THE APPALACHIAN REGIONAL REFORESTATION INITIATIVE (ARRI)
FOREST RECLAMATION ADVISORY

Forest Reclamation Advisory No. 9 August 2012

SELECTING TREE SPECIES FOR REFORESTATION OF APPALACHIAN MINED LAND

V. Davis, J.A. Burger, R. Rathfon, C.E. Zipper, C.R. Miller

The Forestry Reclamation Approach (FRA) is a method for reclaiming coal surface mines to forested post-mining land uses (FR Advisory No. 2, Burger and others 2005). The FRA's fourth step is to plant native trees for commercial timber value, wildlife habitat, soil stability, watershed protection, and other environmental benefits. This advisory provides guidance for selecting native tree species to plant on mine sites that are reclaimed using the FRA in the Appalachian region.

Favorable soil properties and non-competitive ground cover are essential features on mine sites intended for reforestation. Use of the FRA will provide these features for planted trees while also providing conditions suitable for natural seeding of plants from nearby forests.

Selecting Tree Species

More than 100 native tree species and numerous native shrub species grow within Appalachian forests. This diversity reflects the many site conditions found across the region. Forest site conditions are affected by many factors including sunlight, moisture, soil properties, proximity to native seed sources, and competition among species. The native trees most likely to produce healthy, productive forests on mine sites are those well suited to the site's growing conditions (see Photo 1). Landowner objectives, permitting and bond release requirements, and the mine's location relative to species' native ranges should also be considered when selecting trees.

Site Types for Tree Species Selection

Proper species selection for any portion of a mine site is determined by its location on the landscape, because landscape position influences availability of soil moisture and sunlight.

Landscape position is a combination of site aspect and topography, so direction of slope, slope steepness, and location on the slope are the primary factors to consider when selecting tree species for planting (Figure 1).

Aspect is the direction that a slope faces. Slopes facing south receive more solar radiation than north-facing slopes. While east- and west-facing slopes receive similar amounts of sunlight, the west-facing slopes receive sunlight during the hottest part of the day – mid and late afternoon. As a result, slopes with south and west aspects have drier soils than those that face north and east. Northeast- and east-facing slopes are generally most favorable for tree growth because of higher levels of soil moisture, while southwestern slopes are generally least favorable because of their dryness (Figure 2).

Photo 1. This young northern red oak seedling will have an excellent chance to survive, grow, and contribute to the development of a post-mining forest because it was planted on a mine site where FRA reclamation practices were used.

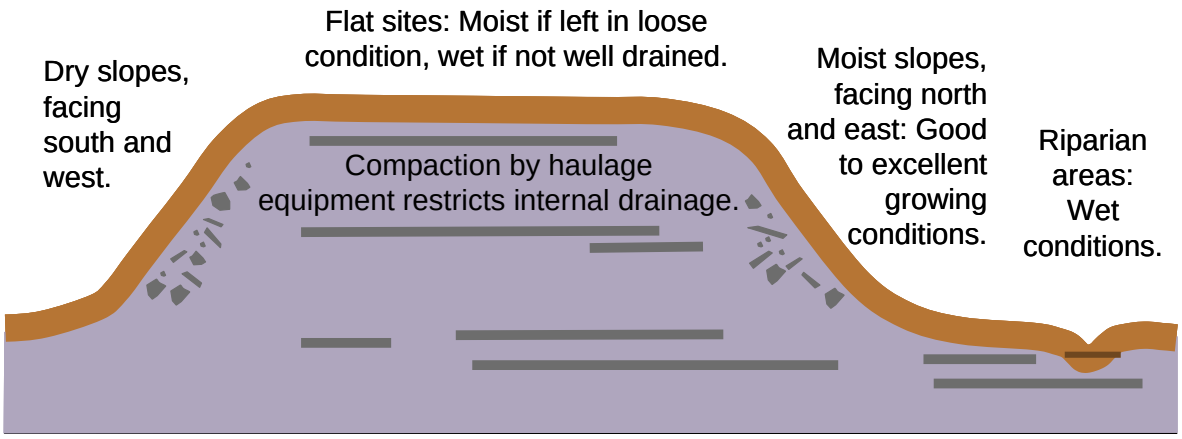

Figure 1. Four site types that commonly occur on coal surface mines and influence tree species suitability.

