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A Guide for Revegetating Coal Minesoils in the Eastern United States

by Willis G. Vogel

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ABSTRACT

This report provides information, recommendations, and guidelines for revegetating land in the Eastern United States that has been disturbed by coal mining. Included are brief descriptions of major coal mining regions in the East, and a discussion of minesoil properties and procedures for sampling, testing, and amending minesoils. Plant species that have been used for revegetating surface-mined lands are identified and described. Selection criteria for plant species and methods and requirements for seeding and planting are explained. Some of the data on tree species used in reforestation were obtained from recent surveys of 30-year-old experimental plantings in several Eastern States.

FOREWORD

The mining of coal, especially surface mining, often is dangerous to environmental resources. Existing vegetation is destroyed, ecosystems are altered, and unreclaimed areas are visually displeasing. One of the adverse effects of mining and vegetation removal is the degradation and pollution of water resources. Erosion on raw exposed minesoils can contribute large quantities of sediment to streams. Where the overburden contains acid-bearing rocks, streams also are polluted with toxic chemical substances.

The revegetation of land disturbed by coal mining is necessary primarily for controlling runoff, erosion, and sedimentation. Simultaneously, the establishment of vegetation improves the visual quality of mined areas and aids in or contributes directly to restoring mined land to productive uses.

The principles and guidelines in this report are applicable primarily to past and current surface-mining operations; they may also apply to surface disturbances caused by underground mining. This report is not directed to the establishment of agricultural crops on areas designated as "prime farmland," though many of the revegetation principles and practices will apply.

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CONVERSION TABLE - ENGLISH TO METRIC

English Unit	Metric Unit	Conversion Factor
	Length	
inch, in	centimeter, cm	2.54
foot, ft	meter, m	0.305
mile, mi	kilometer, km	1.609
	Area	
square feet, ft^2	square centimeters, cm^2	929.030
acre, acre	hectare, ha	0.405
	Weight	
pound, lb	kilogram, kg	0.454
short ton, ton	tonne, t	0.907
short ton, ton	kilogram, kg	907.184
	Volume	
gallon, gal (liquid)	liter, l	3.785
cubic yard, yd^3	cubic meter, m^3	0.764
	Yield or Rate	
pounds/acre	kilogram/hectare	1.121
short tons/acre	tons/hectare	2.242
cubic yards/acre	cubic meters/hectare	1.886
gallons/acre	liters/hectare	9.346
	Temperature	
Fahrenheit, °F	Celsius, °C	0.555(F-32)

SECTION 1

INTRODUCTION

ENVIRONMENTAL IMPACTS OF COAL MINING

Coal is a major fuel for generating electrical energy in the Eastern United States. But the surface effects of mining coal often cause environmental damage. Ecosystems in mined areas, especially where surface mined, are drastically altered and traditional land use patterns are disrupted. Existing vegetation is destroyed on the mined sites, and soil and soil organisms often have been buried or mixed with the other geologic materials that were overturned in the mining process. The habitat for wildlife is altered or eliminated, at least temporarily, and the unreclaimed mined sites are esthetically unpleasant.

Perhaps the most serious impact of coal mining on the environment in the Eastern United States is the degradation and pollution of the water resource, especially in the mountainous Appalachian Region. Hydrologic patterns in mined areas are changed. Results of hydrologic studies have shown that during surface mining and before reestablishment of vegetation, the peak flows are higher in streams in mined watersheds than in unmined. Erosion on raw exposed mined land contributes large quantities of sediment to streams and rivers. The environment for aquatic life is drastically altered, and many of the fauna are killed. Where mined land is acid, streams are further polluted with chemical substances that are toxic to aquatic plants and animals.

REASONS FOR REVEGETATING MINED LANDS

In the East, revegetating lands disturbed by mining is necessary primarily for controlling runoff, erosion, and sedimentation. In fact, results of hydrologic research have shown that after surface-mined areas are fully revegetated, peak flows are actually lower in streams in mined watersheds than in nearby unmined forested watersheds. At the same time, the establishment of vegetation improves the visual qualities of mined areas and usually is oriented toward returning the mined land to a productive use. Some land uses, such as pasture, hayland, wildlife habitat, and production of some agronomic crops, can sometimes be restored or enhanced with the same plant species that are used to establish the initial vegetative cover. Where reforestation and wildlife habitat are the land use goals and erosion control is needed, herbaceous species are planted primarily for immediate erosion control, and trees and shrubs are planted to satisfy the long-range land use objective. Thus, all three revegetation objectives--erosion control, land productivity, and esthetics--are accomplished.

PURPOSE AND SCOPE OF REVEGETATION GUIDE

The primary purpose of this guide is to provide information, principles, and guidelines for vegetating lands disturbed by coal mining in the eastern half of the United States. These lands include many of the current surface-mining operations and surface areas disturbed by underground mining, as well as unreclaimed abandoned or orphan mines and mine refuse piles. The guide was prepared with the assumption that it will be applicable primarily where mining and grading of the surface are completed and the mined areas are ready for the various steps of the revegetation program--sampling and analyses of minesoil, application of amendments, seedbed preparation, plant species selection, and planting of vegetation. The guide does not provide specific requirements or treatments for reclaiming mined areas designated as "prime farmland," though some of the revegetation principles will apply.

Identified and described are plant species that have been used for revegetating mined lands. The selection and establishment of vegetation for conservation purpose, mainly erosion control and watershed protection, are emphasized. But, guidelines and principles also are given for selecting and establishing vegetation for other land uses such as forestry, wildlife habitat, and some agricultural uses. Procedures and principles for sampling, testing, and amending minesoils are discussed. Ideally, each of these steps will be anticipated by mine operators and included in their premining reclamation plan.

The information in this guide is derived from numerous sources, including research and administrative publications of Federal and State agencies and private organizations; direct communications with reclamation specialists in the surface-mining industry and with others engaged in surface-mine reclamation research, administration, and application; and first-hand research and experience by the author and his colleagues. Some of the reforestation recommendations are based on recent surveys of experimental tree plantings that were made about 30 years ago by the Forest Service and several State agricultural experiment stations. References containing information pertinent to revegetating coal surface mines are listed in the bibliography. Included in these references are revegetation guides published by government agencies or private organizations for specific States. Persons involved in surface-mine reclamation also should refer to guides for their respective State.

REVEGETATION PLANNING AND REGULATIONS

Mine operators should be aware of Federal and appropriate State regulations that pertain to the revegetation of lands disturbed by coal mining. For example, Section 780.18 of the regulations promulgated under the Surface Mining Control and Reclamation Act of 1977 requires that each permit application contain a plan for revegetating the mined area. The plan should include a schedule of revegetation activities such as the plant species to be used, the amount of seed or number of seedlings per acre, the planting and seeding methods, mulching materials and methods, and fertilizers and lime and application rates.

The regulations also include requirements for contemporaneous or timely reclamation, period of operator responsibility, topsoil removal and redistribution, tree and shrub stocking standards, ground cover, and land use considerations. These requirements may vary by State but will be at least as stringent as the Federal requirements. Thus, operators should consult State and Federal regulations as their first step in revegetation planning.

SECTION 2

COAL MINING REGIONS

The eastern half of the United States includes three major bituminous coal regions--the Appalachian, the Eastern Interior, and the Western Interior. Anthracite coal is found in the northern end of the Appalachian Region and mineable lignite is found in Arkansas, Louisiana, and eastern Texas (Figure 1). The bituminous coal regions lie mostly within a zone that has an average annual precipitation of about 35 inches or more (Figure 2), and a mean annual temperature that ranges from about 50° to 65°F.* The topography of the Eastern United States ranges from nearly level in portions of Illinois and eastern Kansas to mountainous in the Appalachian States. In general, revegetation problems and practices are similar in all the coal regions; however, local geologic, topographic, and climatic environments create unique problems in each that must be dealt with accordingly.

APPALACHIAN COAL REGION

Geology

The Appalachian coal fields cover approximately 72,000 square miles in parts of nine States, extending from Pennsylvania to Alabama. The coals of Appalachia are of Pennsylvanian Age, and are essentially coextensive with the Appalachian Plateau physiographic province. The most abundant coal-bearing rock types in Appalachia are the fine-grained siltstones and shales. Although less abundant, sandstones and conglomerates are conspicuous because of their resistant nature, frequently forming bold outcroppings and capping mountains. Limestone is prevalent in western Pennsylvania and Ohio, but in the rest of Appalachia, where present at all, lime is found mostly in calcareous shales or as a cementing agent in sandstones and siltstones. The coal beds are distributed throughout the sequence of Pennsylvanian rocks.

Many of the coal-bearing strata contain varying amounts of the mineral pyrite, which is of considerable importance because of its potential for producing acid spoil and acid-mine drainage. However, with local exceptions, the patterns of acid-mine drainage affecting major stream systems indicate that this problem is most prevalent in Pennsylvania, portions of eastern Ohio, a

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*English units are used in deference to the majority of the readers for whom this guide is intended. An English to metric conversion table is on page x.

Figure 1. Coal regions of the Eastern United States: (1) Appalachian; (2) Eastern Interior; (3) Western Interior; (4) Anthracite; (5) Lignite.

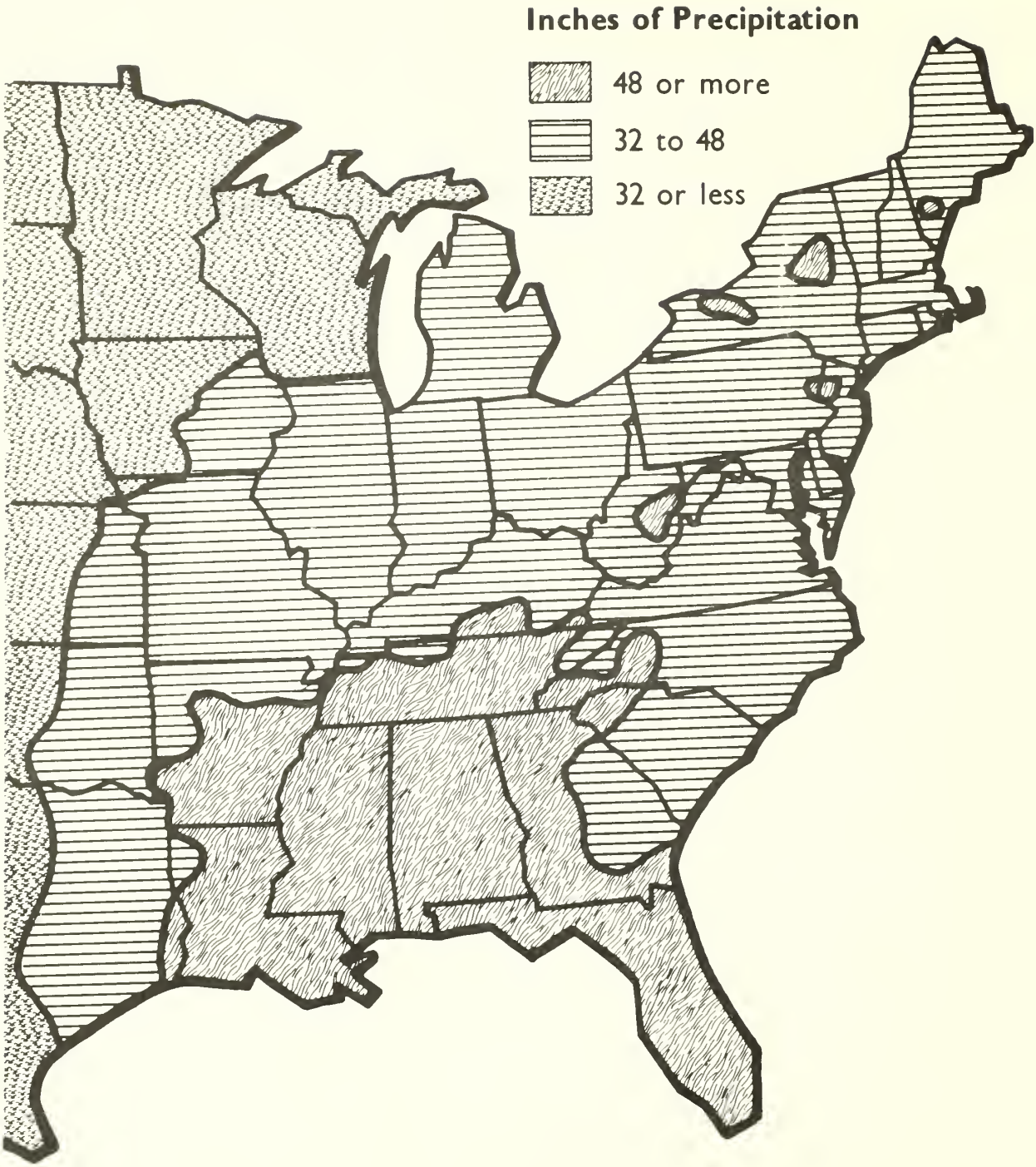


Figure 2. Average annual precipitation for the precipitation zones of the Eastern United States.

band along the boundary of Kentucky with West Virginia and Virginia, and an area in north-central Tennessee. Coal-bearing strata that, chemically, are strongly alkaline are found in a few areas, but are of minor consequence to the region.

Physiography

The Appalachian Coal Region occupies a high plateau that in most parts has been deeply incised by a dendritic stream pattern, giving rise to a rugged mountainous terrain. Altitudes range from 900 to 4,800 feet, with relief in the mountainous areas ranging from 500 to 1,500 feet. Slopes exceeding 30° are common throughout much of the region, with steeper slopes and vertical cliffs along major rivers. Terrain of this nature has necessitated contour and mountain-top-removal mining methods and has created severe erosion and stream sedimentation. In addition, transportation is hampered by the difficulty and expense of building and maintaining roads and railways.

Climate

Precipitation over all of Appalachia averages 47 inches annually. It ranges from 35 inches in Pennsylvania and progressively increases southward to a high of 55 inches in Alabama. The precipitation is fairly well distributed throughout the year. Approximately one-half is lost through evaporation and transpiration. Short periods of dry weather occur infrequently, usually in mid to late summer.

Average annual temperature ranges from about 50°F in Pennsylvania to a little over 60°F in Alabama. Average maximum temperature ranges from about 90° to 100°F, while average minimums range from around -10° to 10°F. Seasonal temperature variations as well as rainfall are strongly influenced by local topographic extremes. Some mountain tops and adjacent valleys experience nearly as much climatic variation as occurs between Pennsylvania and Alabama.

Vegetation

Mixed hardwood forest is the predominant natural vegetation type in most of the Appalachian Region. On the average, forest vegetation still occupies about 85 percent of the land area that is being mined. Nonforested lands are mainly those where the topography has allowed the development of agricultural land uses, primarily pasture.

Cutting of merchantable timber without regard to forest management principles has been a continual process on much of the forested land since original settlement. Today, much of the private forest land is poorly managed or unmanaged and is stocked primarily with low-quality trees, both in species and in form.

EASTERN INTERIOR COAL REGION

Geology

As with the Appalachian Region, the coals of the Interior Regions are of Pennsylvanian age and the coal-bearing strata are predominantly shales, siltstones, and sandstones. However, in the Interior Regions a repeating marine influence is more strongly seen; hence, limestones are more common than in Appalachia.

The marine influence is also seen in the more abundant highly pyritic black shales, especially in southern Illinois and western Kentucky. This shale causes problems with acid spoils and acid-mine drainage. In some areas, shallow underground mines, worked out in the past, have been broken into by subsequent surface mining. This has released copious flows of extremely acid water that has damaged streams and nearby agricultural and forest lands subject to flooding. In other situations, surface mining has sealed or eliminated old underground mines and reduced the flow of acid water.

Physiography

The Eastern Interior Coal Region lies almost entirely within Illinois, Indiana, and the western part of Kentucky, with very minor extensions into Iowa and Missouri (Figure 1). Most of the area in Illinois and Indiana lies within the Central Lowlands physiographic province, while the portion in Kentucky and extreme southern Illinois and Indiana is in the Interior Low Plateaus. The boundary between these two physiographic provinces marks the southern limit of glaciation.

The Central Lowlands, in the vicinity of the coal fields, consists of broad level uplands between steep-sided valleys with broad floodplains. This area is covered with glacial till and loess deposits that, toward the Mississippi River, reach 30 feet in thickness.

The Interior Low Plateaus consist of a slightly westward sloping plateau that is deeply entrenched with meandering rivers. This area has more relief than that to the north, but is still gently rolling. The low, gently rolling topography of the Eastern Interior Coal Region has allowed extensive area-type surface mining and an easily developed road, rail, and river barge transportation system.

Climate

Precipitation in this coal region averages 40 to 50 inches annually, and normally is most abundant during the growing season. Occasionally, there are extended dry periods that jeopardize the establishment of newly seeded and planted vegetation. The spring and summer rains often occur as severe thunderstorms, sometimes with damaging winds, hail, and flooding. Temperature ranges are extreme, with average minimums of -10°F and average maximums of above 100°F. The annual average temperature is about 55°F.

Vegetation

Mixed hardwood forest originally covered much of the Eastern Interior Coal Region, primarily the eastern and southern portions; and tall grass prairie occupied much of the northwestern part of the region. Today, much of the land in this region is used for agriculture. It includes some of the most productive cropland in the nation, especially in the Central Lowlands. Forests occupy most of the land that has not been developed for agriculture and urbanization. In Illinois, about 30 percent of the surface mining is on forested land. This percentage is higher in Indiana and western Kentucky.

WESTERN INTERIOR COAL REGION

Geology

The coals and coal-bearing strata in the Western Interior Coal Region are of Pennsylvanian age and similar to those in the Eastern Interior Region. However, problems with acid drainage from worked-out underground mines and with flooding of adjacent lands are less severe than in portions of the Eastern Interior Region. Minesoil toxicity resulting from acid-bearing strata is relatively minor for the region as a whole, but is serious in some localities. The rock strata dip to the west-northwest; thus, the coal outcrops are on the eastern edge of the region.

Physiography

The Western Interior Coal Region lies within Iowa, Nebraska, Kansas, Missouri, Oklahoma, and Arkansas (Figure 1). The northern portion of this coal region is in the Dissected Till Plain section of the Central Lowland physiographic province. The southern part, lying in Kansas and Oklahoma, is in the Osage Plains and the small area extending into Arkansas falls within the Ozark Plateaus.

The Dissected Till Plain has been glaciated and, hence, is of low relief that ranges from 100 to 300 feet. The glacial till of this area is covered in the more eastern parts with up to 30 feet of loess.

The Osage Plains lies south of the glacial limit so it is of greater relief than the glaciated area of the Central Lowlands to the north. Most of the Osage area consists of upland plains with deeply entrenched rivers, some with valleys a few hundred feet deep.

The Ozark Plateaus resemble the Appalachian Province, but altitudes and relief average lower than in the Appalachians. A maximum altitude of 2,000 feet is reached in the southern part of this province.

Climate

The climate of the Western Interior Coal Field is essentially like that of the Eastern Interior Coal Field, but less humid. Average annual precipitation ranges from about 30 to 40 inches, and is most abundant during the grow-

ing season. However, there can be extended periods of drought. Temperatures are extreme and range from -20°F to over 100°F. This area is even more prone than the other regions to severe spring and summer storms, often with damaging winds, hail, and tornados.

Vegetation

The natural vegetation in much of this region was an intermingling of hardwood forest and tall grass prairie. The eastern and southernmost portions of the region were mainly forested; the western and northernmost portions were primarily tall grass prairie. Most of the prairie areas have been tilled and today are used as pasture or cropland. Some of the forested areas also have been cleared for agricultural uses.

LIGNITE REGION

Mineable lignite is found in the Eastern United States in portions of Arkansas, Louisiana, and eastern Texas. This manual includes limited information on plant species for revegetating land that has been surface-mined for lignite. Undoubtedly, though, many of the problems of revegetation, practices, and recommendations described are applicable to lignite surface mines.

SECTION 3

MINESOILS

PROPERTIES THAT AFFECT VEGETATION ESTABLISHMENT

Minesoils, also called spoils, are the geologic materials that, in surface mining, are removed from above beds of coal. The amounts of the different geologic materials and the manner in which they are handled and mixed during mining and grading directly affect the chemical, physical, mineralogical, and biological properties or characteristics of minesoils. These properties can affect plant growth and should be identified before planting, even where topsoil is reapplied. This knowledge is especially needed for identifying and treating those minesoils with properties that limit or prevent the establishment and growth of vegetation. Ideally, this knowledge also can be helpful in selecting plant species that are best suited or adapted to specific sites or minesoil conditions, especially where the site cannot be changed to suit a given species.

Chemical Properties

The chemical properties of minesoils that are of most concern in revegetation are chemical reaction (pH), acid-induced toxicities, and nutrient deficiencies.

Soil Reaction (Acidity or Alkalinity)--

Soil reaction is the degree or intensity of soil acidity or soil alkalinity expressed as pH. The pH scale ranges from 0 to 14. A pH of 7 is neutral in reaction; lower values indicate acidity and higher values indicate alkalinity. The pH scale is logarithmic, i.e., the intensity of acidity or alkalinity changes tenfold with each unit change in pH. For example, a pH of 4.0 is 10 times more acid than a pH of 5.0 and a pH of 3.0 is 100 times more acid than a pH of 5.0.

Soil reaction (pH) is probably the most useful criterion for predicting the capacity of minesoil to support vegetation. Not only is plant growth affected by pH, but inferences can also be made about other qualities. For example, the availability of some plant nutrients is limited in both extremely acid and strongly alkaline soils, but these nutrients are available to plants in soils that are moderately acid to slightly alkaline.

Minesoils in the East are mostly in the acid range (pH below 7.0), though some are mildly to moderately alkaline (pH 7.0 to 8.5). Problems with revege-

tating the alkaline minesoils are few. Problems with revegetating acid minesoils are more common, especially those that are extremely acid (pH 4.0 and lower). Oxidation of iron sulfides found in the coal and overburden strata is the primary cause of extremely acid and toxic minesoils.

Some plant species are more tolerant of acid conditions than others. Therefore, by knowing the pH of a minesoil, species tolerant of a given pH range can be selected for revegetation purposes. As a general rule, most plant species will grow in minesoil with a pH higher than 5.5. A more limited number will grow in the pH range 4.6 to 5.5. Even fewer species of plants can tolerate minesoil pH below 4.5, and only a very few will grow where pH is below 4.0 (Figure 3). However, these limits can vary in different minesoils depending on the chemical and physical characteristics of the rock constituents of each minesoil.

A pH reading on minesoil also can indicate where an amendment such as lime is needed to neutralize acidity. On some acid minesoils, attempting to establish acid-tolerant plants may be more practical than decreasing acidity with amendments; but on extremely acid minesoils there is no choice. Lime or

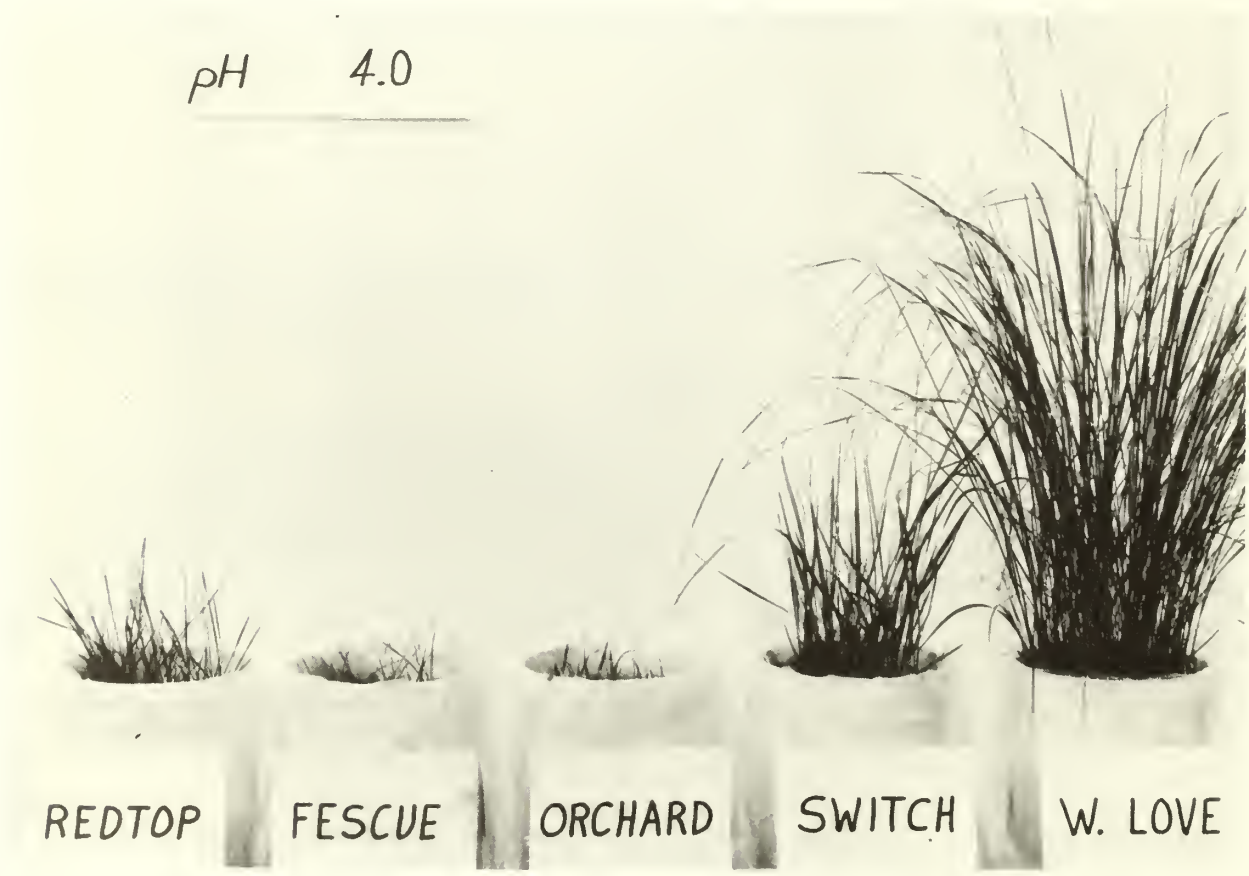


Figure 3. Weeping lovegrass--one of the more acid-tolerant plant species.

some other treatment must be applied to lower or neturalize the acidity if plants are expected to grow. Details on liming and other amendments are presented in Section 5.

Sampling and analyzing overburden strata before mining begins provide an opportunity to predict and prevent problems associated with acid minesoils. Procedures for covering or blending acid-producing materials with nonacid overburden materials or topsoil should be incorporated in the mining operation.

Acid-Induced Toxicities--

Although pH is an indicator for assessing acidity and predicting plantability of minesoils, it does not always explain all of the chemical problems that can be associated with revegetating a particular site. An imbalance of elements, an excess of one element, or a high level of dissolved solids (salts) can be more deleterious to plant growth than acidity itself. For example, elements such as aluminum, iron, manganese, copper, nickel, and zinc that are present in some minesoils become increasingly soluble as the pH decreases below 5.5. When the concentration of these elements exceeds certain levels in the soil solution, they become toxic to plants and interfere with establishment and growth. The concentration of these toxic elements is greater in some geologic materials than in others; therefore, different minesoils, even with the same pH, may not have the same effect on plant growth. Plants may grow satisfactorily in one minesoil with a pH of 4.5 but not grow at all in others with the same pH. Thus, plant species cannot be assigned definite pH tolerance limits that are correct for all minesoils.

Aluminum and manganese are the elements found most often in concentrations toxic to plants. The primary effect of aluminum toxicity is to reduce or inhibit root growth. Manganese toxicity results primarily in reduced shoot growth. In legumes, symptoms of manganese toxicity are expressed by chlorosis (yellowing) of leaf margins sometimes coincident with rust-colored spots on the leaflets.

A recommended practice for treating acid minesoil is to raise the pH to 5.5 or higher by applying lime. At pH 5.5 most of the toxic elements will be precipitated from the soil solution and will no longer have harmful effects on plants.

Nutrient Deficiencies--

Minesoils most often are deficient in nitrogen and phosphorus (Figure 4). Nitrogen is nearly always deficient, especially where topsoil and associated organic materials were removed and buried during mining. Establishment of herbaceous vegetation is always hastened by the application of nitrogen fertilizer.

Plant-available phosphorus is adequate in some overburden materials, but more often it is deficient. Reasons for phosphorus deficiency include: (1) the overburden materials may contain only small amounts of phosphorus-bearing minerals; (2) the phosphorus compounds that are present are insoluble,

Figure 4. Response of vegetation to Nitrogen (N) and Phosphorus (P) fertilizer typical on most minesoils.

especially in very acid and alkaline materials; (3) there is no reservoir of organic phosphorus compounds. Application of phosphorus fertilizer is necessary on minesoils deficient in phosphorus, and it usually hastens the establishment of herbaceous cover even on minesoils that contain plant-available phosphorus in amounts adequate for plant growth.

Plant-available potassium is adequate for plant establishment in most coal minesoils because clay minerals, micas, and some feldspars that constitute a source of potassium usually are present in the overburden materials. Thus, the use of potassium fertilizer usually is not needed to establish vegetation. However, where vegetation is repeatedly harvested and removed, fertilization with potassium may subsequently become necessary. Similarly, potassium levels may in time be reduced by natural weathering and leaching.

Undoubtedly, there are deficiencies of other nutrients on some minesoils, but most of these have not yet been defined by researchers. It is known that on some minesoils, imbalances between calcium and magnesium hinder the establishment and vigorous growth of vegetation.

Physical Properties

Physical properties of minesoils such as stoniness, distribution of particle sizes, bulk density, slope angle, length of slope, color, aspect,

erodibility, and stability can influence the selection, establishment, and growth of vegetation. Some of these properties are difficult to change, whereas others can be altered by earth moving and grading. The adverse effects related to some properties such as dark color and aspect can be altered by mulching the surface. Often, though, adverse physical problems are accepted with the hope that natural weathering processes and vegetation will eventually alter and improve these conditions.

As with chemical problems, the best solution to physical problems is to prevent them. A premining analysis of the overburden could be beneficial in determining how to separate or mix different rock materials during mining and grading so that the materials left on and near the surface will have acceptable physical properties. Replacing topsoil on some areas may improve the physical qualities of the reclaimed surface for plant growth. But in other situations, replacing topsoil may result in a compacted surface with increased potential for erosion.

Stoniness--

Stones and boulders on and near the surface curtail the use of tillage, planting, and seeding equipment. An abundance of stones may influence the choice of species used, especially trees. On extremely stony areas, direct seeding of trees may be more feasible than hand planting seedlings; the choice of tree species is limited then to tree species that can be successfully established by direct seeding.

Particle-Size Distribution--

Particle-size distribution refers to the relative amount or proportion of the various sizes of particles in the whole soil, including sand, silt, clay, and rock fragments. It affects water relations (drainage and water-holding capacity), soil structure, bulk density, erodibility, cation exchange capacity, and workability of the minesoil. Minesoils with predominantly coarse particles dry out quickly, especially at the surface where moisture for seed germination and seedling establishment is most critical. With a high proportion of fine particles, especially clays, minesoils can be plastic when wet and very hard when dry. In minesoils with no adverse chemical characteristics, plant growth is usually most favored where there are near-equal proportions of fine (less than 2 mm) and coarse materials.

Bulk Density--

Bulk density is the weight of a unit volume of dry soil, ordinarily expressed as grams per cubic centimeter. This volume includes both soil solids and pore spaces. Soils that are loose and porous have low bulk density; those that are densely structured or compacted, high in clay content, and nonporous have high bulk density. The size and volume of pores are important to plant growth because they influence the movement of water and air in the soil. The bulk density of minesoils is related mostly to the types and amounts of the geologic and soil constituents and the proportions of different particle sizes. Excessive movement and compaction by grading and soil-moving equipment also can affect bulk density of minesoils.

Slope--

Steepness of slope influences vegetation establishment and land use. Long and steep slopes normally erode more rapidly and are more difficult to vegetate than gentle slopes, short slopes, and level areas. Establishing vegetation near the lower end of long steep slopes can be especially difficult. Probable causes for this difficulty include failure or inability to apply seed and fertilizer on lower slopes, greater erosion and deposition on lower than on upper slopes, and a concentration of larger rocks and coarse material near the bottom of the slopes.

Long slopes erode more severely than short ones because the velocity of runoff water increases as the length of the slope increases. Thus, gully erosion usually is greater on lower than on upper portions of slopes. The elimination of highwalls in mountainous areas may create long steep slopes that increase the potential for accelerated runoff and erosion. Where feasible, the formation of long slopes should be avoided. Where slopes must be long, they should be interrupted with terraces or benches that drain on a 1- to 2-percent grade to a stable outlet or waterway.

Erosion Potential--

As discussed in relation to long slopes, erosion is often the most disruptive of physical factors in establishing vegetation. Obviously, steep slopes have greater potential to erode than level benches or gentle slopes. Minesoils containing a large amount of fine particles normally erode more than those consisting of coarser materials. Stony minesoils are less subject to erosion damage than nonstony ones, but for other reasons they may be more difficult to vegetate.

A quickly established cover of vegetation helps retard erosion and is especially effective in controlling surface or sheet erosion. But on some areas other treatments are needed to help retard erosion, especially gully erosion. The use of mulches or soil stabilizers and mechanical structures such as terraces and contour furrows are helpful in reducing erosion until vegetation is established.

Color--

Dark colors absorb more heat from the sun's rays than light colors. Thus, on black or dark-colored minesoils, the surface temperature can reach levels that are lethal to seedlings. This may occur especially during summer periods, and on south and west exposures. High temperatures also cause soils to dry out more rapidly.

Color can be a clue to chemical characteristics. For example, sandstone with brown interior color is weathered and will not be toxic to plants. Sandstone with gray interior color is unweathered and may be toxic to plants because it may contain unoxidized pyrite. Black shales often are acid and toxic-forming, and should be buried under nontoxic material or topsoil. Occasionally, dark-colored materials are not acid and chemically are the best overburden material available for plant growth. In such cases, the material

should remain on the surface and be mulched or, if possible, lightly covered or blended with topsoil or light-colored spoil material.

Aspect--

Aspect, the direction that a slope faces, can affect the establishment and, thus, the selection of vegetation for mined areas. South- and west-facing slopes normally are hotter and dryer than north- and east-facing slopes. Some plant species are better adapted to south aspects than other species. For example, pine trees usually thrive better than most hardwood trees on south slopes. Mulching to help establish vegetation is usually more beneficial on south and west aspects than on north and east ones.

Biological Properties

Although not visually obvious, the biological components of soil play a vital role in the development and maintenance of vegetation. In fact, the presence of microorganisms and soil fauna are essential for the survival and growth of most plant species and for the reestablishment of natural ecosystems.

Microorganisms--

Minesoils are not completely sterile. They contain bacteria, fungi, and actinomycetes, but the kinds and numbers of these organisms in unvegetated minesoil are few compared with those in agricultural and forest soils. However, as vegetation becomes established, the populations of some of these organisms will increase by natural processes. Other types may need to be artificially introduced. Some microorganisms are symbiotic, which means that they give to and derive benefit from the plants on which they live. For example, *Rhizobium* bacteria live on the roots of legumes and take nitrogen from the air and fix it in nodules for use by the host plant. Similarly, most species of plants have mycorrhizal associations that involve root-inhabiting fungi and plant feeder roots and increase the plant's ability to take up nutrients, especially phosphorus. Mycorrhizal associations are beneficial to the survival and growth of most plants.

Soil Fauna--

Soil fauna are the worms, beetles, bugs, and similar soil-dwelling creatures that are primarily responsible for consuming and altering organic materials such as plant litter, and burying or mixing it in the soil. New minesoils normally are devoid of soil fauna. Their presence becomes most important after vegetation is well established and plant litter begins to accumulate. However, natural reestablishment of soil fauna populations is relatively slow. Most soil fauna are not highly mobile, so several to many years may be required for a mined area to be repopulated by the natural movement of fauna from populations in adjacent undisturbed lands. Obviously, narrow strips of revegetated minesoils will repopulate sooner than large broad areas. Artificial introduction of soil fauna is possible and has proven beneficial

in small experimental plots, but its practicality has not been demonstrated on large areas. Immediate replacement of topsoil is probably the most promising means of reestablishing soil fauna on mined sites.

SOIL REPLACEMENT

Replacement of the A horizon of native soils on surface-mined areas will generally have beneficial effects on the establishment of vegetation, especially where proper techniques are used for soil reconstruction. For example, in areas such as northern Illinois, the native prairie soils are thick and relatively fertile. Where surface mined, many of these areas are regulated as prime farmlands and the soils are reconstructed under special provisions of the Federal Surface Mining Control and Reclamation Act of 1977.

In other mining areas, there is evidence that substitute materials are equal to or better than the A horizon as a plant growth media. In areas such as the mountainous parts of the Appalachian Region, soils often are thin, highly leached, and relatively infertile. Replacing these soils may not always enhance the establishment and productivity of vegetation on mined areas.

The primary benefit of replacing soil is to improve the quality of plant growth medium on areas where the spoils or minesoils are chemically and physically less desirable than the native soils. Usually, soil replacement will create a fairly uniform surface condition over the entire area with few or no rocks to interfere with tillage, planting, and seeding. Another probable benefit of soil replacement, especially of the surface or A horizon, is the potential source of soil fauna and microorganisms such as endomycorrhizal fungi. Where reforestation and wildlife habitat are planned postmining land uses, the presence of seed, rhizomes, or other plant parts in the replaced soil may be of benefit in aiding or hastening the reestablishment of native vegetation. Immediate replacement of soil is most beneficial because populations of many of the biological organisms are reduced or destroyed by long-term storage or stockpiling of soil.

Detrimental effects of soil replacement can occur on areas where covering soils have chemical and physical properties that are less desirable than those of the spoils that will be covered. Where improperly handled, the replaced soil will be compacted and physically degraded by earth-moving equipment. Replaced soils, too, may erode more easily than some spoil materials. Unless scarified or otherwise treated, a barrier to root penetration is sometimes created at the interface between the replaced soil and the covered spoils. Soils may sometimes contain seed of unwanted plant species that compete with the planted species.

In some mining regions, especially in the mountains of Appalachia, there usually is very little topsoil (A horizon) that can be saved for replacement on mined areas. Often, most of the "soil" that is saved and replaced consists of B and C horizons or parent material. This material usually is low in plant nutrients, and often is strongly acid and contains relatively high amounts of exchangeable aluminum. The B- and C-horizon materials often contain a high proportion of silt and clay particles that are easily compacted into a dense,

slowly permeable layer by heavy earth-moving equipment, especially when wet soil is moved. In some areas, these horizons have a large proportion of coarse fragments. Because one benefit of saving and replacing soil may be derived from its biologic and organic components, mixing or blending the soil into the surface layer of spoil could in some cases be more beneficial to the establishment of vegetation than spreading it on the surface of the mined area.

SAMPLING AND TESTING MINESOILS

Knowledge of minesoil properties normally is obtained by analyzing or testing samples from areas that are ready for planting. Soil tests are useful mainly for defining properties that limit or prevent plant growth and for determining the kinds and amounts of amendments needed to correct properties that hinder vegetation establishment. This section discusses sampling procedures and soil tests used for analyzing minesoils, including reasons why the tests are useful and some of their limitations.

Minesoil Sampling

Samples should be representative of the area that is to be vegetated. Normally, samples should be collected after shaping, grading, and soil replacement have been completed. Before sampling, one should inspect the entire site. Areas that obviously are different from others in color and rock or soil type should be sampled as individual units, especially if they are large enough to be handled separately in the revegetation program. But even small areas that appear toxic or vastly different should be sampled separately, because they may require special treatment for establishing vegetation. Delineating the different types of minesoil on a map of the mined area could help to facilitate the reclamation activities.

A recommended method of sampling is to make a composite sample from several randomly collected subsamples in each visually distinct unit or type of minesoil. The number of subsamples needed for the composite sample will depend on the size of the unit, the variability of materials within the unit, and the objective of revegetation. At least 10 subsamples should be included in each composite sample in areas up to about 10 acres. More subsamples are recommended in larger areas, or more than one composite sample could be collected. Areas planned for agricultural uses probably will require more intensive sampling than areas planned for reforestation. An advantage of the composite sample is that minesoil from the entire unit is represented in the sample, but only one sample for each unit needs to be sent to the laboratory for analysis. Remember, the composite sample is realistic only if it represents the minesoil in the area from which it is collected.

