 percent and as high as 75 percent, but the average is about 45 percent.

NO. 9 BANKS

The No. 9, or Sewickly, coal seam is strip mined in Belmont, Harrison, Morgan, Muskingum, Noble, and Washington Counties (4). Forestation studies on No. 9 banks are located in Belmont and Harrison Counties. The overburden is predominantly shale and silt-stone with some limestone and sandstone. Texture of the surface material is usually loamy. Stones, consisting of shale or sandstone, usually cover about 20 percent of the bank surface. The color of the banks varies greatly. These banks are acid, generally having a pH of about 5.5, but often there are toxic spots. In the upper 12 inches of the banks, soil-sized material averages about 35 percent by volume.

SUITABILITY OF SPECIES TO SITE[2]

The wide diversity of materials composing strip-mine banks is related to survival and growth of trees. Some banks are acid or calcareous, others are fine textured or coarse textured, and some contain a high percentage of rock while others are practically devoid of rock. Because banks resulting from mining different coal seams affect survival and growth of trees in different ways, plantings were established to test how certain tree species adapt themselves to a range of strip-mine bank materials. Plantings included hardwoods and pine and for some species several ages of stock. These plantations now serve as good examples of the relative performance of most of the species commonly planted on strip-mined land in Ohio.

PINES

Although pines are not planted as extensively as hardwoods on strip-mined land, they are none the less important. Species tested were white, red, shortleaf, jack, and pitch pine.

The pines tested generally had different survival and growth rates for calcareous, acid, and neutral banks (table 1, p. 29)[3]. Survival rates were usually higher for trees planted on the calcareous banks (No. 8) than on the acid banks (No. 5), but height growth was somewhat faster on the latter. Shortleaf pine was superior when survival and growth were considered jointly. Pitch pine had the best survival and height growth on the No. 5 banks in Tuscarawas County. Two-year-old white pine (2-0) did poorly on the three sites tested.

The influence of the age of stock on survival and growth was variable. Four-year-old white pine (2-2) was generally superior to 3-year-old stock (3-0) and which in turn was superior to 2-year stock (2-0). However, 2-0 red pine generally survived and grew faster than 3-0 red pine on the three sites tested. This difference probably was due to a lack of balance between the roots and shoots of the 3-0 red pine.

In 1955 the survival for all pines on these experimental plots was at least 365 trees per acre, a density considered adequate for 10-year-old pine plantations on strip-mined land. However, the height growth for these pines averaged less than a foot per year since planting.

2/ The common and scientific names of all trees mentioned in this report are given on page 38.

3/ Tables begin on page 29.

It is interesting to note that none of the pine plantations has formed a closed canopy nor accumulated much litter.

HARDWOODS

Early plantings in Ohio indicated that some hardwoods could be successfully grown on certain strip-mined land (1). However, the adaptability of many species was not tested nor were plantings made on widely divergent strip-mine land types until 1946 and 1947 when rather extensive test plantings were made of ten promising hardwood species to determine which species survive and grow best over a range of bank conditions.

The survival rate for black locust was greater than that for any of the other nine species--80 percent for the three sites tested. Likewise, black locust grew faster than any of the other species tested. After 10 years the average height of the locust ranged from 18 feet on the No. 5 banks (Tuscarawas County) to 33 feet on the No. 8 banks (Jefferson County) (fig. 4). On the latter banks many trees reached commercial size in about 10 years (table 2, p. 29).

Crowns of black locust in many plantings formed a closed canopy in 5 to 7 years and some litter has accumulated in these stands. This species is ideally suited for erosion control and soil improvement of strip-mine banks, not only because it survives and grows well but also because, being a legume, it increases the soil nitrogen supply (5). Attacks by the locust borer (*Megacyllene robiniae* (Forst.)) have severely damaged many locust plantations, lowering their usefulness for commercial purposes but not their value as a cover and nurse crop for other species.

Figure 4.--This 10-year-old stand of planted black locust on No. 8 banks contains an estimated 500-600 small posts per acre.

Three other hardwood species (yellow-poplar, Osage-orange, and white ash) were planted on both of the No. 5 banks and on the No. 8 banks. In addition cottonwood (seedlings and cuttings), green ash, a mixture of oak species, basswood, and silver maple were tested on the No. 8 banks in Jefferson County and on the No. 5 banks in Tuscarawas County. Sycamore was tested only on the No. 8 banks and 50 hybrid poplar clones were planted on No. 8 and No. 9 banks.

On No. 8 banks white ash, green ash, Osage-orange, and sycamore survived and grew better than the other species tested (table 3, p. 30). The survival rate for cottonwood from cuttings (46 percent) was less than that for the preceding four species. This cottonwood, however, reached a height of 14 feet in 9 years as compared with a height of about 5.5 feet for green ash in the same length of time. The other species tested on these banks either had low survival rates or grew slowly.

On No. 5 banks in Tuscarawas County, green ash, white ash, and silver maple planted survived and grew better than the other 7 species tested on these banks. The performance of silver maple on the No. 8 banks was much less satisfactory than on the preceding No. 5 banks. Three species were tested on the No. 5 banks in Mahoning County and white ash again proved superior.

The test of hybrid poplar clones on the No. 8 and 9 banks showed that the 5 best clones had an average survival rate of 68 percent and an average total height of more than 9 feet after 5 years. The five poorest had better survival but grew less than half as fast. In general, survival and height growth were better on the No. 9 banks (table 4, p. 30). One of the 50 varieties tested may prove to be an exceptionally fast-growing tree. In the first 5 years after planting it reached a height of about 11 feet which compares favorably to the height growth rate for black locust. However, the tests of this clone on strip-mine banks have been relatively limited whereas black locust has been tested on most types of strip-mine banks.

MIXED PLANTINGS

When first planted on strip-mine banks trees generally lack any protective vegetative cover. This condition may contribute to mortality among the seedlings before they become firmly established. On banks that have at best only a scanty vegetative cover, soil nitrogen is apt to be very low. So black locust was interplanted with other species on strip-mine banks to provide a cover quickly and to help build up the soil nitrogen supply. It was thought that the black locust increase survival and growth rates of the other trees.

Mixed plantings were established on No. 5 banks in Mahoning and Tuscarawas Counties and on No. 8 banks in Jefferson County. Black locust was planted with one or more species in row-by-row mixtures and in alternate three-row, group mixtures. Other plantings mixed locust and other species within rows so that black locust comprised 25, 50, or 75 percent of the trees in a specific plot. Species tested in mixture with black locust were white and red pine, yellow-poplar, Osage-orange, white ash, and several species of oak.