Topography describes the surface shape, relief or terrain, and elevation of a site's position on the land surface. Topography will influence soil moisture availability. Steep slopes are drier than more gentle slopes because they shed more rainfall as runoff, allowing less water to infiltrate the soil. Large, uncompacted, flat areas on mine sites can provide moist soil conditions and good growth potential; while landscape channels, depressions, and stream banks will have wetter soil conditions.

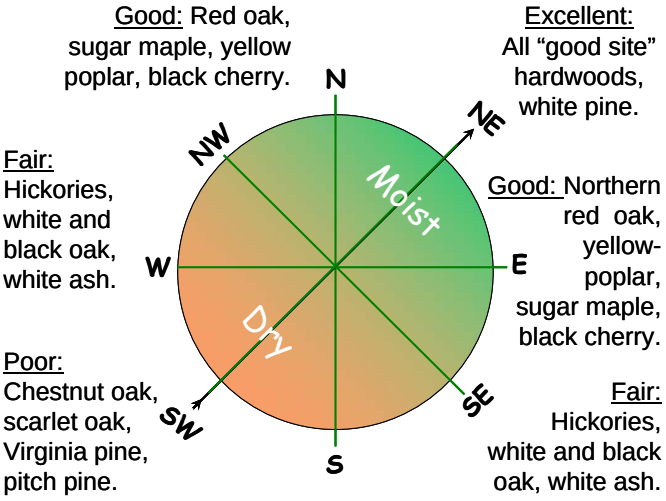

Figure 2. The direction in which a slope faces (its aspect) will influence both soil moisture and sunlight availability and should be considered in tree species selection. Aspect is rated as having excellent, good, fair, or poor tree-growth potential. "Good site" hardwoods are those prescribed for sites with good growth potential in the diagram.

Here, we describe four general landscape positions, or site types, that can be applied to mined landscapes when selecting tree species for planting (Figure 1).

- ***Dry Slopes:*** Slopes facing south and west; areas with dry growing conditions (Photo 2).
- ***Moist Slopes:*** Slopes facing north and east; areas with moist growing conditions and soils that are well drained.
- ***Flat Sites:*** Flat and rolling areas with moist growing conditions if soils are left in a loose condition and with enough landscape relief to allow water to drain easily, or wet if not well drained.
- ***Wet Sites:*** Areas within and adjacent to channels and surface depressions, including reconstructed streams and wetlands: areas with wet soils caused by landscape position or poor internal drainage.

Tree Prescriptions

A *tree prescription* is a list of species to be planted, with planting rates, for any portion of a mine or the entire area. We recommend that tree prescriptions be developed for the major site types that occur within each area to be planted. Most large mines will have several site types, each of which can be targeted for planting with its own tree prescription.

Photo 2. This photo shows north- and south-facing slopes, flats, and riparian areas for which different tree prescriptions or species mixes can be used. The south facing slope in the foreground was reclaimed using the FRA and planted with dry slope species including white oak. Several rows of riparian species planted along the reconstructed stream channel will aid reestablishment of functional aquatic communities.

We provide examples of tree prescriptions that can be applied on Appalachian mined lands (Table 1) for each of the four primary site types (Figure 1). The example prescriptions are for mines where the reclamation goal is native forestland that will produce commercial timber and environmental services.

Mine operators can change these prescriptions as needed. Table 2 includes information for other tree species, and range maps for most native trees can be found on the internet (for example: USFS, 1990, "Silvics of North America"; or USDA,2012, "Plants Database).

Some mines contain only one primary site type. For example, a contour mine on a southern slope would be a "dry slope" over most of its area, so prescribing "dry slope" species for the entire site would be an effective strategy. However, other mines include extensive areas of several site types. For example, a mountaintop mine reclaimed to approximate original contour could be planted with dry-slope species on its south- and west-facing slopes, moist-slope species on north- and east- facing slopes, and wet-site species along drainage channels and ponds.

For all tree prescriptions, species should be planted as a diverse mix across the landscape, not as single-species rows or blocks. Planting a diverse mix can be achieved by planters carrying half of the prescribed species and mixing them as they plant. The person planting the adjacent row could plant different species, so that all prescribed species are mixed into two adjacent rows.

Tree Prescription Advice and Guidance

Select Species Suited to Site Conditions.
Species should be prescribed by a person who is knowledgeable of local tree species, mine site conditions, and landowner and reclamation goals. If this expertise is not available, the Table 1 example may be used. Parties using Table 1 should check that each prescribed species' native range includes the planting area. If not, this publication can be used to select substitutes that are native to the area and suited to site conditions (Table 2).