To describe and map an area in more detail, all samples can be kept separate and analyzed individually, and the sample locations shown on the reclamation map. A disadvantage of individual sampling is the greater cost in time and money for collecting and in labeling samples and for laboratory analyses.

The number of samples collected also may depend on the number and kinds of soil tests that will be made. For example, if only pH is to be determined, many samples could be analyzed at relatively low cost. But tests for nutrient availability, potential acidity, and other items would increase costs. Some States provide guidelines or specify the kind of analyses and the number of samples that should be collected.

To collect soil samples, use a tile spade with a rounded cutting edge or a small garden spade. First, make a vertical cut about 4 to 6 inches deep and discard the soil. Then make a second cut 2 to 3 inches behind the first cut to obtain the sample. Discard rock fragments larger than about 1/2-inch in diameter. If a composite sample is being collected, place this slice in a plastic bucket and continue on to the next sampling site and repeat the sampling procedure. In stone-free soils, samples can be collected with an agricultural soil sampling tube or auger. After the final subsample has been placed in the bucket, thoroughly mix the composite of samples and transfer about 1 quart of the mixed material to a plastic bag, wax or plastic lined paper carton, or similar container. Dry samples can be placed in paper bags. Be sure to identify and label each sample. If the minesoil at each sample point is to be analyzed, follow the previously mentioned procedure for obtaining the sample, but place each sample in a separate container and label the containers.

After all samples have been collected, they should be air dried or dried with artificial heat at low temperatures (40° to 60°C), either in a paper bag or spread out on paper in a dust-free area. When dry, place a portion of the samples in the containers recommended or supplied by your testing agency. The State soil test laboratory in some States provides minesoil testing services either directly or through county extension agents. In some States, minesoil tests may have to be obtained from commercial laboratories.

In routine or standard agricultural procedures, as just described, samples are collected to a depth of about 6 inches. However, at many sites, minesoils offer a potential rooting depth exceeding that on the undisturbed native soils. Such minesoils, then, seem especially well suited for growing deep-rooted plants such as trees, shrubs, and some leguminous herbs. Where such plants are to be established, consideration should be given to sampling minesoils to a greater depth, possibly as much as 4 to 5 feet, in the anticipated rooting zone of the plants. This is especially valid in view of mining and reclamation practices, such as burial of undesirable overburden materials and replacement of soil on the surface, that will cause variation in the chemical and physical properties of the minesoil at varying depths below the surface.

Sampling spoils to a depth of several feet also is important in planning the rehabilitation of abandoned mined lands, especially where movement and grading of spoils are anticipated. For in the process of grading off several feet of spoil, other materials may be uncovered and exposed that have chemical and physical properties which are even more undesirable than those presently on the surface.

Obtaining samples from a depth of several feet will require additional effort and probably additional equipment. Where stones and rock fragments do not interfere, a soil sampling tube or a post hole digger or auger could be used. In more stony material, a pit may have to be dug with a spade and shovel or with a back hoe. Samples should be collected at prescribed depths, say at every foot, or from each layer of material that appears visibly different from other layers. Obviously, if material with adverse properties is found in most of the test profiles, a decision to change plant types or species may be required.

Soil Tests

Many kinds of soil tests can be made on minesoils, but for most revegetation jobs, only a few tests are needed to determine the plantability of the minesoil and prescribe the required amendments. Those tests considered most useful are discussed below.

pH--

Tests for pH are most frequently used for assessing acidity or alkalinity and predicting plantability of minesoil. A pH meter is the standard device for measuring soil pH because it is the most accurate. A common practice is to collect samples of minesoil and send them to a laboratory equipped with a pH meter. Battery-operated pH meters can be obtained for field use. Some disadvantages of using pH meters in the field are that delicate handling and maintenance is required, and that containers, distilled water, and buffer solutions must be transported.

Several types of field kits and other devices are available for measuring pH of soil. However, some of these do not give accurate readings on all minesoils when compared with the pH meter. Field kits, such as the LaMotte-Morgan, that use several pH indicator dyes agreed closely with the pH meter. Some field kits that use only one indicator dye are less accurate. Therefore, before any commercial field kit or other device is adopted for widespread use, it should be compared with a pH meter to determine if it can provide reliable readings.

Lime Requirements--

The pH readings indicate where problems with minesoil acidity or alkalinity may be encountered. However, pH does not indicate the quantity of amendment needed to correct problems of acidity or alkalinity. Methods for determining lime requirements in agricultural soils differ among States; but some methods do not adequately predict lime requirements for acid coal-mine spoils. Therefore, methods should be used that have been determined by qualified soil test facilities to be reasonably accurate for testing minesoil materials in a given area.

SMP Buffer pH--The Shoemaker, McLean and Pratt (SMP) Buffer pH method is used in several Eastern States and is reasonably accurate for determining lime requirements for both agricultural soils and minesoils. It is a fast, routine test developed for acid soils that contain appreciable amounts of

exchangeable aluminum. The test is useful for acid minesoils because aluminum is often the major exchangeable cation contributing to total exchangeable acidity.

Exchangeable acidity and exchangeable aluminum--Lime requirements for acid minesoils also can be based on tests that directly determine exchangeable acidity or exchangeable aluminum. Much evidence is available that shows that the beneficial effects of liming are largely due to the inactivation of exchangeable aluminum. The amount of lime necessary to negate the effects of exchangeable aluminum usually is sufficient for productive plant growth, but it may be less than that required to raise pH to the theoretically optimum 6.5 often recommended for agricultural purposes.

Laboratory procedures for determining exchangeable acidity and aluminum may vary; thus, criteria for lime requirements need to be established for each extraction procedure and for different geologic types. For example, with the aluminum extraction procedure described by Yuan (1959), a satisfactory criterion for liming eastern Kentucky minesoils is: Apply 2,000 pounds per acre of $CaCO_3$ equivalent for each milliequivalent of exchangeable aluminum (meq/100 g).

Potential acidity--The preceding tests measure active or exchangeable acidity in minesoils, but not the total potential acidity that may be produced from further oxidation of pyritic material. Potential acidity will most likely cause revegetation problems in freshly exposed, unweathered geologic materials, and in extremely acid spoils that are partially weathered but still contain oxidizable pyrite. With freshly exposed materials, standard lime requirement tests, including the SMP Buffer pH test, may initially show little need for lime; but as the rock materials weather, acidity will increase and much more lime will be required. For partially weathered pyritic spoils, standard tests may show requirements for large amounts of lime. Yet, even after the addition of lime, these materials may revert to acid conditions because the pyritic materials continue to oxidize.

Several tests are available at some soil testing labs for ascertaining the maximum amount of acid (potential acidity) that might be produced by a completely weathered rock or minesoil. In one test, the pyritic sulfur content is estimated from the total sulfur content of the minesoil sample after the sample is leached to remove sulfates.

A more direct measure of total potential acidity includes the use of hydrogen peroxide to oxidize the reactive pyrite in the minesoil sample. The amount of released acid is determined by titration to neutrality with a standard base.

Application of the full amount of lime indicated by the potential acidity test will reduce the chances that the minesoil will again become extremely acid. One drawback of these tests is that inert and slowly oxidizable forms of pyrite also may be measured and regarded as potentially acid forming; thus, for some minesoils, more lime might be recommended than is necessary to adequately amend the potentially active acidity.

Testing for potential acidity is recommended on fresh, unweathered minesoils that are suspected of becoming extremely acid as they weather. This test is also recommended on some partially weathered minesoils that are already extremely acid and show indications of continuing to be acid for many years. Often, these minesoils contain large amounts of fine-grained pyrites that, with normal weathering, will continue to oxidize for several years.

Phosphorus--

Testing minesoils for plant-available phosphorus (P) usually is recommended because P often is deficient or unavailable to plants. Several methods are available for determining plant-available P in soils; but not all methods give meaningful results in minesoils, nor is any one method necessarily best for testing all types of minesoils. For example, an extracting method known as the Bray #1 has given meaningful results on many of the minesoils derived from rocks of Pennsylvanian Age, but several other standard agricultural tests did not give meaningful results. Thus, results of soil tests for P should be accepted only if the soil testing facility can show that the tests are meaningful for the minesoil materials being tested.

Potassium--

Most standard soil tests for potassium (K) give values that are reasonably meaningful when used on minesoils. However, fertilizer experiments on minesoils have generally shown little or no plant yield increase due to application of potassium fertilizer. Thus, soil testing for K may be of little benefit except for areas designated for agricultural crop production.

Other Tests--

Normally, additional soil tests are not needed for determining the plantability and treatment of minesoils. Exceptions may be where unusual toxicity problems are encountered such as with boron or other minor elements. Most soil nitrogen tests have limited value because much of the nitrogen present in minesoils is not biologically available. Also, nitrogen is nearly always deficient in minesoils and nitrogen fertilization is recommended as a standard practice.

Other soil tests can be made, but because the geology, chemistry, and physics of minesoils are so complex and varied, these tests may have value only where meaningful interpretations of them have been developed for the minesoils being revegetated. To be meaningful, the results of a soil test should correlate with the response of plants growing in the soil being tested.

SECTION 4

PLANT SPECIES FOR VEGETATING MINED LANDS

Plant species that have been used successfully in revegetating surface-mined lands are identified and described in this section. Both common and scientific (Latin) names are listed to clarify species identification (Table 1). Obviously, this list does not include all the plant species that will grow on surface-mined lands. Some species that have been planted experimentally are not listed because their success beyond initial establishment has not been documented; for others, plant survival after several years was very low. A few species, though successful in experimental plantings, are not listed because they are unsuited and have little value for most land uses. Many potentially useful species volunteer on mined land, but some of them have been unsuccessful where artificially planted. Others have not been artificially planted because planting stock or seed has not been commercially available. Use of some of the listed species, too, may be limited at times when planting stock or seed are in short supply or are unavailable.

Several of the listed species have been grown successfully in experimental plantings but have not been used, or seldom used, in large-scale or commercial plantings. In fact, on the majority of successfully reclaimed surface mines, revegetation has been accomplished with the use of relatively few plant species. Greater use could be made of many of the listed species--some for commercial forestry and agricultural uses, and others for increasing vegetative diversity for wildlife habitat and for restoring vegetational types similar to those that existed before mining.

The plant species listed in Table 1 are described individually in this section. The terms used to describe them are explained below.

TYPES OF PLANTS

The plant species are classified into three types--herbs, trees, and shrubs. Each type has an important function in revegetation efforts, but all types may not be needed in every revegetation scheme.

Herbs

Herbs, or herbaceous plants, are nonwoody and are classified as grasses or forbs. Grasses all belong to the Gramineae (grass) family. Most species have a fibrous root system that helps bind together soil particles and prevent erosion. Forbs are herbaceous plants other than those in the grass, sedge, and rush families. They generally are broad-leaved plants that have a

TABLE 1. PLANT SPECIES FOR REVEGETATING COAL SURFACE-MINED LANDS IN THE EASTERN UNITED STATES

Common Name	Scientific Name and Authority[#]
	GRASSES
Western wheatgrass	*Agropyron smithii* Rydb.
*Redtop	*Agrostis gigantea* Roth
*Big bluestem	*Andropogon gerardi* Vitm.
Tall oatgrass	*Arrhenatherum elatius* (L.) Beauv. ex J. & C. Presl
Oats	*Avena sativa* L.
Caucasian bluestem	*Bothriochloa caucasica* (Trin.) C.E. Hubb.
Sideoats grama	*Bouteloua curtipendula* (Michx.) Torr.
Browntop millet	*Brachiaria ramosa* (L.) Stapf
*Smooth brome	*Bromus inermis* Leyss.
Buffalograss	*Buchloe dactyloides* (Nutt.) Engelm.
*Bermudagrass	*Cynodon dactylon* (L.) Pers.
*Orchardgrass	*Dactylis glomerata* L.
*Japanese millet	*Echinochloa crusgalli* var. *frumentacea* (Link) W.F. Wight
Canada wildrye	*Elymus canadensis* L.
*Weeping lovegrass	*Eragrostis curvula* (Schrad.) Nees
Sand lovegrass	*Eragrostis trichodes* (Nutt.) Wood
*Tall fescue 'Kentucky-31'	*Festuca arundinacea* Schreb., selection Ky-31
Red fescue	*Festuca rubra* L.
*Annual ryegrass	*Lolium multiflorum* Lam.
*Perennial ryegrass	*Lolium perenne* L.
*Deertongue	*Panicum clandestinum* L.
Broomcorn millet	*Panicum miliaceum* L.
*Switchgrass	*Panicum virgatum* L.
Dallisgrass	*Paspalum dilatatum* Poir.
*Pearl millet	*Pennisetum americanum* (L.) Leeke
*Reed canarygrass	*Phalaris arundinacea* L.
*Timothy	*Phleum pratense* L.
Canada bluegrass	*Poa compressa* L.
Kentucky bluegrass	*Poa pratensis* L.
*Little bluestem	*Schizachyrium scoparium* (Michx.) Nash
*Rye	*Secale cereale* L.
*Foxtail millet	*Setaria italica* (L.) Beauv.
*Indiangrass	*Sorghastrum nutans* (L.) Nash
*Sorghum	*Sorghum bicolor* (L.) Moench
*Sudangrass	*Sorghum sudanense* (Piper) Stapf
Eastern gamagrass	*Tripsacum dactyloides* (L.) L.
*Winter wheat	*Triticum aestivum* L.

(continued)

TABLE 1. PLANT SPECIES (CONTINUED)

Common Name	Scientific Name and Authority[#]
	FORBS - LEGUMES
Cicer milkvetch	*Astragalus cicer* L.
Partridge pea	*Cassia fasciculata* Michx.
*Crownvetch	*Coronilla varia* L.
Illinois bundleflower	*Desmanthus illinoensis* (Michx.) MacMill.
Soybean	*Glycine max* (L.) Merr.
*Flatpea	*Lathyrus sylvestris* L.
*Sericea lespedeza	*Lespedeza cuneata* (Dum.) G. Don
Prostrate lespedeza	*Lespedeza daurica* var. *schimadai* Matsamune
*Korean lespedeza	*Lespedeza stipulacea* Maxim.
*Common lespedeza	*Lespedeza striata* (Thunb. ex Murr.) Hook. & Arn.
*Kobe lespedeza	*Lespedeza striata* var. Kobe
*Birdsfoot trefoil	*Lotus corniculatus* L.
*Alfalfa	*Medicago sativa* L.
*White sweetclover	*Melilotus alba* Medik.
*Yellow sweetclover	*Melilotus officinalis* Lam.
Kura clover	*Trifolium ambiguum* Bieb.
Alsike clover	*Trifolium hybridum* L.
Crimson clover	*Trifolium incarnatum* L.
Zigzag clover	*Trifolium medium* L.
*Red clover	*Trifolium pratense* L.
*White clover	*Trifolium repens* L.
*Ladino clover	*Trifolium repens* L.
Bigflower vetch	*Vicia grandiflora* Scop.
Hairy vetch	*Vicia villosa* Roth
Cowpea, Black-eyed pea	*Vigna unguiculata* (L.) Walp. subsp. *unguiculata*
	FORBS - NON LEGUMES
*Buckwheat	*Fagopyrum esculentum* Moench
*Common sunflower	*Helianthus annuus* L.
Maximilian sunflower	*Helianthus maximiliani* Schrad.
*Japanese fleeceflower	*Polygonum cuspidatum* Sieb. & Zucc.
	TREES - CONIFERS
Rocky Mountain juniper	*Juniperus scopulorum* Sarg.
*Eastern redcedar	*Juniperus virginiana* L.
European larch	*Larix decidua* Mill.
*Japanese larch	*Larix leptolepis* (Sieb. & Zucc.) Gord.
*Norway spruce	*Picea abies* (L.) Karst
*White spruce	*Picea glauca* (Moench) Voss

(continued)

TABLE 1. PLANT SPECIES (CONTINUED)

Common Name	Scientific Name and Authority[#]
TREES - CONIFERS (continued)	
Red spruce	*Picea rubens* Sarg.
*Jack pine	*Pinus banksiana* Lamb.
*Shortleaf pine	*Pinus echinata* Mill.
Slash pine	*Pinus elliottii* Engelm.
*Austrian pine	*Pinus nigra* Arnold
Longleaf pine	*Pinus palustris* Mill.
Ponderosa pine	*Pinus ponderosa* Dougl. ex P. & C. Laws.
*Red pine	*Pinus resinosa* Ait.
*Pitch pine	*Pinus rigida* Mill.
Pitch x loblolly hybrid	*Pinus rigida* x *P. taeda* (*P. xrigitaeda*)
*Eastern white pine	*Pinus strobus* L.
*Scotch pine	*Pinus sylvestris* L.
*Loblolly pine	*Pinus taeda* L.
*Virginia pine	*Pinus virginiana* Mill.
Douglas-fir	*Pseudotsuga* Carr. spp.
Baldcypress	*Taxodium distichum* (L.) L. Rich.
TREES - HARDWOODS	
*Red maple	*Acer rubrum* L.
*Silver maple	*Acer saccharinum* L.
*Sugar maple	*Acer saccharum* Marsh.
*European black alder	*Alnus glutinosa* (L.) Gaertn.
Sweet birch	*Betula lenta* L.
*River birch	*Betula nigra* L.
Paper birch	*Betula papyrifera* Marsh.
*European white birch	*Betula pendula* Roth
Gray birch	*Betula populifolia* Marsh.
Hickory	*Carya* Nutt. spp.
Pecan	*Carya illinoensis* (Wangenh.) K. Koch
*Chinese chestnut	*Castanea mollissima* Blume
Catalpa	*Catalpa* Scop. spp.
Hackberry	*Celtis occidentalis* L.
Flowering dogwood	*Cornus florida* L.
Russian-olive	*Elaeagnus angustifolia* L.
*White ash	*Fraxinus americana* L.
*Green ash	*Fraxinus pennsylvanica* Marsh.
*Black walnut	*Juglans nigra* L.
*Sweetgum	*Liquidambar styraciflua* L.
*Yellow-poplar	*Liriodendron tulipifera* L.
*Osage-orange	*Maclura pomifera* (Raf.) Schneid.
*Crab apple	*Malus* Mill. spp.
Royal paulownia	*Paulownia tomentosa* (Thunb.) Steud.

(continued)

TABLE 1. PLANT SPECIES (CONTINUED)

Common Name	Scientific Name and Authority[#]
	TREES - HARDWOODS (continued)
*American sycamore	*Platanus occidentalis* L.
*Hybrid poplars	*Populus* L. spp.
*Eastern cottonwood	*Populus deltoides* Bartr. ex Marsh.
Bigtooth aspen	*Populus grandidentata* Michx.
*Black cherry	*Prunus serotina* Ehrh.
Sawtooth oak	*Quercus acutissima* Carruth.
*White oak	*Quercus alba* L.
Shingle oak	*Quercus imbricaria* Michx.
*Bur oak	*Quercus macrocarpa* Michx.
Pin oak	*Quercus palustris* Muenchh.
Chestnut oak	*Quercus prinus* L.
*Northern red oak	*Quercus rubra* L.
*Black locust	*Robinia pseudoacacia* L.
Black willow	*Salix nigra* Marsh.
American basswood	*Tilia americana* L.
	SHRUBS
*Indigobush	*Amorpha fruticosa* L.
Black chokeberry	*Aronia melanocarpa* (Michx.) Elliott
Korean barberry	*Berberis koreana* Palib.
Siberian peashrub	*Caragana arborescens* Lam.
*Silky dogwood	*Cornus amomum* Mill.
Gray dogwood	*Cornus racemosa* Lam.
Red-osier dogwood	*Cornus stolonifera* Michx.
Hawthorn	*Crataegus* L. spp.
*Autumn olive	*Elaeagnus umbellata* Thunb.
*Shrub lespedeza	*Lespedeza bicolor* Turcz.
*Japan lespedeza	*Lespedeza japonica* L. H. Bailey
*Thunberg lespedeza	*Lespedeza thunbergii* (DC.) Nakai
Amur privet	*Ligustrum amurense* Carr.
Japanese honeysuckle	*Lonicera japonica* Thunb.
*Amur honeysuckle	*Lonicera maackii* (Rupr.) Maxim.
*Morrow honeysuckle	*Lonicera morrowii* A. Gray
*Tatarian honeysuckle	*Lonicera tatarica* L.
Western sandcherry	*Prunus besseyi* L. H. Bailey
Chokecherry	*Prunus virginiana* L.
*Fragrant sumac	*Rhus aromatica* Ait.
*Shining sumac	*Rhus copallina* L.
*Bristly locust	*Robinia fertilis* Ashe
Rose-acacia locust	*Robinia hispida* L.
Multiflora rose	*Rosa multiflora* Thunb. ex Murr.
Rugosa rose	*Rosa rugosa* Thunb.

(continued)

TABLE 1. PLANT SPECIES (CONTINUED)

Common Name	Scientific Name and Authority[#]
	SHRUBS (continued)
Memorial rose	*Rosa wichuraiana* Crep.
Purple osier willow	*Salix purpurea* L.
American elder	*Sambucus canadensis* L.
Silver buffaloberry	*Shepherdia argentea* (Pursh) Nutt.
Arrowwood	*Virburnum dentatum* L.

#Names and authorities mostly follow:

Terrell, E. E. 1977. A checklist of names of 3,000 vascular plants of economic importance. USDA Agric. Handbook No. 505.

and

Little, E. L. 1979. Checklist of United States Trees. USDA Agric. Handbook No. 541.

Other sources are:

Staff of L. H. Bailey Hortorium, Cornell Univ. 1976. Hortus Third: A concise dictionary of plants cultivated in the United States and Canada. Macmillan Publ. Co., Inc. New York.

*Detailed information is given on individual description sheets in this section. The other species are briefly described in Tables 2, 3, 4, and 5.

tap root or branching tap root system. The forbs are further classified as legumes or nonlegumes. For vegetating mined lands, legumes usually are used and are especially valuable because they are nitrogen-fixing plants, i.e., by their symbiotic relationship with *Rhizobium* bacteria they convert atmospheric nitrogen into a form in the soil that is usable by plants.

The herbs are especially beneficial for the quick establishment of vegetative cover for erosion control. Some herbaceous species also provide long-term site protection and are suitable for agricultural uses and for wildlife habitat.

Life Span--

The life span of herbaceous plants is either annual, biennial, or perennial (long-lived), whereas trees and shrubs all are perennial species. This knowledge can help the reclamation manager in planning the best use of different species into a revegetation program.

Annuals--These plants make vegetative growth, flower, produce seed, and die all within 1 season or 1 year. Annuals reproduce only from the seed they produce during this life cycle. Some annuals, such as Korean and Kobe lespedeza, usually regenerate (volunteer) a stand each year from the seed they produce, but other annuals such as rye and millet cannot be depended on to volunteer satisfactory stands. Annuals are usually the best species to plant for the quick establishment of a vegetative cover.

Biennials--These are plants that live for only 2 growing seasons. Some biennials such as yellow sweet clover, produce most of their vegetative growth in the year they are sown. In the second year they produce vegetative growth early in the season, then flower, produce seed, and die.

Perennials--Most of these plants live at least 3 years and usually longer. Herbaceous perennials die back to the ground each year but regenerate new growth from roots or crowns. They also reproduce from seed. Plants of a few perennials such as perennial ryegrass are relatively short-lived (2 to 4 years), but most perennials have a longer, usually indefinite, life span.

Season of Major Growth--

Knowledge of when herbaceous plants grow is helpful in determining how and when each species can be used to best advantage in the revegetation scheme. The growth period of herbaceous plants is grouped into two major seasons--cool and warm.

Cool-season species grow mostly in the spring and fall and usually are dormant, semidormant, or grow slowly in the summer. These plants normally are dormant in the winter, though there are exceptions in the southern areas of the coal regions where some of the cool-season species may continue growth during the winter months. Cool-season species normally are most easily established by seeding in the spring and late summer to early fall. A few species, such as alfalfa, crownvetch, and birdsfoot trefoil also will grow in

the summer, but usually are sown in the spring or late summer and are classified as cool-season plants in this guide.

Some cool-season plants are called winter annuals. They normally are sown in the fall. After the seeds germinate, the plants make some growth before going dormant or semidormant over winter. These plants resume growth in the early spring, produce seed in late spring or early summer, and then die. Most of the winter annuals also produce cover when sown in the spring. Rye, winter wheat, annual ryegrass, and hairy vetch are examples of winter annuals.

Warm-season species grow mostly in the late spring and summer and are dormant in early spring, fall, and winter. Warm-season species usually are sown in the spring. Summer annuals, such as foxtail millet and sorghum, are normally sown in late spring and early summer and are especially useful for the quick establishment of vegetative cover. These species complete their life cycle during late summer and early fall. Both summer and winter annuals can be grown to produce mulch in place .

Trees

Trees are large woody plants that generally have a single stem and a definitive crown shape. They are classified as conifers (cone bearers) or hardwoods. Most conifers belong to the pine family and are evergreen (three of the listed conifers are deciduous). Hardwoods belong to plant families other than pine and most are deciduous, i.e., their leaves drop annually.

Trees are not very effective for erosion control in the early stages of growth, but as crown closure and litter formation occur they will provide long-term or permanent cover and site protection. Given sufficient time, some trees produce wood or timber products of commercial value. Many species provide food and cover for wildlife purposes. A few species are nitrogen-fixers. Because they can improve soil conditions, nitrogen-fixers may serve as "nurse" species where interplanted with other tree species.

Tree Size--

The relative height of a mature tree growing in its natural range and on natural soils is classified and defined as follows: small: 20 to 40 feet; medium: 40 to 90 feet; large: 90 to 150 feet. Knowledge of tree size may be useful in selecting trees for screening or landscaping purposes, or to help envision the future appearance of a forest plantation.

Shade Tolerance--

Shade tolerance is the term commonly used to express the capacity of a tree or shrub to develop and grow in the shade of other trees. Although oversimplified, shade tolerance for the purpose of this guide is categorized and defined as follows: tolerant: trees can tolerate or withstand fully shaded conditions (low light intensity) usually for long periods of time; intolerant: trees cannot tolerate shaded conditions (require relatively high light intensity); intermediate tolerance: trees can tolerate partial shading or can tolerate full shade for short periods.

Knowledge of the shade tolerance of a species may seem unimportant in vegetating a newly mined site. Often, however, several species of trees and shrubs are planted together or plantings may be staggered over a period of several years. As plant growth progresses, some species overtop and shade others. Some species are adversely affected by shading but others are not. For example, hardwoods, where interplanted with intolerant species of pine, often overtop and shade the slower growing pine, causing them to lose vigor and eventually die. Conversely, species tolerant of shade such as spruce may initially grow slowly in the shade of larger or faster growing plants, but eventually will equal or emerge above them.

Shrubs

Shrubs are plants with few to many persistent woody stems arising from the ground and without definite crown shape. Shrubs usually are smaller than trees, though in other literature some large shrubs may be classified as trees. Most of the species listed as shrubs herein do not exceed a height of 20 feet at maturity. Shrubs usually do not provide good erosion control in the early stages of growth, but within a few years will provide site protection and can be used for screening. They are especially valuable for wildlife food and cover. Some shrubs are nitrogen-fixers. Some of these are legumes; others, such as autumn olive, have different microbial associates that fix nitrogen.

OTHER CRITERIA FOR SELECTING AND ESTABLISHING SPECIES

Origin

Species are identified as either native or introduced (not native). Many of the introduced species are naturalized and, like the native species, will persist without cultivation. Knowledge of species origin may be useful to reclamation managers because the use of native species is an alternative for some postmining land uses defined by the Federal regulations on surface-mine reclamation.

Area of Use

A small map showing the eastern coal regions is included with the descriptions of the plant species. The areas that are encircled with a heavy line identify the coal regions or portions of them where a plant species has been used successfully, or its use is recommended.

For the herbaceous species, these identified areas indicate where a species is climatically adapted and expected to grow, but its use on surface mines in all of these areas is not necessarily documented.

For trees and shrubs, areas shown are those where the use of a species has been documented. Usually, these areas coincide fairly closely with the natural range of that species; for a few species the natural range is more extensive than that included in the identified areas. Conversely, some species have been used successfully beyond their natural range. For example, the natural range of red pine and jack pine is the northernmost part of the

United States and adjacent southern Canada. Yet, these pine have been used far south of this range.

The probability of long life or permanence of a species usually is greater where planted in or near its natural range than outside its natural range. Planted outside their natural range, some species or some plantings of a species may succumb to extremes in weather, fail to regenerate, or be susceptible to disease and insect pests that usually are not a problem in their natural range.

Elevation Limits

Plants usually grow best in the climatic range in which they are adapted. Topographic elevation influences climate and so can also affect the establishment and growth of plants. For example, most of the Appalachian Region is in the natural range of Virginia pine. But this tree does not grow well above 2,500 feet, especially in the northern half of the Appalachians. Similarly, a warm-climate forb such as sericea lespedeza may germinate and grow at the lower elevations in northern West Virginia, but winter temperatures at the higher elevations may be too severe for the success of that species. Limits are shown for species where elevation is known or suspected to be a factor hindering their establishment.

Lower pH Limit

Acidity (low pH) is a major factor limiting the establishment of vegetation on some of the mined lands in the East. Knowing the acidity tolerance of a species can be helpful in selecting those most suitable for vegetating acid minesoils. However, selecting plants for acid tolerance may be less important in the future due to changing practices in mining and reclamation, such as segregation and planned placement of overburden strata, replacement of native soil, and treatment of acid soils. Alkalinity or high pH causes revegetation problems in only a few eastern areas. For example, in Alabama, the southern pines are difficult to establish on high pH spoils.

Planting Materials

The type of plant materials used to establish the species are identified on the description sheets. With few exceptions, trees and shrubs are most often established by planting nursery-grown seedlings. The age of nursery seedlings recommended for planting on mined lands is shown in parenthesis. However, seedlings of the same age are not always the same size; thus, the buyer must be sure that the seedlings are of the proper size for planting. Hybrid poplars, and sometimes cottonwood, can be established by planting either rooted or unrooted cuttings.

A few of the woody species can be established by direct seeding. Treatment of the seed is recommended for some species. The herbaceous species generally are established from seed. Crowns, sprigs, and sod are used to a limited extent for establishing a few species. Eastern gamagrass and some cultivars of Bermudagrass are species that must be planted vegetatively. Seed of herbaceous legumes and some of the shrubby legumes should be inoculated

with the appropriate *Rhizobium* bacteria. Wide-spectrum or standard inoculants are available commercially for most of the commonly used legumes. Species that require specially prepared inoculum are identified. See Section 5, Vegetation Establishment, for a discussion and recommendations on size of planting stock, spacing of seedlings, time of planting, direct seeding, and inoculation of legume seed.

Seeding Rate

Rates of seeding are recommended for herbaceous species, and for tree and shrub species that can be direct seeded. The rates are given as pounds per acre of pure live seed (PLS). For some species, a range in rates is suggested both for use in mixtures and, where advisable, for seeding alone. The higher rates should be used where environmental conditions are least favorable for seedling establishment, such as on poorly prepared seedbeds and steep slopes. Seeds of some species are susceptible to damage when sown with a hydroseeder; thus, using the higher rates helps compensate for the damaged seeds. The lower rates are suggested for the less humid areas of the East, and especially where seed is planted with drills. Special directions are given for tree species that can be established from planting of nuts. Discussion of seeding rates and explanation of pure live seed (PLS) are given in Section 5.

Time of Seeding

The season or seasons of the year is indicated when a species normally is seeded. Additional information on time of seeding is discussed in Section 5.

Superior Cultivars

Varieties, strains, or selections with one or more superior qualities are listed for some species. When available, the use of superior cultivars usually is recommended over unimproved cultivars. Consult agricultural agencies such as your State Extension Service or the USDA Soil Conservation Service for advice on recommended cultivars for your locality.

Rate of Establishment

This qualitative rating is the length of time usually required for a herbaceous species to become established and develop sufficient foliage to cover 70 percent or more of the ground surface. The rates are: Rapid: the desired cover is established within the first growing season after seeding (for fall sown species, this includes the fall plus the next spring growing periods); Moderate: requires more than 1 growing season to establish the desired cover, but may not require a full second growing season; Slow: requires more than 2 full growing seasons to establish the desired cover.

These criteria apply primarily to a species when sown alone; the rate of establishment could vary some when the species is sown in mixtures. These criteria also assume that (1) seeding is done in the appropriate season for that species; (2) seed was sown on mechanically or frost-prepared seedbeds on minesoils that have been properly limed and fertilized; and (3) the minesoils

do not have other chemical or physical properties that would hinder usual seed germination and plant development.

Major Uses

Major uses of species planted on mined lands are listed on the description sheets. Erosion control and watershed protection are provided by nearly all plants at some stage of development. However, these uses are not listed for most of the tree and shrub species because these plants usually provide little site protection during the first few years after planting. Conversely, many of the herbaceous species provide rapid cover and are especially important for erosion control and watershed protection. Nearly all species contribute to esthetics; for a few species, esthetics and screening can be major uses.

Comments

This item includes other factors of interest or importance, and data on growth performance of some of the tree species. Much of the tree growth data was gathered in a recent survey of 30-year-old experimental plantings. Data on tree performance are averaged from a number of test sites in the States indicated and include percent survival, average diameter at breast height (dbh), average height, and basal area (an indicator of stand density). Most of the basal area values were calculated by multiplying the number of surviving trees per acre (determined from percent survival) by the mean cross-section areas of the trees (determined from average dbh). Trees in the experimental plantings were on a 7- by 7-foot spacing (890 trees per acre).

SPECIES DESCRIPTIONS

Descriptions have been prepared on individual pages for species that are most frequently used and recommended, and for some that have proven successful in experimental plantings but otherwise may have been little used. For species of lesser importance, and those seldom used, similar but less detailed information is given in Tables 2, 3, 4, and 5. The species descriptions are arranged by plant type in the order: grasses, forbs, trees, and shrubs.

REDTOP (*Agrostis gigantea*)

Type of plant: Grass

Origin: Introduced

Life span: Perennial

Season of major growth: Cool

Lower pH limit: 4.0 to 4.5

Planting materials: Seed

Seeding rate: 2 to 4 lb/acre in mixture; 3 to 6 lb/acre alone

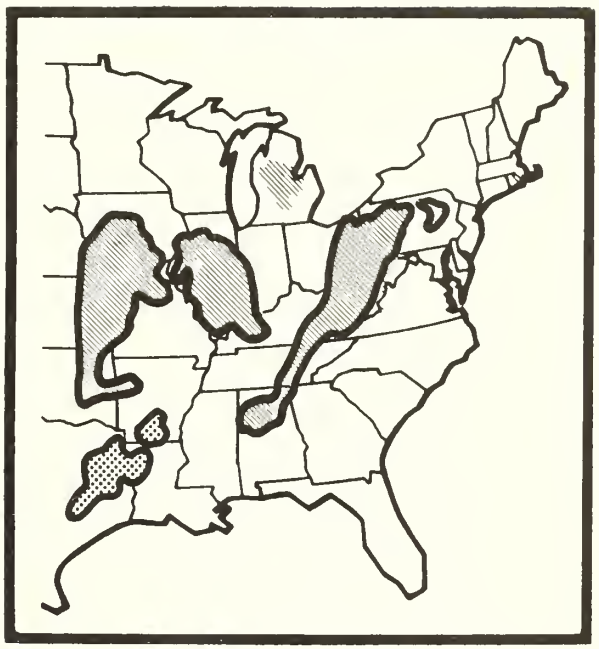
Time of seeding; Spring; late summer

Rate of establishment: Moderate to rapid

Major uses: Erosion control (temporary cover)

Comments: Redtop is tolerant of a wide variety of soil and moisture conditions. It grows on very acid and clayey soils. It is especially adapted to wet sites and poorly drained soils, but is also drought resistant when established. Spreads by seed and rhizomes. Forms a sod that is useful for controlling erosion on sites with overland flows. Sometimes recommended for use in fall seedings, but the small plants produce little cover in the fall. They do initiate new growth and produce rapid cover early the following spring. Redtop is relatively short lived; the stands usually give way to other species after 3 to 4 years. Value as a forage crop is relatively low. Adapted to most of the Eastern United States, except the deep South.

BIG BLUESTEM (*Andropogon gerardi*)
LITTLE BLUESTEM (*Schizachyrium scoparium*)



Type of plant: Grass

Origin: Native

Life span: Perennial

Season of major growth: Warm

Lower pH limit: 4.5

Planting materials: Seed

Seeding rate: 4 to 8 lb/acre in mixture; 8 to 15 lb/acre alone

Time of seeding: Spring

Superior cultivars: 'Kaw' big bluestem, 'Aldous' and 'Blaze' little bluestem

Rate of establishment: Slow to moderate

Major uses: Watershed protection (long-term cover); forage; wildlife habitat; esthetics

Comments: Native to all Eastern States, these species may be slow to develop cover, but once established, the stands require little maintenance. Height of big bluestem may reach 6 to 7 feet; little bluestem 3 to 4 feet. To develop a more diverse stand of native plants, sow these grasses in mixtures with other native species such as partridge pea, Indiangrass, and switchgrass. Include a light seeding of rye or oats in the mixture to provide initial cover, or seed the native grasses into the residue of a summer annual crop grown the year before. Seeds of the bluestems are light and fluffy and can be more difficult to drill or broadcast than seeds of most grasses. Germination and purity of seed often is low, so be sure that seeding rates are based on PLS values. Bluestems can provide summer forage for livestock and cover for game birds and mammals. Where the herbage is not used, occasional removal of heavy litter buildup in older stands will help maintain vigorous plant growth. In pasture, rangeland, or wildlife uses, burning is the best way to remove the heavy litter.

SMOOTH BROME (*Bromus inermis*)

Type of plant: Grass

Origin: Introduced

Life span: Perennial

Season of major growth: Cool

Lower pH limit: 5.0

Planting materials: Seed

Seeding rate: 10 to 15 lb/acre in mixture; 15 to 20 lb/acre alone

Time of seeding: Spring; late summer-early fall

Superior cultivars: Consult local agricultural agencies for recommendations

Rate of establishment: Moderate to slow

Major uses: Forage; erosion control (long-term cover)

Comments: This sod-forming grass is best adapted to the northern half of the Interior Coal Provinces and the northern third of Appalachia. Kentucky-31 fescue performs better for vegetating minesoils in the southern part of these regions. Smooth bromegrass is a leafy palatable forage plant and is usually sown with a legume such as alfalfa. Where established alone it produces a dense sod that provides good erosion control in areas such as grassed waterways that are subject to overland flows. Old stands develop nitrogen deficiency and require fertilization for maintenance. Selection of appropriate seed sources and varieties is important for northern vs. southern latitudes. Consult local agricultural authorities for recommendations on the variety or type suited for a given area.

BERMUDAGRASS (*Cynodon dactylon*)

Type of plant: Grass

Origin: Introduced

Life span: Perennial

Season of major growth: Warm

Lower pH limit: 4.0 (see comments)

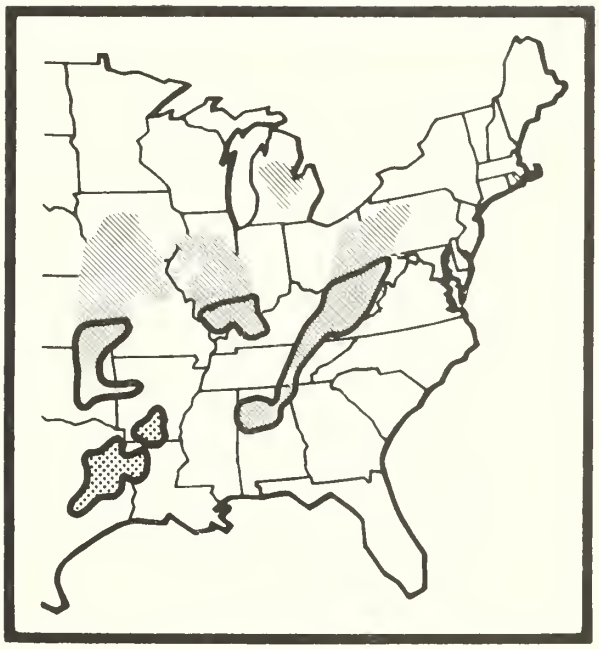
Elevation limit: May winter kill at higher elevations in Appalachians

Planting materials: Sprigs; seed (common Bermuda only)

Seeding rate: 3 to 5 lb/acre in mixtures; 7 to 12 lb/acre alone

Sprig spacing: 2 to 3 feet apart in rows 3 to 4 feet apart

Time of seeding: Mid to late spring after mean daily temperatures exceed 65°F.