In general, survival rates for yellow-poplar, Osage-orange, white oak, and red pine were higher in the pure plantings without locust than in the mixed plantings with locust on the three sites tested. White pine survived somewhat better in mixed plantings on the No. 6 banks but on the No. 5 banks (Tuscarawas County) white pine survival was somewhat better in the pure plantings.

The effects of black locust planted in three different percentage mixtures with yellow-poplar and oak on the No. 8 banks in Harrison County and the No. 6 banks in Muskingum County could not be evaluated. First-year survival rates for yellow-poplar in this study were extremely low and the oaks were almost a complete failure, evidently because of poor-quality planting stock.

Black locust had a variable effect on survival and height growth of the associated planted trees in the row mixtures and a consistent adverse effect on the height growth of white and red pine. Undoubtedly, after the crowns of black locust close, less light reaches the trees in the understory. The number of years between planting and the break-up of the locust crown canopy varies a great deal among different stands and sites. Unless heavy borer attacks open up the locust stand in 5 to 7 years, the overtopped trees should be released from the locust before growth of these species is seriously retarded.

UNDERPLANTING DECADENT BLACK LOCUST STANDS

As has been pointed out, many black locust stands planted on strip-mine banks break-up because of borer attacks before the locust matures, making it desirable to convert to a different species. Natural regeneration on these areas is usually sparse and of poor composition. In order to insure adequate stocking of desirable species it is usually necessary to resort to artificial regeneration.

An underplanting study was made in a decadent black locust stand on ungraded No. 8 banks in Jefferson County. The area was planted to black locust during a 5-year period previous to the establishment of this experiment. A dense cover of blackberry had developed under the locust. Plantings on an adjacent mined area that had only a sparse herbaceous and tree cover served as a check on results. In addition, an adjacent old field was also planted to serve as a comparison with the plantings on the banks. Yellow-poplar, white ash, and white pine were the species planted.

White pine failed completely under the black locust; 75 percent of them died the first year. Yellow-poplar survived well for the first year but failed by the end of 5 years. White ash did best of all under the black locust; after 5 years it had 30-percent survival. All species survived better on the open banks and on the old field; after 5 years 40 percent of the yellow-poplar were still living and more than 60 percent of the white pine and white ash (table 5, p. 31).

The high mortality of the trees planted in the decadent black locust stand was caused by rabbits and dense growth of briars and herbaceous vegetation.

Because of the poor survival of the white pine and yellow-poplar planted under the black locust no comparisons of height growth can be made among the three sites for these species.

The extremely low 5-year survival rates for white pine and yellow-poplar planted in the decadent black locust stand preclude any meaningful height comparisons between these trees and those planted on the open banks or on the open field. However, the number of white ash surviving under the three conditions is adequate for making growth comparisons. White ash, however, grew about twice as fast in the locust stands as on the open bank and the old field.

Any attempt to convert a black locust stand to other species must take into account the tolerance and growth rate of the species, and the density of ground and overhead cover. The better growth made by ash in the decadent black locust stand shows that black locust is a desirable nurse tree for that species. However, to take full advantage of the beneficial effects of the locust and to minimize the adverse effects of cover, underplantings should be made before heavy herbaceous cover develops and just before the break-down of the locust overstory. If plantings can be so timed, better survival is likely and the release work will be less expensive.

PLANTING TREES IN COMBINATION WITH GRASSES AND LEGUMES

Seeding grasses and legumes in combination with tree planting was done primarily to reduce erosion and to test the effects of grass and legume cover on survival and growth of trees. Four sites were tested, including one each on No. 8 banks in Harrison (fig. 5) and Jefferson Counties, one on banks resulting from mining both the No. 5 and No. 6 coal seams in Carroll County, and one on No. 6 banks in Muskingum County.

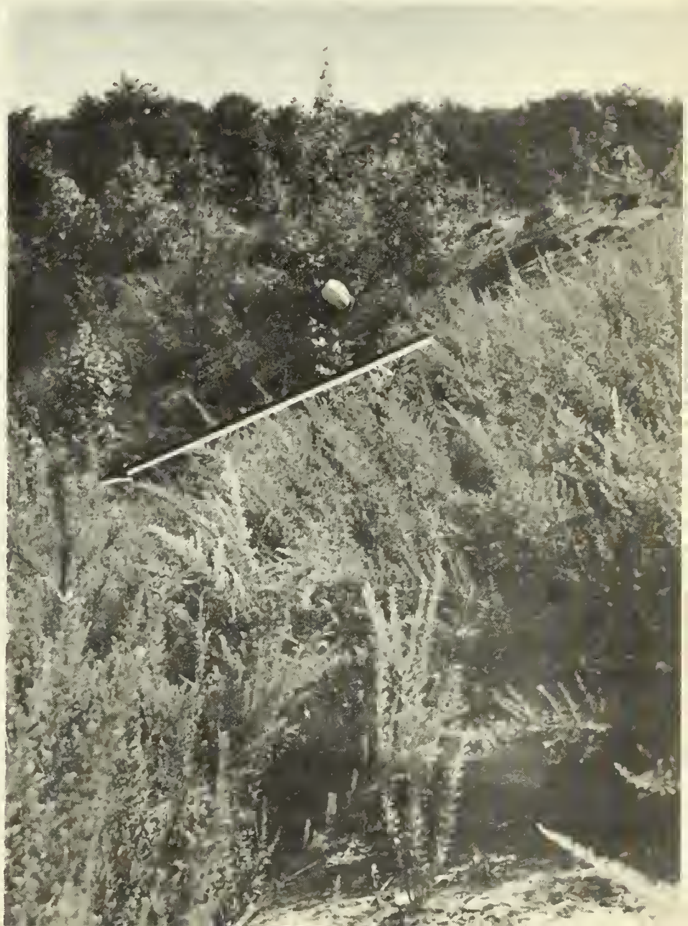


Figure 5.--White pine planted with sericean lespedeza on ungraded No. 8 strip-mine banks. Note the height of the lespedeza in relation to the height of the pine shown by arrow.

On the No. 8 banks the treatments consisted of planting red pine, white pine, green ash, and yellow-poplar in plots seeded to yellow clover and in plots seeded to a mixture of serecian lespedeza and orchardgrass. Unseeded check plots were also planted to trees. On the No. 5 and No. 6 banks the treatments were the same as for the No. 8 banks except that no seedings of yellow clover were made.

The seedings produced dense ground cover on some areas and none in others. This spotty type of cover was maintained for 10 years after seeding. After 10 years there did not appear to be any difference in degree of erosion between the seeded and check plots.