Plant Enough Seedlings To Get The Job Done.
On mines with bond-release requirements of 450 surviving stems or less, we recommend planting 700 trees per acre – equivalent to an 8 feet x 8 feet spacing. Assuming that survival rates on mine sites often average about 70%, the result would be 490 surviving trees per acre (70% of 700 planted). If a larger number of surviving stems is required, the number of planted trees should be increased accordingly. It is important to work closely with the state regulatory authority to identify and establish the tree stocking standards that will be applied at bond release, and to plant enough trees to provide a margin of safety to ensure compliance with bond release standards.

Table 1. Example tree species prescriptions (stems per acre). Use species native to the planting area, and those that are suited to the landscape position of the mine site. If more than 450 surviving stems are required by state regulations, increased planting numbers are advised.

Dry Slopes (south, west)		**Flat Sites** (and rolling)		**Moist Slopes** (north, east)		**Wet Sites:** (riparian)	
Crop trees		*Crop trees*		*Crop trees*		*Crop trees*	
white oak	200	white oak	100	white oak	100	pin oak / river birch †	200
scarlet or post oak	100	northern red oak	100	northern red oak	200	American sycamore	200
black oak	100	sugar maple	100	sugar maple	100	sweetgum	200
chestnut oak	100	yellow- poplar	100	yellow poplar	100		
Virginia pine	100	black cherry	100	black cherry	100		
		black walnut	100				
Nitrogen fixing tree		*Nitrogen fixing tree*		*Nitrogen fixing tree*		*Nitrogen fixing tree*	
black locust	25	bristly locust	20	bristly locust	25	alder	25
Wildlife trees		*Wildlife trees*		*Wildlife trees*		*Wildlife trees*	
common persimmon	25	flowering dogwood	20	eastern white pine	25	black willow	25
eastern redbud	25	bitternut hickory	20	shagbark hickory	25	silky dogwood	25
mockernut hickory	25	eastern white pine	20	green hawthorn or gray dogwood	25	elderberry	25
		American hazelnut	20				

† Select either species, considering native range.

Plant and Mix Multiple Species

Appalachia's native forests are diverse. It is common to find 40 or more tree and shrub species per acre in these forests. On mine sites, soil and site conditions are often quite variable. The presence of multiple species can help a plant community persist if a pest or pathogen severely affects one or several of its species. For these reasons, we recommend planting multiple species.

Wet-site species are often planted as several rows along stream banks, ponds, or wetland borders (Photos 2 and 3). Flowing waters will attract wildlife, thus creating opportunities for unplanted species' recruitment. Most flat site types will be on large area or mountaintop mines far from forest seed sources, so that prescription includes more species than for other site types.

Plant Crop Trees, Wildlife Trees, and N-fixing Trees.

For most mine areas, we recommend that three types of species be prescribed for planting.

- *Crop trees* that will form a forest canopy;
- Tree species selected for *wildlife* benefits; and
- Tree species that will *fix atmospheric nitrogen (N),* improving soil quality.

Crop trees are species such as black cherry, yellow-poplar, sugar maple, and the oaks that can produce economic value for the landowner and form the forest canopy.

Some crop-tree species have heavy seeds that are slow to disperse. For example, oaks and hickories are major forest components throughout much of Appalachia, but their heavy seeds will not travel far without the help of animals. Hence, our prescriptions emphasize heavy seeded crop-tree species that are important components of the region's natural forests, especially the oaks.

Wildlife Trees and Shrubs: Although many crop tree species provide wildlife benefits, tree and shrub species of lesser commercial value but important to wildlife value also occur in natural forests Thus, in addition to crop trees, other tree and shrub species should be prescribed for improving wildlife habitat in the FRA planting.

Species such as flowering dogwood and eastern redbud establish and grow rapidly, producing early canopy structure used by birds for cover and nesting, and fruits and seeds that serve as wildlife food. Attracting wildlife aids natural succession and forest development. Mammals and birds consume fruits and seeds in unmined habitats and then move through the reclaimed mine where seeds passing through them are deposited. If site conditions are favorable, such seeds may germinate to produce live seedlings.

Some tree species occurring in natural forests at relatively low densities, such as common persimmon and black walnut, produce large fruits and seeds. These species' large seeds make them especially valuable as wildlife food sources but also limit their spread into the reclaimed mine landscape by wind and animals. Planting heavy-seeded species as seedlings is usually necessary to establish them on reclaimed mines.