Time of sprigging: Any month; spring and summer best

Superior cultivars: 'Tufcote' (sod type); Midland, Coastal (forage types)

Rate of establishment: Rapid

Major uses: Erosion control (quick, short-to-medium-term cover); forage

Comments: Bermudagrass is adapted to a wide range of minesoil types; but its practical use is limited because the most winter-hardy cultivars must be planted vegetatively with pieces of rhizomes and stolons (sprigs). Common Bermuda can be seeded, but most commercial seed sources are winter hardy only in the southern part of the coal-mining areas. Midland and 'Tufcote' are more winter hardy of the superior cultivars and have survived winters in southern Indiana and northern West Virginia. 'Tufcote' is more tolerant than Midland or Coastal to low soil pH, and reportedly has grown in West Virginia minesoils at pH 3.2. Bermudagrass grows best on moist heavy soils in warm and hot weather, but is also very tolerant of droughty soil conditions and of salty soils. Plants grow and spread rapidly by stolons and rhizomes. It is relatively long lived in its adapted climatic range when soil fertility is maintained. One of the most productive forage grasses in the South with heavy application of fertilizer.

ORCHARDGRASS (*Dactylis glomerata*)

Type of plant: Grass

Origin: Introduced

Life span: Perennial

Season of major growth: Cool

Lower pH limit: 4.5

Planting materials: Seed

Seeding rate: 5 to 8 lb/acre in mixtures; 10 to 15 lb/acre alone

Time of seeding: Spring, late summer to early fall

Superior cultivars: Consult local agricultural agencies for recommended cultivars

Rate of establishment: Moderate to rapid

Major uses: Forage; wildlife habitat; watershed protection

Comments: Orchardgrass is similar to K-31 tall fescue in growth habits and tolerance to acid minesoil, but generally is less persistent, especially where management is not practiced to maintain it. This grass is considered superior to fescue for use in wildlife plantings, especially in food patches and clearings vegetated with herbaceous species for game birds. Grows well in combination with legumes such as alfalfa, red and alsike clovers, or birdsfoot trefoil. It is more adapted than most grasses to growing in shade.

JAPANESE MILLET (*Echinochloa crusgalli* var. *frumentacea*)

Type of plant: Grass

Origin: Introduced

Life duration: Annual

Season of major growth: Warm

Lower pH limit: 4.5

Planting materials: Seed

Seeding rate: 8 to 12 lb/acre in mixture; 20 to 25 lb/acre alone

Time of seeding: Late spring-early summer

Rate of establishment: Rapid

Major uses: Erosion control (quick, temporary cover); wildlife habitat

Comments: Use as a quick cover companion crop with perennial grasses and legumes, or sow alone for growing *in situ* mulch. Similar to foxtail millet; but taller, coarser, more productive of herbage, and provides more residue for overwinter cover. Grows well in wet soils and low places with occasionally standing water. Seed eaten by song and game birds. Used for food plantings for game birds in swampy areas and around ponds. Japanese millet is a cultivated variety of wild barnyardgrass. Grows better than foxtail millet in cool regions.

WEEPING LOVEGRASS (*Eragrostis curvula*)

Type of plant: Grass

Origin: Introduced

Life span: Perennial

Season of major growth: Warm

Lower pH limit: 4.0

Elevation limit: Avoid higher elevations in West Virginia

Planting materials: Seed

Seeding rate: 2 to 3 lb/acre in mixtures

Time of seeding: Spring to early summer

Rate of establishment: Rapid

Major uses: Erosion control (quick, temporary cover)

Comments: This grass is one of the most tolerant of extremely acid minesoils. It has grown well on some minesoils with pH 3.8. Establishes cover easily and quickly, but is relatively short lived (2 to 4 years) unless foliage is removed by mowing, burning, or grazing. It is compatible with many other species and is best used as the quick cover component in a mixture with perennial grasses and legumes, especially in mid- to late-spring seedings. Although it provides good initial cover, weeping lovegrass gradually gives way to the other perennial species. It is suited for use on warm dry sites such as south-facing slopes. The young spring growth of herbage can be used for pasture, but mature plants are relatively unpalatable to livestock. In some areas of the South, it is cut for hay when plants are heading out and the regrowth is used for winter grazing. Climatically, it is best adapted to the southern regions, but sometimes plants survive through winters even in southwestern Pennsylvania and at 2,500 to 3,000 feet in West Virginia. Because of its tiny seed, only a low seeding rate is needed. Where used in mixtures, exceeding the recommended seeding rate may cause extremely dense stands that retard the establishment of the companion perennial species. Common and 'Morpa' are the cultivars most tolerant of acid minesoils.

'KENTUCKY-31' TALL FESCUE (*Festuca arundinacea*, Selection Ky-31)

Type of plant: Grass

Origin: Introduced

Life span: Perennial

Season of major growth: Cool

Lower pH Limit: 4.5

Planting materials: Seed

Seeding rate: 10 to 15 lb/acre in mixtures; 20 to 35 lb/acre alone

Time of seeding: Spring and fall

Rate of establishment: Moderate

Major uses: Watershed protection (medium to long-term cover); forage (pasture and hay)

Comments: Most used and most versatile of the grasses suited for vegetating surface mines. It is adapted to a wide range of environmental conditions including wet soils, droughty soils, acid soils, and alkaline soils. Stand establishment is reasonably fast, but usually should be sown with a "quick cover" grass such as rye in the fall, or weeping lovegrass in mid to late spring. As with most cool-season grasses, stands usually do not thrive unless mixed with a legume or occasionally refertilized. Makes luxuriant growth under black locust. Usually becomes the minor species in mixtures with sericea lespedeza, crownvetch, or flatpea. Value for wildlife, especially for game birds, considered low by most biologists, but sometimes provides winter forage for deer. Generally not recommended for planting in or near wildlife habitat areas. Nearly all tall fescue seed available today is Kentucky-31. 'Alta' tall fescue is similar but seldom used.

ANNUAL RYEGRASS (*Lolium multiflorum*)

Type of plant: Grass

Origin: Introduced

Life span: Annual

Season of major growth: Cool

Lower pH limit: 4.5

Planting materials: Seed

Seeding rate: 4 to 7 lb/acre in mixtures; 20 to 25 lb/acre alone

Time of seeding: Fall or spring (South); spring (North)

Rate of establishment: Rapid

Major uses: Erosion control (quick, temporary cover); forage

Comments: This winter annual is also known as Italian ryegrass. The commercial seed of this species may include seed of common or domestic ryegrass, which is a genetic mixture of Italian and perennial ryegrasses. Annual ryegrass grows 2 to 3 feet tall and is taller and more vigorous than common and perennial ryegrasses. It can be sown in the fall or early spring, but spring seeding is advised where winters are severe. This grass is used mostly for quick temporary cover and sown in mixtures with long-lived (perennial) grasses and legumes. The rapid-growing vigorous plants of annual ryegrass can strongly compete with the companion perennials; thus, its seeding rate should not exceed the above recommendation. In warmer climates, ryegrass could be sown alone in the fall for winter cover, and the component of perennial species sown the following spring or fall. Ryegrass can be pastured or cut for hay in agricultural situations, but such use on newly vegetated minesoils should be deferred until perennial species become well established. Its value for wildlife is limited.

PERENNIAL RYEGRASS (*Lolium perenne*)

Type of plant: Grass

Origin: Introduced

Life span: Perennial

Season of major growth: Cool

Lower pH Limit: 4.5

Planting materials: Seed

Seeding rate: 5 to 10 lb/acre in mixtures; 20 to 25 lb/acre alone

Time of seeding: Fall or spring (South); spring (North)

Rate of establishment: Rapid

Major uses: Erosion control (quick, temporary cover); forage

Comments: This species is a short-lived perennial. Plants usually live only 2 to 3 years and do not successfully reseed to perpetuate the stand. Plants grow from 1 to 2 feet tall. Used mostly to provide quick temporary cover where sown in mixture with long-lived perennial grasses and legumes. This species is less vigorous and less competitive than annual ryegrass with companion species. In warmer climates it can be sown alone in the fall for winter cover. Seeding or planting of permanent or long-lived perennial species could be made the following year. Spring seeding is advised in the northern latitudes because winter killing may occur. Can be used for pasture or hay, especially in the South, but newly seeded minesoils should not be grazed until perennial vegetation is well established.

DEERTONGUE (*Panicum clandestinum*)

Type of plant: Grass

Origin: Native

Life span: Perennial

Season of major growth: Warm

Lower pH limit: 4.0

Planting materials: Seed (stratify for spring seeding)

Seeding rate: 6 to 8 lb/acre in mixture; 12 to 15 lb/acre alone

Time of seeding: Late fall; winter; spring (stratified seed)

Superior cultivars: Tioga

Rate of establishment: Moderate to slow

Major uses: Watershed protection; wildlife habitat

Comments: This grass was selected for use on acid minesoils because it frequently volunteers on low fertility and eroded acid sites. Stands usually develop slowly, but once established they persist without additional fertilizer or maintenance. Probably adapted to all coal-mining regions, but tested on minesoils mostly in the Northeast. Deertongue seed becomes dormant soon after it is harvested and requires cold stratification to produce acceptable germination. Late fall and winter seedings allow natural stratification of seed. Before spring seeding, stratify seed by moist refrigeration at about 37°F for 4 weeks. Deer and turkey use seed and foliage in the rosette stage (new green growth). Stands establish best where seeded alone.

SWITCHGRASS (*Panicum virgatum*)

Type of plant: Grass

Origin: Native

Life span: Perennial

Season of major growth: Warm

Lower pH limit: 4.0 to 4.5

Planting materials: Seed

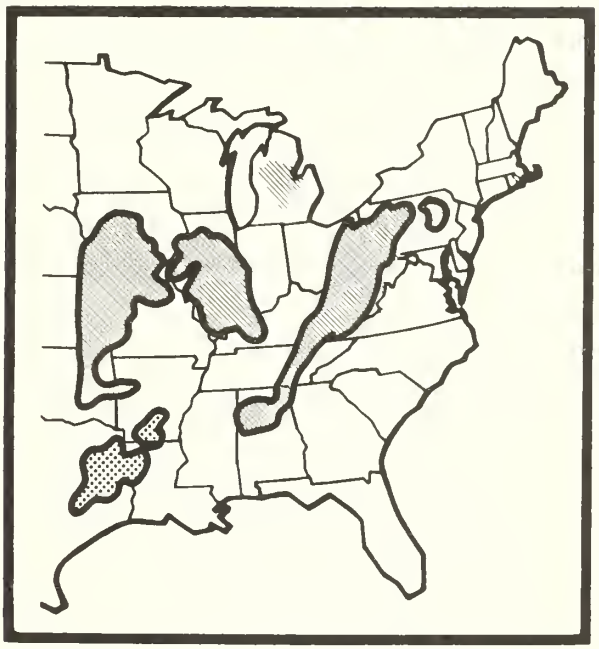
Seeding rate: 2 to 5 lb/acre in mixture; 5 to 12 lb/acre alone

Time of seeding: Spring

Superior cultivars: Blackwell; Kanlow, Caddo, Cave-in rock

Rate of establishment: Moderate to slow

Major uses: Watershed protection (long-term cover); forage; wildlife habitat



Comments: Switchgrass has been used on minesoils in most of the eastern coal States and could be used in all of them. Plants are tall, large-stemmed, and spread by short rhizomes and seed. Unlike some native grasses, switchgrass seed is easy to handle and sow. Stands usually require 2 to 4 years to develop good cover. Once established, stands require little or no maintenance except occasional burning where left solely for cover. They can be highly productive of summer forage if properly managed. Switchgrass and birdsfoot trefoil are compatible for seeding in mixtures, though switchgrass will gradually dominate the stand. A mixture of switchgrass and other native grasses such as Indiangrass, big bluestem, and little bluestem provides a diversity of species similar to that in some natural grassland areas. It also provides cover for some game birds and mammals. A light seeding of rye, wheat, or oats also will help provide quick site protection. 'Blackwell' is the cultivar most widely used on eastern minesoils. It grows about 4 feet tall. 'Kanlow' is taller and more robust, and can tolerate inundation for up to 20 days. Many other cultivars have been tested and most have not proven appreciably better than Blackwell. There are many natural ecotypes of switchgrass, so selections can be made that are adapted to various environmental conditions. Seeding too heavily in a well-prepared seedbed can cause seedling competition.

PEARL MILLET (*Pennisetum americanum*)

Type of plant: Grass

Origin: Introduced

Life span: Annual

Season of major growth: Warm

Lower pH limit: 4.0-4.5

Planting materials: Seed

Seeding rate: 8 to 12 lb/acre in mixture; 20 to 25 lb/acre alone

Time of seeding: Late spring to mid summer

Superior cultivars: Gahi-1; Starr

Rate of establishment: Rapid

Major uses: Erosion control (quick, temporary cover)

Comments: Used primarily for quick, temporary cover in late-spring to mid-summer seedings. Sow as companion crop with perennials, or sow alone for growing mulch in place. Plant or sow perennials into the residue (mulch) the following spring. The plant residue is composed of large stems that will last through the second year and sometimes longer. Pearl millet may grow 6 to 8 feet tall in good fertile minesoil. Can be grown in Kentucky and southward. Will outyield Sudangrass in the Southeast and is free from prussic acid. Seeds are used by songbirds.

REED CANARYGRASS (*Phalaris arundinacea*)

Type of plant: Grass

Origin: Introduced

Life span: Perennial

Season of major growth: Cool

Lower pH limit: 4.5

Planting materials: Seed; sprigs

Seeding rate: 5 to 8 lb/acre in mixture; 8 to 12 lb/acre alone

Time of seeding: Spring; late summer

Rate of establishment: Moderate

Major uses: Erosion control; wildlife habitat

Comments: This grass is recommended primarily for moist or wet sites such as pond shorelines, drainage ditches, grassed waterways, and stream channel banks. This sod-former can be started in gullies by planting sprigs (small pieces of sod) or by covering the joints of freshly cut mature stems with 1 to 2 inches of wet soil. Reed canarygrass shoots will push up through as much as 6 to 8 inches of sediment. Seed often has low germination, so pay attention to the PLS seeding rate. This species is drought resistant and also will grow on upland sites. Generally, legumes sown with this grass are not successful. The seed is used by game birds.

TIMOTHY (*Phleum pratense*)

Type of plant: Grass

Origin: Introduced

Life span: Perennial

Season of major growth: Cool

Lower pH limit: 4.5 to 5.0

Planting materials: Seed

Seeding rate: 4 to 7 lb/acre in mixtures

Time of seeding: Late summer-early fall; spring

Superior cultivars: Consult local agricultural agencies for recommendations

Rate of establishment: Moderate

Major uses: Forage; wildlife habitat; erosion control

Comments: Adapted to cool, humid climates. Used mostly in northern half of Eastern United States. Used primarily for hay. Often used on mined lands as a substitute for Ky-31 fescue in plantings for wildlife habitat. Should be sown with legumes and other grasses. Timothy can be sown in the fall with rye or winter wheat and the legumes, such as red clover or alfalfa, sown the following spring. Timothy is a relatively short-lived perennial, usually persisting about 5 years, especially where not managed for forage production. Can tolerate partial shading.

RYE (*Secale cereale*)

Type of plant: Grass

Origin: Introduced

Life span: Annual

Season of major growth: Cool

Lower pH limit: 4.5

Planting materials: Seed

Seeding rate: 30 to 60 lb/acre in mixture; 80 to 120 lb/acre alone

Time of seeding: Fall, spring

Superior cultivars: Balbo; Abruzzi

Rate of establishment: Rapid

Major uses: Erosion control (quick, temporary cover)

Comments: Rye is widely used as a quick cover companion crop with perennial species. It is most useful and effective in fall seedings and can be sown alone to produce mulch in place. The plants could be killed with herbicide the following spring and perennial grasses and legumes sown into the dead material. Another seeding option is to not use herbicide but sow the perennial species into the matured rye in late summer. Harvesting the rye grain and seeding perennial herbs into the stubble after harvest is yet another option. Rye seed germinates rapidly; the seedlings are vigorous and quickly provide ground cover. Rye can be sown later in the fall than most species and still be expected to produce some winter cover. Superior cultivars normally are recommended but common rye, also called winter rye, is suitable for cover crop purposes.

FOXTAIL MILLET (*Setaria italica*)

Type of plant: Grass

Origin: Introduced

Life span: Annual

Season of major growth: Warm

Lower pH limit: 4.5

Elevation limit: Avoid high altitudes

Planting materials: Seed

Seeding rate: 10 to 15 lb/acre in mixture; 20 to 30 lb/acre alone

Time of seeding: Late spring to mid summer

Superior cultivars: German

Rate of establishment: Rapid

Major uses: Erosion control (quick, temporary cover); wildlife food

Comments: This summer annual grows rapidly and matures in 60 to 80 days after seeding. Requires high summer temperatures for best growth. Plants are leafy with slender stems that provide dense cover while green, but the plant residue decays much more rapidly than that of sorghum, Sudangrass, pearl millet, or Japanese millet. Thus, foxtail millet is less suitable as an *in situ* mulch for winter cover. The German strain has somewhat heavier stems and requires a longer growing period than common foxtail millet. The seed provides food for songbirds.

INDIANGRASS (*Sorghastrum nutans*)

Type of plant: Grass

Origin: Native

Life span: Perennial

Season of major growth: Warm

Lower pH limit: 4.5

Planting materials: Seed

Seeding rate: 5 to 12 lb/acre in mixtures

Time of seeding: Spring

Superior cultivars: Cheyenne, Osage

Rate of establishment: Slow to moderate

Major uses: Wildlife habitat; forage; watershed protection (long-term cover)

Comments: Indiangrass is native to all Eastern States and in some regions will invade naturally into areas where woody vegetation is controlled, such as under powerlines and on roadsides. It can be sown in mixtures with other native grasses and legumes to help develop or restore a facsimile of native grassland types. It is also possible, but more difficult, to establish this grass in pure stands. Indiangrass seed is light and fluffy, and is more difficult to sow than seed of most other species. Application of fertilizer will help establish new seedings but established stands generally require little or no maintenance fertilization. Clumps of this grass provide some of the cover requirements for some species of game birds and mammals. Indiangrass produces good summer forage for livestock. It responds to spring burning with improved vigor, greater forage production, and more rapid stand development.

SORGHUM (*Sorghum bicolor*)
SUDANGRASS (*Sorghum sudanense*)

Type of plant: Grass

Origin: Introduced

Life Span: Annual

Season of major growth: Warm

Lower pH limit: 4.5 to 5.0

Planting materials: Seed

Seeding rate: 15 to 20 lb/acre in mixtures; 25 to 40 lb/acre alone

Time of seeding: Late spring to mid summer

Superior cultivars: Piper Sudangrass. Consult local agricultural agencies for recommendations on sorghum and sorghum-Sudangrass hybrids

Rate of establishment: Rapid

Major uses: Erosion control (quick, temporary cover)

Comments: The sorghums, Sudangrass, and sorghum-Sudangrass hybrids are drought resistant and are useful as the quick, temporary cover component of herbaceous mixtures sown in late spring to mid summer. They also can be sown alone to grow mulch in place; perennial species can be planted or sown into the plant residue (mulch) the following spring. Plant residues from these species will last through the second year and sometimes longer. There are several types and many cultivars of sorghums. They are classified on the basis of use as (1) grass sorghum; (2) grain sorghum; (3) forage sorghum; (4) syrup sorghum; and (5) broomcorn. The grass sorghums include Sudangrass and the sorghum-Sudangrass hybrids and are the most likely choice to seed for quick cover for erosion control. Grain sorghums can be used in wildlife food patches. Forage and grass sorghums can be used for pasture, silage, or fodder in agricultural land uses. Superior cultivars and hybrids have not been delineated for minesoil plantings. CAUTION: When grown under certain environmental conditions, the herbage of these species can be poisonous to livestock.

WINTER WHEAT (*Triticum aestivum*)

Type of plant: Grass

Origin: Introduced

Life span: Annual

Season of major growth: Cool

Lower pH limit: 4.5

Planting materials: Seed

Seeding rate: 30 to 60 lb/acre in mixture; 80 to 120 lb/acre alone

Time of seeding: Fall

Superior cultivars: Consult local agricultural agencies for recommendations

Rate of establishment: Rapid

Major uses: Erosion control (quick, temporary cover); grain crop; wildlife food

Comments: Similar to rye in growth habit and adaptation to site and minesoil conditions. Can be used as a quick cover companion crop with perennial species or can be sown alone to produce mulch in place. In some areas wheat is used for quick cover and harvested for the grain crop. The stubble and straw residue after harvest provide soil cover until fall seeding time when perennial herbs can be sown or another crop of wheat planted and the grain-harvest cycle repeated. The straw residue adds organic matter to the minesoil, thus improving the minesoil for subsequent growth of perennial plants. Wheat grain is preferred over rye as food by most wildlife species. Recommendations on fall seeding dates and on best varieties can be obtained from local agricultural agents.

TABLE 2. GRASS SPECIES OF LIMITED IMPORTANCE OR USE

Common and Scientific Name	Origin	Life Span	Growth Season	Lower pH Limit	Seeding Rate (lb/acre) PLS	States Where Used	Comment
Western wheatgrass *Agropyron smithii*	N[a/]	P[b/]	Cool	4.5	3-5[c/] 8-10	KS, OK[d/]	Rhizomatous, sod forming. Spreads onto adjacent toxic areas. Moist swales and clayey soils.
Tall oatgrass *Arrhenatherum elatius*	I	P	Cool	4.5	10-12 15-20	PA, MD, WV, OH, IN, IL	Drought resistant. Moisture and temperature requirements similar to orchardgrass. Plants persist but not in dense stands. Seed harvesting difficulties limit seed supply.
Oats *Avena sativa*	I	A	Cool	4.5	30-50	All States	Most often used as quick, temporary cover companion crop in spring seedings. Fall-seeded varieties also available.
Caucasian bluestem *Bothriochloa caucasica*	I	P	Warm	5.0	2-3 3-6	KY, MO, KS, OK	Mix with Appalow or Serala sericea lespedeza or birdsfoot trefoil, or maintain with fertilizer.
Sideoats grama *Bouteloua curtipendula*	N	P	Warm	4.5	5-10	KS, OK, MO	Sow in mixtures with other native grasses. Establishes fairly quickly. Good forage. Native to most Eastern States. 'Elreno' is superior cultivar.

(continued)

TABLE 2. GRASS SPECIES (CONTINUED)

Browntop millet *Brachiaria ramosa*	I	A	Warm	4.5	15-20 20-30	AL	Adapted to southern latitudes. For quick, temporary cover in late spring-early summer seedings. Food for song and game birds.
Buffalograss *Buchloe dactyloides*	N	P	Warm	4.5	5-10 10-20	MO, KS, OK	Adapted to droughty minesoils. Low growing. Spreads by stolons. Mix with other native grasses. Slow to moderate establishment. Excellent forage.
Canada wildrye *Elymus canadensis*	N	P	Cool	5.0	10-12	OH, IL, IA	Slow to establish. Sow in mixtures with other native grasses. Adapted to dry sites. Excellent forage. Native to Eastern States except those in Southeast.
Sand lovegrass *Eragrostis trichodes*	N	P	Warm	5.0	1½-3	OH, IN, IL, IA, MO	Moderately rapid cover on most minesoils. Mix with switchgrass and other native grasses.
Red fescue *Festuca rubra*	I	P	Cool	4.5	4-6 8-10	PA, OH, MD, WV, IN, KY-E	Long lived in northern latitudes and high elevations. Fairly shade tolerant. Capable of making dense cover. Several varieties available.
Broomcorn millet *Panicum miliaceum*	I	A	Warm	4.5	10-12	KY	Use in summer annual mix for game bird food. Good for dove. Adapted to northern latitudes Also called proso millet.

(continued)

TABLE 2. GRASS SPECIES (CONTINUED)

Common and Scientific Name	Origin	Life Span	Growth Season	Lower pH Limit	Seeding Rate (lb/acre) PLS	States Where Used	Comment
Dallisgrass *Paspalum dilatatum*	I	P	Warm	4.5	7-12	AL, TN, AR, OK	Bunchgrass that seldom makes full cover. Sow with legumes or other grasses. Good pasture. Seed used by song and game birds.
Canada bluegrass *Poa compressa*	I	P	Cool	5.0	5-10 15-25	OH, IL	Similar to Kentucky bluegrass but better adapted to low-fertility and droughty soils. 'Reubens' is a superior cultivar.
Kentucky bluegrass *Poa pratensis*	I	P	Cool	5.5	5-10 15-25	OH, IN IL, IA	Shallow-rooted sod-former. Adapted to limestone soils in northern latitudes. Not drought tolerant. Slow to establish cover. Has limited value for vegetating minesoils.
Eastern gamagrass *Tripsacum dactyloides*	N	P	Warm	5.0		PA, WV, KY-E, VA	Establish vegetatively. Clumps enlarge by short rhizomes. Use on moist sites. Native to most Eastern States.

[a] I = Introduced; N = Native. [b] A = Annual; P = Perennial.

[c] First line is recommended rate for use in mixtures; second line for seeding alone. Use only in mixtures where one line (range of rates) is shown.

[d] States where use on minesoils is known. States identified by two-letter abbreviation. Single letter following dash indicates portion of State where used or best adapted, e.g., KY-E = eastern Kentucky.

CROWNVETCH (*Coronilla varia*)

Type of plant: Forb-legume

Origin: Introduced

Life span: Perennial

Season of major growth: Cool

Lower pH limit: 5.0 (see comments)

Planting materials: Seed; crowns

Seeding rate: 5 to 10 lb/acre in mixtures; 15 to 20 lb/acre alone

Time of seeding: Spring, late summer to early fall (plant crowns in spring to early summer)

Superior cultivars: Penngift, Chemung, Emerald

Rate of establishment: Slow

Major uses: Watershed protection (long-term cover); forage; esthetics

Comments: Crownvetch is one of the best plants for providing continuous, maintenance-free cover for erosion control. Plants are spread by seed and by rhizomes (underground root stocks); thus they are especially useful for developing total cover on steep slopes. Usually established by direct seeding, but stands can also be started by transplanting crowns (small plants) from older established stands. Seeded stands are most easily established on minesoils with pH 5.5 and higher, but some have been established at lower pHs. As stands develop, plants will spread to and grow on minesoils with pH 4.5 and sometimes lower. Should be sown in mixture with a quick-cover companion grass such as weeping lovegrass or perennial ryegrass. Only a few plants of crownvetch may become established the first year, but they will develop full cover after 3 to 4 years and suppress associated vegetation. Do not plant crownvetch with tree seedlings. A good forage plant but stands can be weakened or lost by overgrazing or by taking more than one cutting of hay annually. Seeds mature continuously over a period of several weeks; thus, efficient and effective seed harvest is difficult. Commercial seed is usually in short supply. The cultivar Emerald is recommended in the Interior Coal Provinces; Chemung and Penngift are used mostly in the Appalachian Region.

FLATPEA (*Lathyrus sylvestris*)

Type of plant: Forb-legume

Origin: Introduced

Life span: Perennial

Season of major growth: Warm

Lower pH limit: 4.0 to 4.5

Planting materials: Seed (special inoculum)

Seeding rate: 20 lb/acre in mixtures; 30 lb/acre alone

Time of seeding: Spring

Superior cultivars: Lathco

Rate of establishment: Slow

Major uses: Watershed protection (long-term cover)

Comments: Flatpea is a long-lived viny species with tendril-bearing stems and a climbing growth habit. Stand density increases mostly by rhizomes. Stand development is slow but eventually a complete ground cover is established that suppresses associated vegetation and prevents establishment of volunteer plants. Flatpea should not be used in combination plantings with trees. It is drought resistant and more tolerant than crownvetch and most other legumes of acid minesoils. Its primary value is for erosion control on critical slope areas. Where given free choice to graze a number of grasses and legumes, cattle did not eat flatpea but horses did.

SERICEA LESPEDEZA (*Lespedeza cuneata*)

Type of plant: Forb-legume

Origin: Introduced

Life span: Perennial

Season of major growth: Warm

Lower pH limit: 4.5

Elevation limit: Not above 2,000 feet in northern West Virginia or 1,200 feet in Pennsylvania

Planting materials: Seed

Seeding rate: Hulled and scarified seed--10 to 20 lb/acre in mixtures; Increase rate by 10 to 15 lb/acre for unscarified or unhulled seed

Time of seeding: Late winter to early summer (In mid summer to early fall, at least one-half of seed should be unhulled)

Superior cultivars: Interstate; Serala; Appalow (a low-growing form); Caricea

Rate of establishment: Slow

Major uses: Watershed protection (long-term cover); esthetics; forage

Comments: Sericea is widely used for erosion control and soil building, especially in the central and southern Appalachian Coal Field. Use in northern latitudes is limited by short growing season that prevents seed set. Stand establishment is relatively slow; thus it should be sown with a "quick cover" grass, such as weeping lovegrass. In mixture with grass, sericea usually becomes the dominant species after about 3 to 4 years. It usually forms dense stands that prevent or retard the natural invasion of other plants. It is considered low in value for wildlife by most biologists. Sericea can be used for grazing and cut for hay when the forage is young and tender (plants should not be over 10 to 12 inches tall for these uses). Can benefit tree growth in combination plantings providing trees grow above the lespedeza (see section on combination plantings). The main advantage of sericea for reclamation is that it provides a long-term or permanent cover that requires little or no maintenance.

KOREAN LESPEDEZA (*Lespedeza stipulacea*)

Type of plant: Forb-legume

Origin: Introduced

Life span: Annual

Season of major growth: Warm

Lower pH limit: 5.0

Elevation limit: Not above 2,000 feet in northern West Virginia or 1,200 feet in Pennsylvania

Planting materials: Seed

Seeding rate: 6 to 12 lb/acre in mixtures; 20 to 25 lb/acre alone

Time of seeding: Spring

Superior cultivars: Climax (late maturing); Iowa 6 (early maturing, use in northern part of lespedeza region); Rowan (intermediate maturing)

Rate of establishment: Moderate to rapid

Major uses: Wildlife food; forage (hay and pasture); forestry (companion legume with trees); watershed (early cover)

Comments: Readily reseeds in adapted climatic range; thus it can be considered as a long-term component of vegetative cover. Provides early or quick legume component in spring sown grass-legume mixtures. Plant residue provides poor ground cover in winter. More sensitive than sericea and Kobe lespedeza to excess soil manganese. Seed of Korean is a preferred food by quail. Produces high-quality hay.

COMMON LESPEDEZA (*Lespedeza striata*)
KOBE LESPEDEZA (*Lespedeza striata*) var. Kobe

Type of plant: Forb-legume

Origin: Introduced

Life span: Annual

Season of major growth: Warm

Lower pH limit: 4.5

Elevation limit: Below 2,000 feet at northern limits of range

Planting materials: Seed

Seeding rate: 8 to 15 lb/acre in mixtures; 25 to 30 lb/acre alone

Time of seeding: Spring

Superior cultivars: Kobe, Tenn. 76

Rate of establishment: Rapid to moderate

Major uses: Wildlife food; forage (hay and pasture); forestry (companion legume with trees)

Comments: Common lespedeza is also called Japanese lespedeza, Japanese clover, and striate lespedeza. It has a low-growth form and is less productive of herbage than the varieties Kobe and Tenn. 76. Kobe is the most widely used and most familiar cultivar of this lespedeza. It is similar to Korean in growth form but it matures later and is not adapted as far north. It is more tolerant than Korean of high levels of manganese in the soil. Readily reseeds in its adapted climatic range. Generally used for quickly establishing a legume in mixtures with grasses or with grasses and perennial legumes. Recommended as a ground cover species for use with pine in the southern pine region. Growth stops after first killing frost and cover value of plant residue diminishes as winter progresses.

BIRDSFOOT TREFOIL (*Lotus corniculatus*)

Type of plant: Forb-legume

Origin: Introduced

Life span: Perennial

Season of major growth: Cool

Lower pH limit: 4.5

Planting materials: Seed

Seeding rate: 5 to 8 lb/acre in mixtures; 10 to 12 lb/acre alone

Time of seeding: Spring, late summer to early fall

Superior cultivars: Empire, Viking, Mansfield, Dawn

Rate of establishment: Rapid to moderate

Major uses: Watershed protection (medium-term cover); forage

Comments: This relatively low-growing legume grows best in the northern half of the coal mining regions. Stands also are easily established near the southern limits of the adapted area (Kentucky and southern West Virginia) but their life span usually is shorter than in the northern areas. Trefoil has a high tolerance to salt and higher tolerance than most legumes to excess manganese in minesoils. Plants are smaller, less aggressive, and inferior in cover qualities compared with those of crownvetch, flatpea, and sericea lespedeza. Generally, trefoil is most useful for erosion control and for forage where sown in mixture with a grass such as tall fescue, timothy, or orchardgrass. The cultivar Empire has a more decumbent growth and is more winter hardy than Viking or Mansfield. Viking has better seedling vigor. Narrowleaf trefoil (var. *tenuifolium*) is a linear-leaved variant that has a more prostrate growth form than birdsfoot. Its performance is similar to birdsfoot on minesoils. Dawn is a disease-resistant cultivar used in southern Missouri. Research in several Southern States is underway to select and breed cultivars adapted to southern regions.

ALFALFA (*Medicago sativa*)

Type of plant: Forb-legume

Origin: Introduced

Life duration: Perennial

Season of major growth: Cool

Lower pH limit: 5.5

Planting materials: Seed

Seeding rate: 4 to 12 lb/acre in mixtures; 12 to 18 lb/acre alone

Time of seeding: Spring; late summer

Superior cultivars: Ranger, Buffalo. Consult local agricultural agencies for recommendations

Rate of establishment: Rapid to moderate

Major uses: Forage; wildlife habitat; erosion control

Comments: This widely grown species is one of the most valuable forage plants in the United States. It thrives on fertile, nonacid, and well-drained soils. Use of alfalfa on mined lands has been mostly in northern Illinois and similar areas where the minesoils do not require additions of lime or fertilizer. Not recommended for acid minesoils unless the soils are limed to near neutrality (pH 7.0) and adequately fertilized with phosphorus. Use primarily on areas that will be managed for forage production or wildlife openings. It makes good pasture when mixed with orchardgrass, smooth bromegrass, or tall fescue. Although generally considered a cool-season species, alfalfa makes succulent growth in the summer as well as in spring and fall. Stands are subject to damage by alfalfa weevil and several diseases. Some varieties are not winter hardy. Consult local agricultural authorities for advice on cultivars that are winter hardy and resistant to diseases and insects.

YELLOW SWEETCLOVER (*Melilotus officinalis*)
WHITE SWEETCLOVER (*Melilotus alba*)

Type of plant: Forb-legume

Origin: Introduced

Life span: Biennial

Season of major growth: Cool

Lower pH limit: 5.5

Planting materials: Seed (scarified)

Seeding rate: 4 to 7 lb/acre in mixture; 10 to 15 lb/acre alone

Time of seeding: Spring

Rate of establishment: Rapid

Major uses: Erosion control (quick cover)

Comments: Sweetclover generally is considered intolerant of acid soils, but resistant to drought. It makes rapid growth and quickly provides a vegetative cover. On suitable soils it may suppress slower growing companion perennial species, especially where its seeding rate is excessive. Plants mature the second year, produce seed, and die. New plants will volunteer from seed most years thereafter. Sweetclover is a valuable plant for bee pasture (honey production). In agriculture, it is used mainly as a soil-improving crop. Can be used for hay and pasture, but livestock bloat is a potential hazard when grazed. Annual varieties of white sweetclover are available.

RED CLOVER (*Trifolium pratense*)

Type of plant: Forb-legume

Origin: Introduced

Life span: Biennial-perennial

Season of major growth: Cool

Lower pH limit: 5.0

Planting materials: Seed

Seeding rate: 4 to 8 lb/acre in mixtures; 8 to 12 lb/acre alone

Time of seeding: Spring; late summer (southern U.S.)

Superior cultivars: Kenland; Pennscott

Rate of establishment: Rapid

Major uses: Erosion control (short-term cover); wildlife habitat; forage

Comments: Red clover is one of the most important hay crops grown on farms in the Northeastern United States. Its use on mined lands is primarily to improve or enrich the minesoil and to add to species diversity in food plantings for wildlife. It should be sown with long-lived grasses and legumes because it has a biennial or short-lived perennial growth habit. It is used as a winter annual in the South. Although stands of red clover thin out, a few plants will continue to volunteer for several years from seed. Red clover requires a high level of soil phosphorus. It is less drought resistant than alfalfa and is best adapted where adequate moisture is available throughout the growing season. It is subject to damage and stand reduction by several diseases and insect pests.

WHITE CLOVER (*Trifolium repens*)
LADINO CLOVER (*Trifolium repens*)

Type of plant: Forb-legume

Origin: Introduced

Life span: Perennial

Season of major growth: Cool

Lower pH limit: 5.5

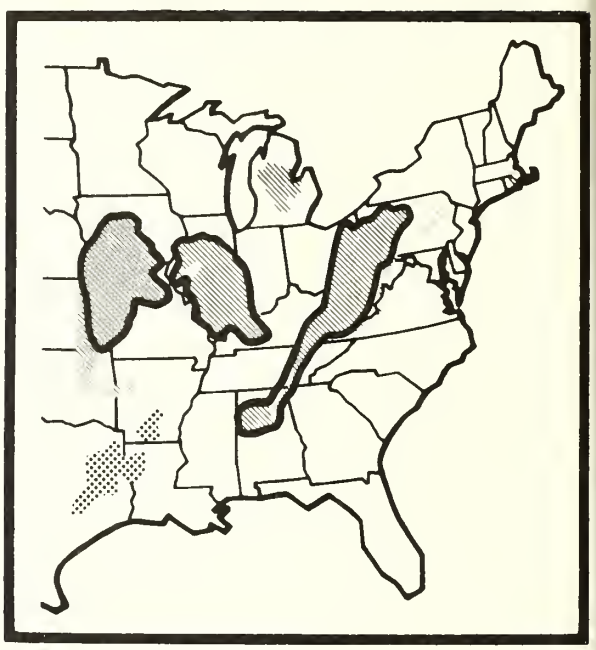
Planting materials: Seed

Seeding rate: 2 to 4 lb/acre in mixtures

Time of seeding: Spring; late summer

Superior cultivars: Ladino

Rate of establishment: Moderate to rapid



Major uses: Wildlife habitat; forage

Comments: Common white clover is used for pasture throughout the Eastern United States. However, on minesoils it should be used primarily to provide diversity in species composition, especially in food patches or openings planted for wildlife. It should be planted with grasses and other legumes. Planted alone, white clover provides inadequate ground cover during the winter. Due to peculiar growth and reproductive habits, there is no assurance of stand persistency from year to year. Although usually considered a perennial, much of the new growth each year may volunteer from seed. Ladino, a large form of white clover, is the most widely sown cultivar for use as hay and pasture.

BUCKWHEAT (*Fagopyrum esculentum*)
COMMON SUNFLOWER (*Helianthus annuus*)

Type of plant: Forb-nonlegume

Origin: Buckwheat--Introduced
Sunflower--Native

Life span: Annual

Season of major growth: Warm

Lower pH limit: Buckwheat--4.5
Sunflower--5.0

Planting materials: Seed

Seeding rate: Buckwheat--25 to 40 lb/acre in mixtures; Sunflower--4 to 6 lb/acre in mixtures

Time of seeding: Late spring-early summer

Rate of establishment: Rapid

Major uses: Wildlife habitat; quick, temporary cover; esthetics; food crop

Comments: Mix with other summer annual species to provide diversity in fall and winter foods for wildlife, especially for song and game birds. Neither species should be depended on alone for cover. Buckwheat can make late summer cover but the plant residue is insufficient for *in situ* mulch over winter. Sunflower plants usually are too sparsely spaced for good cover on the soil surface. Thus, these species usually should be sown with perennial grasses or legumes, or be followed in the fall with a seeding of another quick cover crop such as rye or wheat. Buckwheat is excellent for bee pasture (honey production). Both species add to the visual appeal (esthetics) when in full bloom.