Survival for red pine was about 12 percent higher in the seeded plots than in the check plots (table 6, p. 31). Survivals for white pine and yellow-poplar were similar in seeded and in check plots. Seeding to grasses and legumes increased tree height growth less than a foot in 9 years. The height growth of green ash appeared to be retarded in the lespedeza-orchardgrass plots.

It is difficult to evaluate the effects that seeded grasses and legumes may have had on reducing erosion and on survival and growth of the planted trees due to the patchy cover that resulted. However, some of the variable survival and growth results can be attributed to the sporadic occurrence of cover on the plots. It appeared that trees growing in dense clumps of lespedeza for example were subjected to competition that may have reduced height growth, whereas between these clumps conditions were similar to the check plots. Invasion of the seeded and check plots by native herbaceous plants further complicated the situation. A complete cover of grasses and legumes would undoubtedly help to check erosion but it is unlikely that planted trees would survive or grow well under such conditions.

DIRECT SEEDING

Direct seeding to establish stands of forest trees on various sites has long been of interest to those concerned with reforestation. Heavy sod, dense vegetation, and pilfering animals often make this method unsuited to old-field conditions. However, newly formed strip-mine banks are free from vegetation as well as pilfering animals. Moreover, the sown seed comes directly into contact with the mineral soil and hence is close to the soil moisture supply.

To test the effectiveness of direct seeding on strip-mined land seeding tests were established for a number of tree species on several strip-mine bank types. Seedings were made on No. 8 banks in Harrison and Jefferson Counties, No. 6 banks in Muskingum, Carroll, and Hocking Counties, and No. 5 banks in Tuscarawas and Mahoning Counties. In one study eleven species were tested on the No. 6 and No. 8 banks: Black cherry, white ash, bur oak, black walnut, black locust, sycamore, jack, pitch, shortleaf, loblolly pine, and eastern redcedar. In a second experiment white oak and shortleaf pine were tested on the No. 6 banks in Hocking County. A third study tested black walnut and red oak in pure seedings and in row mixtures with black locust and other planted trees on the No. 5 banks (Tuscarawas and Mahoning Counties) and on the No. 8 banks in Jefferson County.

Eastern redcedar, black cherry, and white ash seed failed to germinate in the field. At the end of the first year the highest survivals were 52 percent for bur oak and 29 percent for black walnut. All of the other species had survivals of 20 percent or less. The white oak on the No. 6 banks in Hocking County was a complete failure; survival for the pine was fairly high but not sufficient to provide adequate stocking. Black walnut and red oak seedlings in pure plantings and in row mixtures on the No. 8 and No. 5 banks failed.

Direct tree seeding on ungraded strip-mine banks has generally been a failure. The reasons for failure are many but on strip-mined land it is often due to washing away or covering of seed by erosion. This has been especially true for light-seeded species. Animals from nearby fields or woods also may have destroyed some seed.

However, the trees that did survive are now making excellent growth. The strip-mine reclamation law for Ohio now requires banks to be graded to a gently undulating topography so much of the area reclaimed from now on will be more or less level or gently rolling. Direct seeding of heavy seeded species on these banks may be more successful than on ungraded banks. However, direct seeding should not be attempted where the seed may be pilfered by animals.

The poor results of direct seeding ungraded banks indicates that this method of forestation of strip-mine banks is, at present, an uncertain method of attaining adequate stocking.

Figure 6.--Comparative growth of black locust on the "cut" and "fill" sections of No. 8 graded banks in Harrison County. "Cuts" (compacted) are to the left and "fills" (uncompacted) are to the right of the man in the photo.

EFFECT OF GRADING STRIP-MINED LAND ON PLANTED TREES

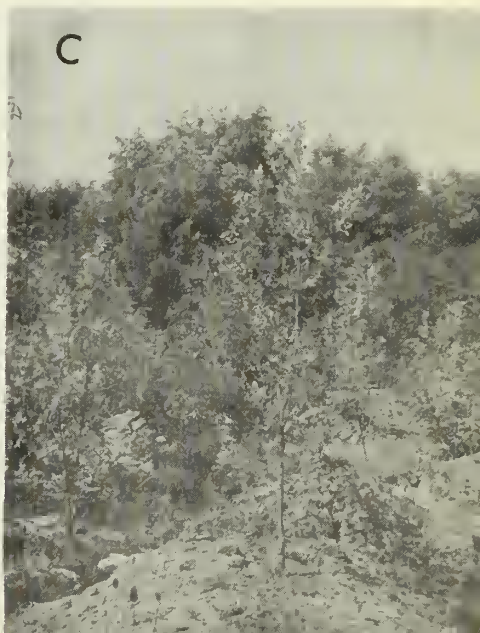
Proper aeration of the soil is important to plant growth. When soils are compacted the size of the large pores is decreased. How much pore size is reduced depends among other things on the character of the soil and the cause of the compaction. Although the degree of compaction caused by grading strip-mine banks was not measured, some compaction undoubtedly occurred, especially on the banks that had a relatively high clay content. The effect of grading strip-mine banks on survival and growth of planted trees depends on a number of things including the species planted and the type of bank.

In order to test the effect of grading strip-mine banks on the survival and growth of planted trees, white ash, yellow-poplar, and white pine were planted on graded and ungraded No. 7 banks in Columbiana County and on graded and ungraded No. 8 banks in Harrison County.

Survival of black locust on the relatively sandy textured No. 7 banks and on the clayey No. 8 banks was as good on the graded as on the ungraded banks (table 7, p. 32). Yellow-poplar, however, was almost a complete failure on graded No. 8 banks but survived as well on the graded as on the ungraded No. 7 banks. Generally, survival tended to be somewhat higher on the graded banks that contained significant amounts of shale and sandstone (No. 7 banks) than on banks having a high clay content (No. 8 banks).

Without exception, trees planted on the graded No. 8 banks grew slower than those planted on the ungraded banks (fig. 6). Trees generally grew slower on graded No. 7 than on ungraded No. 7 banks (fig. 7). It was apparent that grading banks generally retarded height growth of most of the planted trees.

Figure 7.--Ten-year-old white pine (A), yellow-poplar (B), and white ash (C) on No. 7 banks. A is graded; B and C are ungraded. Average heights of trees are 6.6, 6.7, and 10.6 feet, respectively.



As the plantation grew older the adverse effects of grading on growth became even more pronounced than when the plantations were younger (figs. 8 and 9). Black locust seems to be less affected by grading than the other three species. But even the locust on the graded No. 8 banks is not as tall after 10 years as the locust on the ungraded No. 8 banks.