Certain species produce physical structures that will aid habitat development as they mature. For example, native pines planted at low densities will provide winter cover for wildlife species such as white-tailed deer. As another example, shagbark hickory and white oak have exfoliating bark that can provide shelter for bat species, including the endangered Indiana Bat. Most crop tree species also provide wildlife benefits. For example, oaks produce acorns, an important winter food source for game species

Photo 3. Planting several rows of wet-site species along water channels can accelerate restoration of streamside vegetation, as has occurred on this mine. Riparian woody vegetation aids functioning aquatic communities in reconstructed streams by shading the channel and producing organic matter that enters the stream.

such as white-tailed deer. As we use the term here, wildlife trees are those planted in addition to crop trees for providing additional wildlife benefits.

Nitrogen (N) Fixing Trees remove N from the air, transforming it to organic forms that enrich the soil. Unless constructed from salvaged forest soils that contain surface organic material (see FR Advisory No. 8, Skousen and others 2011), mine soils will generally be low in N, an essential plant nutrient. If not taken up by plants, the N applied as fertilizer will remain in the soil to support forest development only for the first few years. Thus, we recommend planting at least one tree species that is able to "fix" N from the atmosphere.

Encourage Natural Succession

The term *natural succession* describes the natural progression of plants becoming established and replacing other plants over time on disturbed areas. The FRA is designed to create a tree growth environment that will support natural succession to develop a diverse forest plant community (Photo 4) (see FR Advisory No. 5, Groninger and others 2007,).

Early-succession trees are often referred to as pioneer plants because they colonize open areas, need full sunlight to germinate (they are not *shade tolerant*), grow very fast and are short-lived. ***Mid-succession** trees* replace the pioneer species over time, have intermediate shade tolerance, and are also fast growing but longer-lived than the pioneer species.

Late-succession species make up most of the trees in the mature forest, they can grow and establish well in full shade (they are *shade tolerant*). Late-succession species such as sugar maple, American beech, and shagbark hickory establish and grow more slowly than early- and mid-succession species but are long-lived and will eventually replace them in the developing forests, especially on moist sites. On dry sites, the oaks will persist.

We recommend prescribing a compatible mix of early-, mid- and late-succession tree species that will shorten the period of time from bare ground to a diverse, valuable, mature forest. This can be accomplished by planting a mix of *crop trees* and *wildlife trees*.

Species Specific Considerations

Hickories and black walnut are heavy-seeded late-succession species. Unfortunately, efforts to plant them on surface mines have often met with low success. Because of their importance as crop trees and wildlife habitat, hickories and black walnut should be included in tree prescriptions in low numbers as an effort to ensure that some do become established and eventually serve as seed sources. Hickories are important to wildlife, providing both mast and habitat on dry and moist slopes and flat areas. Black walnut can be prescribed for moist sites that have been reconstructed using salvaged soils (see FR Advisory No. 8, Skousen and others 2011).

White and green ash have been used in mine reclamation plantings with good success. We have not included ash species in Table 1 because an invasive insect pest, the emerald ash borer, is highly destructive to ash trees. Although the ash borer is not a current threat within most of the Appalachian coalfield, its range is spreading rapidly. Hence, many nurseries have ceased their production of ash seedlings.

Historically, American chestnut was a dominant forest species throughout Appalachia. However, most American chestnut have succumbed to invasive pests, a pathogenic fungus commonly known as the chestnut blight and the water mold *Phytophthora* root rot. Efforts are underway to develop blight and root-rot resistant hybrids of American chestnut that grow well on mine sites. However, the ability of currently available hybrids to withstand these pathogens over full life cycles has not been demonstrated.

American elm is another native tree species that is being affected by a fungal pest. Like American chestnuts, blight-resistant American elm hybrids are being developed.

Photo 4. This south-facing slope on a Tennessee mine site, photographed during its seventh growing season, was reclaimed with the FRA and planted with oaks, green ash, yellow-poplar and eastern white pine. Volunteer species including sweet birch, red maple, black gum, and black cherry also became established.

Site Specific Considerations

Although site type (Figure 1) is the major consideration for selecting tree species, other site conditions can also influence species selection.