JAPANESE FLEECEFLOWER (*Polygonum cuspidatum*)

Type of plant: Forb-nonlegume

Origin: Introduced

Life span: Perennial

Season of major growth: Warm

Lower pH limit: 3.5

Planting materials: Seed; crowns

Seeding rate: 3 to 5 lb/acre

Time of seeding: Spring

Superior cultivars: Belmont (exceptionally tolerant of acid); *v. compactum* (dwarf fleeceflower)

Rate of establishment: Slow

Major uses: Watershed protection; cover and food for wildlife; esthetics

Comments: This escaped ornamental, also called Japanese Knotweed and Mexican bamboo, is a large, multistemmed, and heavily branched forb that grows up to 8 feet tall. It is sometimes called a shrub because the heavy robust stems give the plants a shrublike appearance. However, the stems die back to the ground each fall and new growth arises in the spring from root crowns and rhizomes. The plants produce an abundance of seed, and when in full bloom have a fleecy appearance. This species will grow and spread on extremely acid minesoil. The accession 'Belmont' was collected from plants that reportedly were growing on minesoil with a pH as low as 3.2. It is a good erosion control plant, especially for extremely acid spoils, because it spreads by seed into gullies and over considerable distances on barren areas. However, it does not readily spread by seed into stands of established vegetation. Dwarf fleeceflower is a low-growing variety (18 to 30 inches tall) used commercially as an ornamental ground cover. It is less acid tolerant than common or 'Belmont' fleeceflower.

TABLE 3. FORB SPECIES OF LIMITED IMPORTANCE OR USE

Common and Scientific Name	Origin	Life Span	Growth Season	Lower pH Limit	Seeding Rate (lb/acre) PLS	States where used	Comment
LEGUMES							
Cicer milkvetch *Astragalus cicer*	I[a/]	P[b/]	Cool	5.0	8-12[c/] 15-20	KS[d/]	A long-lived legume for dryland conditions. Spreads slowly by rhizomes.
Partridge pea *Cassia fasciculata*	N	A	Warm	5.0	20-30	KY, IN	Reseeds, usually in sparse stands. Seed is eaten by game birds. Sow in mixtures. Native to most Eastern States.
Illinois bundleflower *Desmanthus illinoensis*	N	P	Warm	5.0	5-10	KS, OK	Reproduces from seed. Drought resistant. Component of native prairie. High forage value.
Soybean *Glycine max*	I	A	Warm	5.0	30-50	KY, AL, IL, KS (Adapted to all States)	For quick cover in early summer and for wildlife food. Provides little residue for winter cover. Sow with quick cover grasses such as sorghums for overwinter *in situ* mulch. Cash crop on prime farmland.
Prostrate lespedeza *Lespedeza daurica* var. *schimadai*	I	P	Warm	4.5	15-20	IN, IL, IA, MO, KS	Similar to sericea, but low growing. A good ground cover to plant with trees. Not successful in Appalachia.

(continued)

TABLE 3. FORB SPECIES (CONTINUED)

Common and Scientific Name	Origin	Life Span	Growth Season	Lower pH Limit	Seeding Rate (lb/acre) PLS	States where used	Comment
Kura clover *Trifolium ambiguum*	I	P	Cool	5.0	6-8 8-12	WV	Slow to establish. Spreads by rhizomes, forms a sod. Drought resistant, also tolerates wet soils. Requires special inoculum. Seed supply scarce and uncertain.
Alsike clover *Trifolium hybridum*	I	P	Cool	5.0	3-5	MD, WV, KY, OH, IN, IL	Adapted to wet soils and sites with overland flows. For wet sites mix with grass such as redtop and Ky-31 fescue. Provides food for wildlife.
Crimson clover *Trifolium incarnatum*	I	A	Cool	5.0	10-15 15-25	WV, TN, AL, AR, TX	Winter annual grown mostly in the Southeast. Sow in late summer and fall. Can be used alone for winter cover, and sow perennial species the next spring. Reseeding varieties preferred. Adapted northward to Maryland, Ohio, and Illinois.
Zigzag clover *Trifolium medium*	I	P	Cool	5.0	6-8 8-12	WV	Long lived, disease and insect resistant. Spreads by rhizomes. Tolerant of wet and dry soils. Requires special inoculum. Seed supply scarce and uncertain.

(continued)

TABLE 3. FORB SPECIES (CONTINUED)

Bigflower vetch *Vicia grandiflora*	I	A	Cool	5.5	15-20	PA, OH KY	Winter annual. Can be seeded into existing stands of grass. Reseeds itself.
Hairy vetch *Vicia villosa*	I	A	Cool	5.5	20-30 40-50	WV, KY, IN, IL	Winter annual. Sow in fall. Mix with perennial grass such as Ky-31 fescue, or sow with rye for overwinter cover; then seed perennials the next year.
Cowpea *Vigna unguiculata*	I	A	Warm	4.5	20-30	KY	Grown in the Southeastern States. Use for summer cover and wildlife food. Provides little residue for winter cover. Mix with sorghum or Sudangrass for overwinter *in situ* mulch.
NONLEGUMES							
Maximilian sunflower *Helianthus maximiliani*	N	P	Warm	5.0	3-6	KS	Successfully established with native grasses on abandoned spoils graded to rolling topography, limed, and disced. For wildlife and range. SCS cultivars 'Prairie Gold' and 'Aztec'

[a/] I = Introduced; N = Native.

[b/] A = Annual; P = Perennial.

[c/] First line is recommended rate for mixtures; second line for seeding alone. Use only in mixtures where one line (range of rates) is shown.

[d/] States where use on minesoils is known. States identified by two-letter abbreviation.

EASTERN REDCEDAR (*Juniperus virginiana*)

Type of Plant: Tree-conifer
Size: Small
Intolerant to shade

Origin: Native

Lower pH limit: 5.0

Planting material: Seedlings (1-0, 2-0)

Major uses: Wildlife cover and food; esthetics and screening; forest products (fenceposts, Christmas trees, chests, novelties)

Comments: Eastern redcedar is commonly believed to be associated primarily with limestone-derived soils, and will perform best on calcareous and mildly acid minesoils. However, soil acidity may be less critical than soil surface conditions or the presence of competing woody vegetation. In Illinois, redcedar appeared suited for most mined-land conditions except those with unstable sandy surfaces. Trees at 30 years were being shaded out by planted and volunteer hardwoods. Ohio plantings gave poor results. Will probably grow, but has had little or no testing in the other Appalachian States. Probably best suited for use in Western Interior and Lignite Regions.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Mo., Kans., Okla.	9	30	22	5.0	27	27
Illinois, Indiana	11	30	22	4.4	--	21
Iowa	3	8	39	--	5	--

JAPANESE LARCH (*Larix leptolepis*)

Type of plant: Tree-conifer
Size: Medium
Intolerant to shade

Origin: Introduced

Lower pH limit: 4.0 to 4.5

Elevation limit: Not below 3,000 feet in West Virginia

Planting materials: Seedlings (1-0, 2-0)

Major uses: Forest products (posts, mine props, lumber, boxes, crates, and planing-mill products); esthetics and screening

Comments: This deciduous conifer is used mostly in Pennsylvania. Growth is more rapid than for other conifers. Provides more ground cover than most conifers due to greater needle fall. Growth rate greatly reduced on leveled, compacted minesoils. Japanese larch is easier to establish and its growth rate and form are superior to European larch. Larch initiates spring growth early, sometimes before seedlings can be dug in the nursery. Thus, planting stock may become damaged by heating during shipment and cause increased mortality of the planted seedlings.

Growth performance: 5.4 inches dbh and 31 feet tall, averaged at three 30-year-old plantations in Pennsylvania.

WHITE SPRUCE (*Picea glauca*)
NORWAY SPRUCE (*Picea abies*)

Type of plant: Tree-conifer
Size: White--Medium
Norway--Large
Tolerant to shade

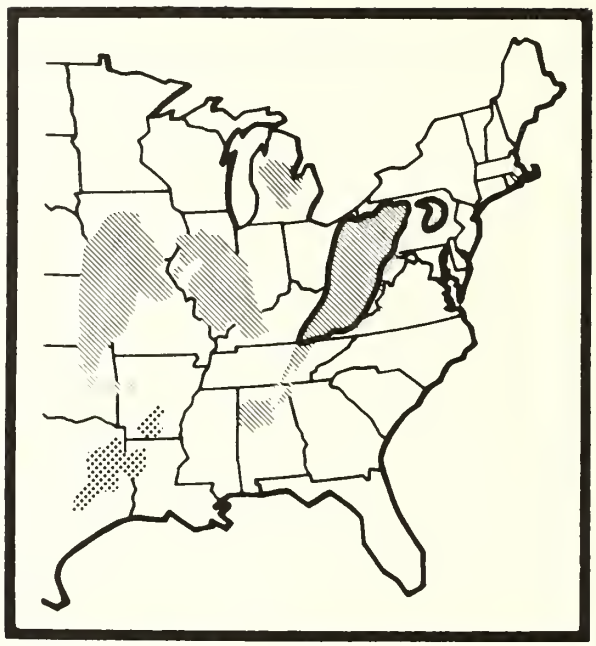
Origin: White--Native
Norway--Introduced

Lower pH limit: 4.5 to 5.0

Elevation limit: Not below 2,500 feet in West Virginia and eastern Kentucky

Planting material: Seedlings (2-0, 3-0)

Major uses: Wildlife cover and food; esthetics and screening; forest products (pulp, musical instruments, general building purposes, and interior parts of furniture); Christmas trees



Comments: Spruce occur naturally in northern temperate regions of the world. Their use is recommended primarily in the northern Appalachians and at the higher elevations of the central Appalachians. Because they are less adapted than pines to dry, low-fertility sites, spruce should be planted on better quality minesoil and on cool, moist sites. Growth is slow for the first few years, but growth rate usually increases after this period. Because they are shade tolerant, spruce persist at a reduced growth rate in the understory of other woody species. In West Virginia, the growth of spruce interplanted with autumn olive was very slow for the first 3 to 4 years; but by age 10 the spruce were matching or exceeding the height of the autumn olive. Spruce are valuable for providing winter shelter for some species of wildlife. They are widely used for shelterbelts, screening, and esthetic purposes.

JACK PINE (*Pinus banksiana*)

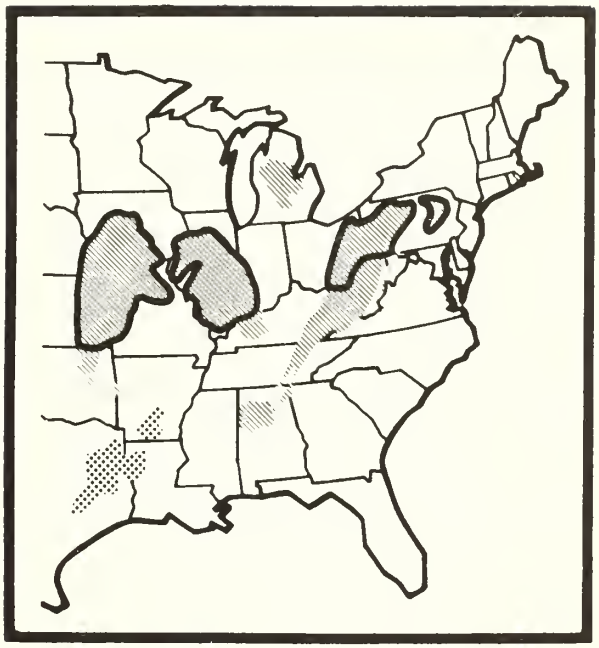
Type of plant: Tree-conifer
Size: Medium
Intolerant to shade

Origin: Native

Lower pH limit: 4.0

Planting material: Seedlings (2-0)

Major uses: Esthetics and screening; wildlife cover and food; Christmas trees; forest products (pulp, poles, posts, mine timbers, and lumber)



Comments: Early survival and growth was best in northern areas, especially in pure and mixed-pine plantings. Performed well in block plantings on anthracite spoil in Pennsylvania. Survival was low in Missouri, Kansas, and Oklahoma plantings. Performed poorly in mixed plantings with hardwoods in Illinois and Indiana. Adapted to acid, dry, and sandy site conditions. Subject to damage and mortality by the pine sawfly. Can be planted for Christmas trees. Provides relatively good ground cover with an abundant layer of pine straw. Known also as Banks pine. Natural range is northernmost States.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Mo., Kans.	7	30	13	6.0	33	23
Illinois, Indiana	11	30	8[a/]	3.8	--	6
Pennsylvania	4	30	--[a/]	4.7	30	--

[a/] 48 percent survival at age 10 (23 sites).

SHORTLEAF PINE (*Pinus echinata*)

Type of plant: Tree-conifer
Size: Medium
Intermediate tolerance to shade

Origin: Native

Lower pH limit: 4.5

Elevation limit: Not above 2,500 feet

Planting material: Seedlings (1-0, 2-0), Seed (stratified, insect and rodent repellent)

Seeding rate: 1/2 to 1 lb/acre

Time of seeding: Spring (stratified seed), late fall-early winter (unstratified seed)

Major uses: Forest products (pulp, poles, mine timbers, building materials); wildlife cover and food; esthetics and screening

Comments: Best performance of this southern pine is mainly within its natural range. Adapted to a wide variety of mined sites, but not in minesoils above pH 6.0. Often competes poorly where interplanted with hardwood species that will overtop it. Generally should be planted in pure stands or can be mixed with other pines. In eastern Kentucky, survival of this pine was not affected but growth was increased where interplanted with European alder. Young trees often are subject to damage by pine tip moth, but usually recover.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Mo., Kans., Okla.	8	29	23	6.6	33	49
Illinois, Indiana	11	30	6	5.0	--	7
Ohio	1	30	11	5.1	34	14
Indiana	1	35	--	8.1	50	190
Tennessee Valley	13	14 to 25	--	3.9	29	--
Eastern Kentucky	1	10	75	3.7	19	50

AUSTRIAN PINE (*Pinus nigra*)

Type of plant: Tree-conifer
Size: Medium
Intermediate tolerance to shade

Origin: Introduced

Lower pH limit: 4.0

Planting material: Seedlings (2-0, 3-0)

Major uses: Esthetics and screening; wildlife cover; Christmas trees; forest products (pulpwood, lumber)

Comments: This pine, introduced from Europe, probably has not been widely used for surface-mine plantings. It is similar to the native red pine in appearance, climatic adaptation , and growth performance on acid minesoils. Survival of Austrian pine was poor in eastern Kentucky and was lower than for other pines on anthracite minesoils in Pennsylvania. Not as susceptible as red pine to pine shoot moth. Young seedlings are reportedly damaged from girdling by rodents. Recommended in Ohio for use on fine-clay minesoils that are poorly drained and with pH 5.0 to 7.0, but should not take preference over native pines on sites that are suitable for them. Has been used in the United States chiefly for windbreaks, ornamental, and esthetic purposes.

RED PINE (*Pinus resinosa*)

Type of plant: Tree-conifer
Size: Medium
Intermediate tolerance to shade

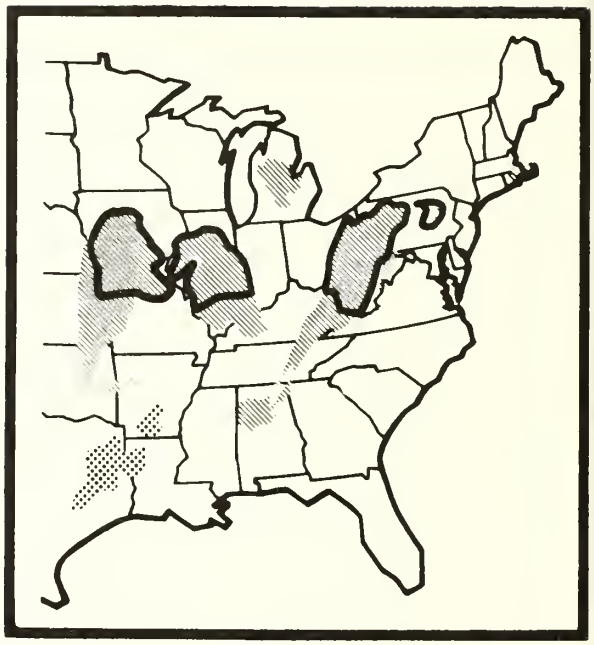
Origin: Native

Lower pH limit: 4.0 to 4.5

Elevation limit: Not below 2,200 feet in West Virginia

Planting material: Seedlings (2-0, 3-0)

Major uses: Forest products (pulp, planing-mill products); esthetics and screening; wildlife cover and food; Christmas trees



Comments: An attractive tree that performed well on a variety of minesoils, especially in the northern Appalachian region. Highly susceptible to European pine shoot moth; thus it should not be planted in areas that have a high incidence of this insect. Red pine can be used for Christmas trees and is excellent for screening. Has been successful in alternate row plantings with hybrid poplar in Pennsylvania. Its wood is used for many purposes. Natural range is northernmost States.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Illinois, Indiana	11	30	8	4.3	--	7
Ohio	6	30	20[a/]	7.2	36	50
Pennsylvania	2	30	--[a/]	7.3	29	--

[a/] 49 percent survival at age 10 (8 sites).

PITCH PINE (*Pinus rigida*)

Type of plant: Tree-conifer
Size: Medium
Intolerant to shade

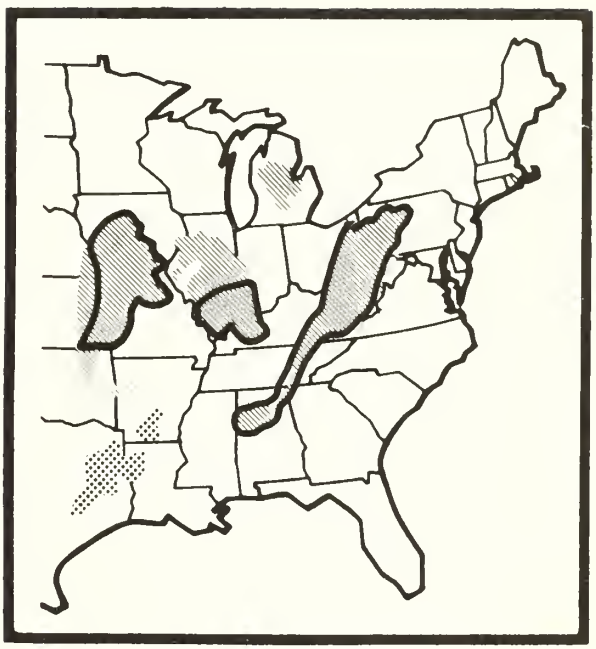
Origin: Native

Lower pH limit: 4.0

Elevation limit: Not above 3,000 feet

Planting material: Seedlings (1-0)

Major uses: Esthetics and screening; wildlife cover and food; forest products (pulp, structural timbers, lumber, and millwork)



Comments: Similar to Virginia pine in adaptation, site requirements, and uses. Has better esthetic and wood qualities than Virginia pine. Especially useful for extremely acid and relatively dry sites that are not suitable for more valuable tree species. Survival was poor in plantings in the Interior Coal Provinces, especially in Missouri, Illinois, and Indiana. Best performance is in the Appalachian Coal Province. Often planted in mixtures with other pines, but normally not with hardwoods. In eastern Kentucky, survival of this pine was not affected but growth was increased where interplanted with European alder.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Missouri	4	30	<1	7.6	25	1
Kansas	4	30	16	6.6	31	34
Illinois, Indiana	11	30	6	5.3	--	8
Ohio	1	30	34	6.5	37	70
Eastern Kentucky	1	10	93	3.4	16	52
Western Kentucky	1	20	25	5.4	30	35
Pennsylvania	4	30	--[a/]	4.7	23	--

[a/] 36 percent survival at age 10 (18 sites).

EASTERN WHITE PINE (*Pinus strobus*)

Type of plant: Tree-conifer
Size: large
Tolerant to intermediate tolerance to shade

Origin: Native

Lower pH limit: 4.0

Planting material: Seedlings (2-0, 3-0)

Major uses: Esthetics and screening; forest products (Christmas trees, mill work); wildlife food and cover

Comments: A widely planted desirable timber species for moderately acid mine spoils. Has been used primarily on sandstone sites (acid to neutral) in Indiana. More tolerant than most pine species of higher pH spoils. Growth for first few years after planting is notoriously slow but is very fast after this species reaches the sapling stage. Height and dbh were increased where interplanted with European alder in eastern Kentucky. Is shade tolerant and, thus, better suited than other pines for mixed plantings. Natural range is Northern and Northeastern States and Appalachian mountains. Seedlings from North Carolina seed source should be planted south of 39th parallel. Use northern seed sources above this latitude.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Illinois, Indiana	11	30	10	5.1	--	13
Ohio	7	30	26	8.0	42	81
Pennsylvania	2	30	--[a/]	6.1	27	--

[a/] 39 percent survival at age 10 (16 sites).

SCOTCH PINE (*Pinus sylvestris*)

Type of plant: Tree-conifer
Size: Medium
Intolerant to shade

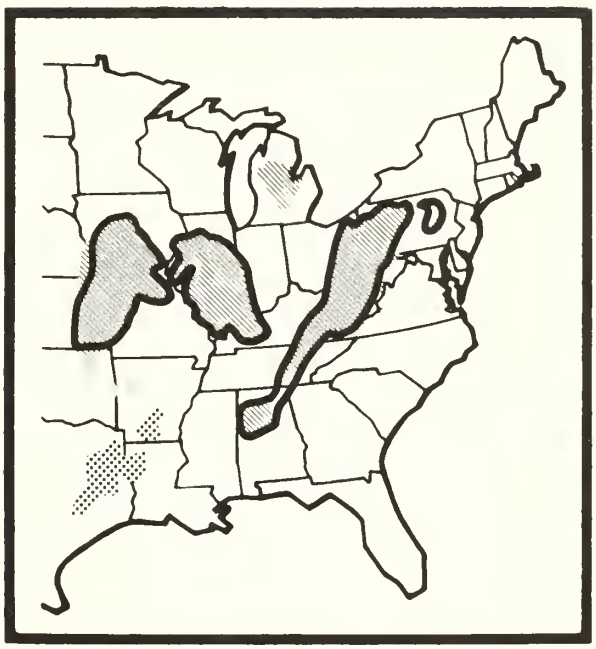
Origin: Introduced

Lower pH limit: 4.0

Planting material: Seedlings (2-0, 3-0)

Seedling spacing: 5 x 5 feet or 6 x 6 feet (for Christmas trees)

Major uses: Christmas trees; esthetics and screening; wildlife cover and food



Comments: Most widely planted introduced tree species in the United States. It is the pine with the greatest natural range and it grows in many different ecological situations. Sources differ in many characteristics such as seed size, tree color, form, and susceptibility to heat, cold, and drought. Widely planted for Christmas trees both on and off mined sites. Seed source is important because some Scotch pine turn yellow in the fall. Has also been used in reforestation but has reputation for crookedness of young stem. Choice of seed source is important to avoid this characteristic.

LOBLOLLY PINE (*Pinus taeda*)

Type of plant: Tree-conifer

Size: Large
Intermediate tolerance to shade

Origin: Native

Lower pH limit: 4.0

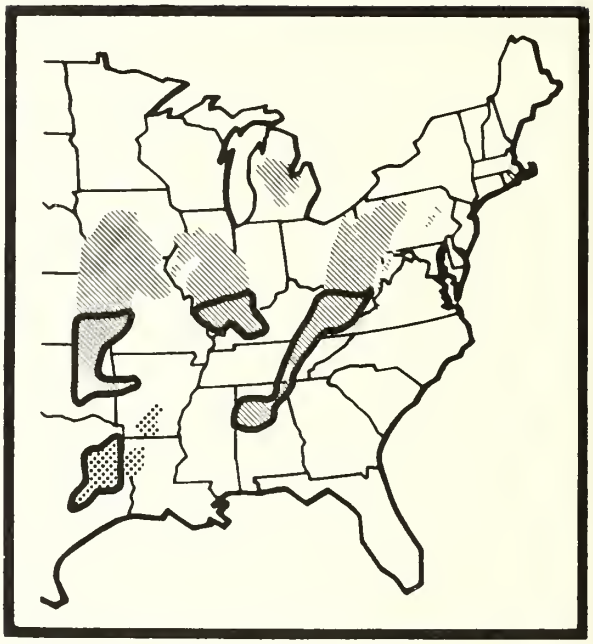
Elevation limit: Not above 2,500 feet

Planting material: Seedlings (1-0); Seed (stratified, bird and rodent repellent)

Seeding rate: 1 to 1-1/2 lb/acre

Time of seeding: Spring (stratified seed); late fall-early winter (unstratified seed)

Major uses: Forest products (pulp, poles, lumber); esthetics and screening; wildlife cover and food



Comments: Loblolly is a fast-growing southern pine adapted to a wide range of minesoil types. Its natural range is southward from central Arkansas and southern Tennessee, yet it is often planted and usually thrives several hundred miles north of this range. However, natural reproduction and success of direct seeding diminishes outside of its natural range. The trees are vulnerable to damage from ice and heavy snow and cannot withstand prolonged periods of subzero temperatures. Only ecotypes from the northern part of its natural range should be used in the northern plantings. Growth rate of loblolly can be improved by planting it with a legume such as Kobe, Korean, or sericea lespedeza. In eastern Kentucky, planting in alternate rows with European alder increased growth of loblolly.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre
Mo., Kans., Okla.	8	30	21	9.8	43	98
Illinois, Indiana	11	30	15	7.6	--	42
Western Kentucky	1	20	28	5.0	37	34
Tennessee Valley	19	8 to 22	--	5.4	34	--
Eastern Kentucky	1	10	52	3.9	21	38

VIRGINIA PINE (*Pinus virginiana*)

Type of plant: Tree-conifer
Size: Small
Intolerant to shade

Origin: Native

Lower pH limit: 3.5 to 4.0

Elevation limit: Not above 2,500 feet in West Virginia

Planting material: Seedlings (1-0); Seed (stratified, insect and rodent repellent)

Seeding rate: 1/4 to 1/2 lb/acre

Time of seeding: Spring (stratified seed), late fall-early winter (unstratified seed)

Major uses: Esthetics and screening; wildlife cover and food; forest products (pulp); Christmas trees

Comments: Virginia pine is the most widely planted conifer on minesoils, especially in the Appalachian Region. It is adapted to a wide range of minesoil types and is especially useful for vegetating acid and droughty sites. Within its natural range this pine often is a pioneer species on minesoils and other disturbed lands. Plantings established in the Eastern and Western Interior Coal Provinces, which are outside its natural range, generally give way after 15 to 20 years to volunteer hardwood species. Direct seeding is sometimes successful, but chances of success are less than for planting nursery seedlings. This pine has high value for wildlife cover and food, especially when planted in blocks or strips that alternate with herbaceous and other woody species.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Mo., Kans., Okla.	8	30	20	6.5	30	41
Illinois, Indiana	11	30	11	7.0	--	26
Western Kentucky	1	20	27	5.3	30	37
Tennessee Valley	3	12	--	3.9	25	--
Eastern Kentucky	2	10	84	3.4	20	47

RED MAPLE (*Acer rubrum*)

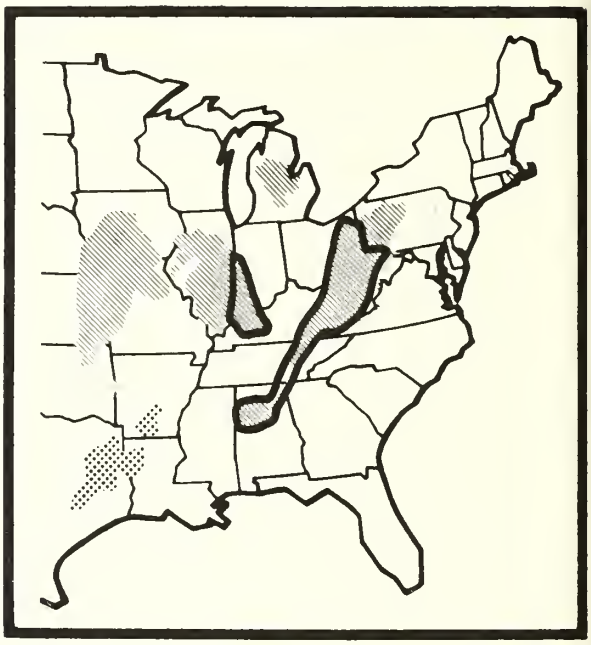
Type of plant: Tree-hardwood
Size: Medium
Intermediate tolerance to shade

Origin: Native

Lower pH limit: 4.5

Planting material: Seedlings (1-0)

Major uses: Forest products (pulp, core stock, veneer, crates, and planing-mill products); wildlife food



Comments: A fairly fast-growing, short-lived tree. Adapted to a range of minesoil conditions--from quite wet to dry sites, both fine- and coarse-textured minesoils, and pH 4.5 to 7.0. Most often planted in mixtures with other hardwoods. Usually will reproduce by natural seeding. Should not be planted in pure stands. In Indiana, pure stands with closed canopies are nearly devoid of herbaceous and woody understory vegetation.

Growth performance: In Indiana, 28-year-old plantings at four sites averaged 6.0 inches dbh, 47 feet in height, and 60 ft^2/acre basal area.

SILVER MAPLE (*Acer saccharinum*)

Type of plant: Tree-hardwood
Size: Medium to large
Intermediate tolerance to shade

Origin: Native

Lower pH limit: 4.0

Elevation limit: Not above 2,500 feet

Planting material: Seedlings (1-0)

Major uses: Forest products (fuel, pulp, corestock, veneer, crates, and planing-mill products); wildlife food

Comments: Grows on most minesoil types but does best on loamy ones with fair drainage and pH 4.5 to 7.0. Most frequently planted in mixtures with other hardwoods. A relatively fast-growing, short-lived tree with poor form. Most of the trees are multistemmed (70 to 80 percent in Illinois and Indiana plantings). Usually maintains itself in the stand by natural seeding. Grew well when underplanted in black locust.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Illinois, Indiana	11	30	29	5.1	--	37
Ohio	1	30	26	5.7	35	41

SUGAR MAPLE (*Acer saccharum*)

Type of plant: Tree-hardwood
Size: Medium
Tolerant to shade

Origin: Native

Lower pH limit: 4.5

Planting material: Seedlings (1-0, 2-0)

Major uses: Forest products (furniture, veneer, gunstocks, and cabinet work); wildlife food and cover

Comments: This tree, also called hard maple, has not been widely planted on surface-mined lands. Yet it could be one of the more valuable species for planting in mixtures with other hardwoods. Does best on moist but well-drained minesoils with predominantly loamy texture and pH 5.5 to 7.5. Initial growth is slow. In western Kentucky, sugar maple was more successful planted in mixture with black locust than in pure stands. At 10 years, the best survival and growth occurred where it was grown in a 50-percent mixture with black locust on lower slopes and well-drained bottoms. Many of the maples had single, straight, and well-formed stems; but on ridges, upper slopes, and in pure stands, more than one-half of the trees had multiple stems. The seed are used by various species of wildlife.

EUROPEAN BLACK ALDER (*Alnus glutinosa*)

Type of plant: Tree-hardwood
(Nitrogen-fixer)
Size: Medium
Intolerant to shade

Origin: Introduced

Lower pH limit: 3.5 to 4.0

Planting material: Seedlings (1-0)

Major uses: Esthetics and screening; forestry (nurse tree, site improvement); watershed protection; wildlife cover and food; pulpwood

Comments: Adapted to a wide range of minesoil types. Good early survival and rapid growth in most areas. Especially valuable on extremely acid minesoils in the northern regions. Performs better than black locust at elevations above 2,500 feet. Valuable as a nurse crop for other tree species. For a nurse crop, plant alder in every other row or every third row with other species. Alder has persisted for 15 to 20 years in the northern regions, but in eastern Kentucky stands start to die back at about 10 years. Longevity in southern Appalachia is uncertain, but stands up to 10 years old are still thriving in Alabama. Survival usually is low in droughty situations.

RIVER BIRCH (*Betula nigra*)

Type of plant: Tree-hardwood
Size: Medium
Intolerant to shade

Origin: Native

Lower pH limit: 4.0

Elevation limit: Not above 2,000 feet

Planting material: Seedlings (1-0)

Major uses: Esthetics and screening; wildlife food and cover; forest products (furniture, cabinets, crates)

Comments: The only southern species of birch. Grows naturally on banks of streams, ponds, and swamps where soil is often flooded for part of the year, and is well suited for fair to poorly drained acid minesoils. Should be planted in mixtures and used primarily where the soil is too acid for other hardwoods. Trees usually have poor form. In Missouri, trees growing on the more acid spoils are taller, have better form, and fewer multiple stems than trees on the better sites where ground cover is greatest.

EUROPEAN WHITE BIRCH (*Betula pendula*)

Type of plant: Tree-hardwood
Size: Medium
Intolerant to shade

Origin: Introduced

Lower pH limit: 3.5 to 4.0

Elevation limit: Higher elevations in West Virginia

Planting material: Seedlings (2-0)

Major uses: Esthetics and screening; forest products (veneer, furniture, pulpwood, planing mill products); wildlife food and cover

Comments: One of the most successful species for planting on extremely acid spoils in Pennsylvania. Young trees may start producing seed 3 to 4 years after establishment. Numerous seedlings often become established on adjacent areas by natural seeding from the planted trees. Attempts at establishment by artificial seeding are seldom successful. The native gray birch (*Betula populifolia*) and paper birch (*B. papyrifera*) perform similarly on mine spoils in Pennsylvania. White birch made rapid early growth on acid minesoils (pH 3.8) at two sites in eastern Kentucky. Natural range is Northern and Northeastern States.

CHINESE CHESTNUT (*Castanea mollissima*)

Type of plant: Tree-hardwood
Size: Medium
Intermediate tolerance to shade

Origin: Introduced

Lower pH limit: 4.5

Planting material: Seedlings (1-0)

Major uses: Wildlife food and cover

Comments: An exotic species that has been planted in an attempt to replace the native American chestnut, but the commercial value of its wood is uncertain. It has been planted mostly for nut production and as an ornamental. Four superior strains have been selected for the quality of their nuts and are propagated for orchard purposes. This tree has performed fairly well in test plantings on surface mines, especially on sites with moderately good exposure and minesoil quality (pH 5.0 to 7.0). For surface-mine reclamation, its value appears greatest for use in wildlife habitat plantings.

In 20- to 30-year-old plantings of Chinese chestnut in Indiana, some of the trees in stands with closed canopies are changing from an orchard-form to a timber-form characteristic. Natural reproduction was observed to be occurring in stands over 12 to 15 years old.

WHITE ASH (*Fraxinus americana*)

Type of plant: Tree-hardwood
Size: Medium
Intermediate tolerance to shade

Origin: Native

Lower pH limit: 4.0

Elevation limit: Not above 3,000 feet

Planting material: Seedlings (1-0)

Major uses: Forest products (pulp, tool handles, furniture, veneer, baseball bats, and tennis rackets); wildlife food and cover

Comments: Long-term survival on surface mines is relatively good but growth is usually slower than for other hardwoods. Has not been planted as extensively as green ash. Climatically adapted to all eastern coal regions but not tested on surface mines in all States. Should be planted in mixtures with other hardwoods. Interplanting with European alder nearly doubled height and dbh of white ash in eastern Kentucky. Direct-seeding trials in Ohio produced poor results. White ash is a valuable forest species. The trunk usually is long, straight, clear and cylindrical. White ash grades much higher than green ash.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Ohio	4	30	45[a/]	5.0	36	55
Pennsylvania	2	30	--[a/]	2.5	19	--

[a/] 65 percent survival at age 10 (13 sites).

GREEN ASH (*Fraxinus pennsylvanica*)

Type of plant: Tree-hardwood
Size: Medium
Intermediate tolerance to shade

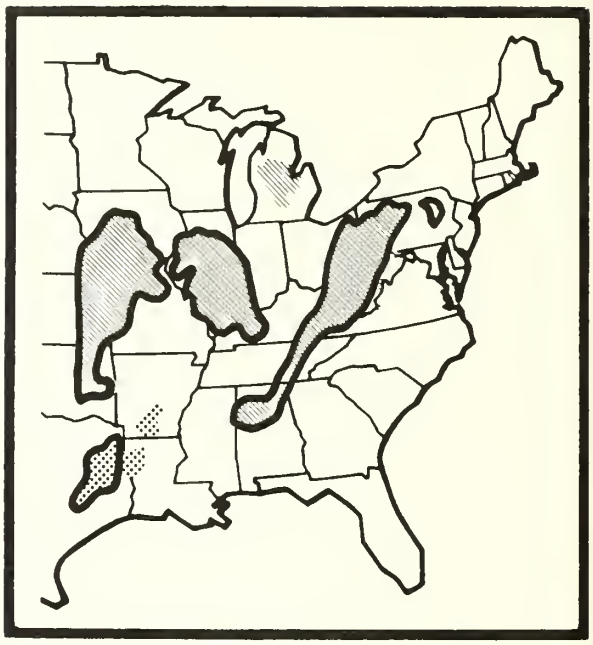
Origin: Native

Lower pH limit: 4.0

Elevation limit: Not above 2,500 feet

Planting material: Seedlings (1-0)

Major uses: Wildlife food and cover; forest products (pulp, tool handles, furniture, baseball bats, and tennis rackets)



Comments: Green ash has been widely planted on surface mines mainly because of its relatively good initial and long-term survival. But, growth is generally poor compared with most other hardwood species. Best growth is on moist sites in minesoils containing a relatively high proportion of soil-size (<2mm) material. Ash should be planted in mixtures with other hardwoods. Trees of this species usually have poorly formed trunks that detract from their value.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Mo., Kans., Okla.	9	30	33	3.8	28	23.0
Illinois, Indiana	11	30	53	4.7	--	56.8
Ohio	4	30	55[a/]	4.0	27	42.7
Pennsylvania	2	30	--[a/]	2.5	15	--

[a/] 69 percent survival at age 10 (15 sites).

BLACK WALNUT (*Juglans nigra*)

Type of plant: Tree-hardwood
Size: Large
Intolerant to shade

Origin: Native

Lower pH limit: 5.5

Planting material: Seedlings (1-0); Seed (stratified for spring seeding)

Seeding rate: 2 or 3 seeds (nuts) per spot

Time of seeding: Fall (unstratified seed), spring (stratified seed)

Major uses: Forest products (veneer, furniture, gunstocks, novelties); wildlife food

Comments: Black walnut has performed best in Indiana, Illinois, and Missouri on moist sites on ungraded minesoils that were slightly acid to slightly calcareous (pH 6.0 to 7.5). Establishment was successful from both seedlings and seed. Survival and growth generally have been poor on Appalachian minesoils, probably due to greater acidity. Although initial growth is relatively slow, black walnut can develop into a valuable forest product. Nuts are a cash crop in some localities. For a timber crop, plant in mixtures with other hardwoods. For spring seeding, the nuts should be stratified outdoors over winter in moist sand, or refrigerated in plastic bags, moist peat, or sand at 34° to 41°F for 90 to 120 days.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
			DIRECT SEEDED			
Mo., Kans., Okla.	9	30	13	4.8	32	15
Illinois, Indiana	11	30	30	6.1	--	54
Ohio	5	30	4	4.1	32	3
			PLANTED SEEDLINGS			
Illinois, Indiana	11	30	21	5.2	--	28
Western Kentucky	1	20	25	2.8	21	9
Illinois	1[a/]	30	42	7.3	--	108

[a/] Planted under decadent black locust.