No predictions can be safely made as to how long the adverse effects of grading banks on height growth will persist but there is evidence that for yellow-poplar, white ash, and white pine, these effects will continue for some years more (fig. 10).

Figure 8.--Ten-year-old black locust trees on ungraded No. 7 strip-mine banks average 29 feet in height and 3.2 inches in diameter.

Figure 9.--Ten-year-old white ash on graded No. 7 strip-mine banks average 8.4 feet in height.

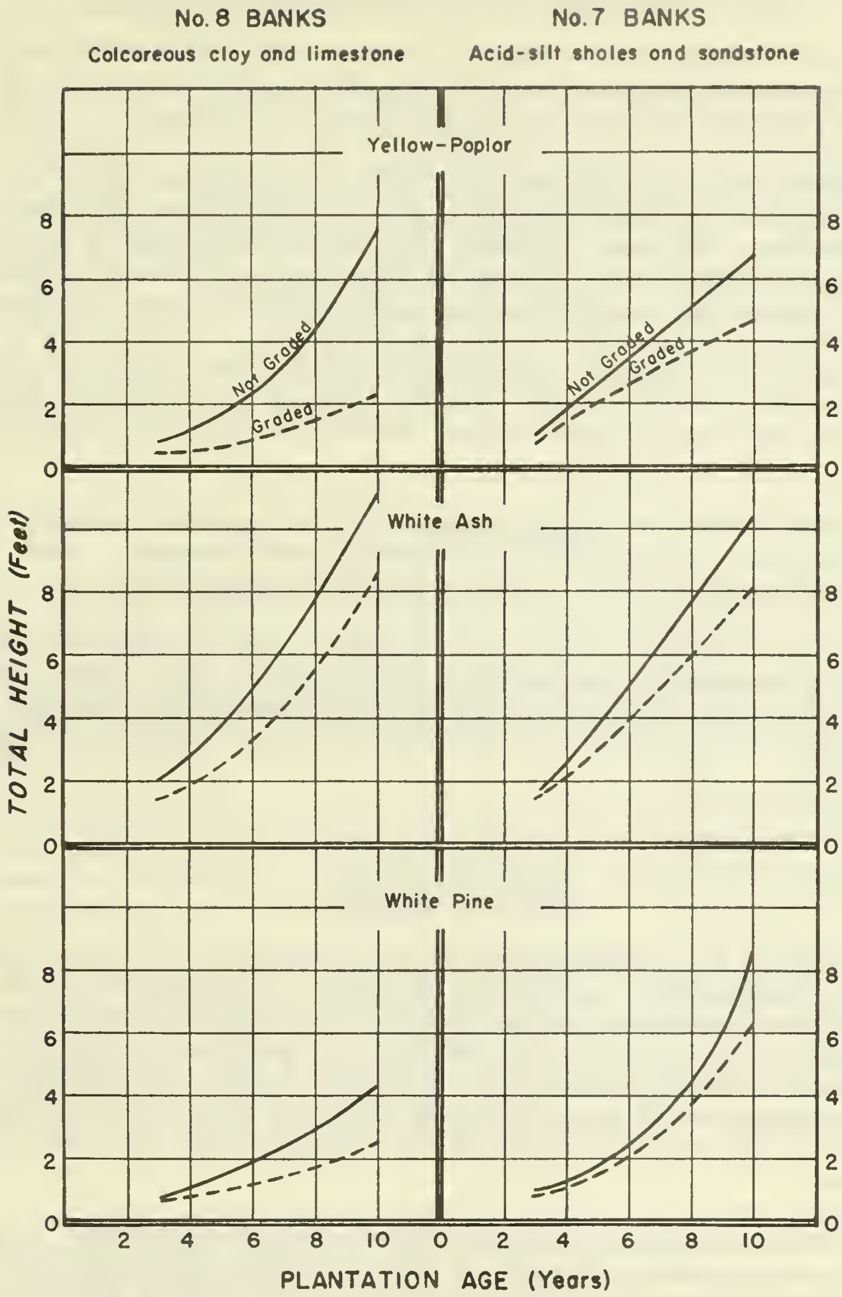


Figure 10.--Height growth of trees planted on graded and ungraded strip-mine banks.

USE OF FERTILIZERS IN PLANTATION ESTABLISHMENT

When first formed strip-mine banks are composed largely of unweathered soil material and so nutrient content may be lower than is required for the most rapid growth of trees.

Exploratory fertilization tests were established on ungraded No. 5 banks in Mahoning County. A fertilizer mixture composed of about 36 grams of diced meat scraps and about 4 grams of potassium sulfate was incorporated into the soil around yellow-poplar, white ash, and white pine trees when they were planted.

After 10 years the number of white ash and yellow-poplar surviving was greater in the treated than in the untreated plots, but white pine survived better in the untreated plots (table 8, p. 32).

Only white ash showed a marked height growth response to fertilization. The ash in the treated plots averaged a foot taller (12 percent) than those in the untreated plots.

No recommendations for fertilizing trees on strip-mine banks can be made on the basis of this limited test. More information is needed about the nutrient requirements of trees and how nearly these requirements are satisfied by the nutrients in bank materials.

PLANTING METHODS

Almost all seedlings are hand planted on strip-mine banks using a planting bar, a planting mattock, or a grub hoe. The roots of the seedlings can be placed in a slit or hole and the soil may be tamped by various means. The planting method used may affect survival and growth of planted trees. In addition, the time required to plant a given number of seedlings by various methods may be markedly different and hence affect the cost of planting.

Three methods of planting trees were tested on No. 8 banks in Jefferson County and on No. 5 banks in Tuscarawas County. The methods tested were (1) the side-hole method using a grub hoe or a mattock, (2) the center-hole method using a mattock to dig the hole and a tamper to pack the soil around the roots of the planted trees, and (3) the bar-slit method in which a bar is used to both open and close the slit in which the tree is placed. Yellow-poplar and white pine were planted by the three test methods.

White pine (2-2) and yellow-poplar (1-1) were planted on the No. 8 and No. 5 banks and, in addition, 1-0 yellow-poplar was included in the No. 5 bank plantings.

The bar-slit method was found to be the cheapest of the three planting methods tested (11) and, although its use has not always resulted in as good survival rates as the other two methods (table 9, p. 33), in general neither survival rates nor growth rates of trees planted by the bar-slit method are sufficiently lower to justify using the other two methods. The bar-slit method has been used by a private commercial company to successfully plant large areas of strip-mine banks. So, unless the banks are very hard or contain a high percentage of rock making insertion of the bar difficult, the bar-slit method can be recommended for planting most strip-mine banks.