Tree Growth Medium

The replaced mine soil must be able to provide growing trees with moisture, nutrients, and a drained and aerated soil condition if those trees are to survive and grow well. Soils selected and replaced using FRA practices will support most native species, but some soil conditions will limit species selection (see FR Advisory No. 8, Skousen and others 2011).

Most native tree species grow well in moderately acidic soils with pH in the 5.0 to 6.5 range. Soil pH levels above 7.0 are often found in mine soils constructed with unweathered spoils and will limit tree species selection. The FRA prescribes soil construction using "topsoil, weathered sandstone and/or the best available material." On most mines, materials will be available to enable construction of moderately acidic soils. This is fortunate because only a few of the species available for planting are able to tolerate highly alkaline or acidic soil. Bur oak and shumard oak can tolerate soil pH above 7.5, while a few species, including pin oak, can tolerate soil pH below 4.0.

Soil compaction will also limit species selection. A few native species such as green ash and American sycamore can survive in compacted soils, but most species will not survive. If a mine site is compacted, future forest productivity will be significantly diminished. The FRA recommends leaving soils loose and uncompacted. Where equipment traffic causes soil compaction, such soils should be ripped to produce loose conditions prior to planting.

Climate

Many hardwood species such as northern red oak and white oak occur throughout the Appalachian region and can be planted widely, but some species should be restricted only to certain site conditions. Species like sugar maple, bigtooth aspen, and red spruce are adapted to cool climates and will be more successful in northern areas and at elevations above 3000 feet in central Appalachia. In contrast, species such as southern red oak are adapted to the warmer climates of southern areas and lower elevations. Table 2 includes information on species' climate suitability.

Proximity to Seed Sources

Some tree species, like red maple, yellow-poplar, and American sycamore have wind-blown seed that can travel great distances, and they establish readily on mine sites with favorable soils. If an adequate seed source exists near the mine site, then these species do not need to be planted.

How "Flats" and "Moist Slopes" Differ

Large flat areas on mine sites often have poor *internal drainage*, meaning they lack subsurface channels to carry infiltrating water and air into the rooting zone. Poor internal drainage is a problem for planted trees because such soils retain excessive moisture and restrict access by plant roots to soil air. Although we generally recommend species for flat and rolling areas similar to those used on moist slopes, large flats with little surface relief will often have sufficient soil moisture to support wet-site species.

Wet-site species, however, will rarely do well on slopes because slopes have better internal drainage. The FRA recommends that soils be kept loose, but this is often accomplished more readily on slopes. More importantly, gravity aides the movement of subsurface water within the planted trees' rooting zone on sloped sites.

Standards for Success

Federal law (SMCRA) requires coal mining operations to restore the land's pre-mining capability. Many mining operations are conducted on lands that were forested prior to mining. Proper use of the FRA should produce a healthy forest that satisfies that SMCRA mandate. Selecting and planting tree species that are well suited to site conditions is essential to successful reforestation with the FRA.

Planted trees of many species will survive and grow well if the land is reclaimed using the FRA. Placing trees on soil and landscape conditions for which they are well suited will increase their survival and growth, improving prospects for

prompt and trouble-free bond release. Proper use of the FRA will also allow volunteers of certain species to establish, increasing the restored forest's diversity and land use capability. Tree species should be selected for planting considering their suitability for the soil and landscape conditions on the mine site, and understanding that the resulting forest's composition will be a mix of planted and volunteer species.

References

J. Burger, D. Graves, P. Angel, V. Davis, C. Zipper. 2005. The Forestry Reclamation Approach. ARRI Forest Reclamation Advisory No. 2. http://arri.osmre.gov/fra.htm

J. Groninger, J. Skousen, P. Angel, C. Barton, J.A. Burger, C.E. Zipper. 2007. Mine reclamation practices to enhance forest development through natural succession. ARRI Forest Reclamation Advisory No. 5. http://arri.osmre.gov/fra.htm

J. Skousen, C. Zipper, J. Burger, C. Barton, and P. Angel. 2011. Selecting materials for mine soil construction when establishing forests on Appalachian mine sites. ARRI Forest Reclamation Advisory No. 8. http://arri.osmre.gov/fra.htm

U.S. Forest Service (USFS). 2012. Fire Effects Information, Plant Species Life Form, Tree List. http://www.fs.fed.us/database/feis/plants/tree/

U.S. Forest Service (USFS). 1990. Silvics of North America. Agriculture Handbook 654. 877 p. http://www.na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm

U.S. Department of Agriculture (USDA). 2012. Plants Database. http://plants.usda.gov/

Acknowledgements

Faculty and researchers from the following universities and organizations ***contributed*** to this Forest Reclamation Advisory: American Birds Conservancy, Ohio University, Ohio State University, Pennsylvania State University, Purdue University, The American Chestnut Foundation, Southern Illinois University, United States Geological Survey, United States Forest Service, University of Kentucky, University of Maryland, University of Tennessee, Virginia Tech, and West Virginia University..