SWEETGUM (*Liquidambar styraciflua*)

Type of plant: Tree-hardwood
Size: Large
Intolerant to shade

Origin: Native

Lower pH limit: 4.0

Elevation limit: Below 2,500 feet

Planting material: Seedlings (1-0)

Major uses: Forest products; (pulp, veneer, plywood, interior parts of furniture, lumber); wildlife food and cover

Comments: Survival of planted seedlings of this valuable commercial hardwood has been erratic among areas. Best survival has been in Indiana, southern Illinois and southern Ohio; survival was poor in northern Illinois, West Virginia, and some sites in Kentucky and Alabama. Early growth of seedlings is relatively slow, but later growth is rapid. In older plantings, many of the surviving trees have good form and size. Growth is best in fine loam minesoils on moist sites. In Illinois, best growth was on minesoils in the 4.0 to 5.0 pH range. Planting sweetgum in a mixture with other valuable hardwoods such as black walnut, tulip-poplar, and northern red oak is recommended. In eastern Kentucky, growth was increased where interplanted with European alder.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre
Illinois, Indiana	11	30	27	6.4	--	54
Oklahoma	1	30	2	12.8	60	16
Eastern Kentucky	1	10	65	1.7	15	--

YELLOW-POPLAR (*Liriodendron tulipifera*)

Type of plant: Tree-hardwood
Size: Large
Intolerant to shade

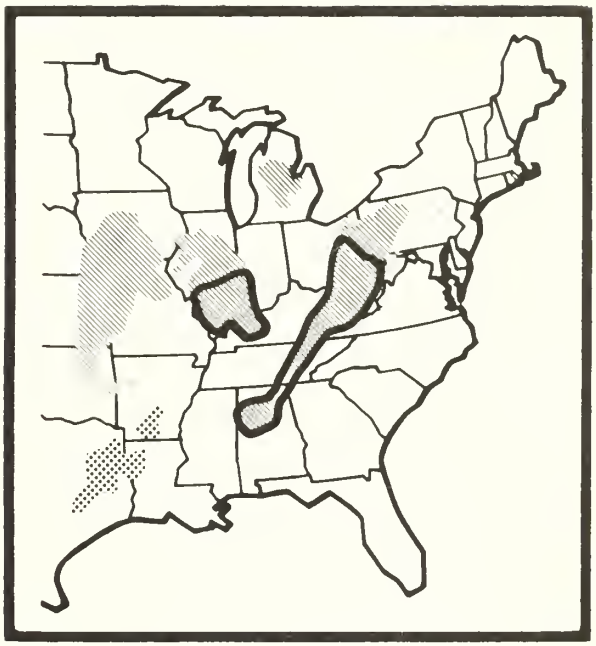
Origin: Native

Lower pH limit: 4.5

Elevation limit: Not above 3,000 feet

Planting material: Seedlings (1-0)

Major uses: Forest products (pulp, lumber, veneer, plywood, furniture, mill work); wildlife food and cover



Comments: Results (survival) with this valuable forest species have been variable on surface-mined lands, but total failures are rare. Performs best on fine-loamy minesoils that have fair to good drainage and pH 5.0 to 7.0. Should be planted in mixtures with other hardwoods. In Illinois and Indiana, growth was especially good where planted under decadent black locust. In eastern Kentucky, height and dbh were nearly doubled where interplanted with European alder. The trunk is tall, straight, and usually free of side branches. The flowers are an excellent source of nectar for honey bees. This tree also is called tulip-poplar and tuliptree.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Illinois, Indiana	11	30	7	7.6	--	20
Ohio	10	30	19	8.7	45	69
West Kentucky	1	20	24	3.5	33	14
Illinois	1[a/]	22	--	8.1	58	--
Illinois	1[a/]	30	23	8.4	60	79

[a/] Planted under decadent black locust.

OSAGE-ORANGE (*Maclura pomifera*)

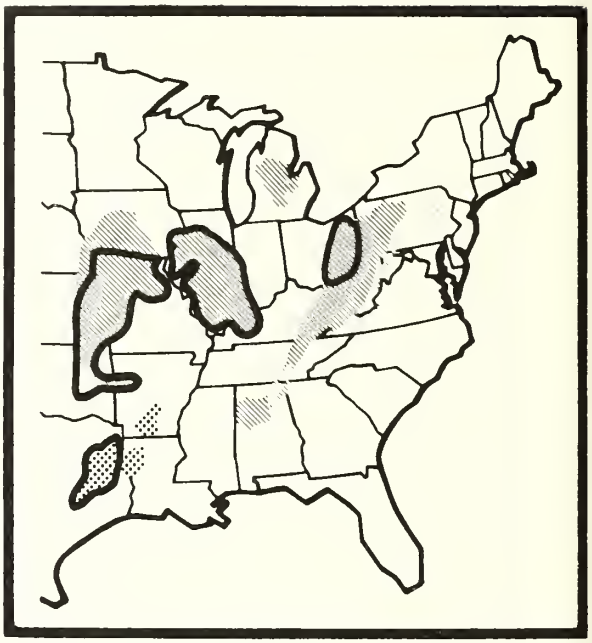
Type of plant: Tree-hardwood
Size: Small
Intermediate tolerance to shade

Origin: Native

Lower pH limit: 4.5

Planting material: Seedlings (1-0)

Major uses: Wildlife food and cover; hedgerows and screening; forest products (posts)



Comments: A small tree native to a small area of eastern Texas, southeastern Oklahoma, and southwestern Arkansas, but has been widely planted and naturalized in many of the Eastern States. Adapted to most surface-mine conditions but performs best on the less acid and well-drained minesoils. In Illinois, initial mortality of planted seedlings was high, but subsequent survival has remained about the same. Osage-orange has relatively little value as a forest species. It has been planted mostly for hedgerows and windbreaks, and cut mainly for fenceposts. Provides good cover and food for wildlife and could be planted along edges as a screen or barrier.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)
Illinois, Indiana	11	30	33	4.4	--
Ohio	2	30	39	3.1	20

CRAB APPLE (*Malus* spp.)

Type of plant: Tree or shrub-hardwood
Size: Small
Intolerant to shade

Origin: Introduced

Lower pH limit: 4.5

Major uses: Wildlife food and cover; esthetics

Comments: The small tree is classified as a shrub in some literature. Several introduced species and horticultural varieties have been established successfully, including Siberian crab apple (*M. baccata*), Japanese flowering crab apple (*M. floribunda*), tea crab apple (*M. hupehensis*), toringo crab apple (*M. sieboldii*), and others not identified. These have been tested on numerous sites mostly in the central and northern Appalachians, but probably are adapted in most of the coal-mining States. Planted primarily for wildlife habitat and esthetic purposes. Usually produces an abundant crop of fruit. Recommend planting in small scattered blocks or on a 20- by 20-foot spacing over larger areas. Seedlings are especially subject to damage by deer browsing and rodents. Fertilizer to stimulate growth of crab apples is not recommended because it increases palatability of seedlings over other woody plants not fertilized.

AMERICAN SYCAMORE (*Platanus occidentalis*)

Type of plant: Tree-hardwood
Size: Large
Intolerant to shade

Origin: Native

Lower pH limit: 4.0 to 4.5

Elevation limit: Not above 2,500 feet

Planting material: Seedlings (1-0)

Major uses: Forest products (pulp, lumber, veneer, mill work, furniture, and gunstocks)

Comments: Makes rapid growth, especially on moist sites. Dieback may occur at higher elevations in the Appalachian Region. Does not establish satisfactorily in dense herbaceous or shrubby cover. Often establishes by natural seeding on mined areas. Plant in pure blocks, or in multiple row mixtures with other hardwoods, but planting in mixture with black locust may reduce survival. In eastern Kentucky, survival of sycamore was not affected but height and dbh were doubled where interplanted with European alder.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Missouri	3	29	15	9.1	48	60
Kansas	3	29	26	5.2	38	34
Oklahoma	1	29	7	8.2	46	23
Western Kentucky	1	20	41	3.8	33	29
Eastern Kentucky	3	10	62[a/]	1.7	17	--

[a/] 5-year survival.

HYBRID POPLARS (*Populus* spp.)

Type of plant: Tree-hardwood
Size: Medium
Intolerant to shade

Origin: Crosses of several native and introduced species

Lower pH limit: 4.0 to 4.5

Planting material: Rooted cuttings; unrooted cuttings (8-10" long)

Spacing: 8- x 8-foot minimum

Major uses: Esthetics and screening; forest products (pulp, corestock, and crates)

Comments: Major assets are good survival and rapid growth. Greatest use has been in Pennsylvania. Best performing clones in one region may not be the best in another region. Cuttings can be taken from established hybrid poplar trees. Select trees that have performed well. Make cuttings in late winter or early spring before sap starts to rise. Select branches that are between 3/8 and 3/ 4 inches in diameter and cut into pieces 8 to 10 inches long. Cover cuttings with damp sawdust and store in cool place until ends of cuttings callous over and buds start to swell. Plant cuttings vertically with buds pointing up so that at least one or two buds are above ground (usually about 1 to 2 inches of cutting above ground). Poplars can be planted in alternate rows with conifers (except larch).

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Eastern Kentucky	1	9	95	3.1	27	44
Pennsylvania	8	10	45	5.4	31	64
Pennsylvania	2	30	--	9.0	63	--

EASTERN COTTONWOOD (*Populus deltoides*)

Type of plant: Tree-hardwood
Size: Large
Intolerant to shade

Origin: Native

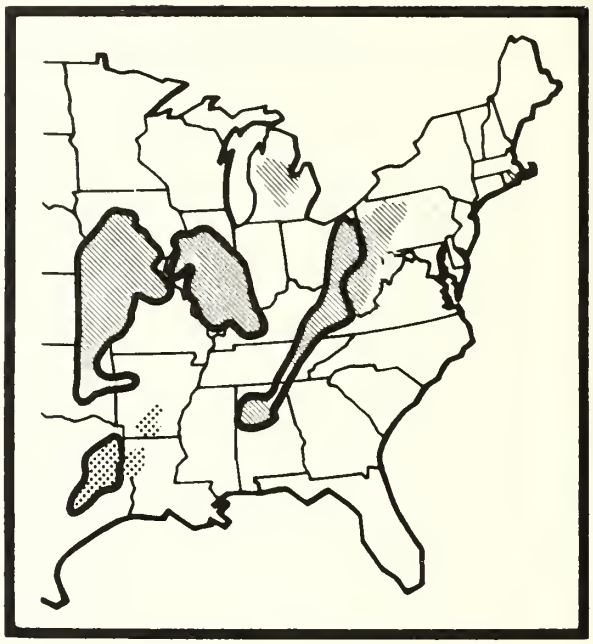
Lower pH limit: 4.5

Elevation limit: Not above 2,500 feet

Planting material: Seedlings (1-0); cuttings

Seedling spacing: 8 x 8 feet

Major uses: forest products (pulp, lumber, and veneer)



Comments: A rapid-growing tree that often establishes by natural seeding on barren minesoils, especially in the Interior Coal Provinces. This species has survived and grown surprisingly well on upland mined sites in eastern Kentucky and Tennessee. Recommend planting in blocks or in bands of several rows in mixtures with other hardwoods. In eastern Kentucky, interplanting with European alder increased height of cottonwood by 30 percent and dbh by 20 percent after 10 years of growth.

Growth performance: Volunteer trees that are 30 to 35 years old often attain height of 65 to 70 feet and dbh of 12 to 15 inches. Planted cottonwood in Illinois and Indiana averaged 11 inches dbh and 104 ft^2/acre basal area at age 30.

BLACK CHERRY (*Prunus serotina*)

Type of plant: Tree-hardwood
Size: Medium
Intermediate tolerance to shade

Origin: Native

Lower pH limit: 4.5

Planting material: Seedlings (1-0)

Major uses: Forest products (furniture and veneer);
wildlife food

Comments: Experimental plantings have been made mostly in Missouri, Kansas, and Oklahoma, where growth performance of black cherry was similar to that of other hardwoods. A few plantings in West Virginia and Pennsylvania reportedly had good survival, but black cherry is not generally recommended in these states. Attempts at establishment by direct seeding have failed, yet black cherry is one of the more abundant volunteer species on naturally and artificially reforested surface mines. Grows best on moist sites and is tolerant of competition. Should be planted in a mixture with other hardwoods or underplanted in deteriorated black locust stands.

Growth performance: In Missouri, Kansas, and Oklahoma, 30-year-old plantings at nine sites averaged 22 percent survival, 5.2 inches dbh, 36 feet in height, and 29 ft^2/acre basal area.

WHITE OAK (*Quercus alba*)

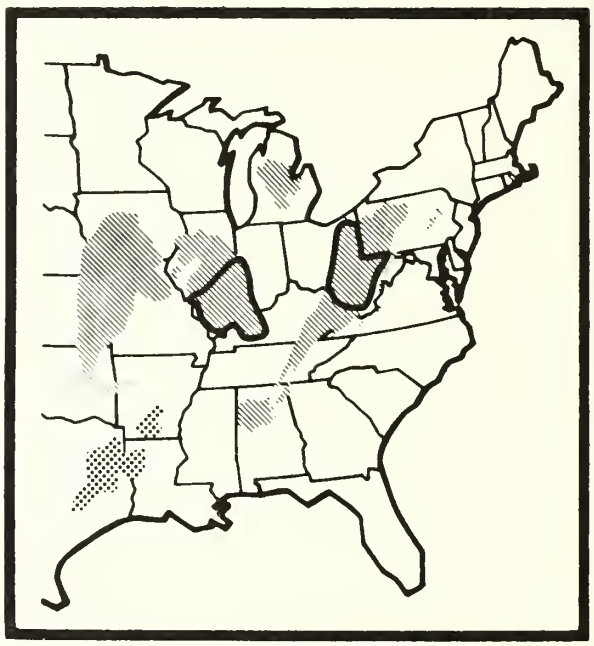
Type of plant: Tree-hardwood
Size: Large
Intermediate tolerance to shade

Origin: Native

Lower pH limit: 5.0

Planting material: Seedlings (1-0)

Major uses: Forest products (flooring, cooperage, and furniture); wildlife food



Comments: Survival and growth of this oak usually is best in mixed plantings with black locust. In western Kentucky, red and white oaks grew best in mixtures of 25- to 50-percent black locust and survived best with 75 percent locust. White oak has not been widely planted on mined lands, probably because of relatively poor survival. Occasional successes and high value of this species warrant further testing. Seedlings and saplings will persist for many years where overtopped by faster growing trees.

Growth performance: In Ohio, 30-year-old plantings at three sites averaged 7 percent survival, 5.0 inches dbh, 30 feet in height, and 8 ft^2/acre basal area. In southern Illinois, 30-year-old trees at one site averaged 5.1 inches dbh.

BUR OAK (*Quercus macrocarpa*)

Type of plant: Tree-hardwood
Size: Large
Intermediate tolerance to shade

Origin: Native

Lower pH limit: 4.0

Planting material: Seedlings (1-0, 2-0); seed (acorns)

Seeding rate: 2 or 3 acorns per planting spot

Time of seeding: Fall

Major uses: Forest products (rough lumber, barrel staves, flooring, railroad ties, and pulp); wildlife food (acorns)

Comments: One of the better performing hardwoods in surface-mine plantings in Missouri, Kansas, and Oklahoma, established successfully from both seedlings and seed. Grows on a variety of minesoil types. Reportedly one of the most drought-resistant oaks and does well on exposed sandy sites. Tolerates heavy competition from herbaceous cover and grows well in mixture with black locust and other species. Acorns of bur oak have no seed dormancy and germinate almost immediately after falling. Collect acorns immediately after they have fallen and plant in the fall. Plant acorns 1/2 to 1 inch deep, using two or three per seeding spot to increase chances of getting a fully stocked stand. Space the seeding spots the same as for planted seedlings.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
			DIRECT SEEDED			
Mo., Kans., Okla.	10	30	24	4.8	28	27
Ohio	3	30	37	5.8	33	60
			PLANTED SEEDLINGS			
Mo., Kans., Okla.	9	30	39	5.0	29	47

NORTHERN RED OAK (*Quercus rubra*)

Type of plant: Tree-hardwood
Size: Medium
Intermediate tolerance to shade

Origin: Native

Lower pH limit: 4.0

Planting material: Seedlings (1-0)

Major uses: Forest products (sawtimber, veneer, furniture, paneling, flooring, and pulp); wildlife food and cover

Comments: Has relatively slow early growth, but growth rate increases with age and red oak becomes one of the better performing hardwoods. Performs best on moist sites on minesoils with high percentage of soil-size (<2mm) particles. Young seedlings subject to damage from rodents and deer. May be planted in pure stands, but planting in mixtures with other hardwoods is preferred. Direct-seeding trials in Ohio produced poor results.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	(ft^2/acre
Illinois	2	35	--	9.8	72	137
Ohio	3	30	14[a/]	5.7	33	22
Pennsylvania	5	30	--[a/]	5.3	37	--

[a/] 62 percent survival at age 10 (9 sites)

BLACK LOCUST (*Robinia pseudoacacia*)

Type of plant: Tree-hardwood
(Nitrogen-fixer)
Size: Medium
Intolerant to shade

Origin: Native

Lower pH limit: 4.0

Elevation limit: Not above 3,000 feet

Planting material: Seedlings (1-0), seed (scarified)

Seeding rate: 1 to 3 lb/acre (in mixture with herbaceous species)

Time of seeding: Spring, fall, winter

Major uses: Site improvement (nurse tree with hardwoods); wildlife food and cover; fenceposts, fuel; watershed protection

Comments: Most frequently and widely used tree for surface-mine plantings, adapted to a wide range of minesoil types. Easily established by direct seeding and planted seedlings. Provides quick overstory cover due to rapid growth. Phosphorus fertilizer benefits seedling growth, especially where direct seeded. Spreads by root sprouting and seed. Susceptible to damage by locust borer that may cause trees to die 10 to 20 years after planting. Surviving healthy trees can be cut for fenceposts. Locust seed is prime quail food in some areas. Use as a "nurse" tree is controversial. Locust improves a site for growth of other trees, especially for natural invasion of hardwoods; but its thorny branches can physically damage leaders and bark of smaller, slower growing adjacent trees. Locust should make up no more than 25 percent of a hardwood mix.

Growth performance:

Location	No. test sites	Age (years)	Percent survival	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)
Mo., Kans., Okla.	10	30	35	6.1	42	63
Illinois, Indiana	11	30	36	6.4	--	72
Ohio	7	30	24	5.9	36	41
Western Kentucky	1	20	50	4.6	36	51
Tennessee Valley	7	11 to 19	--	4.4	39	--

TABLE 4. TREE SPECIES OF LIMITED IMPORTANCE OR USE

Common and Scientific Name	Origin	Tolerance	Lower pH Limit	Major Uses	States Where Used	Comment
CONIFERS						
Rocky Mountain juniper *Juniperus scopulorum*	N[a/]	I[b/]	5.0	H, E[c/]	KS[d/]	Western species used in recent plantings
European larch *Larix decidua*	I	I	5.0	F	PA, WV, OH	Deciduous. For northern Appalachians and high elevations.
Red spruce *Picea rubens*	N	T	5.0	H, E, F	WV	For northern Appalachians and high elevations.
Slash pine *Pinus elliottii*	N	M	4.5	F, H, E	AL	Plant or direct seed in pure stands. For southern latitudes. Has grown well in northern Alabama.
Longleaf pine *Pinus palustris*	N	I	4.5	F, H, E	AL	Plant or direct seed in pure stands. For southern latitudes. Well suited on spoils where surface soil is not replaced.
Ponderosa pine *Pinus ponderosa*	N	I	3.5*	F, E, H, C	PA, KS	*On Pennsylvania spoils. Western species; seed source important. Older plantings in Kansas damaged by needle cast fungus.

(continued)

TABLE 4. TREE SPECIES (CONTINUED)

Pitch x loblolly hybrid pine *Pinus rigida* x *P. taeda*	N	I	4.0	F, E, H	WV, KY-E	Experimentally planted only. Growth faster than either parent. Research underway to increase planting material.
Douglas-fir *Pseudotsuga* spp.	N	T	4.0	F, E, H, C	PA	Western species; seed source important.
Baldcypress *Taxodium distichum*	N	M	5.0	F, H	OH, IN, IL, KY-W, OK, MO	Deciduous. Used on poorly to well-drained sites. Often planted near lakes and wet sites.
HARDWOODS						
Sweet birch *Betula lenta*	N	I	4.0	H, F	PA, MD, WV, OH, KY-E	Value to wildlife greatest in northern Appalachians.
Paper birch *Betula papyrifera*	N	I	3.5	F, E, H	PA	For northern Appalachians and high altitudes.
Gray birch *Betula populifolia*	N	I	3.5	E, H	PA	For northern Appalachians and high altitudes. Similar to European white birch.
Hickories *Carya* spp.	N	I	5.0	H, F	IL	Species used in recent plantings include: *C. ovata, C. tomentosa, C. cordiformis, C. glabra, and C. laciniosa.* No older plantings for long-term evaluation. Grow best on neutral soils.

(continued)

TABLE 4. TREE SPECIES (CONTINUED)

Common and Scientific Name	Origin	Tolerance	Lower pH Limit	Major Uses	States Where Used	Comment
Pecan *Carya illinoensis*	N	I	5.0	H, F	IN, MO, KS, OK	Older plantings in Missouri and Kansas damaged by repeated browsing by deer.
Catalpa *Catalpa* spp.	N	M	5.0	E, F	AL, IL, MO, KS, OK	Mostly in older experimental plantings. Species *bignonioides* does well in Alabama.
Hackberry *Celtis occidentalis*	N	M to T	5.0	H, F, E	IL, MO, KS	Often numerous volunteer seedlings on older sites where forest vegetation is becoming reestablished. Artificial plantings mostly recent.
Flowering dogwood *Cornus florida*	N	T	4.5	H, E	KY-E, IN, IL, MO	Fruit and browse for wildlife. Survival often quite low. Natural seedings sometimes found in established woody vegetation.
Russian olive *Elaeagnus angustifolia*	I	M	5.5	H, E	PA, KY-E OH, IL, IN, TX	Small tree or large shrub. Much used for shelterbelts in Midwest.
Royal paulownia *Paulownia tomentosa*	I	M	4.5	F, E	WV, KY-E TN, AL	A rapid growing tree with high market value for export to Japan. Has escaped from cultivation but difficult to

(continued)

TABLE 4. TREE SPECIES (CONTINUED)

						seed artificially. Nursery seedlings and plantation programs available from American Paulownia Corporation.
Bigtooth aspen *Populus grandidentata*	N	I	4.0	H, F	OH, WV	Will not reproduce in shade. Plant in pure blocks. For northern latitudes and higher elevations in Appalachia.
Sawtooth oak *Quercus acutissima*	I	I	4.0	H	PA, OH, WV, KY-E, TN, AL	Performed moderately well in Appalachian test plantings, especially where soil moisture was favorable. Planted mainly for acorn production. Not recommended above 2,500 feet. Plant 1-0 seedlings.
Shingle oak *Quercus imbricaria*	N	I	4.5	H, F	IL	Often volunteers on older sites where forest vegetation is becoming reestablished. Artificial plantings mostly recent.
Pin oak *Quercus palustris*	N	I	4.0	H, F, E	KY-E, KS MO	Use below 1,500 feet. Volunteers on older forested sites.
Chestnut oak *Quercus prinus*	N	M	4.5	F, H	OH, KY-W IN, IL, IA	Similar site requirements as white oak.

(continued)

TABLE 4. TREE SPECIES (CONTINUED)

Common and Scientific Name	Origin	Tolerance	Lower pH Limit	Major Uses	States Where Used	Comment
Black willow *Salix nigra*	N	I	4.5	H, E, F	IL, TX	Most suited for low wet sites and stream margins. Can withstand flooding and silting. Artificial plantings mostly recent.
Basswood *Tilia americana*	N	M	5.0	F, H	OH	Use in mixtures of hardwoods.

[a/] I = Introduced; N = Native.

[b/] T = Shade tolerant; I = Shade intolerant; M = Intermediate tolerance.

[c/] F = Forest products; H = Habitat for wildlife; E = Esthetics and screening; C = Christmas trees.

[d/] States identified by two-letter abbreviation. Single letter following dash indicates portion of State where best adapted, e.g., KY-W = western Kentucky.

INDIGOBUSH (*Amorpha fruticosa*)

Type of plant: Shrub-legume
(Nitrogen-fixer)
Intermediate tolerance to shade

Origin: Native

Lower pH limit: 4.0

Elevation limit: Not above 3,000 feet

Planting material: Seedlings (1-0);
seed (special inoculum)

Seeding rate: 1/2 to 1 lb/acre
(seed in pods)

Time of seeding: Spring, fall, winter

Major uses: Wildlife food and cover;
watershed protection

Comments: This woody legume is native east of the Mississippi river but has been used mostly in the Appalachian Coal Region. Plants normally grow to about 8 to 10 feet tall on minesoils. They have a growth form and appearance similar to the sumacs. Establishment is usually good but plant growth is fairly slow; plants may average about 2 feet in height after 3 growing seasons. Plants of indigobush are a good site conditioner for the invasion of other native species; they often support a lush herbaceous understory due to their nitrogen-fixing capability. Some observers reported little or no regeneration even though annual seed production was heavy. Fruit normally ripens in August. For direct seeding, seed in pods usually are sown. Because the seeds have an impermeable seed coat and high percentage of dormant seed, germination of some of the seed will be delayed for 2 to 3 years after sowing. Special inoculum is available, but inoculating seed has not been necessary for successful establishment of plants.

SILKY DOGWOOD (*Cornus amomum*)

Type of plant: Shrub
Tolerant to shade

Origin: Native

Lower pH limit: 4.0

Planting material: Seedlings (1-0)

Major uses: Wildlife food and cover

Comments: Silky dogwood has been tested and used more than other species of dogwood for revegetating surface mines. It will begin producing fruit after 3 to 5 years of age. Fruit matures in late summer and falls soon after. It is an excellent food source for many species of birds and mammals. Dogwoods also provide excellent browse for deer. Gray dogwood (*C. racemosa*) has similar qualities and uses, but has been planted less widely. Silky dogwood has been established successfully by direct seeding. Its native range is mainly east of the Mississippi River.

AUTUMN OLIVE (*Elaeagnus umbellata*)

Type of plant: Shrub
(Nitrogen-fixer)
Intermediate tolerance to shade

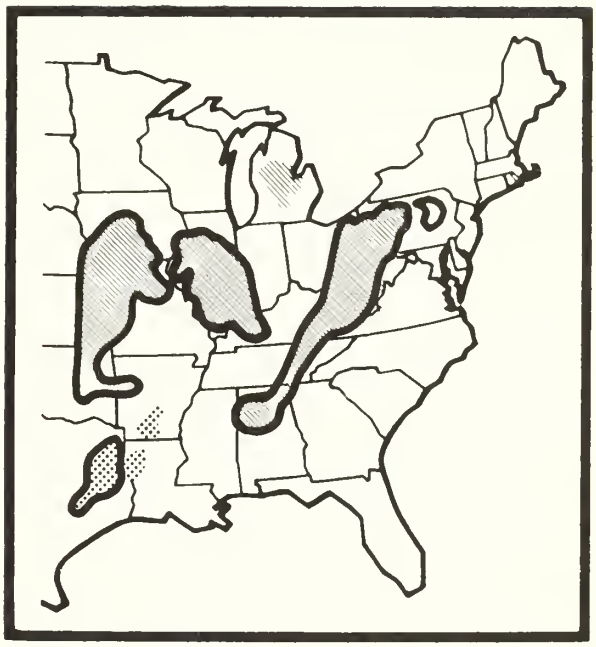
Origin: Introduced

Lower pH limit: 4.0

Planting material: Seedlings (1-0)

Superior cultivars: 'Cardinal', 'Elsberry'

Major uses: Wildlife food and cover; watershed protection; esthetics and screening



Comments: This nonleguminous nitrogen-fixing species is adapted in all of the eastern coal regions. It is easily established on a wide range of minesoil types and conditions. Initial survival and growth usually is good even where planted in an established cover of herbaceous vegetation. Growth of adjacent plants and understory grasses is enhanced by its nitrogen-fixing capability. It has been used as a nurse plant with crop trees. Plants often grow to a height of about 20 feet. After 3 to 4 years, they begin producing abundant fruit that is used in the fall and winter by birds and mammals. Plants also provide browse for deer. Direct seeding is usually unsuccessful but plants can be spread by dissemination of seed by birds. Has the potential to become a "pest" plant and has been banned in some counties in West Virginia. The cultivar 'Cardinal' was selected for its high fruit yield and longer retention of fruit on the plant. Other shrubby species of *Elaeagnus* have been tried in some of the Appalachian States. Cherry olive (*E. multiflora*) and thorny olive (*E. pungens*) performed nearly as well as autumn olive on acid spoil in eastern Kentucky. Silverberry (*E. commutata*) performed poorly on slightly acid spoil in Pennsylvania.

SHRUB LESPEDEZA (*Lespedeza bicolor*)
JAPAN LESPEDEZA (*Lespedeza japonica*)
THUNBERG LESPEDEZA (*Lespedeza thunbergii*)

Type of plant: Shrub-legume
(Nitrogen-fixer)
Intolerant to shade

Origin: Introduced

Lower pH limit: 4.5

Elevation limit: Not above 2,500 feet

Planting material: Seedlings (1-0);
Seed (scarified)

Seeding rate: 1 to 3 lb/acre

Time of seeding: Spring, late winter

Superior cultivars: 'Natob' bicolor

Major uses: Wildlife food and cover;
esthetics and screening

Comments: The shrub lespedezas have been widely planted for wildlife food and cover; the seeds are a valuable food for quail, and rabbits bark the stems in winter. Mature plants are from 4 to 10 feet tall. Plants in full bloom are esthetically attractive and attract numerous honey bees. Establishment is usually most rapid and assured with planted seedlings, but is also accomplished by direct seeding. Normally, seed is mixed and sown with herbaceous species; establishment of the shrub lespedeza plants may not be readily obvious until the second growing season. Use standard lespedeza inoculum on seed. Three species of shrub lespedeza are identified above, but their classification is difficult and confused because of hybridization among species and variants of species. Common *L. bicolor* is the most abundant and widely planted. Some taxonomic authorities consider *L. japonica* as a variant of *L. thunbergii*. 'Natob' *L. bicolor* matures seed earlier and is more winter hardy than other cultivars of shrub lespedeza grown in the United States. It can be grown as far north as Pennsylvania. Common *L. bicolor* and *L. japonica* are recommended for the mid and southern regions and only at lower elevations in West Virginia. *L. thunbergii* is recommended for the southern areas. Seed supplies of pure species and cultivars are scarce or nonexistent.

AMUR HONEYSUCKLE (*Lonicera maackii*)
MORROW HONEYSUCKLE (*Lonicera morrowii*)
TATARIAN HONEYSUCKLE (*Lonicera tatarica*)

Type of plant: shrub
Intermediate tolerance to shade

Origin: Introduced

Lower pH limit: 5.0

Planting material: Seedlings (1-0, 2-0)

Superior cultivars: 'Rem Red' and 'Cling red' amur honeysuckle

Major uses: Wildlife food and cover; esthetics and screening

Comments: These shrubs, planted in combinations with other woody species, add to the diversity in food and cover for wildlife. Plant growth is slow for the first 2 years and seedlings may be adversely affected by tall herbaceous competition. There is little difference in performance among species, except in date of fruit maturity and geographic adaptability. 'Rem Red' amur is adapted over the entire range shown; tatarian is adapted to all areas except Tennessee and Alabama, where Morrow honeysuckle has been used successfully. Fruit of Morrow and tatarian matures in June to August and falls from the plant soon after maturing. Fruit of 'Rem Red' amur honeysuckle matures in September to November and may remain on the plant well into winter. Planting some of all species lengthens the time that they supply food to wildlife. Direct seeding has been unsuccessful, but regeneration and spread of plants to adjacent areas does occur from seed from established plants that is disseminated by birds. These species initiate spring growth earlier than most other shrubs; thus, freshly dug nursery seedlings may already be growing and be susceptible to heat damage while in transit or awaiting planting.

FRAGRANT SUMAC (*Rhus aromatica*)
SHINING SUMAC (*Rhus copallina*)

Type of plant: Shrub
Shade tolerance:
Shining--Intermediate
Fragrant--Tolerant

Origin: Native

Lower pH limit: Shining--4.0
Fragrant--4.5

Planting material: Seedlings (1-0, 2-0); root cuttings

Major uses: Wildlife food and cover; esthetics

Comments: The sumacs are native to all of the Eastern United States. They have not been tested on surface mines in all of the coal regions, but they often volunteer on minesoils that are several years old; chances for success of planted seedlings seem promising. Shining sumac has shown the best growth characteristics in test plantings and spreads by seed and root suckers. Smooth sumac (*R. glabra*) and staghorn sumac (*R. typhina*) also show promise but were not tested as much as shining and fragrant sumacs. In West Virginia, 15-year-old plantings of shining sumac had developed full stands and height of 6 to 7 feet. Fragrant sumac had open stands and height of 3 to 4 feet. Suggested use is for wildlife plantings in blocks of 100 to 200 plants spaced 4 to 5 feet apart. Sumac volunteers on abandoned spoils in some areas.

BRISTLY LOCUST (*Robinia fertilis*)

Type of plant: Shrub-legume
(Nitrogen-fixer)
Intolerant to shade

Origin: Native

Lower pH limit: 3.5

Planting material: Seedlings (1-0),
Seed (scarified, special inoculum)

Seeding rate: 2 to 5 lb/acre

Time of seeding: Spring, fall, winter

Superior cultivars: 'Arnot'

Major uses: Erosion control; wildlife
cover and food

Comments: Bristly locust is one of the best plants to use for erosion control on extremely acid minesoils. The plants will spread primarily from root suckers that begin to form during the first growing season. Dense thickets will form even on eroded sites because root suckering is stimulated where the roots are exposed by erosion. Evidence of becoming a "pest" plant is not apparent even where stands are 12 to 15 years old. Root suckering is retarded or will not occur in well-sodded areas. Usually established by planting 1-year-old seedlings at 6 by 6-foot spacing, but can also be direct seeded. Seeds must be scarified before planting. Plants grow to a height of 8 to 10 feet in about 5 years. Dense thickets of this species provide cover for wildlife. Rose-acacia locust (*Robinia hispida*) is similar to bristly locust in appearance and growth habit, and has the same usefulness for vegetating surface mines.

TABLE 5. SHRUB SPECIES OF LIMITED IMPORTANCE OR USE

Common and Scientific Name	Origin[a/]	Lower pH Limit	Major[b/] Uses	States[c/] Where Used	Comment
Black chokeberry *Aronia melanocarpa*	N	4.5	H, E	PA, OH, IN	Small shrub. Field plant 2-0 seedlings.
Korean barberry *Berberis koreana*	I	4.0	H, E	PA, KY-E, IN	Small shrub. Field plant 2-0 seedlings.
Siberian peashrub *Caragana arborescens*	I	4.0	H	Ky-E	Has grown well on acid minesoil in east Kentucky. Reported use in Poland on fly ash piles with pH 10 to 11.
Gray dogwood *Cornus racemosa*	N	5.0	H, E	WV, KY-E, VA, TN, AL	Similar to silky dogwood. Produces fruit in 4 to 5 years. Intermediate shade tolerance.
Red-osier dogwood *Cornus stolonifera*	N	4.5	H, W, E	PA, WV, KY-E VA, TN	Suited for seepage areas and along ponds. Spreads by underground shoots. Dense root system provides protection against overland flow.
Hawthorn *Crateagus* spp.	N	5.5	H, E	PA, WV, KY-E	Tall shrubs; there are many hybrids and varieties. Washington hawthorn (*C. phaenopyrum*) is the most widely used and available. Field plant 1-0 seedlings. Intolerant.
Amur privet *Ligustrum amurense*	I	4.5	H, E	PA, WV, KY-E, OH, VA, TN	Naturalized in Southeastern United States. Medium-size shrub. Field plant 1-0 or 2-0 seedlings. Tolerant.

(continued)

TABLE 5. SHRUB SPECIES (CONTINUED)

Japanese honeysuckle *Lonicera japonica*	I	4.5	H	All States	Naturalized in all Eastern States. Seldom planted but often present due to natural invasion. Can become a "pest" in agricultural and forestry land uses. One of the best species for wildlife habitat. Retains green foliage in winter. 'Halls' improved cultivar. Tolerant.
Western sandcherry *Prunus besseyi*	N	4.0	H	KY, TN, OH, IN, AL	A 3- to 6-foot bushy shrub good for wildlife cover and food. Produces fruit in 2 to 3 years. Plant 1-0 seedlings.
Chokecherry *Prunus virginiana*	N	5.0	H	KY-E, TN	Tall shrub, 8-18 feet, widely adaptable. Excellent food and cover plant for wildlife. Spreads from root sprouts. Easily established from 1-0 seedlings.
Rose-acacia locust *Robinia hispida*	N	3.5-4.0	W, H, E	PA, MD, WV, KY, VA, TN, OH, IN	Similar to bristly locust (*R. fertilis*). Plant 1-0 seedlings or direct seed. Intolerant.
Multiflora rose *Rosa multiflora*	I	5.0	H, W	PA, WV, MD, KY, VA, OH, IN, IL	Has become "pest" plant in many agricultural areas and now is seldom planted. An excellent plant for providing cover and food for game birds and small mammals.
Rugosa rose *Rosa rugosa*	I	5.0	H, E	PA, WV, KY-E	An excellent food and cover plant for wildlife; survival and growth on minesoils less than desired. Intolerant.

(continued)

TABLE 5. SHRUB SPECIES (CONTINUED)

Common and Scientific Name	Origin[a/]	Lower pH Limit	Major Uses[b/]	States Where Used[c/]	Comment
Memorial rose *Rosa wichuraiana*	I	5.5	H, W	PA, MD, WV, KY, VA, OH, IN, IL	A good plant for wildlife habitat but spreads by runners that will climb on trees and shrubs. Also spreads by seed and can be a "pest" plant similar to multiflora rose. Establish with 1-0 seedlings.
Purpleosier willow *Salix purpurea*	I	5.0	H	PA, WV, VA, OH, IN, IL	Useful along ponds, seepage areas. Grows best in pH range 5.0 to 6.0
American elder *Sambucus canadensis*	N	5.0	H, E	KY-E, TN, AL	Excellent food and cover plant for wildlife, especially songbirds. Establish with 1-0 seedlings.
Silver buffaloberry *Shepherdia argentea*	N	4.0	H, W	PA, OH, IN	Thorny shrub 6 to 10 feet tall. Fixes nitrogen. Growth similar to autumn olive, but no spreading by seed noted. Field plant 2-0 seedlings.
Arrowwood *Viburnum dentatum*	N	4.5	H, E	PA, KY-E	Field plant 1-0 or 2-0 seedlings. Also propagated by cuttings or by layering. Tolerant. Other species of *Viburnum* may be useful.

[a/] I = Introduced; N = Native.

[b/] H = Habitat (food and cover) for wildlife; E = Esthetics and screening; W = Watershed protection (erosion control)

[c/] States identified by two-letter abbreviation. Single letter following dash indicates portion of State where best adapted, e.g., KY-E = eastern Kentucky.

SECTION 5

VEGETATION ESTABLISHMENT

Adherence to proper seeding and planting procedures and use of appropriate soil amendments and mulches will greatly increase success in establishing vegetation. This section includes information on grading; preparing seedbeds; seeding methods; planting tree and shrub seedlings; seeding and planting equipment; and using and applying fertilizer, lime, and mulch.

GRADING AND LEVELING

Grading, leveling, or smoothing of the mined site normally precedes revegetation activities. Designed grading and shaping can enhance the land for most uses. In addition, a newly graded minesoil usually provides a suitable seedbed. However, some grading practices can hinder successful revegetation and should be avoided. For example, grading minesoils when wet or muddy can alter the physical properties of soil particles and create a compacted and pavement-like surface. Grading dry materials to a fine or smooth finish also can produce surface conditions that are undesirable for vegetation establishment.

Grading of some types of spoils, especially those with a predominance of clay and silt particles, is known to be detrimental to the survival and growth of planted tree seedlings. In some of the plantings, tree growth has been adversely affected for as long as 30 years after planting. Conversely, on spoils with a predominance of coarse particles, grading was beneficial to the survival and growth of tree seedlings. Thus, the effects of grading on vegetation establishment seem to be largely related to the type of spoil materials. Because they often contain large amounts of clay-size or fine particles, the topsoils, subsoils, and parent materials used to cover mined areas may create problems--particularly where they are intensively graded and compacted by earth-moving equipment. Soil compaction should be alleviated by ripping or chiseling before attempting to establish vegetation.

The effects of earth moving and grading on revegetating abandoned mine spoils also should be carefully considered and planned before the moving of earth begins, because it is possible that redisturbance of the spoils could create additional problems relating to environmental pollution and revegetation. For example, because they are weathered and leached, minesoils at and near the surface may be less acid or toxic than spoil materials as some depth beneath the surface. Thus, grading off several feet of spoil would expose the unweathered acid-producing materials and cause revegetation problems similar to those that existed many years previously when the area was first mined.

Additional expense and effort would then be required in amending the acid material or in acquiring topsoil or other covering material.

SEEDING PRACTICES

With few exceptions, herbaceous species are established from seed; a few species of trees and shrubs also have been established successfully on mined lands by seeding. In many cases, success in establishing vegetation is more dependent on the use of a few, relatively simple seeding practices than it is on species selection.