TEST OF SOIL CONDITIONERS

In the past several years chemical substances have been developed that are capable of increasing the percentage of the coarse soil fraction in clay soils. This is brought about by the aggregation of finer soil particles into larger units making the soil coarser, which may have a significant effect on the survival and growth of planted trees.

A series of plots testing the effect of a polyelectrolytic resin soil conditioner (Krilium) on tree survival and growth was established on graded No. 8 strip-mine banks in Harrison County. These banks have a high clay content.

Yellow-poplar, green ash, and white pine were planted in the test plots. On some of the plots resin was broadcast on the bank surface at the rate of 1 pound per 100 square feet, on others resin was applied in spots where the trees were planted at an equivalent rate (14 grams per spot). Half the plots were disked and half not. Suitable non-treated check plots were included in the test.

At the end of the second year the highest survival rates for yellow-poplar and green ash occurred in the plots that had the resin applied broadcast followed by disking (table 10, p. 34). White pine survived best in plots receiving the broadcast treatment without disking. The poorest survival for all species was in plots where the surface was disked and the resin was applied in spots, suggesting a possible harmful effect on survival.

No significant height growth difference attributable to treatments is evident among the three tree species. On the basis of these results the use of a polyelectrolytic resin to improve the physical structure of strip-mine bank material cannot be recommended because the resin did not significantly increase either survival or growth. Even if survival and growth had been significantly increased, the relatively high cost of the resin would probably prevent its being used extensively in strip-mine bank rehabilitation work.

EFFECT OF ASPECT AND SLOPE POSITION ON HEIGHT GROWTH

Aspect and slope position generally have a pronounced effect on the growth of trees in forest stands. Ungraded strip-mine banks exhibit a range of aspects and slopes of varying lengths. It is reasonable to suppose that tree growth in stands on strip-mine banks would be affected by aspect and slope position. So data from plantations on ungraded No. 5 banks in Tuscarawas County and ungraded No. 8 banks in Harrison County were analyzed to evaluate the effects of aspect and slope position on planted trees.

These data were taken from two experiments testing the adaptation of species to site. Results for all pines tested--white, red, jack, pitch, and shortleaf--were combined. Likewise, average heights of several hardwoods--white and green ash, yellow-poplar, cottonwood, silver maple, Osage-orange, basswood, several oaks, and sycamore--were averaged (table 11, p. 34).

Aspect had little effect on tenth year heights of pines or hardwoods on the No. 8 banks. However, trees were taller on the northeast aspect of the No. 5 banks than on the southwest aspect.

The slope position on the No. 8 banks had no great effect on height growth of either the pines or the hardwoods. However, the heights of both pines and hardwoods on the No. 5 banks were greater on the lower slopes and bottoms than on the tops or upper slopes, probably because of the accumulation of fine soil particles (fig. 11) eroded from the tops and upper slopes (fig. 12) of these banks. On the No. 8 banks little loss of fine soil particles from the slopes is evident. The open, loose character of the No. 5 banks is conducive to erosion whereas the No. 8 banks have a high percentage of clay and are more or less compacted which prevents the fine materials from being moved easily down slope.

Figure 11.--In 10 years siltation has completely covered the lower stem of this ash tree resulting in many adventitious roots. Arrow shows ground line at time of planting.

Figure 12.--In 10 years several inches of soil have eroded away from near the top of this No. 5 bank. Arrow shows ground line at time of planting.

EFFECT OF ACID TOXICITY ON HEIGHT GROWTH

The adverse effect of high acidity (extreme low pH) on the survival of trees planted on strip-mine banks has been widely recognized. In 1946 a study was established on graded and ungraded No. 6 banks in Tuscarawas County to test the effect of grading banks on the survival and growth of planted trees. When these plantings were made it was recognized that high mortality might result on the many acid areas (pH 3.8 or lower) scattered over the banks.

At the end of the first growing season about one half of the yellow-poplar, a third of the white pine and a fourth of the white ash were dead on the leveled banks. Much of this mortality can be attributed to toxicity. Ten years after planting only a few dwarfed trees remained in some areas of the graded banks but in other portions of the plots survival was good and height growth was excellent (fig. 13). The heights of trees and pH were measured on nine paired toxic and non-toxic areas on the leveled banks.

The effect of very low pH on the growth of the planted trees is evident (table 12, p. 35). Probably the areas devoid of trees or areas on which tree growth has been markedly reduced had much lower pH values 10 years ago than they do today. That these bare areas are still toxic is evident from the fact that they have a very scanty cover of vegetation even though they are adjacent to forms of vegetation that readily invade similar but non-toxic areas.

Figure 13.--Toxic and non-toxic area on No. 6 banks 10 years after planting. The bare area in the foreground and the stunted trees are striking contrasts to the stocking and height growth of the pine on the non-toxic area further back.

Figure 14.--Ten-year-old black locust planted on No. 8 banks. Stand at left is badly damaged by locust borer; stand at right is fairly free of borer damage. The "soil" under the damaged stand is much finer in texture than that under the undamaged stand.

PLANTATION HAZARDS

Major insect damage to strip-mined-land plantations has been caused by two insects: The locust borer and the European pine tip moth. The locust borer (Megacyllene robiniae (Forst.)) damage does not greatly impair the value of black locust as a site improver or as an aid in controlling erosion, but it does reduce the tree's commercial value (fig. 14). The Forest Insects Division of the Central States Forest Experiment Station is currently carrying on studies designed to control this pest.

The European pine tip shoot moth (Rhyacionia bouliana (Schiff)) attacks red pine as well as other species of pine and causes distorted trees and a loss of height growth (fig. 15). Serious damage has been caused by this insect to red pine planted on the No. 5 banks in Tuscarawas County and lesser damage to red pine has been observed in a number of other plantations.

Figure 15.--Attacks by the European pine shoot moth gave these 8-year-old red pine this bushy appearance.

Twigs of white ash planted on the No. 7 banks in Columbiana County have been slightly damaged by cicadas (*Migicicada septendecim* (L.)).

Numerous examinations of strip-mined-land plantations have failed to disclose any apparent disease symptoms. While there may be diseases present, very little damage or loss from disease has been noted.

Rabbits and mice have caused some damage to plantations established on strip-mine land but in most cases the damage has not been severe. Rabbits damage trees by partially girdling the stems or by biting off the tops, especially yellow-poplar and red oak and to a lesser extent other hardwood species. The damage is not permanent, however, because most of the trees sprout and begin growth anew. The chief effect of rabbit damage is to retard the development of the trees affected.