Victor Davis (treesfra@gmail.com), ARRI Science Team.

James Burger (jaburger@vt,edu) and Carl Zipper (czip@vt.edu), Virginia Tech, Blacksburg.

Ron Rathfon (ronr@purdue.edu), Purdue University, Dubois, Indiana.

Christopher Miller (crmiller@osmre.gov), Office of Surface Mining, U.S.D.I., Knoxville, Tennessee.

Table 2. Suitable Woody Species for Appalachian Mine Site Reclamation. (A spread sheet with additional information is available on the ARRI website along with this Advisory)

Species	Latin	Leaf Type[a]	Site Type	Potential crop tree?[b]	Growth Rate[c]	N Fixer?	pH Range[d]	Cli-mate[e]
boxelder	*Acer negundo*	d	wet		rapid		M-H	
red maple	*Acer rubrum*	d	all	see note	rapid		L-M-H	
sugar maple	*Acer saccharum*	d	moist, flat	yes	slow		L-M-H	C
gray alder	*Alnus incana*	d	wet		rapid	M	M	
speckled alder	*Alnus incana ssp. rugosa*	d	wet		mod.	L	L-M-H	
hazel alder	*Alnus serrulata*	d	wet		rapid	M	M	
mountain alder	*Alnus viridis ssp. crispa*	d	wet		mod.	L	L-M-H	
allegheny serviceberry	*Amelanchier laevis*	d	moist, flat		mod.		L-M-H	
false indigo bush	*Amorpha fruticosa*	d	moist		slow	M	L-M-H	
yellow birch	*Betula alleghaniensis*	d	moist, flat		slow		L-M-H	C
sweet birch	*Betula lenta*	d	moist, flat		mod.		L-M	
river birch	*Betula nigra*	d	wet	yes	rapid		L-M	W
bitternut hickory	*Carya cordiformis*	d	moist, flat	see note	slow		L-M-H	
pignut hickory	*Carya glabra*	d	dry	see note	slow		L-M-H	
shellbark hickory	*Carya laciniosa*	d	moist, flat	see note	slow		M	
shagbark hickory	*Carya ovata*	d	moist, flat	see note	slow		L-M-H	
mockernut hickory	*Carya tomentosa*	d	dry	see note	slow		L-M	
American chestnut	*Castanea dentata*	d	dry, moist	see note	rapid		L	
northern catalpa	*Catalpa speciosa*	d	moist, flat		rapid	L	M	
New Jersey tea	*Ceanothus americanus*	d	dry, moist		slow	L	L-M	
common hackberry	*Celtis occidentalis*	d	moist, flat		rapid		M-H	
common buttonbush	*Cephalanthus occidentalis*	d	moist, wet		mod.		L-M-H	
eastern redbud	*Cercis canadensis*	d	moist, flat		slow		M-H	
silky dogwood	*Cornus amomum*	d	moist, flat		mod.		M	
flowering dogwood	*Cornus florida*	d	moist, flat		mod.		L-M-H	
gray dogwood	*Cornus racemosa*	d	all		mod.		L-M	
American hazelnut	*Corylus americana*	d	moist, flat		mod.		M	
green hawthorn	*Crataegus viridis*	d	moist, flat, wet		mod.		L-M-H	
common persimmon	*Diospyros virginiana*	d	moist, wet		slow		L-M-H	