Seedbed Preparation

A suitable seedbed is required for the successful establishment of seeded vegetation. A suitable seedbed is one that provides numerous microsites favorable for seed germination and seedling growth. An example of this is sometimes seen on mined areas where seeded vegetation is well established in depressions left by tracks of crawler tractors, but few plants are found between depressions.

Preparation of a seedbed by mechanical tillage or scarification often is essential, especially on minesoils that are crusted or compacted, and for seedings made in late spring, summer, and fall. However, broadcast seedings made on the surface in late winter and early spring sometimes are successful without mechanical preparation of a seedbed because the seed are "planted" by the alternate freezing and thawing of the soil. Also, tillage may not be necessary where seeding is done immediately after grading.

A seedbed can be prepared with a variety of implements. The physical condition of the land surface and size of the area are factors governing the size and type of implements that can be used effectively. Normally, heavy-duty implements will be more useful and suffer less breakage than lighter ones. Disc harrows of several types and chisel plows are useful for tillage in a variety of minesoil conditions (Figures 5 and 6).

Heavy-duty offset disc harrows and bog harrows can effectively break up surface compaction, incorporate lime, and prepare a seedbed on many types of minesoils. But they do not break up subsurface compaction nor satisfactorily till soils with many large rocks. When one or two discs ride over a large rock, the entire gang of discs is raised out of the ground. This interrupts tillage and may cause breakage of the one or two discs that are supporting the weight of the entire gang of discs.

Tillage with chisel plows produces narrow furrows that improve infiltration of water, especially where furrows are made on the contour. Plowing depth can be 2 to 3 times greater with chisel plows than with disc harrows; thus, with sufficient tractor power, soil compaction can be broken at greater depths with chisel plows. Chisel plows are suited for tilling rocky soils because each shank, or chisel, operates independently against the tension of heavy springs to allow the chisel points to ride over or bypass large surface and subsurface rocks. Chisel plows provide good seedbeds for broadcast

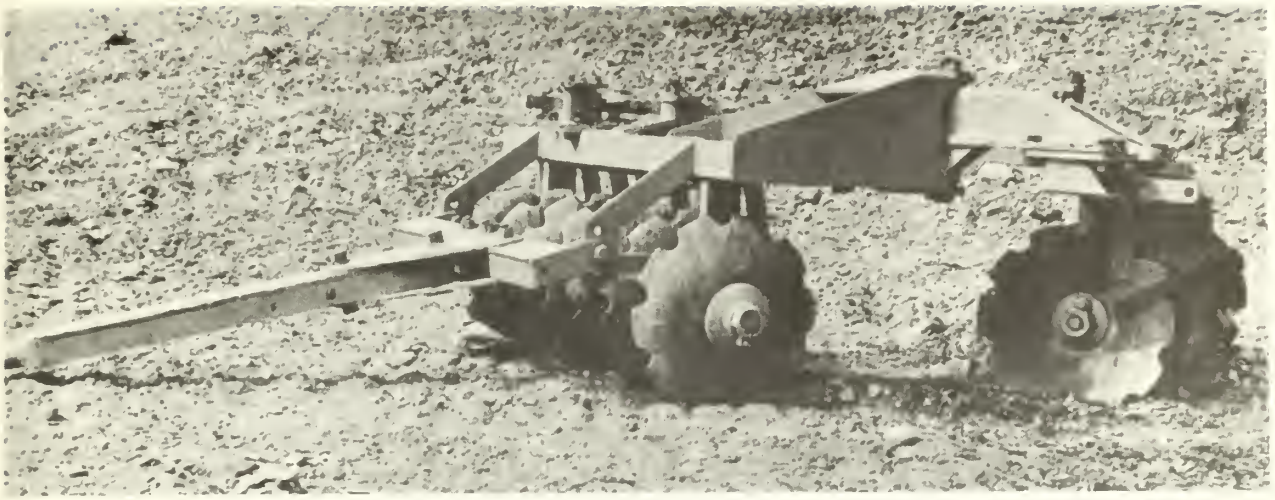


Figure 5. Offset disc harrow for preparing the seedbed or incorporating lime. (Photo courtesy of Rome Industries)

Figure 6. Chisel plow for preparing a seedbed or incorporating lime.

seeding and they effectively mix amendments with the soil. Shanks will break occasionally and rapid wear of chisel points can be expected in stony minesoils, especially sandstones. Small- to medium-size rocks that can be pulled out of the ground by the chisel plow may be unsightly and interfere with the use of other agricultural implements.

For minesoils that are extremely or deeply compacted, ripper teeth attached to a bulldozer or grader may be required as an initial step in seedbed preparation. For soils that are not compacted or firmly crusted, the use of a spring tooth harrow, spike tooth harrow, flexible harrow, or similar light-duty implement can be used to scarify the soil surface. Although it is usually an uneconomical and inefficient use of equipment, bulldozers can be used for seedbed preparation. "Front blading" offers one advantage over "back blading" in that the dozer tracks provide depressions that collect water and favor seed germination and seedling growth. "Tracking in" with a dozer is about the only method available for preparing a seedbed on steep slopes.

A commercial implement called the Klodbuster™ has limited application for scarifying short slopes that are clear of boulders, tree stumps, and other obstacles.

Some of the seedbed preparation practices that are recommended for agricultural soils are not always necessary or appropriate for preparing a suitable seedbed on minesoils. For example, a smooth, finely tilled seedbed prepared by repetitive discing can adversely alter the physical characteristics of some minesoils and actually hinder vegetation establishment. On such materials, a single pass with a disc or chisel plow is sufficient. In addition, precipitation is more effectively trapped and held in a seedbed left in a roughened condition than in a smoothly prepared one.

Methods of Seeding

Basically, there are two ways to apply seed: broadcast and drill. Seed can be mixed with water and broadcast through a hydroseeder; or broadcast dry by hand, or by ground-seeding equipment, or by aircraft. Seed can also be planted with a grain drill, grassland drill, or rangeland drill.

The hydroseeder is very popular, especially in the mountainous Appalachian Region, for seeding steep slopes and highwalls that cannot easily be seeded with other types of equipment (Figure 7). Another advantage of the hydroseeder is that seed, fertilizer, and hydromulch all can be mixed together with water to form a slurry that can be applied in the one pass over the area. Disadvantages of the hydroseeder are that a source of water must be available near the seeding job and a considerable amount of time is required to fill the tank with water. Each tank of slurry covers a relatively small area, especially when hydromulch is included in the slurry. The slurry agitation system in some types of hydroseeders may damage seeds of some grasses and large-seeded legumes. But the germination of some species, especially legumes with hard seed, may be enhanced by scarification. Extra seed to compensate for those that may be damaged can be added in the hydroseeder.

Figure 7. The hydroseeder.

Several kinds and sizes of broadcast seeders are available for dry application of seed. These seeders range in size from hand-operated cyclone seeders that hold about a bucket full of seed to those that hold several bushels and are mounted on a tractor or pickup truck. Broadcast seeding can also be done with a conventional lime spreading truck, though there may be some difficulty in accurately controlling rate of seed dispersal.

Aircraft are most efficient and useful for seeding large acreages and areas where mud or other adverse surface conditions prevent the use of ground equipment. Helicopters generally are more versatile than fixed-wing aircraft for seeding out-of-the-way or hard-to-reach areas. For greatest efficiency, a landing strip close to the work area is required. A substantial amount of ground-support equipment also is required for transporting seed and handling at the landing site.

Seeding with drills may require more time and greater expense for equipment than seeding with some of the broadcast seeders. However, with drills, fewer seed are required because most of the seed are planted at a uniform depth and covered. Because seed are placed in a microenvironment that increases their chances for germination and growth, the advantage of seeding with drills is greater in the climatically drier zones than in the more humid ones.

The use of grain drills and grassland drills is limited to areas that are free of stones and level and smooth enough for normal use of farm equipment. The rangeland drill is a rugged, heavy-duty implement designed for seeding grain, grass, and legume seeds on rough stony rangelands in the West (Fig. 8).

Figure 8. The rangeland drill.

This drill also has been tested on surface-mined land in western Kentucky and is capable of withstanding the rigors of operating on stony spoils with little breakage. Another advantage of the rangeland drill is that it forms furrows that catch and hold surface runoff; thus, the environment for seedlings is improved. Tillage before seeding with a drill may be necessary on minesoils that are compacted or have formed hard crusts.

Time of Seeding

The best time for seeding varies from one region to another. In most regions of the East, weather patterns favor early spring seeding for cool-season species; but fall seeding may produce the greatest success in some areas. For example, in western Kentucky, fall seedings often are more successful than spring seedings because spring-sown plants sometimes drought out during rainless periods in late spring and early summer. Early to mid spring normally is the best time to sow perennial and some annual warm-season species. Mid spring to early summer is the best time for seeding most summer annual species.

Sometimes, mining is completed and an area is ready for seeding in the summer or winter months. Seeding in late spring and summer is more risky than early-spring or fall seedings, and is not recommended in areas with hot dry summers. But in some regions of the East, such as much of Appalachia, summer rainfall usually is sufficient to establish stands of warm season annuals sown in late spring to mid summer. Occasionally, summer precipitation also is adequate for establishment of cool and warm season perennial species. Thus, in areas where summer precipitation normally is adequate, mined sites that are

graded and ready for seeding in late spring and summer should be seeded as soon as possible after grading is completed. Usually, this will shorten the period of time that the minesoils lie barren and exposed to erosion.

Mid-winter seeding is sometimes done in the southern latitudes, but it is not the usual practice in the central and northern latitudes because adverse weather and soil conditions often hinder access and travel on mined areas. Besides, seed sown in winter will not germinate until spring and much of it could be lost due to erosion and siltation.

Seeding dates obviously will not be the same in all regions. For example, the spring seeding period in Illinois may extend from about March 15 to May 1, but in Alabama it may be from February 1 to March 15. Recommended dates for late summer and fall seeding are July 15 to August 20 in Pennsylvania, whereas August 15 to October 15 is suggested for Kentucky. Recommendations for best seeding dates in a given region can be obtained from local farmers and agricultural service agencies.

Seed Quality

The use of good-quality seed that has been properly tested and tagged will help ensure the successful establishment of vegetative cover. Seed quality can be determined from information listed on the seed tag. Two of the values listed on the seed tag--pure seed and germination percentage--are used to determine pure live seed (PLS). Pure live seed is useful for figuring proper seeding rates and the real cost of seed.

To calculate PLS, multiply the percent of pure crop seed times the germination percentage and divide by 100. For example, if a batch of seed contains 95 percent pure seed and has 80 percent germination, the percent of pure live seed (PLS) is 76; (95 x 80) ÷ 100 = 76 percent. This means that in a quantity of seed weighing 100 pounds, only 76 pounds have the potential to germinate.

When purchasing seed, comparative pricing should be done on the basis of pure live seed. This is especially important when buying species that inherently differ in purity and germination between seed lots. To determine the cost per 100 pounds of pure live seed--the real or actual cost of seed--divide the cost per 100 pounds by the percent PLS and multiply by 100. For example: Lot A of fescue seed costs $35.00 per 100 pounds and has 89 percent PLS; ($35.00 ÷ 89) x 100 = $39.33, the cost per 100 pounds of pure live seed. Lot B of fescue seed costs $31.00 per 100 pounds but has only 68.4 percent PLS; ($31.00 ÷ 68.4) x 100 = $45.32 per 100 pounds of pure live seed. Although its bulk price was less, seed lot B actually costs more than lot A for an equal amount of pure live seed.

Other items that describe seed quality, such as the percentage in weight of weed seed and the name and number per pound of noxious weed seed, also are listed on the seed tag. The presence of certain noxious weed seed may be so potentially harmful that high germination would not be the most important consideration in seed quality. The date of test also should be noted to be sure that seed germination has been recently tested.

Using seed of unknown quality presents an added risk in establishing vegetation. However, such use may be necessary and justified where, for example, locally collected seed of native plants are added to the seeding mixture to increase species diversity. However, seed of unknown quality should not be depended upon to be the major contributor to a stand of vegetation.

Seeding Rates

Seeding rates recommended in this manual are expressed in pounds per acre PLS. The use of PLS seeding rates instead of bulk seeding rates will ensure that an adequate amount of viable seed is sown. This is especially important for proper seeding of species, such as some of the native grasses, that often have relatively low purity and germination. To calculate the amount of bulk seed needed to meet PLS recommendations, divide the PLS seeding rate by the percent PLS and multiply by 100. For example, if a batch of switchgrass seed has 60 percent PLS, and the recommended PLS seeding rate is 12 lb/acre, then (12 ÷ 60) x 100 = 20 lb/acre bulk seeding rate. Obviously, if only 12 pounds of switchgrass seed were sown, not nearly enough viable seed would have been sown to meet the seeding recommendations.

The PLS seeding rates suggested here usually are sufficient for vegetating minesoils that have properly prepared seedbeds and are adequately fertilized, limed, and mulched. Sowing additional seed seldom compensates for failure to prepare a seedbed or apply needed amendments. Seeding at too high a rate can cause seedling competition and result in a reduced stand, especially in drier environmental and climatic situations and in well-prepared seedbeds. In seed mixtures of herbaceous species, the temporary species especially should not be sown in excess of recommended rates because they may retard or prevent establishment of the permanent species. In some situations where temporary species are sown alone for growing mulch in place, the use of additional seed may be justified.

Inoculation of Legume Seed

Seed of herbaceous legumes should be inoculated with the appropriate strain of rhizobia. The value of inoculating seed of leguminous shrubs and trees is uncertain because some of these species have been successfully established from noninoculated seed. Inoculants are commercially available for most species of herbaceous legumes; however, for some of the woody legumes and uncommon seldom used herbaceous legumes, inoculum must be specially prepared by the manufacturer.

There are several methods of inoculating seed. For dry seeding, the inoculant can be mixed with lightly moistened seed just before sowing. The inoculant should be generously applied--using even more than that recommended by the manufacturer. Moistening seed with a "sticker" such as sugar mixed with water, molasses, or synthetic gums helps bind the inoculum to the seed and extends longevity of the rhizobia. Soil implant inoculants are available whereby the rhizobia is placed in the soil instead of on the seed. Preinoculated legume seed can be purchased from some seed dealers.

When seeding with a hydroseeder, the inoculant is added to the slurry just before it is spread. When mixed with a slurry that includes fertilizer, the inoculating bacteria may be killed by high acidity (low pH) caused by the fertilizer. To reduce loss of the bacteria the slurry pH should be kept above 5.0 and spread as soon as possible after mixing. Where slurry pH is below 5.0, hydrated lime can be added at 100 pounds for each 1,000 gallons of water to lessen the effect of the acidity. For hydroseeding, inoculants should be added at double the amount recommended for dry seeding.

Commercial inoculants are stamped with an expiration date because the viability period of the packaged rhizobia is limited. Inoculant with an expired date should not be used. The environment in which inoculant is stored also affects its viability. High temperatures will destroy it, so beware of buying and using inoculant stored or displayed in abnormally warm places such as in attics or next to stoves. Inoculant should be kept in a cool place, and partially used packages should be tightly resealed. Use inoculant only on the legume species for which it is specified.

PLANTING WOODY SPECIES

Woody vegetation often becomes established by natural seeding but adequate stands of commercially valuable forest trees seldom develop naturally on surface-mined lands. Thus, artificial forestation is the only sure way to establish fully stocked stands of desirable species. Artificial planting of woody species also hastens the initial establishment of food and cover plants beneficial for wildlife. Subsequent natural seeding adds needed diversity to the habitat.

The success of any planting is affected by the (1) quality of planting stock; (2) method of planting; (3) care of planting stock; (4) spacing; and (5) time of planting. Paying attention to proper establishment procedures is as important as selecting appropriate plant species.

Quality of Planting Stock

Planting stock often is defined in terms of age such as 1-0, 2-0, 2-1, and so on. A 1-0 seedling is produced in 1 year, lifted from the seedbed, and ready for immediate planting in the field. A 2-0 seedling is left in the seedbed for 2 years. A 2-1 seedling is grown for 2 years in the seedbed, then transplanted and grown 1 year in a transplant bed before it is lifted for field planting. The sum of the two numbers is the age of the seedlings.

Plantable stock of many of the suitable species is produced in one year. However, the size of planting stock can vary among nurseries and with different seasons in the same nursery. Thus, the quality of planting stock should be judged mainly by the size and balance of the seedlings instead of solely by age. Stem diameter, and length and weight of roots in relation to length and weight of tops, are generally considered the best criteria for judging stock quality. Root and top pruning, a practice for adapting seedling size to different methods of planting, also affects stock quality.

Generally, greater stem diameters mean better survival of seedlings. For most conifers and hardwoods, a minimum stem diameter of 0.1 to 0.15 inches (2.5 to 4 mm) is recommended. However, the maximum stem diameter that should be planted is limited or determined by the length of roots. In most planting jobs, roots are pruned to standard lengths to accommodate the methods of planting; for example, 6 inches with planting bars and 8 inches with mattocks. If the diameter and length of top are excessive in proportion to the length of pruned roots, an imbalance in the physiological processes of the seedling could greatly decrease its chances for survival. Seedlings of most hardwoods can be top pruned with no significant effect on survival. Top pruning can facilitate packing, shipping, and handling of hardwood seedlings. Top pruning is not advised for conifers.

Planting stock standards for the Central States region were developed by the USDA Forest Service for tree species commonly planted on mined lands (Tables 6 and 7). For conifers, the standards are based on stem diameters (at the ground line) and the relation of top lengths to root lengths after pruning. For shortleaf pine, for example, the recommended minimum stem diameter is 0.15 inches; if roots are pruned to 6-inch lengths, the tops should be longer than two-thirds the length of the roots (4 inches) and shorter than 8 inches. For hardwoods, the standards are based only on stem diameters; maximum stem diameters are prescribed only if roots are pruned to lengths of 8 inches or less. Planting stock standards may vary somewhat in other regions.

For the future, another factor to consider is the selection and use of planting stock inoculated with the appropriate mycorrhizal associates. The species of mycorrhizal fungi normally present in nursery beds may not be adapted to the inhospitable environment of minesoils. In addition, fumigation and fertilization practices used in most nurseries are detrimental to the existence of the fungi. Hopefully, as additional knowledge is gained about the mycorrhizal fungi and other beneficial microorganisms, nurseries will develop or adapt techniques for producing or inoculating planting stock with the mycorrhizal species that are most beneficial for the survival and growth of seedlings on mined areas.

Methods of Planting

Seedlings of trees and shrubs usually are hand planted; a planting bar (dibble) or mattock is used to make the holes (Figures 9 and 10). The planting bar is a better choice for use in minesoils that are stony or compacted. The planting hole should be large enough so that the seedling roots can be spread out and not bent or doubled under. Seedlings should be planted to the same depth at which they were growing in the nursery. The soil should be pressed firmly around the planted seedling.

Hand planting is necessary on steep slopes and small areas and is done with crews of a few to several planters (Figure 11). For large planting crews, one person should be responsible for the care of the planting stock and for distributing it to the planters. On steep slopes, where rocks could slide or roll, no planter should work directly below another.

TABLE 6. PLANTING STOCK STANDARDS FOR HARDWOODS PLANTED ON SURFACE-MINED LAND IN THE CENTRAL STATES[a/]

Species	Stem Diameter at Ground Line	
	Minimum	Maximum (For roots pruned to 8 inches or less)
	----------Inches----------	
Maple, silver	0.15	0.40
Ash, green and white	0.10	0.35
Walnut, black	0.20	0.35
Sweetgum	0.15	0.40
Tulip poplar	0.25	0.35
Osage-orange	0.15	0.40
Sycamore	0.10	0.35
Cottonwood	0.15	0.40
Oak; bur, northern red, and chestnut	0.15	0.40

[a/] From U.S. Department of Agriculture. 1960. Forestation of strip-mined land in the Central States. U.S. Dep. Agric., Agric. Handb. 166.

Tractor-drawn tree planting machines can be used on large, relatively level areas that are free of stones. Usually 15 to 20 percent is the safe maximum slope for machine planting on contour. For safety, steeper slopes, up to 30 percent, should be planted up and down slope; however, furrows running up and down slope can create channels for initiating gulley erosion. Care should be taken that the machine covers the furrow sufficiently and packs soil around the seedling roots. It is desirable to have someone follow the machine and tamp around loosely packed seedlings.

Hybrid poplars often are propagated from cuttings. A planting hole for cuttings can be made with the planting bar or mattock, but a pointed planting bar made from steel rod about 3/4-inch in diameter works best. The hole should be deep enough to place at least two-thirds of the poplar cutting in the ground. The cuttings usually are about 10 inches long. The buds on the cutting should point upward.

Care of Planting Stock

Planting stock should be protected from exposure to sun and drying during shipment and delivery to the planting site. Seedlings should be planted as soon as possible. If necessary to keep stock several days before planting, moisten unopened bundles and store in a cool, shaded place. For seedlings

TABLE 7. PLANTING STOCK STANDARDS FOR CONIFERS PLANTED ON SURFACE-MINED LAND IN THE CENTRAL STATES[a]

Species	Minimum Diameter of Stem at Ground Line	Allowable Range in Length of Tops	
		For roots pruned to 6 inches	For roots pruned no shorter than 8 inches
	----------Inches----------		
Eastern redcedar	0.15	4 - 6	6 - 12
Jack pine	0.10	4 - 6	6 - 12
Shortleaf pine	0.15	4 - 8	6 - 12
Red pine	0.15	4 - 6	6 - 12
Pitch pine	0.15	4 - 8	6 - 12
Eastern white pine	0.15	4 - 8	6 - 12
Loblolly pine	0.10	4 - 6	6 - 12
Virginia pine	0.10	4 - 6	6 - 12

[a] From U.S. Dep. Agric., Agric. Handb. 166, 1960.

that cannot be planted within 2 weeks after delivery, the bundles should be opened, inspected, moistened and "heeled in," or placed in cold storage at 34° to 38°F. Stock of most species can be held safely in cold storage for 3 to 4 weeks.

While planting, seedlings must be kept moist in a canvas planting bag or bucket (Figure 12). Tree roots exposed to drying can be damaged or killed very quickly. Coating seedling roots with kaolin clay is sometimes done to retard root drying while planting. To make the coating, mix 100 pounds of kaolin clay in 25 gallons of water. Dip the roots in the clay slurry. Planting trays or buckets, but not planting bags, are recommended for carrying coated seedlings.

Spacing

The spacing of planted trees and shrubs varies with locality, purpose of the planting, species, and requirements of regulatory agencies. For commercial forestry (timber production), ideal spacing is wide enough to postpone the first thinning until merchantable products can be obtained, and close enough to ensure good form and development. As a rule, conifers are planted at a slightly wider spacing than hardwoods. Planting 800 to 1,000 trees per acre usually is recommended for conservation purposes and for development of a productive forest. Spacing at 6 by 7 feet (about 1,000 trees per acre) or 7

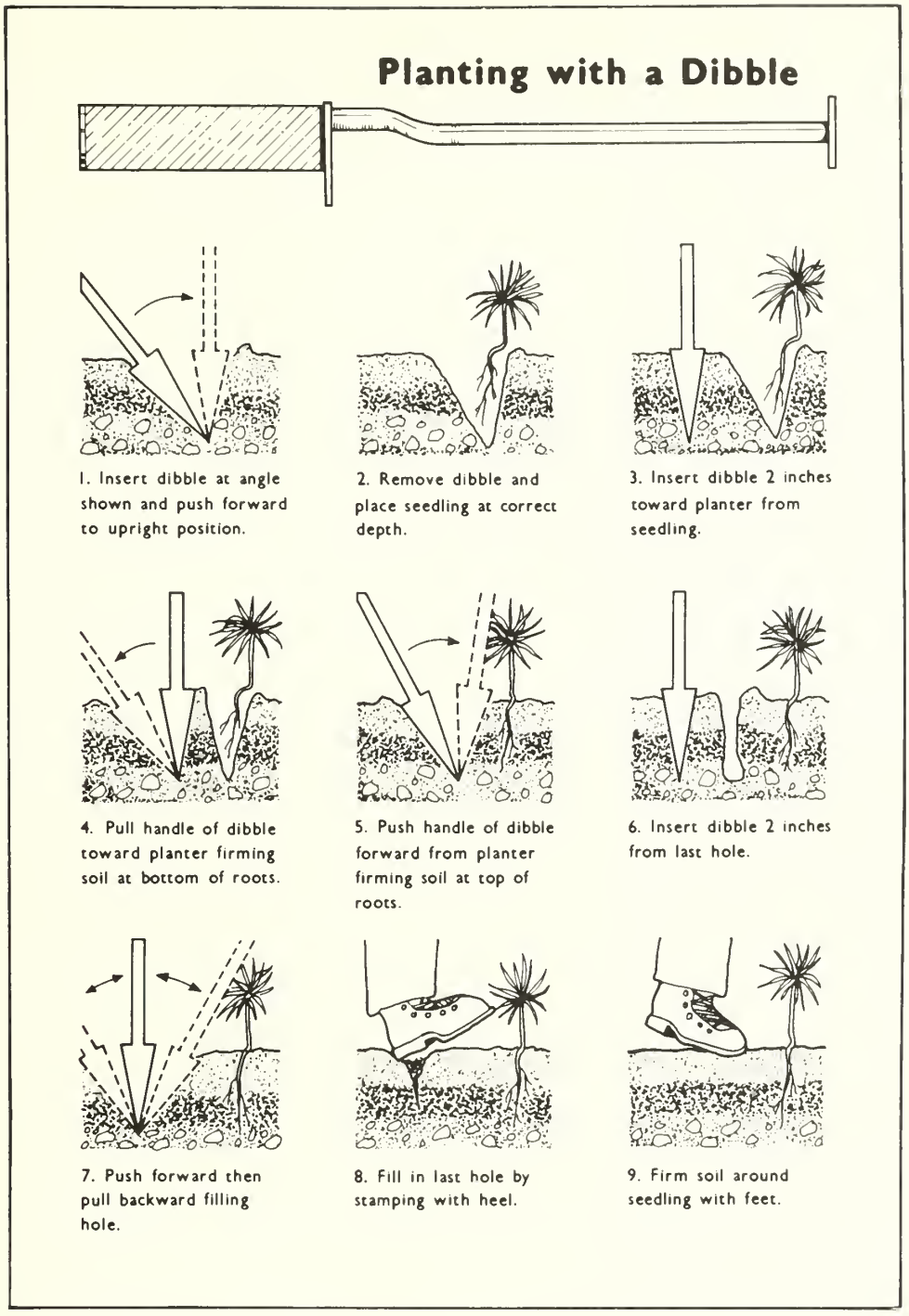


Figure 9. Planting tree and shrub seedlings with a dibble. (Redrawn with permission from John Wiley & Sons, Inc. and Alabama State Forester)

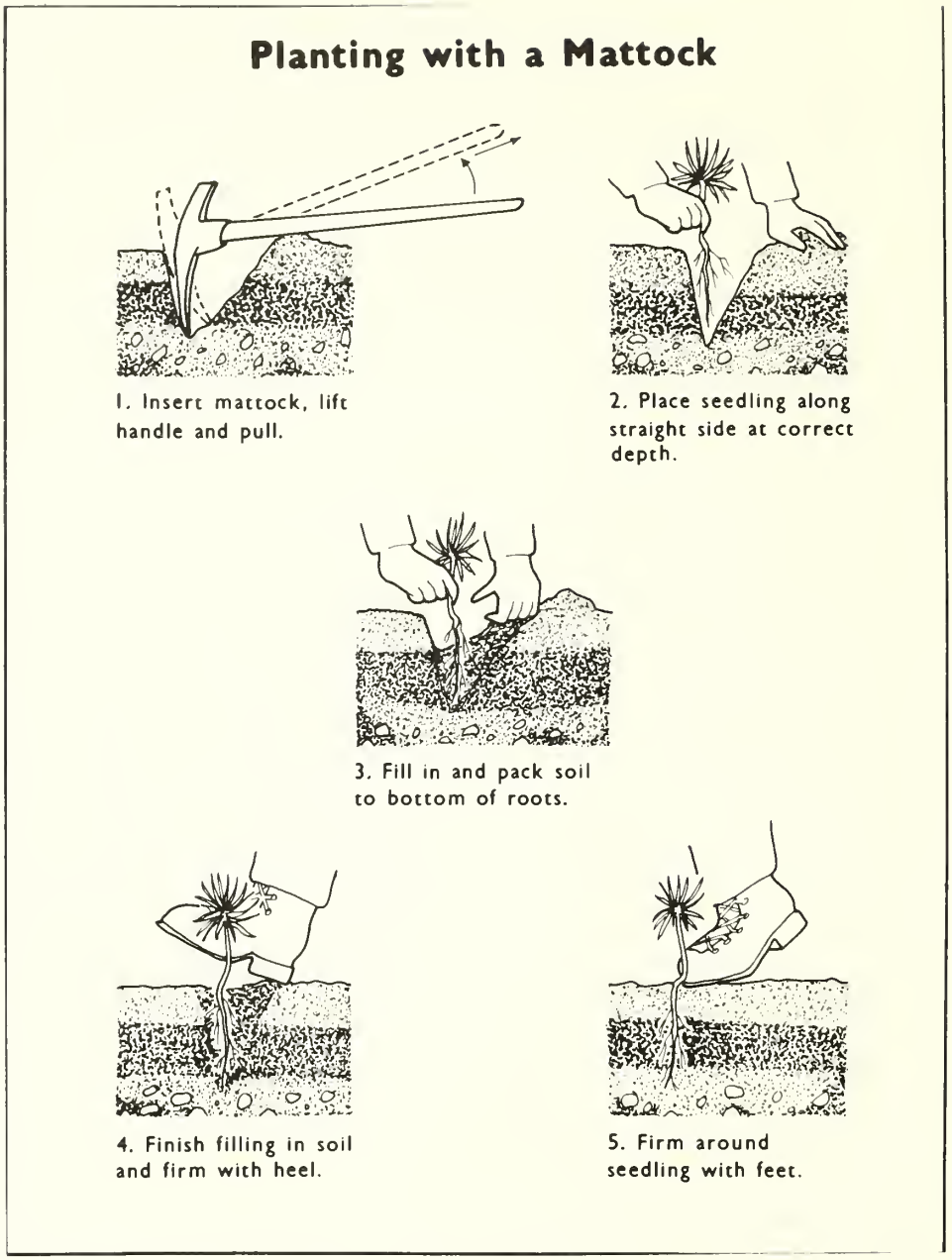


Figure 10. Planting tree and shrub seedlings with a mattock. (Redrawn with permission from John Wiley & Sons, Inc. and Alabama State Forester)

Figure 11. Planting trees with a dibble.

by 7 feet (about 900 per acre) is frequently recommended for mixed hardwood plantings. Spacing at 7 by 8 feet or 8 by 8 feet is recommended for conifers.

Christmas tree plantings usually are spaced 5 by 5 feet, sometimes 6 by 6 feet. For hybrid poplars planted alone, an 8- by 8-foot spacing is recommended, but if planted in alternate rows with a conifer, black locust, or black alder, a 7- by 7-foot spacing is advised. Closer spacings may be desired for screen plantings along roads, in block plantings of shrubs used for wildlife habitat, and on slopes where erosion control is a major concern.

The usual planting procedure is to space seedlings uniformly over an entire area. An alternate method that may improve stabilization and erosion control on slopes is to plant the seedlings close together (4 to 5 feet apart) in two to four closely spaced rows (5 to 6 feet apart) on the contour. The spacing of seedlings in one row should alternate with the spacing in the adjacent rows. The distance between groups of rows should be 20 to 40 feet. This spacing also provides a suitable planting pattern for wildlife habitat, especially when shrubs are used.

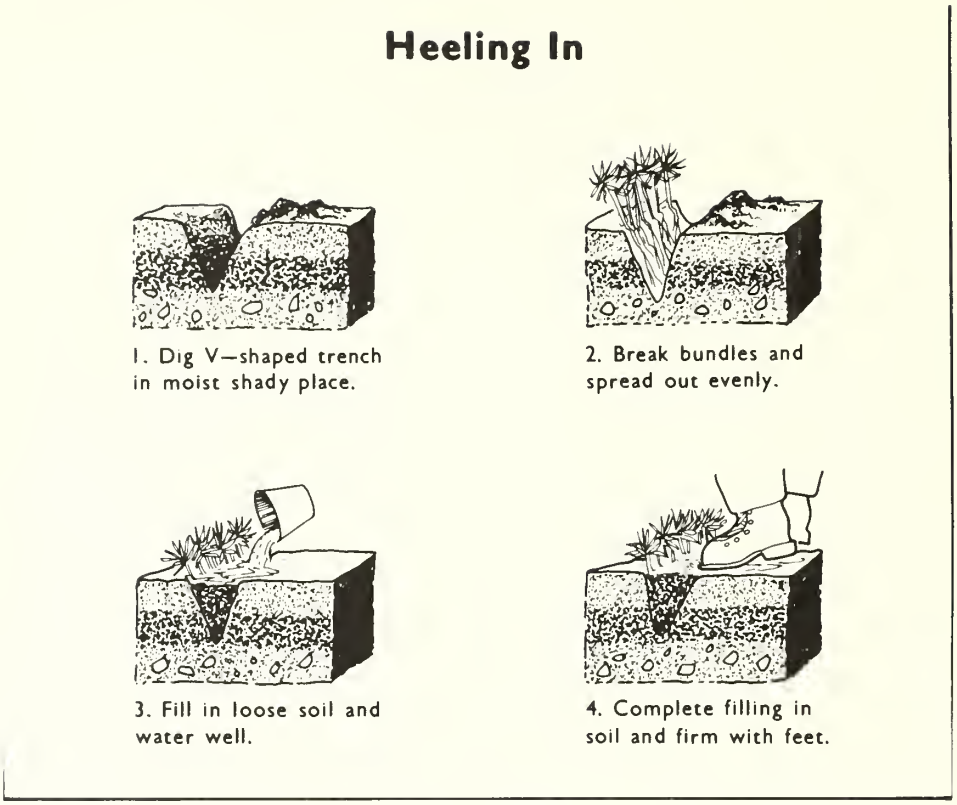


Figure 12. Methods of handling seedlings before planting. (Redrawn with permission from John Wiley & Sons, Inc. and Alabama State Forester)

Following are the approximate number of trees planted per acre at various spacings:

5' x 5' = 1,740	7' x 7' = 890
6' x 6' = 1,200	6' x 9' = 805
6' x 7' = 1,035	7' x 8' = 780
6' x 8' = 905	8' x 8' = 680
	8' x 10'= 545

Planting Patterns

Following principles discussed in Section 6 for planting woody species in mixtures, one of several patterns can be chosen. A random mixture implies that the species are intimately mixed and the seedlings planted with no designed or selected pattern for their placement. Random planting requires additional labor because it is necessary to mix the seedlings before giving them to the planting crews.

In single row mixtures, one species is planted per row. A different species is planted in an adjacent row. In multiple row mixtures, two or more adjacent rows are planted with the same species. Then, another set of two or more rows are planted with a different species. Rows usually run the full length of the area being planted.

In block or group mixtures, one species is planted in a block or group comprised of several rows that are of some predetermined length. A different species is planted in an adjacent block of similar or other predetermined size. Randomly placing small blocks or groups of single species most nearly simulates the pattern of reproduction in a natural forest.

Where included in tree mixtures, nitrogen-fixing nurse trees that are uniformly spaced throughout the planting probably provide the most benefit to adjacent crop trees. The spacing arrangement for nurse trees is related to their percentage composition in the mixture. For example, to make up 25 percent of the mixture, nurse trees should be planted in every other space in alternate rows. To make up one-third of the mixture, plant the nurse species in every third row (Table 8). A spacing pattern can also be designed where nurse trees make up 20 percent or less of the mixture, but randomly mixing them with the crop trees may be the easiest planting procedure.

Time of Planting

Late winter through early spring normally is the best time for planting woody species. Planting can begin when the ground is no longer frozen and as soon as seedlings can be obtained from the nursery. Depending on weather conditions, the beginning date for planting may vary as much as 3 weeks from one year to another. Planting of nursery stock usually should be terminated by May 15 in northern regions and by April 15 in central to southern regions. Planting can be extended later into the spring at the higher elevations in Appalachia than it can at lower elevations.

TABLE 8. EXAMPLES OF PLANTING PATTERNS FOR TREE MIXTURES

Type of Mixture	Row	Planting Pattern														
Random Mixture of Crop Species with 25% Nurse Trees	1	d	c	a	b	e	d	e	b	a	c	d	a	b	c	e
	2	N	b	N	c	N	a	N	e	N	d	N	d	N	a	N
	3	c	c	b	a	d	e	d	a	b	d	a	b	e	c	e
	4	d	N	c	N	a	N	d	N	c	N	b	N	e	N	b
Single Row Mixture of Crop Species with 33% Nurse Trees	1	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
	2	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	3	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
	4	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c
	5	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	6	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Multiple Row Mixture of Crop Species with 25% Nurse Trees	1	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
	2	a	N	a	N	a	N	a	N	a	N	a	N	a	N	a
	3	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
	4	N	b	N	b	N	b	N	b	N	b	N	b	N	b	N
	5	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
	6	c	N	c	N	c	N	c	N	c	N	c	N	c	N	c
	7	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c
	8	N	a	N	a	N	a	N	a	N	a	N	a	N	a	N
Block or Group Mixture of Crop Species	1	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b
	2	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b
	3	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b
	4	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b
	5	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b
	6	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b
	7	d	d	d	d	d	d	d	d	c	c	c	c	c	c	c
	8	d	d	d	d	d	d	d	d	c	c	c	c	c	c	c
	9	d	d	d	d	d	d	d	d	c	c	c	c	c	c	c
	10	d	d	d	d	d	d	d	d	c	c	c	c	c	c	c
	11	d	d	d	d	d	d	d	d	c	c	c	c	c	c	c

a, b, c, d, e = crop trees; N = nurse trees.

Late fall or early winter planting has been only partially successful, the successes occurring mainly on the more "ideal" planting sites. Seedlings planted in the fall are susceptible to frost heaving and the resultant drying of roots. Where fall planting is necessary or desirable for distributing job loads or because of labor shortages in the spring, it should be restricted to minesoils least susceptible to frost heaving, for example, those with moderate to dense ground cover or barren sites that are sandy or loose shaly loams.

Container-Grown Seedlings

Woody plant seedlings grown in containers in a greenhouse have been used to extend the planting season into late spring and even early summer. The container-grown seedlings can be taken from the greenhouse, hardened off for a couple of weeks in a sheltered outdoor location, and directly planted on the mine site. Or, they can be hardened off, placed in refrigeration at 43°F, and planted at a later date. In a test planting in Tennessee, container-grown seedlings planted on July 1 had 87 percent survival, whereas bareroot stock that had been refrigerated had 3 percent survival. However, in Pennsylvania, survival of container-grown seedlings in most test plantings was no better than survival of bareroot seedlings when planted in the usual spring planting.

Some types of containers are unsuitable for use on minesoils because they are easily frost heaved from the ground. Tubeling type containers, especially those made of plastic, are most susceptible to frost heaving; peat pot and peat pellet type containers are least susceptible.

Direct Seeding

The direct seeding of trees and shrubs appears to be an attractive alternative to hand planting seedlings, especially on steep slopes. However, direct seeding on surface mines has been successful with only a few species; even with these, results have not been consistent. Thus, direct seeding woody species is advised only where there is a history of reasonable success.

Direct seeding is the principle method of planting southern pines on mined areas in Alabama, and is reasonably successful in southeastern Tennessee. But in Central and Northern States, success with direct seeding of any species of pine has been inconsistent and usually considered risky. Where used, pine seed should be treated with bird and rodent repellent. Cold stratification (33° to 41°F) of pine seed in a moist medium usually improves first-year germination.

Black locust and shrub lespedeza have been established successfully by direct seeding in much of the Appalachian Region, and indigobush and green ash have been established successfully in West Virginia. Direct seeding of these species is not advised at elevations above 3,000 feet or in the northern part of Appalachia.

Direct seeding of black walnut has produced variable results. In Illinois, some of the plantings that were direct seeded in the late 1940's were more successful than those established from seedlings. But, in Missouri, Kansas, and Oklahoma, establishment of seeded walnut was relatively poor in

most plantings. In eastern Ohio, direct seeded walnut were near failures. In Missouri and Kansas, seeded bur oak produced satisfactory stands in some plantings, but overall were less successful than planted seedlings.