Mice sometimes completely girdle and kill trees but such damage to plantations has been slight. However, mice, squirrels, and other rodents are suspected of causing failure of direct seeding attempts by pilfering the seed thereby reducing the number of potential seedlings.

NEED FOR FUTURE RESEARCH

Research done by various interested agencies has resulted in practical means of reclaiming strip-mined land by forestation. There is need, however, for continuing this research. Specific phases needing further study are discussed below.

A practical, economical way to prevent borer damage to black locust trees is needed. This would make it possible for this species to yield a commercial product as well as improve the soil and serve as a nurse crop.

ADAPTION OF SPECIES TO GRADED SITE

The present strip-mine reclamation law in Ohio requires that strip-mined land be graded to produce a gently undulating surface. Nearly all studies in the adaptations of species to site in Ohio made to date have been on ungraded banks. Although the results obtained on the ungraded banks are applicable in a general way to graded banks, more testing is needed to clearly establish which species are adaptable to the conditions found on graded strip-mined land. Existing plantations now established on graded banks throughout the strip-mine region of Ohio should be utilized fully to secure this information.

MANAGEMENT OF STRIP-MINE PLANTATIONS

Many strip-mine plantations are now reaching "manageable age". Studies are needed to determine how to economically convert decadent black locust plantations to other species through planting. Studies are also needed to determine the most economical way to release underplanted trees in black locust plantations. The problem is primarily one of timing and intensity of release. Information will soon be needed to determine how to manage pure hardwood and coniferous plantations on strip-mined land. Many existing plantations have reached a stage of development where their management can be studied.

STRIP-MINED LAND MATERIALS

Strip-mined land should be described and classified in terms similar to those used in evaluating other land for forestation. The factors studied should be related to the growth of the planted trees and readily measurable on the land. These studies could be made by examining existing plantations that now occupy a wide variety of strip-mine banks.

The problem of toxicity on strip-mined land should receive further study. Not only should the effect of pH (acidity) on the growth of trees be studied but the influence of pH on the solubility of toxic substances in bank materials should also be investigated. Studies of the chemical fertility of strip-mine sites should also be initiated. Many problems relating to toxicity of strip-mined land materials and to nutrition of trees on this land would be better understood if more were known about the reaction of the planted trees to the chemical complex of the different strip-mine types. Such knowledge would aid in selecting the species best adapted to the many strip-mine sites occurring in the mining region.

CONCLUSIONS

The initial phase of finding ways to put strip-mined land back into productive use has in a real sense been solved. The studies reported here as well as those of other agencies clearly show that a variety of trees and forage plants can be successfully grown on strip-mine banks (tables 13, 14, 15, p. 35, p. 36, p. 37). There is every reason to believe that eventually this newly restored land will grow satisfactory stands of forest trees and that the products from these stands will be of economic value. Even now some of these juvenile stands furnish posts and Christmas trees. However, these plantations must be properly managed if they are to yield the highest economic returns. Therefore, the emphasis is now shifting from rehabilitation to management. The solution of management problems will occupy a larger share of the efforts of those concerned with the problem of strip-mined land. More detailed information will be needed as the intensity of management increases.

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TABLES

Table 1.--Tenth-year survival percentages and average total heights of pine planted on three ungraded strip-mine types in Ohio

Planting stock		Plantation age	Calcareous clay and limestone pH 7.0 No. 8 banks Jefferson County		Silty-shale pH 3.0 - 5.0 No. 5 banks Tuscarawas County		Silty-shale pH 6.5 - 7.8 No. 5 banks Mahoning County	
			Survival	Height	Survival	Height	Survival	Height
		Years	Percent	Feet	Percent	Feet	Percent	Feet
White pine	2-2	10	75	4.3	75	6.7	45	5.0
	3-0	10	43	4.2	28	4.4	34	4.8
	2-0	10	37	3.6	35	5.5	10	3.1
Red pine	2-0	10	72	5.2	42	2.2[1]	59	6.2
	3-0	10	56	4.7	38	3.3[1]	49	5.4
Shortleaf pine	2-0	9	43	6.1	48	8.1	--	--
Pitch pine	2-0	9	56	4.9	86	7.7	--	--
Jack pine	2-0	8	64	5.7	--	--	--	--

1/ Damaged by European pine tip moth.

Table 2.--Ten-year results of 1-0 black locust plantings on three ungraded strip-mined types in Ohio

Planting site	Survival	Height	Diameter breast height	Posts[1] per acre
	Percent	Feet	Inches	Number
Calcareous clay and limestone--pH 7.0 (No. 8 banks, Jefferson County)	78	33	3.6	569
Acid, silty shales--pH 3.0-5.0 (No. 5 banks, Tuscarawas County)	82	18	2.2	30
Silty shales--pH 6.5-7.8 (No. 5 banks, Mahoning County)	83	25	3.0	300

1/ Seven-foot lengths, to a minimum 3-inch top.

Table 3.--Tenth-year survival and heights of hardwood trees planted on three ungraded strip-mined types in Ohio

Planting stock		Plantation age	No. 8 banks Jefferson County Calcareous clay and limestone pH 7.0		No. 5 banks Tuscarawas County Silty-shale pH 3.0 - 5.0		No. 5 banks Mahoning County Silty-shale pH 6.5 - 7.8	
			Survival	Height	Survival	Height	Survival	Height
		Years	Percent	Feet	Percent	Feet	Percent	Feet
Green ash	1-0	9	90	5.5	77	7.8	--	--
White ash	2-0	10	75	5.9	60	7.3	68	6.8
Sycamore	1-0	8	75	4.4	--	--	--	--
Osage-orange	1-0	10	62	5.9	38	6.6	42	6.0
Yellow-poplar	1-1		62 1/	3.4	22 1/	9.8	23 1/	3.4
Silver maple	1-0	9	52	4.4	78	6.8	--	--
Cottonwood	(cuttings)	9	46	14.2	38	9.5	--	--
	1-0	9	28	9.3	10 1/	8.6	--	--
Yellow-poplar	1-0		22 1/	5.0	23 1/	7.5	10 1/	4.2
Basswood	1-0	9	21	3.5	22	6.3	--	--
Mixed oaks	1-0	9	--	--	37	7.3	--	--

1/ Poor-quality planting stock.

Table 4.--Survival and average total height of cuttings of 50 poplar (Populus) hybrid clones planted on two graded strip-mine types

Plantation age (years)	Graded No. 9 banks Acid shale		Graded No. 8 banks Limestone and clay	
	Survival	Height	Survival	Height
	Percent	Feet	Percent	Feet
1	92	1.0	78	1.0
2	91	1.8	74	1.6
3	91	3.0	67	2.8
5	90	7.0	66	5.8

Table 5.--Survival and average total heights of trees underplanted in a decadent black locust stand, planted on open banks, and an open field

Species and age class		Decadent black locust stand: Survival	Decadent black locust stand: Height	Open banks: Survival	Open banks: Height	Open field: Survival	Open field: Height
		Percent	Feet	Percent	Feet	Percent	Feet
Yellow-poplar	1-1	4	3.5	42	1.1	73	2.9
White ash	2-0	30	3.7	89	1.7	76	2.1
White pine	2-2	2	.8	65	1.2	84	2.9

Table 6.--Effect of grasses and legumes on survival and height growth of trees planted on ungraded banks in Ohio, after 9 years

SURVIVAL PERCENT

Planting stock		No. 8 banks (limestone, calcareous shales and clay pH 7.0+)			No. 5 and 6 banks (silty shales, sandstone, and clay pH 4.0-5.0)	
		Lespedeza-orchard-grass	Sweet clover	Nothing	Lespedeza-orchard-grass	Nothing
Red pine	3-0	63	64	52	42	29
White pine	3-0	60	50	71	31	42
Yellow-poplar	1-0	32	30	46	10	20
Green ash	1-0	94	98	95	32	51

HEIGHT IN FEET

Red pine	3-0	3.4	3.6	3.9	4.6	4.2
White pine	2-2	3.7	3.4	3.4	4.4	3.9
Yellow-poplar	1-0	6.5	7.3	7.0	5.3	5.4
Green ash	1-0	7.4	10.3	10.1	6.3	7.6

Table 7.--Effect of grading on survival and height growth of planted trees after 10 years

NO. 7 BANKS (SANDSTONE, ACID-SILT SHALES--pH 5.0-7.0) COLUMBIANA COUNTY

Species and age class		Graded		Ungraded	
		Survival	Height	Survival	Height
		Percent	Feet	Percent	Feet
Black locust	1-0	97	29.0	93	29.0
White ash	2-0	98	8.4	95	10.6
White pine	3-0	90	6.6	60	9.0
Yellow-poplar	1-1	72	4.8	72	6.7

NO. 8 BANKS (CALCAREOUS CLAY AND LIMESTONE--pH 7.0) HARRISON COUNTY

Species and age class		Graded Survival (Percent)	Graded Height (Feet)	Ungraded Survival (Percent)	Ungraded Height (Feet)
Black locust	1-0	85	24.2	83	25.4
White ash	2-0	85	8.8	97	11.4
White pine	3-0	60	2.5	67	4.2
Yellow-poplar	1-1	6	2.3	36	7.6

Table 8.--Effect of fertilizer on survival and height growth of trees planted on ungraded No. 5 banks after 10 years

Planting stock		Fertilized		Not fertilized	
		Survival	Height	Survival	Height
		Percent	Feet	Percent	Feet
White ash	2-0	70	6.5	53	5.5
Yellow-poplar	1-1	42	3.5	25	3.4
White pine	2-0	35	3.4	60	3.3

Table 9.--Effect of planting method on survival and height growth of planted trees in Ohio after 5 years

Planting method	Planting stock	No. 8 banks Jefferson County (Clay and limestone)		No. 5 banks Tuscarawas County (Acid-silt shale and sandstone banks)	
		Survival	Height	Survival	Height
		Percent	Feet	Percent	Feet
Bar-slit	White pine (2-2)	81	1.8	43	2.3
Bar-slit	Yellow-poplar (1-1)	33	1.7	24	3.0
Bar-slit	Yellow-poplar (1-0)	35	1.3	--	--
Mattock and tamper	White pine (2-2)	80	1.6	64	2.2
Mattock and tamper	Yellow-poplar (1-1)	54	2.1	27	3.8
Mattock and tamper	Yellow-poplar (1-0)	33	1.7	--	--
Side-hole mattock	White pine (2-2)	56	1.7	35	1.6
Side-hole mattock	Yellow-poplar (1-1)	45	1.6	16	3.2
Side-hole mattock	Yellow-poplar (1-0)	36	1.5	--	--

Table 10.--Effect of polyelectrolytic resin treatment and disking on survival and height growth of trees planted on graded No. 8 banks after 2 years

DISKED

Species	Resin treatment: Broadcast: Survival	Broadcast: Height	In spots: Survival	In spots: Height	None: Survival	None: Height
	Percent	Feet	Percent	Feet	Percent	Feet
Yellow-poplar	73	1.3	30	1.0	70	1.4
White ash	80	1.0	57	.9	73	1.1
White pine	70	.8	60	.6	90	.7
NOT DISKED						
Yellow-poplar	45	1.6	40	1.2	60	1.3
White ash	67	1.0	60	1.0	77	1.0
White pine	95	.5	60	.6	75	.5

Table 11.--Effect of aspect and slope position on height growth of trees planted on ungraded banks, after 10 years

(Height in feet)

NO. 5 STRIP-MINE BANKS

Species	Aspect: Northeast	Aspect: Southwest	Slope position: Top	Slope position: Upper	Slope position: Lower	Slope position: Bottom
Pines	7.8	6.6	6.0	7.1	7.9	9.5
Hardwoods	8.3	6.8	6.7	6.5	8.2	10.1
NO. 8 STRIP-MINE BANKS						
Pines	5.1	4.9	--	5.2	5.1	--
Hardwoods	4.8	4.9	--	6.4	6.2	--

Table 12.--Effect of toxicity on 10-year height growth of trees planted on No. 6 graded banks

Planting stock	Non-toxic area: Average total height	Non-toxic area: Surface acidity (1955)	Toxic area: Average total height	Toxic area: Surface acidity (1955)
	Feet	pH	Feet	pH
Yellow-poplar (1-1)	14.0	4.6	5.3	4.0
White ash (2-0)	11.5	5.1	7.2	4.0
White pine (3-0)	6.7	4.8	2.6	4.4

Table 13.--Relative success for a number of tree species used in forestation of strip-mine land in Ohio