Broadcast seeding on a mechanically prepared or frost-heaved seedbed in late winter or early spring is the most common method for direct seeding species with small seeds. A stand of more evenly spaced trees can be achieved by spot seeding. Row seeding machines can be used on minesoils that are relatively level and free of stones. Large seed, such as acorns and black walnut nuts, should be hand planted 1 to 3 inches deep at uniformly spaced spots. Two or three seed per spot are recommended to compensate for the nonviable seed, loss of seed, and mortality of young plants.

Availability of Planting Stock

Planting stock of woody species can be obtained from State-operated and private nurseries. The State-operated nurseries usually provide only those species most commonly planted in State reforestation programs. Some States provide plants only for in-state use. Others will sell surplus stock to customers outside their own State. Generally, the State nurseries provide stock that is of the quality and size suitable for planting mined lands.

Many private nurseries also advertise seedlings in quantities and size normally used in planting mined lands. Private nurseries usually are the only source of species that are not commonly used in mined-land reclamation. Those interested in planting woody species should order seedlings at least a year in advance of planting time. For some species, it may be necessary to notify nurseries even sooner because the selected species may not normally be raised in the quantities needed for reclamation planting.

To ensure the hardiness of woody plants, purchase seedlings that have been propagated from plants growing in climatic conditions similar to the area to be planted. Research has shown that variations in the characteristics of parent trees due to climatic conditions may be carried on through their seed.

SOIL AMENDMENTS

Successful establishment of vegetation usually requires the application of one or more soil amendments. Fertilizer, for example, is required on most minesoils for the establishment of herbaceous species, and lime is required on acid minesoils. By contrast, the response of newly planted tree seedlings to these amendments is less predictable. Recommendations for use of soil amendments differ among and within regions due to differences in geology, soils, and land uses. Ideally, these recommendations should be based upon research, experience, and soil-test methods that are meaningful for the minesoils in each area.

Fertilizer

Fertilizer requirements and recommendations vary with different land uses and management situations. For agricultural uses, fertilizer application should be based mainly on soil tests and follow the recommendations of local agricultural specialists for the crop being planted. Criteria for agricultural use may include split applications for crop establishment and periodic applications thereafter for crop maintenance.

For forestry and wildlife habitat land uses, fertilizer is applied primarily for the initial establishment of vegetative cover for erosion control. Generally, this requires a lower fertilizer rate than for agricultural uses, and maintenance applications usually will not be required. Ideally, without maintenance applications, the initial cover will gradually diminish in density or change in composition and thereby improve the chances for planted and natural-seeded woody species to develop.

Soil testing for fertilizer needs is less important for forestry or wildlife habitat land uses, or where herbaceous cover is established primarily for erosion control or esthetic purposes, than it is for agricultural uses. Without a soil test or with no previous knowledge of fertility requirement, a minimum rate of fertilizer recommended for establishing herbaceous seedings is about 60 pounds of nitrogen (N) and 100 pounds of phosphate (P_2O_5) per acre. On spoils that have not been "topsoiled," application of potassium fertilizer usually is not needed; but where it is used, a rate of about 30 pounds per acre of potash (K_2O) is suggested. Native soils in some regions are low in potassium; thus, a higher rate of potash may be justified on mined areas that have been topsoiled.

The benefits of fertilizing woody species are not as predictable or economically attractive as fertilizing herbaceous species. Woody species fertilized with nitrogen or phosphorus, or both, usually show a positive response in height growth, vigor, and color. But, in some plantings, the mortality of newly planted tree seedlings has been increased by the use of fertilizer--both from broadcast application and from placing fertilizer pellets in the planting hole. In other plantings, tree survival was not affected by fertilizer. For example, in an experimental planting in eastern Kentucky, phosphate and nitrogen fertilizers placed in 6-inch deep slits 8 to 10 inches from the tree seedlings increased the growth of sycamore, sweet gum, black locust, and black alder, but did not affect their survival during the first 3 years after planting. In other plantings, the early growth of black locust and European alder was increased by placing dicalcium phosphate directly in the planting hole, but tree survival was not affected. Seemingly, survival is related to tree species, soil moisture, time of planting and fertilizer application, placement of fertilizer, fertilizer formula, and rate of nutrient release. Slow-release fertilizers may have advantages for use in reforesting surface-mined lands.

The establishment and early growth of direct-seeded trees and shrubs usually are improved by fertilization with nitrogen and phosphorus. However, where trees and herbaceous species are seeded together, the rapid vigorous growth of the herbaceous vegetation in response to fertilizer may suppress or prevent establishment of seeded trees.

Maintenance Fertilization--

Requirements for maintenance fertilization of established vegetation are determined primarily by land use objectives. For agricultural uses, fertilization programs for continued crop productivity may be required similar to those in the management of any agricultural land. Because the fertility of minesoils can vary in different areas, the requirements for maintenance fertilization in agricultural uses must be determined mainly from experience and periodic soil testing.

For reforestation and wildlife habitat, little, if any, refertilization should be needed once the required vegetative cover and number of woody species are established. Thereafter, natural processes are mainly responsible for the continued maintenance and development of plant communities. For example, herbaceous and woody legumes help provide nitrogen via the associated nitrogen-fixing bacteria. Populations of other microorganisms that aid plant nutrition, especially mycorrhizal fungi that help plants obtain phosphorus from the soil, also will increase as vegetation becomes established. Application of fertilizer, especially at high rates, can impede the development and function of these beneficial organisms. Thus, refertilization is not advised where it may interfere with natural processes that benefit the development of plant communities.

Fertilizer Terminology--

Fertilizer recommendations often are confusing to those unfamiliar with fertilizer terms. Most commercial fertilizer materials include three major nutrients: nitrogen, phosphorus, and potassium. Fertilizer recommendations usually are made on the elemental basis for nitrogen (N) and on the oxide basis for phosphorus and potassium, i.e., phosphate (P_2O_5) and potash (K_2O). The "analysis" of a fertilizer material is the listing of the percent of each nutrient, always in the order: N - P_2O_5 - K_2O. For example, fertilizer labeled as 8-24-16 contains 8 percent by weight of N, 24 percent of P_2O_5, and 16 percent of K_2O. Fertilizer labeled as 10-10-10 contains 10 percent by weight of each nutrient. This applies to both dry and liquid fertilizers. Thus, if a gallon of liquid fertilizer is labeled as 10-20-10 and weighs 10 pounds, it contains only 1 pound of N, 2 pounds of P_2O_5, and 1 pound of K_2O.

Fertilizers that contain only one of the nutrients are called "straight" fertilizers. For example, 34-0-0 is ammonium nitrate and contains only nitrogen. Fertilizer labeled 0-46-0 is concentrated super-phosphate and contains only P_2O_5; muriate of potash, labeled 0-0-60, contains only K_2O. "Mixed" fertilizers contain two or all three of the nutrients; for example, 18-46-0, 0-20-20, or 8-16-8.

Fertilizers can be obtained in various formulae, but there are advantages to using or mixing "high-analysis" fertilizers--those that contain the greatest amount of the nutrient or nutrients. For example, a mix of 220 pounds of 0-46-0 fertilizer plus 180 pounds of 34-0-0 fertilizer will provide 60 pounds of N and 100 pounds of P_2O_5, the suggested per-acre rate for establishing ground cover. With this mixture, 400 pounds per acre of bulk fertilizer are needed. But if a fertilizer such as 10-10-10 were used, 1,000 pounds of bulk

fertilizer would be required to meet the 100 pounds per acre P_2O_5 requirement. This amount of fertilizer would also supply 100 pounds of N and 100 pounds of K_2O. The amount of N would be somewhat in excess of that required or needed; the K_2O may not be needed at all or be in excess of need. The advantages, then, of combining and using high-analysis fertilizers such as 0-46-0 and 34-0-0 instead of low-analysis fertilizers such as 10-10-10 are:

(1) Less bulk material is involved; thus, transportation, handling, and storage costs are reduced. For application by aircraft it is especially important to apply the most nutrients in the least amount of bulk material. (In the previous example, 1,000 pounds of 10-10-10 had to be used compared to 400 pounds of the high-analysis mix.)

(2) Cost is less because the cost of fertilizer is based on the cost per pound of nutrients. Applying unneeded nutrients increases cost of applying fertilizer.

(3) High-analysis fertilizers usually have a lower salt concentration per unit of available nutrients; this reduces the chances of salt damage to seed, especially when mixed together in a hydroseeder.

Application--

Fertilizer usually should be applied at about the same time that seeding is done, preferably when the seedbed is being prepared. However, when seeding is done in the dormant season, fertilizer, except for phosphorus, should not be applied until about the time that the seeds begin to germinate in the spring. Incorporating fertilizer, particularly phosphorus, into the minesoil is generally recommended, especially on fine-textured soils and spoils. But additional tillage for mixing fertilizer into mine soils may not be necessary where the fertilizer is applied on a roughened, freshly tilled seedbed.

Fertilizer can be applied dry with cyclone or broadcast-type spreaders, pull-type flow spreaders, regular lime-spreading trucks or those with the Estes Aerospread™ attachment, and with aircraft. It can also be spread by hand on small areas.

Fertilizer can be spread also in a hydroseeder, either by itself or mixed with the seed. Where mixed with seed, the slurry should be spread as soon as possible to prevent damage to seed by the salt solution formed from the mixture of water and fertilizer. This salt solution also can kill the bacteria in the legume inoculant as discussed previously.

Lime

Lime is used on mined areas to decrease or neutralize soil acidity. The requirement for lime depends on the degree of soil acidity, land use objective, and acid tolerance of plant species used. Obviously, minesoils and refuse materials that are extremely acid or contain high levels of sulfides will require the greatest quantities of lime. In fact, application of lime on these materials usually is essential for vegetation establishment. On soils that

are less acid, lime may not be needed to establish vegetation, but its use usually improves and hastens vegetation growth and development.

Standards for lime requirements usually are expressed in terms of liming the soil to a prescribed pH level. For agricultural uses, a pH of about 6.5 is generally recommended. For forestry and wildlife habitat land uses, a pH of at least 5.5 usually is prescribed. The reason for this is that plant species used for reforestation and wildlife habitat development generally are better adapted to acid soil than are species used primarily for agricultural purposes.

Liming Materials--

The ability of a liming material to neutralize acid is evaluated by comparing it with the neutralizing ability of pure calcium carbonate. This neutralizing ability or value is expressed in percent. For example, the neutralizing value of hydrated lime is 135 percent, but some agricultural lime may be as low as 80 percent. This and other chemical information should be available for liming materials sold commercially for agricultural uses.

Agricultural lime (ground limestone) is the material most used for amending acid soils. Limestone from different quarries and different parts of the country may vary in its neutralizing value or "calcium carbonate equivalent." Thus, adjustments to increase liming rates should be made where lime with a low neutralizing value is used. For example, if a liming recommendation calls for 2,000 pounds per acre of calcium carbonate equivalent (CCE) and lime has a neutralizing value of 85 percent, then: $(2{,}000 \div 85) \times 100 = 2{,}350$ pounds, the actual amount of agricultural lime required.

It is also important that agricultural lime be ground to meet particle-size or fineness standards recommended by the U.S. Department of Agriculture. Most dealers licensed to sell agricultural lime meet these or similar standards required by State regulation. Finely ground limestone dissolves faster than coarsely ground and thereby reacts faster with the acid in the soil. Adjustments should be made to increase liming rates where lime with a coarse grind is used. In fact, using additional lime, even as much as double the recommended rate, can benefit establishment and maintenance of vegetation on spoils high in sulfides, because a greater quantity of the finely ground limestone is available to quickly react with the active acidity. The slower dissolving coarse particles may provide a reserve for neutralizing acid produced in the future from oxidizing sulfides; but in some situations, the coarse particles of limestone become coated with iron oxides and are rendered ineffective for neutralizing acid.

Limestones from different geologic formations also vary in the content of magnesium carbonate. Those containing little or no magnesium are called calcitic, those with relatively high amounts are called dolomitic. The neutralizing value of dolomitic limestone usually is higher than calcitic limestone. Either type of limestone can be used on most minesoils, though dolomitic materials are most beneficial for soils low or deficient in magnesium. By contrast, toxicity to plants is known to occur on some acid minesoils treated with high rates of dolomite.

Hydrated lime, too, is useful for amending acid soils, but this material is more expensive than agricultural lime and more difficult to apply with conventional equipment. However, the use of hydrated lime may be desirable where it is necessary to treat small, hard-to-reach areas. The neutralizing value of hydrated lime is 135 percent; only 1,480 pounds of it are required to equal the neutralizing ability of 2,000 pounds of pure calcium carbonate. All of the hydrated lime is immediately effective for neutralizing acid; therefore, it does not have the lasting effect as does agricultural lime that contains both fine and coarse particles.

Some industrial waste products such as calcium silicate slag and alkaline fly and bottom ashes also have been used as liming materials, but they usually are less effective than agricultural and hydrated limes and sometimes cause other problems. For example, fly ash from some sources contains levels of boron that are toxic to vegetation grown on sites treated with large amounts of the fly ash.

Rock phosphate provides a long-term, slowly available source of phosphorus for plant growth and also helps to neutralize acidity. However, it has less neutralizing ability than agricultural lime at similar rates. The feasibility of using rock phosphate must be based primarily on the cost of obtaining and applying it as compared to the cost of using lime and high-analysis phosphorus fertilizer.

Determining Liming Rates--

Ideally, soil tests should be used to determine liming rates on all acid minesoils and refuse materials. However, where the appropriate soil tests cannot be obtained, general guides such as the following based on soil-water pH values usually produce acceptable results for liming minesoils that are not extremely acid (above pH 4.0).

pH (Soil-water suspension)	Rate (tons/acre CCE)*
6.1 and higher	None
6.0 to 5.5	1 to 2
5.4 to 4.6	3 to 4
4.5 to 4.0	5 to 6

*Calcium carbonate equivalent

For determining lime requirements on minesoils and refuse materials that are extremely acid (below pH 4.0) and those known or suspected to be high in sulfides, soil testing is especially important because lime requirements can vary greatly in these materials, even among those with the same pH. On materials where standard soil tests--such as the SMP Buffer pH--indicate liming rates of 20 to 25 tons per acre or more, a total sulfide analysis (potential acidity test) also is recommended and lime application should be increased accordingly. If the total sulfide analysis cannot be obtained, lime should

be applied at about 1.5 times the rate indicated in the standard soil test. An alternate strategy is to apply and incorporate at least 25 tons of lime per acre and retest with the standard soil test 4 to 6 months later. Additional lime as indicated by the test should be applied and incorporated. A temporary cover crop for reducing erosion should be sown during the periods between tests.

Liming rates indicated by soil tests normally are the amounts necessary to amend soils to a depth of about 6 inches (also referred to as the plow layer). Accordingly, lime should be incorporated about 6 inches deep. But in extremely acid material, this means that the growth of plant roots is limited to the depth to which lime has been incorporated. Thus, to increase the potential rooting depth of vegetation on extremely acid materials, lime should be incorporated 10 to 12 inches deep, or deeper if possible. However, where there is deeper incorporation of lime, the quantity of lime applied must be increased accordingly; for example, where incorporated 12 inches deep, the rate of lime indicated by soil tests should be doubled.

The need for maintenance application of lime, as with initial application, should be determined by land use requirements. Top dressing with lime to maintain a pH of about 6.5 is recommended for agricultural production. Maintenance applications for forestry and wildlife habitat may not be required unless periodic soil tests indicate a continual decline in pH below 5.5, or a visual inspection indicates that lime is needed to maintain existing vegetation.

Application--

Agricultural lime can be spread with conventional lime-spreading trucks on areas that are accessible to vehicles. Application on steep slopes as well as on accessible areas can be made with the Estes Aerospreader--a blower-impactor device that is mounted on a lime-spreading truck. Hydrated lime can be applied on relatively smooth and level land with a pull-type, gravity-flow spreader, and on steep slopes with a hydroseeder.

Before seeding or planting vegetation, lime should be incorporated into the soil, preferably to a depth of about 6 inches. A heavy duty disc or chisel plow is useful for incorporating lime on most minesoils; but on steep slopes, incorporating lime by any means is a major difficulty. Some form of tillage up and down slope may be possible with a dozer, but the furrows would collect runoff water and quickly initiate gully erosion. Lime applied on the surface and not incorporated will be of little benefit in establishing vegetation, but it is of some value for topdressing areas that are already vegetated.

Lime can be applied at any time that the spreading equipment has access to a site. Ideally, agricultural lime should be applied and incorporated several weeks or even several months before seeding. This probably can be accomplished on most older mined sites and refuse piles. However, newly mined areas should be seeded as soon as possible after the grading is completed. Thus, lime usually will have to be applied immediately after grading and given little or no reaction time in the soil before seeding. One way to compensate

for the reduced reaction time is to apply from 10 to 50 percent additional lime. Extremely acid materials that initially require large amounts of lime also will require the greater percentage of additional lime. Large quantities of agricultural lime properly incorporated usually will not inhibit establishment of seeded vegetation. For example, in eastern Kentucky, agricultural lime has been applied on extremely acidic spoils high in sulfides at 8 times the rate indicated by soil test without adverse effect on the seeded vegetation.

Organic Materials

Organic amendments can benefit plant establishment, especially on minesoils whose physical, chemical, and biological properties are unfavorable for the growth of vegetation. Addition of organic materials can decrease bulk density of the minesoil and increase water infiltration and retention. Chemically, organic amendments can reduce acidity, increase cation exchange capacity, and add plant nutrients. Irrigating extremely acid spoils with sewage effluent, for example, leaches toxic chemicals out of the rooting zone, dilutes concentration of salts, provides nutrients to plants, and lowers surface temperatures. Some organic materials also provide an energy source for beneficial soil microorganisms and soil fauna.

Organic amendments that have been tested and used on mined areas are mostly agricultural, industrial, municipal, residential, and forestry-related wastes or residues. They include products such as barnyard and poultry manures, sewage sludge and effluent, composted garbage (solid municipal wastes), leaves, and combinations of garbage or leaves with sewage sludge. Crop residues such as straw and residues such as bark and wood chips from sawmills and wood conversion plants have been used both as soil amendments and as mulches.

Factors influencing rates of application of the different organic materials include the purpose for which they are applied, physical and chemical properties of the minesoil, depth of incorporation, and cost of obtaining and applying the materials. Suggested rates of application for some of the materials are: barnyard manure and composted garbage, 15 to 30 tons per acre; leaves, 2 to 4 tons per acre (air dry); sewage sludge and effluent, volumes equivalent to 20 to 50 tons per acre of dry matter.

Several factors affect the economics of using waste and residue products, especially the costs of processing, transportation, and application. For materials such as sewage effluent, special distribution and application equipment entails high initial investment and costly maintenance. The economics of using wastes in reclaiming mined land should be evaluated in terms of costs and benefits both to the producers of the wastes and to those using it for revegetation purposes.

The incorporation of some organic materials, such as animal manure and composted sewage sludge, adds plant nutrients to the soil. However, the incorporation of materials that are not composted and are high in cellulose, such as whole-tree chips, will cause a deficiency of nitrogen to plants during the decaying process, so additional nitrogen fertilizer must be applied for the benefit of the vegetation. Where establishment of herbaceous vegetation

is concerned, a rule of thumb is to add an extra 15 to 25 pounds of nitrogen for each ton of high cellulosic or noncomposted organic material that is incorporated into the soil. This extra nitrogen usually is not required where organic materials are applied on the surface as mulch.

Microbiologic Materials

Microorganisms are essential to the establishment of permanent vegetation on mined lands. Although not an amendment in the same sense as fertilizer or lime, some types of microorganisms can be artificially added to plant materials or to the soil to aid plant establishment and growth. For example, inoculating legume seeds with *Rhizobium* bacteria ensures that the legume plants will become effective nitrogen-fixers. Similarly, under natural conditions, most plant species depend greatly on a symbiotic association with mycorrhizal fungi. For example, the survival and growth of pine on mined areas have been enhanced by inoculating the seedlings with *Pitholithus tinctorius*, an ectomycorrhizal fungus that is tolerant of high temperatures and acid conditions. Spores of this fungus, produced above ground in mushroom-like structures, are disseminated by wind and readily form an association with pine seedlings under natural conditions. Pine seedlings also can be artificially and more quickly inoculated by applying fungal spores directly to seedling roots just before planting, or by growing the seedlings in artificially inoculated nursery beds. Incorporating spores on the seed coat of conifer seed by pelletizing is another promising method of inoculation.

The endomycorrhizal fungi, another type of fungal associate, produce spores underground that are not as easily disseminated as the spores of ectomycorrhizal fungi. To inoculate plant seedlings with the appropriate endomycorrhizal fungal associate, the seedlings must be grown in nursery beds in which the fungal spores are naturally present. Because mycorrhizal fungi are naturally present in soil, spreading or mixing topsoil on the mine surface is one way to introduce these organisms into the minesoil. Where used as a mulch or soil amendment, bark that has had contact with soil is another probable source for the introduction of fungal spores into the minesoil. Spores of the endomycorrhizal fungi also can be spread through feces of soil-inhabiting rodents such as field mice and voles. Thus, a vegetative cover that provides habitat for these rodents contributes indirectly to the spread of endomycorrhizal fungal spores that subsequently aid plant growth and natural plant succession.

MULCHES

Mulches aid revegetation by reducing surface or sheet erosion, conserving soil moisture and protecting seeds and seedlings during the initial establishment of vegetative cover, and modifying extremes in the soil's surface temperature. Mulches aid vegetation establishment especially under conditions of environmental stress and on minesoils that have physical and chemical characteristics that hinder establishment and growth of plants.

The mulching materials most used in mined-land revegetation are organic products and residues from agriculture and wood-processing industries. The

choice of mulch for a specific reclamation job will depend on the availability and cost of material, transportation costs, ease and cost of application, and personal bias. Some residue materials, such as bark, often can be obtained at little or no cost, but handling, transportation, or application may require costly or specialized equipment. Sometimes an alternative mulching material is available but not accepted by the user because of lack of knowledge and uncertainty of its value. Wood chips, for example, are believed erroneously by some to be acid producing and toxic to vegetation.

Agricultural Residues

Raw residues from agriculture are some of the better and most used mulches, especially straw of cereal grains such as wheat and oats, and hay that consists mainly of grass. Straw is sometimes preferred because it does not decay as rapidly as hay. Hay mulch may be preferred where revegetation is for land uses such as wildlife habitat, because it may contain seed of its grass, legume, and weed components. However, where seeding is for agricultural uses, plants produced from these seeds may not be desired. Similarly, seed that has not been threshed from grain straw can produce vegetation that inhibits establishment of the seeded plant species.

Rates of application for straw and hay mulches should be 1-1/2 to 2 tons per acre. Resistance to wind and water movement is increased by tacking down the mulch with asphalt emulsion or other chemical tacks, or by pressing it into the soil with a disc-like implement called a Krimper™.

Other agricultural residues that may be used for mulch include peanut hulls, crushed corn cobs, shredded corn stalks or fodder, and bagassee, a residue from sugar cane mills. These and similar crop residues are used mostly in local areas and seldom are important on a regional basis.

Wood Residues

Residues such as bark, wood chips, and sawdust from sawmills and other wood-processing plants have been used as mulches. Raw or processed hardwood bark is an excellent material for erosion control and for aiding vegetation establishment. Sawdust is the least desirable material. The weight of hardwood bark and its interlocking fibers enable it to stay in place without tacking material, even on steep slopes. Pine bark, wood chips, and sawdust are less desirable than hardwood bark partly because they are lighter in weight and will more easily float in runoff water. In addition, wood chips and sawdust have a higher cellulose content than bark; thus nitrogen requirement for the microorganisms that decompose them is potentially higher than for bark. However, the concern that these wood residues contain toxic components harmful to vegetation has been overemphasized. Adverse effects on plants have been documented for only a few of the minor hardwood species.

Recommended rates of application for bark and wood chips depend partly on the revegetation job. For most seedings, 45 to 60 cubic yards per acre (3/8 to 1/2-inch deep) are adequate for reducing erosion and conserving soil moisture. Where soils are drouthy or the effective rooting zone is shallow, such as in extremely acid spoils amended less than 6 inches deep with lime, rates

of 60 to 100 yd^3/acre (1/2- to 3/4-inch deep) are recommended for greater conservation of soil moisture. Moisture conservation is even greater at rates over 100 yd^3/acre, but the emergence of some plant species with small seeds is restricted. However, where woody species alone are preferred over a herbaceous cover, bark or wood chips at rates of 400 to 500 yd^3/acre (3 to 4 inches deep) will prevent seedling emergence of most herbaceous species.

Processing whole-tree chips on the mine site from trees that will be removed ahead of mining is a potential source of wood chip mulch. The primary factors limiting such a venture are the expense of purchasing specialized equipment for hauling and chipping logs and the additional labor required. The establishment of a business venture to provide this service on several mines may be a way to circumvent the high cost to an individual mine.

Wood Fiber and Cellulose

Processed wood fibers prepared from selected woods, and reprocessed waste paper, often referred to as wood cellulose, are popular mulching materials that are applied with a hydroseeder. The fibers in these materials are short; thus, their durability as a mulch also is short lived. Most of the fiber and cellulose mulches are colored with dye so that they are plainly visible when applied on the ground; this aids the operator in obtaining uniform coverage. These materials are sold in bales that are easily handled and conveniently stored.

Rates of application that have been used for the wood fiber "hydromulches" often are insufficient to provide effective erosion control or conserve moisture. At least 1,500 pounds per acre, and preferably higher rates, are needed. However, the higher rates greatly increase the cost of application, because the hydroseeder is limited in the amount of mulch that it can handle in each load. For example, a hydroseeder with a 3,000-gallon tank can hold 1,500 pounds of fiber mulch--enough for 1 acre. On the average, up to 6 loads, or treatment for 6 acres, can be applied in an 8-hour day. In comparison, up to 40 acres can be mulched with straw in an 8-hour day using a power mulcher.

Often, these mulches are applied in a slurry mixture with seed and fertilizer. Such a mixture allows some of the seed to be perched above the soil surface in a web of mulch, thus exposing the germinating seed and tender seedlings to drying and extremes of temperature. The probability of this causing seedling mortality is greatest in areas of low rainfall, but it can occur even in humid areas during prolonged dry periods. A preferred procedure in these circumstances is to apply seed and fertilizer first, and the mulch in a separate application.

Other Mulching Materials

Mats and netting made from wood fibers and other assorted organic and synthetic materials are effective for controlling erosion in specialized uses. The cost of these materials is prohibitive for general use in surface-mine revegetation. Sites for their use generally are those considered critical for esthetic purposes or erosion control, and should be prepared under controlled or engineered standards. For example, netting may be useful in an emergency

spillway on an earthen dam that requires quick, positive protection while a complete vegetative cover is being established.

A layer of crushed rock or gravel provides an effective mulch; however, the cost of material and application may be excessive for wide-scale use.

Application Methods

Application of mulches usually requires specialized equipment, especially on large areas and steep slopes. Some of the equipment also is suitable for spreading some of the organic amendments mentioned previously.

Straw and Hay--

Several types of mechanical mulchers are available for spreading straw, hay, and similar materials. Most often these materials have been baled. They are fed into the mulchers, separated by beaters, and blown out through a discharge spout. Power mulchers that handle standard-size square bales are made by several companies and are the most commonplace. Some are equipped to spray a chemical tack on the mulch as it leaves the discharge spout. Mulch can be blown a maximum distance of 80 feet in ideal wind conditions and it can be applied both up and down slope. About 40 acres can be mulched in an 8-hour day. Four people are required to operate a power mulcher efficiently. A fifth person is needed where a Krimper is used to press the mulch into the soil.

Another type of mulcher that is commercially available from a Colorado firm was developed by modifying a rotary tub grinder. An advantage of this Roto-Grind Mulcher™ is that it handles large (1,500 pounds) round bales, as well as the small standard-size bales and loose straw and hay. It also spreads bark, wood chips, composted garbage and similar materials, and is not damaged by foreign objects. Mulch can be blown 60 to 70 feet in ideal spreading conditions. This machine is more useful for mulching flat and gently rolling land than steep slopes. It requires two persons for efficient operation and probably a third where crimping is done. From 20 to 40 acres can be mulched in an 8-hour day.

Modifications of other standard farm machinery also have been made or are being developed. One, a manure spreader for applying straw and hay mulch, was developed by the Equipment Development Center of the USDA Forest Service at Missoula, Montana. Blueprints for modifying the manure spreader are available. Another innovation is a Hesston Stak Processor™ that was modified with a flail device for distributing straw and hay mulch from large (1,500 pounds) round bales. The Stak Processor normally is used to lift and transport large bales of hay and to shred and distribute the hay in windrows for feeding cattle. Information on the flail modification is available from Western Energy Company, Colstrip, Montana. Use of these modified spreaders is limited to level and gently sloping terrain.

Straw and hay mulch can be applied by hand on small areas and slopes that are beyond reach of a mulch blower.

Bark and Wood Chips--

Shredded bark, wood chips, corn cobs, sawdust, composted municipal wastes and similar products used for mulch or as organic amendments can most easily be applied with an Estes Spreader™ , a blower/impactor, or thrower, mechanism that is attached to a conventional or modified hopper of a lime-spreading truck (Figure 13). The thrower mechanism is most advantageous for spreading mulches on steep slopes, either up or down, but it also spreads efficiently on level areas. Mulches such as bark and wood chips can be thrown about 75 feet up a 2:1 slope and as much as 125 feet horizontally. In addition to the thrower mechanism, the spinners that are standard equipment on spreader trucks can be used to apply mulch on level or gently sloping areas. The thrower and spinners can be used together or independently. To avoid damage to the thrower mechanism, materials that contain large particles, such as pieces of boards, and foreign objects must be screened or ground before loading into the spreader. The Estes Spreader is also used for applying lime and fertilizer.

Figure 13. The Estes Spreader.

The modified tub grinder mulcher described previously spreads bark, wood chips, and most any other organic material. Bark, wood chips, baled leaves, and materials of similar form can be spread on level to gently sloping areas with a standard farm manure spreader (Figure 14). Spreading these materials by hand is difficult and tedious even on small areas.

Figure 14. Leaves, bark, and wood chips--mulching materials that can be spread with a standard manure spreader.

Wood Fiber and Cellulose--

The wood fiber and wood cellulose mulches are applied with a hydraulic seeder, more commonly called a hydroseeder or hydromulcher. Two people usually are required to operate a hydroseeder. The main advantage of the hydraulic method of mulching is that mulch can be easily applied to areas, such as the far end of steep slopes, that cannot be reached by other methods. The spreading distance by the larger hydroseeders is as much as 200 feet. For treating areas beyond that distance a hose attachment is available. One drawback of hydromulching is that only a relatively small area can be treated with each load of material. For example, a hydroseeder loaded with a slurry containing seed, fertilizer, and hydromulch will treat about one-tenth as much area as a load of slurry containing only seed and fertilizer.

Mulches Grown in Place

Quick-developing annual grasses can be sown for growing mulch in place. The grass species should be compatible with the season; for example, winter annuals such as wheat and rye are sown in late summer to fall and summer annuals such as sudangrass, sorghums, pearl millet, or Japanese millet are used for late spring through early summer seedings. For growing mulch in place, the seeding rate of the annuals should be increased over that normally sown, and soil amendments should be applied as needed to promote plant growth.

Perennial species can be subsequently established by seeding or planting them directly into the annual crop residue (in-place mulch). Where mulch is produced by summer annuals, this planting can be done the following spring. But spring planting of perennials into a winter annual crop may first require

the use of a herbicide to kill the annual-plant competition. This would be most essential for establishing woody species. Seeding perennial herbs could wait until late summer, after the winter annual vegetation is mature.

SOIL STABILIZERS

Soil stabilizers are organic and inorganic chemical products that are applied in water solutions to the soil surface to temporarily stabilize the soil against wind and water erosion, and to retard the evaporation of soil moisture. In the humid East, the effectiveness of chemical stabilizers is relatively short lived compared to most mulches. The stabilizers are expected mainly to control erosion only until vegetative cover is sufficiently established to protect the site.

Soil stabilizers often are classed by their basic formulas, e.g., polyvinyl acetates, acrylic copolymers, elastometric emulsions, and natural vegetable gums. There are many of these products on the market and similar products may differ from each other only because of additives mixed with the basic formula. The additives affect curing time, crust durability, and moisture infiltration rates. The effectiveness of these products is further influenced by dilution rate with water, soil properties, weather conditions, and amendments such as fertilizer added to the solution to aid vegetation establishment.

Some of the stabilizers form a thin film on the surface that provides temporary protection against soil movement. But most of these products infiltrate as much as 1 inch into the soil and bind the soil particles together to form a crust that resists erosion. High content of soil moisture limits the depth of infiltration, so the use of stabilizers may be more effective on soils with moisture content below field capacity. Also, warm dry weather is more conducive than cool damp weather to proper curing of the stabilizers. Tough crusts may form that physically restrict seedling emergence of some plant species, especially grasses and forbs with tiny seeds.

Many of the stabilizer products can be used as chemical tacks to hold straw, hay, and other lightweight mulches in place. The stabilizers also are used in combination with wood fiber and wood cellulose mulches. In fact, the wood fiber-stabilizer combinations are used more frequently than stabilizers alone. Presumably, site protection obtained with low rates of the combined materials is comparable to that obtained with high rates of either product used alone. A combination recommended and used in some Eastern States is: 50 gallons per acre of stabilizer mixed with a minimum of 500 pounds per acre of wood fiber or wood cellulose.

Because they can be applied with a hydroseeder, soil stabilizers have an advantage over most mulches for treating long steep slopes and other hard-to-reach places. However, for general application, mulches still are more widely used and provide several advantages over soil stabilizers. One reason is that soil stabilizers cost more and require more precise preparation and procedural control than do mulches. Also, the use of soil stabilizers is a relatively

recent development and there still is insufficient knowledge about the comparative value of different products and about the most effective application rate for specific soils, sites, and weather conditions.

It is not possible here to list all of the soil stabilizer products currently available, or to make a comparative rating of their value. For those interested in using soil stabilizers, advice should be sought from research reports on their use and from reclamation companies, highway departments, and conservation agencies. Sales promotional data are not always reliable sources of information; and many products sold as soil stabilizers have come and gone from the market.

Hydroseeders most often are used for applying soil stabilizers, either alone or in combination with wood fiber or wood cellulose mulches. Conventional pump and spray equipment also can be used for applying soil stabilizers.

SECTION 6

LAND USES AND SPECIES MIXTURES

Regulations promulgated under the Surface Mining Control and Reclamation Act of 1977 direct that postmining land uses be similar to or higher or better than the premining land uses. Also required is that vegetational productivity be restored to levels similar to productivity levels on unmined lands in the vicinity supporting similar types of vegetation. Land uses concerned primarily with vegetation and defined in the regulations are forest, range, fish and wildlife habitat, pasture, hayland, and cropland. Vegetative cover for protecting the soil surface from erosion is required in conjunction with all land uses.

Revegetation strategies for most of the land uses require mixtures of plant species and plant types. For example, at least two herbaceous species normally are used in the establishment of pasture and range. Revegetation for forestry and wildlife habitat generally includes several woody species and one to several herbaceous species. In addition to being functional, mixtures of plant types improve esthetic or visual interest and diversity. Only in some agricultural uses, such as grain and row crops, is one species usually involved.

For most of the above land uses, either introduced species or combinations of introduced and native species normally are planted. It is usually impractical to immediately reestablish stands of vegetation that are entirely "native," especially where a herbaceous cover is needed quickly for erosion control. For example, in vegetating for forestry and wildlife habitat, many of the commonly used tree species are native, but most of the herbaceous species and frequently used shrubs are introduced. With a few exceptions, the establishment of native herbs and shrubs will depend largely on natural seeding (invasion) from surrounding native stands. Thus, the development of predominantly native vegetation may require from several to many years depending largely on the combinations, density, and persistence of the introduced species used for ground cover.

Species mixtures and planting patterns for several land uses are discussed in this section. It is not feasible to list all of the species combinations that could be used in the different areas of the East. However, the several examples given may help to illustrate the rationale for mixing species for the various land uses.

EROSION CONTROL

Regardless of the intended use of reclaimed land, the establishment of vegetation is necessary first of all for control of water and wind erosion. Vegetation for watershed protection is especially important in mountainous and sloping areas where erosion caused by runoff is potentially greatest. Herbaceous species especially are important for the quick, initial establishment of a stabilizing vegetative cover.

Herbaceous Mixtures

Examples of seeding mixtures suggested primarily for erosion control are shown in Table 9. These mixtures include an annual or short-lived perennial species that provides quick but temporary cover. One of these should be chosen and added to the permanent mixture that contains at least one perennial grass and one perennial legume. Ideally, the perennial species will succeed and replace the temporary species. Where there is a choice of species of grasses or legumes, the species best adapted to the minesoil properties and climate should be selected. It is especially important to follow seeding rate recommendations for the quick-cover temporary species, because higher rates of these species could produce dense stands that prevent or retard establishment of the permanent species.

Mixtures for spring, summer, and fall seeding are suggested for the Appalachian Region. For other regions, mixtures are for spring or fall seedings. Some of the mixtures are also suited for forage production; however, a few of the species that are well suited for erosion control and site stabilization are not the most compatible with other land uses. For example, sericea lespedeza and flatpea are excellent for long-term erosion control, but their value for forage and wildlife habitat is lower than that of other legume species. Thus, consideration should be given to selecting species for their suitability for the approved land use, as well as for controlling erosion. See Section 4 for descriptive information on individual plant species.

Woody Species

Seedlings of most tree and shrub species provide little or no erosion control when newly planted and during their first few years of growth. But once they are large enough to achieve crown closure and litter begins to accumulate on the soil, trees and shrubs contribute significantly to site protection. Obviously, rapid-growing trees and shrubs are the ones that will most readily contribute to erosion control. Black locust, planted or direct seeded, is a rapid-growing tree that is especially useful for providing site protection on steep slopes. Other relatively fast-growing tree species include European alder, hybrid poplars, cottonwood, and sycamore. Autumn olive, a fast-growing plant, and bristly locust, a prolific sprouter, are shrub species that provide reasonably rapid erosion control.

TABLE 9. SUGGESTED HERBACEOUS MIXTURES FOR EROSION CONTROL

(Seeding rates: pounds per acre PLS)

Region	Seeding Time	Temporary (Quick Cover) Species[a] (Use one with permanent mix)		Permanent (Long-lived) Species	
Northern Appalachia	Early Spring to Mid Spring	Annual ryegrass	5	Ky-31 tall fescue	15
		Perennial ryegrass	10	Birdsfoot trefoil	6
		Oats	48	or	
		Weeping lovegrass	2-1/2	Crownvetch	10
				or	
				Flatpea	20
	Mid Spring to Mid Summer	Foxtail millet	12	Ky-31 tall fescue	15
		Japanese millet	15	Birdsfoot trefoil	8
		Weeping lovegrass	2-1/2	or	
				Crownvetch	10
				or	
				Flatpea	20
	Mid Summer to Early Fall	Rye	40	Ky-31 tall fescue	20
		Winter wheat	40	Birdsfoot trefoil	8
		Annual ryegrass	5	or	
				Crownvetch	20
Mid and Southern Appalachia, Western Kentucky, Arkansas, Oklahoma	Early Spring to Mid Spring	Perennial ryegrass	10	Ky-31 tall fescue	15
		Oats	48	Korean and/or Kobe lespedeza[b]	10
		Weeping lovegrass	2-1/2	Sericea lespedeza	10
		Annual ryegrass	5	or	
				Crownvetch	10
	Mid Summer to Early Fall	Rye	40	Ky-31 tall fescue	20
		Winter wheat	40	Sericea lespedeza	
		Annual ryegrass	5	(1/2 unhulled seed)[c]	20
		Perennial ryegrass	10	or	
		Crimson clover	12	Crownvetch	10

(continued)

TABLE 9. SUGGESTED HERBACEOUS MIXTURES (CONTINUED)

Region	Seeding Time	Temporary (Quick Cover) Species[a] (Use one with permanent mix)		Permanent (Long-lived) Species	
Mid and Southern Appalachia	Mid Spring to Mid Summer	Weeping lovegrass	2-1/2	Ky-31 tall fescue	15
		Sorghums	18	Sericea lespedeza	10
		Pearl millet	10	Korean and/or Kobe lespedeza[b]	12
		Foxtail millet	12		
		Browntop millet	15		
Illinois, Indiana, Iowa, Northern Missouri	Early Spring to Mid Spring	Oats	40	Tall fescue	15
		Annual ryegrass	5	or	
		Perennial ryegrass	10	Smooth bromegrass	15
				Alfalfa	10
				or	
				Birdsfoot trefoil	8
				or	
				Crownvetch	10
Missouri, Kansas, Oklahoma	Early Spring to Mid Spring	Oats	32	Tall fescue	18
				Alfalfa	5
				or	
				Crownvetch	8
	Late Summer to Early Fall	Winter wheat	60	Tall fescue	20
		Rye	56	Alfalfa	6

[a] Use only one of the temporary species at rates shown. If more than one is used, reduce seeding rate of each species in proportion to number used, i.e., for two species use one-half seeding rate of each.