Species[1]	Relative success by strip-mine land variables[2]: Graded banks		Ungraded banks		Bank aspect		Slope position	
	Acid	Calc.	Acid	Calc.	N-E	S-W	Upper	Lower
Green asb	-	-	G	G	G	G	G	G
White asb	G	G	G	G	G	G	G	G
Basswood	-	-	F	P	F	F	F	F
Cottonwood	-	-	P	F	F	F	F	G
Cottonwood (cuttings)	-	-	G	G	G	G	G	G
Kentucky coffeetree	F	F	F	F	-	-	-	-
Black locust	G	G	G	G	G	G	G	G
Silver maple	-	-	G	G	G	G	F	G
Cbestnut oak	F	F	F	F	-	-	-	-
Northern red oak	-	-	F-G	F	F	F	F	G
White oak	-	-	F	P	F	F	F	G
Osage-orange	-	-	G	G	G	G	G	G
Hybrid poplar (cuttings)	G	G	-	-	-	-	-	-
Yellow-poplar	F	P	G	G	G	G	F	G
Sycamore	-	-	G	-	G	G	F	G
Eastern redcedar	-	-	F	-	F	F	F	F
Eastern white pine	G	P-F	G	G	G	G	F	G
Jack pine	-	-	-	G	G	F	G	G
Pitcb pine	-	-	G	F	G	G	F	G
Red pine	-	-	F	G	G	G	F	G
Shortleaf pine	-	-	G	G	G	G	F	G
European larch	F	F	F	F	-	-	-	-

1/ 1-3-year-old seedlings.
2/ G = Good; F = Fair; P = Poor.

Table 14.--Tolerance of tree species to extreme acidity and herbaceous cover

Species	Tolerance to: Acidity as low as pH 4.0	Tolerance to: Heavy herbaceous cover
Green ash	G	G
White ash	G	G
Basswood	F	F
Cottonwood	P	F
Cottonwood cuttings	F	F
Kentucky coffeetree	F	-
Black locust	G	G-F
Silver maple	G	F
Chestnut oak	F	-
Northern red oak	F	F
White oak	F	F
Osage-orange	G	F
Hybrids poplar	F	F
Yellow-poplar	P	P
Sycamore	G	F
Eastern redcedar	F	-
Eastern white pine	G	F-G
Jack pine	-	F
Pitch pine	G	-
Red pine	G	F
Shortleaf pine	G	F
European larch	F	-

G = Good
F = Fair
P = Poor

Table 15.—Comparative rating of species for planting on strip-mined land in Ohio

Species	Overall rating	Remarks
Green ash	Good	Adapted to all plantable strip-mine sites but is best suited to moist sites. On barren banks should be planted in mixture with black locust (25 percent) or other hardwoods.
White ash	Good	For best growth should be planted on lower slopes and bottoms of banks having a high percentage of clay and loam. Will tolerate compaction caused by grading banks having a high clay content. Can be planted in mixture with black locust (25 percent).
Basswood	Fair	Grows best on lower slopes and bottoms. Can probably be planted in mixture (25 percent) with black locust.
Cottonwood	Good - Fair	Adapted to a wide variety of strip-mined land. Good planting stock essential.
Cottonwood (cuttings)	Good	Same as cottonwood. Tests showed that the cuttings survived and grew faster than the seedlings.
Black locust	Good	Better early survival and growth on most sites than any other species tested. On clay sites stands begin to break up after about 7 years because of borer attack. This species is valuable as a nurse tree and as a site improver.
Silver maple	Good - Fair	Adapted to most plantable strip-mined land but makes fastest growth on moist sites. Can be planted with black locust (25 percent). Tends to form multiple sprouts.
Chestnut oak	Fair	Is adapted to drier sites but grows faster on more moist sites.
Northern red oak	Fair	Should be planted on lower slopes for fastest growth. Sites should have a high percentage of soil. Can be planted in mixture (25 percent) with black locust but locust should not be permitted to overtop the oaks.
White oak	Poor	Grows slowly. Should only be planted on medium acid to calcareous sites having high loam and clay content. Should not be planted on ridges or upper slopes.
Osage-orange	Good	Does well on most strip-mined land, either in pure stands or in mixture (25 percent) with black locust.
Hybrid poplars (50 tested)	Good	Suitable for planting on most graded strip-mined land. Survive well and grow rapidly.
Yellow-poplar	Fair	Should only be planted on lower slopes and bottoms of banks composed of loamy and well-drained clayey material. Should not be planted on very acid banks. Can be planted with black locust (25 percent). Locust should not be permitted to overtop the poplar for more than 3 years.
Sycamore	Good	Very suitable for planting moist sites but also grows well on mid-slopes. Can be planted with black locust (25 percent).
Eastern redcedar	Fair	Grows well with black locust or in pure stands on calcareous, strip-mined land. Very limited plantings in Ohio.
Eastern white pine	Fair - Good	Should not be planted with black locust or other species that will overtop it. Plantings should be confined to relatively coarse-textured strip-mine sites having high percentage of soil. Does not grow well on calcareous, fine-textured bank material.
Jack pine Pitch pine	Good Good	Should not be planted with black locust or other species that will overtop it. Will grow on relatively dry ridges but grows faster on lower slopes.
Red pine	Poor - Good	Red pine plantations have been severely damaged by the European pine shoot tip moth. Plantings should not be made in areas of known infestation.
Shortleaf pine	Good	Adapted to a wide variety of strip-mined land but grows best on moderately acid sites. Should not be planted with black locust or with species that will overtop it. Plantings should be confined to the southern half of the State.
European larch	Fair	Should be planted in pure stands. On relatively moist sites containing some coarse-textured material this tree may grow well especially in the northern half of the State.

TREE SPECIES MENTIONED

Common and scientific names of tree species listed in the study from "Check List of Native and Naturalized Trees of the United States (Including Alaska)", by Elbert L. Little, Jr.

Common Name	Scientific Name
American basswood	Tilia americana L.
American sycamore	Platanus occidentalis L.
Ash	
green	Fraxinus pennsylvanica Marsh.
white	F. americana L.
Black cherry	Prunus serotina Ehrh.
Black locust	Robinia pseudoacacia L.
Black walnut	Juglans nigra L.
Eastern cottonwood	Populus deltoides Bartr.
Eastern redcedar	Juniperus virginiana L.
European larch1/	Larix decidua Mill.
Kentucky coffeetree	Gymnocladus dioicus (L.) K. Koch
Oak	
bur	Quercus macrocarpa Michx.
chestnut	Q. prinus L.
northern red	Q. rubra L.
white	Q. alba L.
Osage-orange	Maclura pomifera (Raf.) Schneid.
Pine	
eastern white	Pinus strobus L.
jack	P. banksiana Lamb.
loblolly	P. taeda L.
pitch	P. rigida Mill.
red	P. resinosa Ait.
shortleaf	P. echinata Mill.
Poplar	Populus X varieties
Silver maple	Acer saccharinum L.
Yellow-poplar	Liriodendron tulipifera L.

1/ This species is not included in the Check List.

Agriculture - Forest Service - Columbus, Ohio

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