[b] These annual lespedezas usually reseed each year and may become a permanent component of the vegetative cover.

[c] One-half or more of sericea lespedeza seed should be unhulled and unscarified to reduce amount of fall germination and ensure sufficient seed for germination the next spring.

AGRICULTURE

Except for steeply sloping areas, most reclaimed surface mines have potential for agricultural uses. The type of agricultural use depends on the characteristics of overburden and soil materials, the intensity of the restoration procedures, the land use before mining, the presence of an agricultural economy in the area, and legal requirements. Areas developed for row crops and truck or vegetable crops generally require intensive restoration procedures such as removal of stones and replacement of A and B soil horizons. Areas reclaimed for pasture normally require the least intensive restoration procedures.

Forage Production

Pasture, hayland, and range are the land uses concerned with the production of forage crops. Herbaceous mixtures useful for pasture are similar to those suggested for erosion control. However, because they are more palatable to livestock, grass species such as orchardgrass and timothy can be substituted for Ky-31 tall fescue. In the South, Bermudagrass and Bahiagrass are desirable pasture species for summer grazing, as is perennial ryegrass for fall and spring grazing. Similarly, legumes such as red clover, Ladino clover, and alfalfa are more suitable than sericea lespedeza and flatpea for forage.

Often, the species that are better choices for livestock forage are relatively short lived or require a higher level of management for maintenance than those species recommended primarily for erosion control. A seeding mixture for the establishment of pasture may not require quick-cover companion species, especially on level to gently sloping areas where accelerated erosion will not be a problem. On the other hand, annuals for temporary cover can also provide a temporary forage crop. However, early or premature grazing by livestock on any new seeding will be injurious to the successful establishment of a desirable pasture.

Seedings for hayland often include fewer species than for other uses. For example, alfalfa often is sown alone or with one grass species such as smooth bromegrass or orchardgrass. In much of the Appalachian Region, Ky-31 tall fescue is used for hay, either alone or in mixture with red clover or white clover. Timothy and red clover have long been a popular combination for hay in the Northeastern United States.

Range usually implies the use of native species for forage. Customarily, most of the range-type seedings have been done in the Western Interior Coal Region, namely in Kansas, Oklahoma, and western Missouri. Restoration of the tall grass prairie that is native in that region is virtually impossible because some 200 to 300 species of grasses, forbs, and shrubs are known components of the tall grass prairie. Most range-seeding mixtures used on mined lands in this area include several species of native warm-season grasses. When available, seed of prairie forb species can be included. A suggested range seeding mixture is as follows:

Species	Pounds per acre (PLS)
Switchgrass	2
Big bluestem	3
Little bluestem	3
Indiangrass	4
Side-oats grama	4
Illinois bundleflower	5

These native species also can be sown and used for pasture on mined lands in most of the Eastern Interior and Appalachian Regions. However, establishment of these species normally is slow compared with most of the introduced warm- and cool-season species used in the East. Two or three years are required for establishment of an acceptable stand; but once established, these native species will gradually increase in density and may require little or no maintenance fertilization. However, grazing management practices usually applied to the exotic cool-season grass pastures in the East are not appropriate for the native warm-season grasses. Excessive and season-long grazing by livestock will limit or prevent the successful establishment of these grasses.

Cropland and Horticulture

These uses include plant species, cultural practices, and management systems beyond the scope of this guide. Generally, these uses pertain to the growing of one species under intensive management similar to that practiced on unmined agricultural land. Crops that have been grown successfully on reclaimed land include corn, oats, wheat, soybeans, and buckwheat. Apple orchards and vineyards also have been established, and vegetable crops have been grown experimentally. Technical advice on developing these uses should be sought from agronomic and horticultural specialists in each area.

FORESTRY

Forestry is a logical land use for many areas currently being mined, as well as for many abandoned or orphan mine sites. However, reforestation efforts have been minimal in recent years due to changing economic, political, legal, and social pressures. Previously, the planting of trees often was considered the most expeditious way to revegetate mined lands. Recent evaluations of 25- to 50-year-old forest plantings throughout the Eastern United States show that on many of the mined sites the combination of planted and natural vegetation is producing young forests that appear similar to forests on adjacent unmined sites (Figure 15). Many of the trees now are approaching or have reached marketable size. Some species such as black walnut and tulippoplar show promise for producing a favorable economic return.

Factors to consider in selecting tree species include: the forest management objective, species preferences in current markets, predicted preferences in future markets, the proposed level of management, and site and minesoil characteristics. The forestry objective can range from short-term crops such as Christmas trees to long-term crops for timber production. Levels of

Figure 15. A 30-year-old mixed hardwood forest on surface-mined land in Ohio that has developed from planted and naturally established vegetation.

management can be intensive, requiring regular care and treatment, or extensive, requiring little care or treatment. Obviously, markets for the harvested crop should be within a hauling distance that is economical.

Where feasible, species should be matched with site and minesoil quality. For example, preference should be given to planting high-value hardwoods such as black walnut, yellow-poplar, and sugar maple on slightly acid to neutral loam and silt loam minesoils that are well drained but not drouthy. Conversely, some of the pine species are a better choice for sandy acid soils on warm (south-facing), moderately drouthy sites.

Christmas Tree Production

Planting and management for Christmas trees is an intensive forestry practice. Species should be selected that are marketable in the region. For example, Scotch pine is very popular in the Eastern States and can be grown in all but the southernmost coal producing areas. Other pines used for Christmas trees are red, eastern white, Austrian, ponderosa, and jack. Norway and white spruce also are used, but generally do not reach marketable size as quickly as pine. Pure plantings of a proven species usually are recommended, but mixed plantings of two or three species may reduce the risk of loss from insects and disease or from a change in market demand. Low-growing herbaceous species are recommended as a ground cover. Mowing and the use of herbicides may be needed to reduce competition by herbaceous plants.

Management needs include a road system for maintenance, harvest, and fire protection. Fencing may be needed to protect the plantings from livestock, theft, and vandalism. Care of Christmas trees also includes shearing to shape trees for market; application of fertilizer; and protection from insects, disease, and fire. Specific information on Christmas tree production is available from State universities, agricultural extension agents, and Christmas tree growers associations.

Pulpwood Production

Revegetating mined land for pulpwood production can include either intensive or extensive management. Intensive management usually entails the planting of one fast-growing pulp species such as shortleaf, loblolly, or longleaf pine, European alder, hybrid poplars, cottonwood, sycamore, or bigtooth aspen. Management practices may include periodic inspections for detection and control of insects and diseases, thinning, control of competing vegetation, and fertilization. With hybrid poplars and some of the other hardwoods, two or more rotations of pulp may be obtained from sprouts that originate after the first cutting.

Extensive management for pulpwood can be accomplished with pure or mixed plantings. Trees cut for pulpwood may consist mainly of those removed when thinning stands designated for timber production or when creating openings for wildlife habitat. Only selected trees would be left uncut to develop into veneer or sawlogs.

Timber Production

This management objective implies a long-term commitment. The overall level of management is extensive but it can become periodically intensive when trees would benefit from thinning, pruning, and other cultural practices. Access for periodic inspection, cultural treatments, and fire protection is desirable. Due to the long time span until timber harvest, interim benefits such as wildlife habitat and recreational use also can be considered.

For some timber production programs, especially with pine, planting of only one or two tree species may be desired. With hardwoods, mixtures of species more often are preferred. Herbaceous and shrubby species can be included to provide initial site protection and to add vegetational variety for esthetic values and for the enhancement of wildlife habitat as an interim land use. However, shrubs should be limited to 25 percent or less of the total planting because Federal standards require that, where commercial forest is the approved postmining land use, at least 75 percent of the countable trees and shrubs shall be commercial tree species at the end of the 5-year period of responsibility.

Pure vs. Mixed Plantings

Trees may be planted either in pure stands of a single species or in mixed plantings of two or more species. In general, stands of one species are easier to plant, manage, and harvest; but they are more susceptible to insect and disease epidemics, and lack diversity for visual quality and wildlife habitat. Mixed plantings improve the possibilities for natural regeneration and diversity, and usually occupy the site more fully than do pure plantings. The following are some general guides for pure and mixed plantings of trees.

1. Pure plantings of pine usually are favored over pine mixtures. Where two or more pine species are desired, a block or group of several rows of one species should be alternated with blocks of the other species. A block or group should consist of at least five rows. An exception may be a mixture of species with similar growth rates such as pitch and shortleaf pines.

2. Mixing hardwoods with intolerant pine species is not recommended. Hardwoods usually shade out the pine. Mixing groups or blocks of pine and hardwoods are acceptable, especially where diversity in cover types are desired for esthetic purposes and wildlife habitat. Intimate mixing of tolerant conifers such as spruce and white pine with tolerant hardwoods and slow-growing hardwoods is acceptable.

3. Hardwood species, such as hybrid poplar and European alder, that will produce a quick crop (pulpwood) may be planted in alternate rows with conifers (except larch with hybrid poplar). A coniferous stand will follow after the hardwoods are harvested.

4. A few hardwoods--cottonwood, sycamore, and hybrid poplar--preferably should be planted in pure stands or block mixtures. Most other hardwoods also may be planted in pure stands or blocks, but mixtures generally are recommended.

5. Black locust, European alder, or autumn olive may be beneficial as "nurse" species in hardwood mixtures. Red oak, white oak, chestnut oak, yellow-poplar, black walnut, sweetgum, green and white ash, and sugar maple are some of the most promising species for planting with a nurse crop. The nurse species should generally make up no more than one-fourth to one-third of a hardwood mix.

6. The presence of black locust and European alder will encourage the natural establishment of indigenous forest species. Thus, planting mixtures of numerous tree species may, in the long run, offer little advantage over simple mixes that include these nurse species.

Examples of several hardwood mixtures for timber production are shown in Table 10. Obviously, many combinations of species besides those suggested are possible, and the choice of species should be influenced by factors such as the natural range of the species, minesoil characteristics, availability of planting stock, market preferences, potential commercial value and the character of the surrounding landscape. For a given locality, consult appropriate natural resource agencies or services and State revegetation guides for additional advice on forestry procedures and species selection.

Tree-Herbaceous Combinations

The seeding of herbaceous species before or concurrent with the planting of trees nearly always is required for preventing erosion. But the herbaceous cover also may slow or prevent establishment of the trees. Where herbaceous cover is established first, it may be necessary to kill or suppress it with herbicides or cultivation before planting trees. But in the more humid regions of the East, especially in Appalachia, it is possible to establish trees by planting them concurrent with the seeding of herbaceous species.

The success or failure of trees planted concurrent with herbaceous seedings appears to be partly, if not largely, related to the amount and distribution of precipitation during the growing season. Results of limited research also suggest that some herbaceous species are more compatible than others with woody species planted at the same time. For example, ryegrass and Ky-31 tall fescue are more suppressive than weeping lovegrass to the survival and early growth of direct-seeded black locust.

In eastern Kentucky, where Ky-31 tall fescue, sericea lespedeza, and Korean lespedeza were planted with trees, the growth of trees was suppressed in cover that was predominantly fescue but after 3 years was favored in cover that was predominantly lespedeza. Thus, legumes seem to be a better choice than grasses for use with trees, providing the legume plants are not so large and dense that the tree seedlings are smothered before they can grow above the legume plants. Low-growing legume species and varieties, therefore, are preferred for combination plantings with trees. In southern Appalachia, for example, Kobe and Korean lespedezas are frequently used as a ground cover with newly planted pine. Tall and aggressive legumes such as common sericea lespedeza, crownvetch, and flatpea are least recommended for combination plantings with trees. Where climatically adapted, the following herbaceous mixture is suggested for a ground cover with trees.

TABLE 10. SUGGESTED HARDWOOD MIXTURES FOR PLANTING ON SURFACE-MINED LANDS

Location	Species	Composition (percent)
Northern Appalachia	Northern red oak	25
	Green or white ash	25
	European white birch	25
	Black locust or European alder	20
	Autumn olive	5
Central and Southern Appalachia	Yellow-poplar	20
	Northern red oak	20
	White or green ash	15
	Sycamore	20
	Black locust or European alder	25
Lower Midwest (Southern Illinois, Southern Indiana, and Western Kentucky)	Black walnut	15
	Yellow-poplar	15
	Sweetgum	15
	Northern red oak	15
	Silver maple	15
	European alder	25
Western Interior Region	Bur oak	15
	Green ash	15
	Black walnut	15
	Black cherry	15
	Sycamore	15
	Black locust	25

Species	Pounds per acre (PLS)
Weeping lovegrass	2
Orchardgrass	5
Korean or Kobe lespedeza	10
Sericea lespedeza (cv. Appalow)	8

Temporary Cover--

Annual species may be used effectively in tree planting programs where a temporary cover is established one year and trees are planted the following spring. A heavy seeding rate of oats, barley, wheat, or rye could be used where early spring seeding is required. Where adapted, Korean or Kobe lespedeza seed could be included. For late spring and early summer seedings, summer annuals such as sorghum, pearl millet, and Japanese millet are useful.

Late summer and fall seeding of winter annuals such as wheat, rye, annual ryegrass, and hairy vetch poses an additional problem for tree planting in that these species will be established and actively growing in the spring when the newly planted tree seedlings are trying to become established. Herbicides or tillage in spots or strips may be required to suppress the fall-planted cover before the tree seedlings are planted.

Seeding and Planting in Alternate Strips--

Trees and herbaceous cover can be established together by seeding strips of herbaceous species that alternate with strips planted only to trees. The width of the seeded strips can vary to facilitate the desired tree spacing. Where trees are planted at an 8- by 8-foot spacing, for example, a 5-foot-wide strip of a grass-legume seeding should alternate with a 3-foot-wide strip that is not seeded. The tree seedlings are planted 8 feet apart in the middle of the unseeded strip. The herbaceous cover in alternating strips will provide adequate ground cover for erosion control yet produce minimum competition to the tree seedlings during the initial growth period.

Alternate strip planting will work best on areas that can be traversed with farm equipment, because a grain or grass seeding drill and a pull-type fertilizer spreader would be most useful for establishing strips that are uniform in width. On sloping land the strips should run on contour.

WILDLIFE HABITAT

The place where a wildlife species usually lives is called its habitat. The basic components of habitat are food, cover, water, home range, and interspersion. All are essential for the success of wildlife. Food provided by a variety of plants must be available during all seasons and within foraging range of protective cover. Different types of plant cover are required for different purposes such as brooding and nesting, escape, and shelter. Some species of wildlife require open water; others obtain moisture from succulent plants, dew, or their own metabolic processes. The home range of a species is the size of its habitat or living area. The required size varies for different species. Interspersion is the arrangement of food, cover, and water within the living area of a species. Food and cover that otherwise meet the needs of a species may be of little value where they are not properly interspersed.

Habitat for wildlife can be developed either as the primary land use or in association with other land uses. However, it should not be assumed that every revegetation effort will automatically develop or improve wildlife habitat. Most any vegetational community will in some degree contribute to habitat, but the best habitat is developed by planning and providing for the needs of the desired wildlife species. In revegetating surface-mined areas, the maximum benefit for wildlife usually is obtained by establishing vegetational communities that are not presently available or that are in short supply in the vicinity. For example, in a region that is predominantly deciduous forest, communities of coniferous trees where established will provide greater diversity of food and cover than plantings of mixed hardwoods. Because they

often are lacking in forested and agricultural areas, shrub communities are especially beneficial to wildlife.

Each species of wildlife has different habitat requirements. Thus, the vegetation established for different land uses will affect the diversity and productivity of wildlife populations. For example, bird populations in the East are most diverse and productive in a mixed hardwood forest. Different species of birds are attracted to and inhabit open grasslands; others prefer edges between forest and grassland that are partially vegetated with shrubs and small trees. Thus, even in a forested region, the overall diversity of bird species is increased by developing shrub and grassland vegetational types on surface-mined areas. Similarly, the planting of tree and shrub communities in grassland and agricultural regions will increase the diversity of birds and mammals.

Habitat can be developed on mined land to favor one or two species, several species, or wildlife in general. But newly revegetated surface mines should not be expected to provide habitat for all resident species of wildlife. For example, squirrels inhabit forests in advanced stages of succession. Ruffed grouse and wild turkey may derive benefit only from those newly revegetated sites that are adjacent to or interspersed with natural undisturbed forest or woodland. For bobwhite quail, cottontail rabbit, white-tail deer, and other species, how little or how much of the habitat requirement is derived from the early stages of revegetation depends on the size of the area; type, age, and interspersion of planted vegetation; and the type and interspersion of land uses in the surrounding unmined areas. Thus, habitat requirements should be determined before attempting to establish habitat for particular species of wildlife.

Herbaceous Mixtures

Grass-legume mixtures similar to those listed in Table 9 are suggested for seeding on steep slopes and other areas subject to severe erosion. For other sites, grasses such as orchardgrass, timothy, deertongue, Kentucky and Canada bluegrasses, and smooth bromegrass are recommended in place of Ky-31 tall fescue in seed mixtures for wildlife habitat. Similarly, limited use should be made of common sericea lespedeza, crownvetch, and flatpea because these legumes usually dominate the vegetational cover and limit the diversity in food and cover. Also, the dense persistent cover of these legumes may retard or prevent the invasion and establishment of indigenous plant species that contribute to habitat diversity. Herbaceous legumes that are desirable food plants but less aggressive and persistent than the three mentioned previously should be used. These include red clover, white clover, alsike clover, alfalfa, birdsfoot trefoil, partridge pea, prostrate lespedeza, and the annual lespedeza species.

Mixtures of native warm-season grasses--switchgrass, Indiangrass, big bluestem, and little bluestem--are useful for providing nesting cover for certain game birds and cottontail rabbit. Mixtures containing Japanese millet, redtop, reed canarygrass, and alsike clover are suggested for wet or poorly

drained areas and pond borders. Mixtures seeded in food patches for game and song birds could include common sunflower, cowpea, soybean, broomcorn millet, foxtail millet, browntop millet, or buckwheat.

Woody Plant Mixtures

Trees and shrubs are important components of wildlife habitat. In fact, development of wildlife habitat is a major reason for planting shrubs on reclaimed surface mines (Figure 16). For wildlife plantings, shrubs and trees usually are planted in rows, clumps, or blocks of a single species. Adjacent rows of different shrub or tree species can be employed to develop a "tepee" effect; that is, the tallest species are planted in the center row of a strip and shorter species are planted in the outer rows.

Figure 16. An informal planting of bicolor lespedeza that provides cover and food for wildlife.

Many woody plants provide both food and cover, but the relative importance of these values varies with different species of wildlife. Time of fruit or seed maturity and the duration of fruit or seed retention on the

plant differ among tree and shrub species. Planting several species that differ in time of maturity and retention of fruit will extend the period that food is available to wildlife.

The benefits of woody plants to wildlife do not occur as quickly after planting as they do with some herbaceous plants. For most woody species, 3 or more years of growth are required before they contribute effective amounts of cover and food to the wildlife habitat. Some tree species, such as some of the oaks, may require many years before they contribute mast to the habitat. Thus, wildlife plantings should include a variety of woody plants that will provide food continuously for a relatively long period.

Planting Patterns

Diversity is the basic principle in developing habitat for wildlife. Planting patterns that provide variety and diversity in types and arrangement of vegetation are the most beneficial when all species of wildlife are considered as a group. For example, the planting of trees and shrubs in rows, strips, clumps, and blocks in and around open areas seeded to herbs creates a desirable interspersion of food and cover types and provides for better distribution of wildlife (Figure 17).

Habitat can be improved on any reclaimed site by alternate rather than solid plantings of trees, shrubs, and herbs. For example, where contour mining creates a highwall, bench, and outslope, a basic planting pattern in the Appalachian hardwood forest region could be as follows: (1) plant several rows of conifers parallel and adjacent to the highwall; (2) plant strips, blocks, or clumps of shrubs alternating with strips or blocks of herbs on the bench; (3) plant several rows of conifers along the edge of the bench adjacent to the outslope; and (4) plant the entire outslope with herbs and several strips of shrubs or black locust trees.

A suggested pattern for expansive sites such as leveled off ridgetops would include strips of grass-legume mixtures 100 to 150 feet wide alternating with strips of shrubs and trees 30 to 50 feet wide. In some of the woody plant strips, the inner rows should be trees and the outer rows shrubs. Clumps of fruit-producing trees also can be placed randomly throughout the open areas. Where an area is less than 150 feet wide, one to three rows of woody vegetation through the middle, or scattered clumps of woody plants, may create sufficient diversity in habitat. The open areas, seeded to grasses and legumes, should be at least 1/2 acre but no more than 5 acres.

Wildlife habitat can be incorporated with other land uses chosen for the reclaimed mine. Single rows of dense shrubs between small pastures and crop fields can provide escape cover, shelter, and variety in food for game birds and small mammals. Extensive tracts revegetated for pasture, hay, or range can be diversified with occasional strips (up to 20 feet wide) of shrubs such as autumn olive, amur privet, shrub lespedeza, shrub honeysuckles, arrowwood, or rose-acacia. Similar plantings may also serve as woodland-field borders at the edge of pastures or cropland. Several rows of conifers and shrubs or small, fruit-producing trees planted at right angles to the direction of the

Figure 17. Interspersion of trees, shrubs, herbs, water, and landform provides habitat diversity that is essential for wildlife.

prevailing winds can provide windbreaks for cropland or pasture while improving nesting, escape, and winter cover for game birds

The boundaries or edges of plantings need not be uniform or exacting. Ragged, irregular edges increase the value of a planting to wildlife, and they also may add esthetic interest to a site.

Mixed forest plantations will provide good habitat for most species of wildlife that naturally inhabit forest land. Establishing blocks of conifers, up to 1 acre in size, within larger plantations of mixed hardwoods increases the variety of available food and cover types while providing potential wood products. Blocks of hardwoods may be separated from the conifers by grass-legume strips to provide more edge and open areas. Food patches of 1/8 to 1/2 acre seeded to species such as cowpea, partridge pea, soybean, wheat, white clover, or orchardgrass will benefit some species of wildlife in a forest area. One food patch in about 40 acres is suggested. Prescribed harvesting of pulpwood and timber also may create diversity in wildlife habitat.

Vegetation, especially forest vegetation, changes with time; in turn, the quality and quantity of food and cover available for wildlife will be

altered as the forest canopy closes in. To counteract this natural process of change, maintenance procedures are necessary. For example, open areas that become overgrown with woody plants may require cutting, discing, or controlled burning and reseeding to extend the longevity of the desired type of habitat.

The preceding discussion focuses on planting patterns for habitat for wildlife in general. Obviously, where habitat is desired primarily for one or two species of wildlife, variations in planting patterns must be provided that are most beneficial to those species. Additional recommendations on habitat requirements, management of the wildlife, and maintenance of habitat should be obtained from professional wildlife biologists and other reference sources.

ESTHETICS

Esthetic values should be considered in plans for revegetating surface-mined lands. The concept of esthetics involves all of the senses, but it is most often equated with the visual sense to denote quality and attractiveness or "visual appeal" of the landscape scene or scenes being viewed. The major components of the characteristic landscape are landform, vegetation, water forms, and structures.

Vegetation removal during mining and reestablishment during reclamation create significant changes in the visual relationships of cover types, patterns, and open spaces. This is especially noticeable in landscapes with continuous forest cover as found in Appalachia. Revegetation for esthetic purposes is concerned with reestablishing the visual character of the landscape by integrating the postmining land use or uses of the reclaimed area with the surrounding area.

Land use objectives and an evaluation of the characteristic landscape should guide revegetation treatments and esthetic design. Revegetation plans should include the following design considerations.

Selection. Species that have visual similarity to those in surrounding unmined areas should be used to minimize contrasts in color and texture. The use of mixtures of shrubs and trees will avoid a monoculture effect; herbaceous material alone will not always make a reclaimed site visually compatible.

Function. Introduce vegetation of varying height and configuration to define space, separate incompatible uses, blend and soften the impact of structures, and mask or screen visually objectionable or undesirable objects and views which have visual contrast.

Arrangement. Visual interest in the landscape depends on the composition and patterns of openings in forested lands, or plantings of trees and shrubs in open, nonforested lands. The physical arrangement and location of plants should be related to the natural pattern of existing vegetation to complement surroundings.

Variety. Landscapes rich in variety are desirable. Vegetation can enhance an area where there is little variety. For example, species can be introduced to provide spring color, to highlight fall color, and to create contrast (conifer with deciduous) in form, foliage, growth habit, and size. Openings can add variety to a forested landscape that otherwise might be a monotonous cover of trees.

Viewing Distance. The distances from which reclaimed areas are viewed may differ greatly. As these distances differ, the observer's impression of the visual contrast will change. For example, the size and shape of a reclaimed area appears larger where the key viewing point is relatively close, and smaller where it is far away.

Size and shape. For esthetic improvement, the size and shape of openings or plantings should be varied according to the viewing distance. Geometric-shaped openings usually are unnatural forms. Irregular and free-form shapes expose less area to view, soften the visual contrast between plantings and openings, and simulate natural conditions. Strategically located islands, clumps, and groups of vegetation help to alter the apparent size or shape of openings.

Edge. Changes in vegetational types often create abrupt visual contrast due to differences in soil or vegetation color and types. For example, in Appalachia, many contour surface mines are located in forests. Reclamation with herbaceous material creates an abrupt, sharp edge between the opening and surrounding undisturbed woods. This unnatural configuration can be modified by planting shrubs and small trees to undulate or feather the edge between the openings and undisturbed forest.

Spacing. Openings and plantings that are uniform and regimented in size, shape, and spacing seldom are visually pleasing and lead to monotony and lack of unity in the landscape. Dispersal and irregular spacing can be used to minimize contrast.

Vistas. Where there are worthwhile opportunities, select individual or groups of trees, such as conifers and flowering trees, to accentuate, focus, frame, and give scale and dimension to views of outstanding physical features (rock outcrops, lakes, streams, falls, etc.) and panoramas of the landscape.

Additional recommendations on planning and designing visual quality requirements, landscape management, and maintenance of the landscape character should be obtained through the services of a landscape architect.

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GLOSSARY

ACID-PRODUCING MATERIAL: Geologic material (rock strata) containing sufficient pyrite of a reactive form that when exposed to air and water will cause the formation of sulfuric acid.

AMENDMENT: Material such as lime, fertilizer, and manure added to minesoil to make it productive or more productive of vegetation.

ARTIFICIAL PASTURE: Grazing lands under relatively intensive management, usually supporting introduced forage species and receiving periodic cultural treatments, such as tillage, fertilization, mowing, and irrigation.

ARTIFICIAL REVEGETATION: The establishment of vegetation by mechanical or unnatural methods.

AVAILABLE NUTRIENT: The part of the supply of a plant nutrient in the soil that can be taken up by plants.

BROADCAST SEEDING: Spreading or scattering seed on the soil surface.

BROWSE: That part of current leaf and twig growth of shrubs, woody vines, and trees available for animal consumption.

BRUNCHGRASS: Grasses so called because their growth characteristic is a distinct tuft, clump, or bunch.

CANOPY: The cover formed by the aerial portion of trees and shrubs. Measured as the vertical projection downward of the leaves and branches. Similar to overstory.

CATION: An ion carrying a positive charge of electricity. The most common cations in eastern minesoils are calcium, magnesium, potassium, hydrogen, aluminum, iron, and manganese.

CATION EXCHANGE CAPACITY: A measure of the total amount of exchangeable cations that can be held by the soil. It is expressed in terms of milliequivalents per 100 grams of soil (meq/100 g).

CLAY: Mineral soil particles less than .002 mm in diameter. As a textural class, soil that contains 40 percent or more clay-size particles, less than 45 percent sand, and less than 40 percent silt.

COMPACTION: The closing of pore spaces among the particles of soil and rock; most often caused by repeated running of heavy equipment over an area or by excessive trampling by livestock. At lower depths, caused by weight of soil above.

CONTOUR: An imaginary or measured line that is kept at the same elevation (level) for its entire length, usually in reference to tillage or terracing at right angles to the direction of slope.

DENSITY: The number of plants or specific plant parts per unit area of ground surface.

DOMINANT SPECIES: The major constituent of a plant or animal community.

DRILL SEEDING: Planting seed in rows with an implement called a drill.

ENVIRONMENT: Sum of all external forces, conditions, and substances that affect organisms in any way.

EROSION: The wearing away of the land surface by detachment and transport of soil and rock materials caused by the action of moving water, ice, wind, and other geological agents.

GULLY EROSION: Caused by water accumulating or concentrating in channels; soil is removed to considerable depths.

RILL EROSION: The formation of numerous small channels only several inches deep.

SHEET EROSION: The removal of a fairly uniform layer of soil from the surface by runoff.

SPLASH EROSION: The spattering of soil particles caused by the impact of raindrops or water dripping from tall vegetation. On slopes, the soil particles are moved down slope by the repeated spattering of raindrops; also may be removed by surface runoff. A dense cover of herbaceous vegetation prevents splash and sheet erosion and retards or slows rill and gully erosion but may not prevent it.

EXCHANGEABLE: Describes the ions in the absorbing complex of soil that can be exchanged with other ions. For example, when acid soils are limed, calcium ions exchange for hydrogen ions in the complex.

EXCHANGEABLE ACIDITY: The amount of ions, mostly hydrogen, aluminum, and iron that, brought into the soil solution by ion exchange, can react with basic materials such as lime; measured as acidity.

EXOTIC: An organism that is not native to the area where it is found.

FERTILIZER: Any natural or manufactured material added to soil to provide one or more plant nutrients.

FIELD CAPACITY: The amount of water held in the soil after the excess or gravitational water has drained away.

FORAGE: All browse and herbaceous plant material that can be used as food by domestic livestock or wildlife. Forage may be either grazed or harvested for feeding.

FORAGE PRODUCTION OR YIELD: The weight of forage produced in a designated period on a given area. May be expressed as green, air dry, or oven-dry weight.

GERMINATION: Beginning of growth or sprouting as from a seed.

GRAZING CAPACITY: The maximum stocking rate possible without inducing damage to vegetation and related resources.

GROUND COVER (OF VEGETATION): The total area of live aerial and basal parts of plants, or the combined parts of plants and plant litter that, projected vertically downward, provides cover to the ground. Usually expressed as percent of ground surface that is covered by vegetation when viewed or measured directly from above. Also called vegetative cover.

HERB: Any flowering plant except those developing persistent woody stems above ground.

HERBAGE: Herbs taken collectively, often used in the same sense as forage, except that it may include plant material not acceptable to animals.

HORIZON, SOIL: A layer of soil, approximately parallel to the soil surface, with distinct characteristics produced by soil-forming processes.

A HORIZON: The surface horizon of a mineral soil having maximum biological activity, or eluviation (removal of materials dissolved or suspended in water), or both. See TOPSOIL.

B HORIZON: A soil horizon beneath the A horizon, or surface soil, in which clay, iron, and aluminum, with accessory organic matter, have accumulated by receiving suspended material from the horizon above it. In soils with distinct profiles, the B horizon is roughly equivalent to the term "subsoil."

C HORIZON: The unconsolidated rock material in the lower part of the soil profile like that material from which the upper horizons, or part of them, have developed. See PARENT MATERIAL.

HUMUS: The decomposed organic fraction of soil.

HUMID CLIMATE: A climate with a high average relative humidity and enough precipitation to support predominantly forest vegetation. The precipitation effectiveness index ranges from 64 to 128.

INTERPLANTING: Anyone of several ways of planting one species or type of plant in association with another species or type of plant.

INTRODUCED SPECIES: A species not a part of the original plant or animal communities in a given area.

INVADERS: Plant species that move into an area, usually a disturbed area, by natural seeding from surrounding areas.

INVASION: The migration of organisms from one area to another in which they become established.

ION: As used in soils, refers to an electrically charged element or combination of elements resulting from the breaking up of an electrolyte in solution. Since most soil solutions are highly dilute, many of the salts exist as ions. For example, potassium chloride in most soils exists as potassium ions (cation) and chloride ions (anions). Cations are positively charged, anions negatively charged.

LANDSCAPE: The combination of characteristics that give an area a distinguishing appearance in contrast to other areas.

LEACHING: The removal of soluble materials by the passing of water through soil.

LIME: In common usage, the term applied to all limestone-derived materials used as amendments to reduce acidity in acid soils.

LITTER: Undecomposed plant residuum on the soil surface.

LOAM: In general terms, a soil of intermediate texture between the coarse-textured or sandy soils and the fine-textured or clayey soils.

LOESS: Geologic deposits of fine-grained, predominantly silt-size material, presumably transported by wind.

MAST: Nuts and acorns that are consumed by animals.

MICROORGANISMS: Forms of life that are microscopic or submicroscopic.

MINESOIL: The mixture of earth and rock materials left on the mined area to serve as the growth medium for plants after shaping and grading is completed and the area is ready for planting. Generally, does not include replaced topsoil. Similar to spoil.

MYCORRHIZAE: The morphological association, usually symbiotic, of fungi and roots of seed plants.

NATIVE SPECIES: A species that is part of the original flora or fauna of an area.

NATURAL REVEGETATION: The reestablishment of plants, or propagation of new plants over an area by natural processes.

NITROGEN FIXATION: The conversion of atmospheric (free) nitrogen to nitrogen compounds that are eventually usable by plants. Nitrogen-fixing organisms associated with plants such as legumes are called symbiotic, i.e., the plants and organisms each contribute to the benefit of the other.

NUTRIENT: Any element or compound taken into a plant or animal that is essential to its growth.

ORGANIC MATERIAL: Nonmineral matter composed of compounds consisting primarily of carbon, hydrogen, and oxygen, and derived from living organisms.

OVERBURDEN: The earth and rock materials that lie above the coal seam.

OVERSTORY: The taller vegetation growing above vegetation with a lower growth form, e.g., trees are an overstory to herbs and shrubs.

OXIDATION: A chemical change of an element or compound involving the addition of oxygen or its chemical equivalent. In the weathering of pyritic materials, sulfur is oxidized to form sulfuric acid.

PARENT MATERIAL: The unconsolidated mass of rock material from which the soil profile develops. Usually synonymous with C horizon.

PASTURE: Grass or other growing plants used as food by grazing animals.

PERMANENT VEGETATION: Communities of vegetation consisting mostly of plant species that are long lived and that regenerate themselves indefinitely under appropriate management.

PLANT COMMUNITY: An aggregation of plant species within a specific area.

PLANT SUCCESSION: The natural process of vegetational development whereby an area becomes occupied successively by different plant communities of higher ecological order.

PRAIRIE: A tract of land that was originally treeless and covered predominantly with grasses and forbs.

PRECIPITATION EFFECTIVENESS (P-E) INDEX: The sum of the 12 monthly quotients of precipitation divided by evaporation.

PROPER GRAZING: The degree and time of grazing of current year's growth that, if continued, will either maintain or improve the condition of pasture or range consistent with conservation of associated natural resources.

PYRITE: A mineral compound of iron and sulfur, most forms of which produce acidic conditions when exposed to water and oxygen.

RANGE: Land producing native forage for animal consumption and lands that are revegetated naturally or artificially to produce a plant cover that is managed as native vegetation.

REFORESTATION: The natural or artificial restocking of an area with trees.

REVEGETATION: The reestablishment of vegetation by either natural or mechanical means.

RHIZOBIA: The bacteria that live symbiotically with leguminous plants within nodules on their roots.

RHIZOME: A horizontal undergound stem, usually sending out roots and aboveground shoots at the nodes (joints).

ROOT ZONE: The part of the soil inhabitated by the roots of plants.

SAMPLE: A part of a population taken to estimate the quantity or quality of the whole.

SAND: Soil particles with diameters between 0.05 and 2.00 mm. The textural class name of any soil containing 85 percent or more of sand and not more than 10 percent clay.

SANDSTONE: A cemented or otherwise compacted sedimentary rock composed predominantly of sand-size grains.

SCARIFY: Abrasion of the hard seedcoat, mostly of legume seeds, to decrease time required for germination. Also, to scratch or loosen the soil surface as for seedbed preparation.

SEEDBED: Soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

SEEDLING: In forestry, a plant at least 1 year old that is dug from a nursery bed for transplanting. May also refer to young plants less than 1 year old that are grown indoors in containers. With herbaceous species, a small plant from time of initial emergence of root and shoot from the germinating seed until initial development of the secondary root system.

SHALE: Sedimentary rocks generally formed by consolidation of clay or clay-like material, and exhibiting distinct cleavage parallel to the bedding. Similar rocks without cleavage are claystones.

SILT: Soil particles ranging in diameter from 0.05 to 0.002 mm. Also, the textural class name of soil containing 80 percent or more silt and less than 12 percent clay. Loosely applied to sediments deposited from water.

SOD GRASSES: Grasses with stolons or rhizomes that form a sod or turf.

SOIL: The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

SOIL TEXTURE: Refers to the relative proportions of groups of soil particles of various size in a mass of soil. Specifically, the relative proportions of sand, silt, and clay in the fine-earth portion of minesoils.

SPECIES COMPOSITION: The relative proportions of various plant species in the total cover or yield of vegetation on a given area.

SPOIL: The overburden materials removed from above the coal and placed near the excavation or back in it after the coal is removed. Similar to minesoil.

SPOIL BANK: The deposited pile of ungraded spoil or overburden.

STAND: An effective number of one or more plant species of the same life form.

STOLON: A stem growing horizontally on the surface of the soil and that forms roots and shoots at the nodes.

SUBSOIL: Generally, similar or synonymous to the B horizon of soils with distinct profiles. Cannot be accurately defined in soils with weak profile development.

SYMBIOTIC: Refers to the living together of two different organisms with a resulting mutual benefit.

TILLAGE: The operation of implements through the soil to prepare seedbeds and rooting beds.

TOPSOIL: The original or present dark-colored upper soil; or the original or present A horizon; also synonymous with surface soil or surface plow layer. Applied to soils in the field, the term has no precise meaning unless defined as to depth or productivity in relation to a specific kind of soil.

TOXIC SPOIL (MINESOIL): Spoils (minesoils) with levels of aluminum, manganese or other elements that adversely affect plant growth. Broadly, spoils with pH below 4.0.

UNDERSTORY: Vegetation growing beneath the canopy of taller vegetation, e.g., herbs and shrubs growing beneath a canopy of overstory of forest trees.

VEGETATION: Vascular plants in general including grasses, forbs, trees, and shrubs occurring naturally or planted intentionally.

VEGETATIONAL: Concerned with vegetation. Not synonymous with vegetative.

VEGETATIONAL COVER: See Ground Cover.

VEGETATIVE: In a strict sense, the nutritive and growth function of plants in contrast to sexual reproductive functions. Although often done so in common usage, this term should not be confused with vegetation or vegetational.

VEGETATIVE REPRODUCTION: Propagation of new plants by any asexual method.

VOLUNTEER PLANTS: Vegetation springing up spontaneously without having been planted artificially.

WATERSHED: Total land area above a point on a stream that contributes water to the stream flow at that point.

WEATHERING: The physical and chemical changes, disintegration, and decomposition of rocks and minerals resulting from the effects of weather, climate, and microorganisms.

Vogel, Willis G. A guide for revegetating coal minesoils in the Eastern United States. Broomall, PA : Northeast. For. Exp. Stn.; 1981; USDA For. Serv. Gen. Tech. Rep. NE-68. 190 p.

Provides information, recommendations, and guidelines for revegetating land in the Eastern United States that has been disturbed by coal mining. Includes brief descriptions of major coal mining regions in the East, and a discussion of minesoil properties and procedures for sampling, testing, and amending minesoils. Plant species used in revegetating surface-mined lands are identified. Selection criteria for plant species and methods and requirements for seeding and planting are explained.

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Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

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