American beech	*Fagus grandifolia*	d	moist, flat	see note	slow		L-M-H	
white ash	*Fraxinus americana*	d	moist, flat	see note	mod.		L-M-H	
green ash	*Fraxinus pennsylvanica*	d	moist, flat, wet		rapid		L-M-H	
water locust	*Gleditsia aquatica*	d	wet		mod.	L	M-H	
honeylocust	*Gleditsia triacanthos*	d	moist, wet		rapid		L-M-H	
Kentucky coffeetree	*Gymnocladus dioicus*	d	moist, flat		slow	L	M-H	
American witchhazel	*Hamamelis virginiana*	d	moist, flat		slow		L-M	
American holly	*Ilex opaca*	e	moist, flat		slow		L-M-H	
common winterberry	*Ilex verticillata*	d	all		mod.		L-M-H	
black walnut	*Juglans nigra*	d	moist, flat	see note	rapid		L-M-H	
eastern redcedar	*Juniperus virginiana*	e	moist, flat		slow		L-M-H	
sweetgum	*Liquidambar styraciflua*	d	moist, wet	yes	rapid		L-M-H	
yellow-poplar	*Liriodendron tulipifera*	d	moist, flat, wet	yes	rapid		L-M	
sweet crab apple	*Malus coronaria*	d	moist, flat		slow		M	
red mulberry	*Morus rubra*	d	moist, flat		mod.		M	
hophornbeam	*Ostrya virginiana*	d	moist, flat		slow		L-M-H	
sourwood	*Oxydendrum arboreum*	d	dry, flat		slow		L-M	
red spruce	*Picea rubens*	e	moist, flat	yes	mod.		L-M	C
shortleaf pine	*Pinus echinata*	e	moist, flat	yes	rapid		L-M	W
pitch pine	*Pinus rigida*	e	dry		rapid		L	
eastern white pine	*Pinus strobus*	e	moist, flat	yes	rapid		L-M	
loblolly pine	*Pinus taeda*	e	dry	yes	rapid		L-M-H	W
Virginia pine	*Pinus virginiana*	e	dry		rapid		L-M-H	
American sycamore	*Platanus occidentalis*	d	moist, flat, wet	yes	rapid		L-M	
eastern cottonwood	*Populus deltoides*	d	moist, wet	yes	rapid		L-M	
bigtooth aspen	*Populus grandidentata*	d	moist, flat, wet		rapid		L-M	C
American plum	*Prunus americana*	d	moist, flat		mod.		M	
pin cherry	*Prunus pensylvanica*	d	moist, flat		rapid		L-M-H	
black cherry	*Prunus serotina*	d	moist, flat	yes	rapid		L-M-H	C
white oak	*Quercus alba*	d	dry, moist, flat	yes	slow		L-M	
scarlet oak	*Quercus coccinea*	d	dry	yes	rapid		L-M	
southern red oak	*Quercus falcata*	d	dry, flat	yes	mod.		L-M-H	W
bur oak	*Quercus macrocarpa*	d	dry, moist, flat	yes	mod.			
chestnut oak	*Quercus montana*	d	dry	yes	slow		L-M	
chinkapin oak	*Quercus muehlenbergii*	d	dry	yes	mod.		M-H	
pin oak	*Quercus palustris*	d	moist, wet	yes	rapid		L-M	
northern red oak	*Quercus rubra*	d	moist, flat	yes	mod.		L-M-H	
Shumard oak	*Quercus shumardii*	d	dry, flat	yes	mod.		M-H	W
post oak	*Quercus stellata*	d	dry	yes	slow		L-M	
black oak	*Quercus velutina*	d	dry	yes	mod.		L-M	
bristly locust	*Robinia hispida*	d	dry, moist, flat		rapid	M	L-M-H	
black locust	*Robinia pseudoacacia*	d	all		rapid	M	L-M-H	
black willow	*Salix nigra*	d	wet		rapid		L-M-H	
American black elderberry	*Sambucus nigra ssp. canadensis*	d	moist, flat, wet		rapid		L-M-H	
sassafras	*Sassafras albidum*	d	moist, flat		mod.		L-M-H	
American basswood	*Tilia americana*	d	moist, flat	yes	mod.		L-M-H	
American elm	*Ulmus americana*	d	moist, flat	see note	rapid		M-H	
slippery elm	*Ulmus rubra*	d	moist, flat		rapid		M-H	
highbush blueberry	*Vaccinium corymbosum*	d	wet		mod.		L-M-H	
southern arrowwood	*Viburnum dentatum*	d	all		slow		L-M	
blackhaw	*Viburnum prunifolium*	d	dry, moist		slow		L-M-H	

[a] Leaf Type: d = deciduous, e = evergreen.

[b] Notes concerning crop trees: Hickories, American beech, and black walnut have growth forms that are well suited for crop trees, but consistent success in planting these species on coal surface mines has not been demonstrated. Red maple is not recommended for planting because it volunteers readily. American chestnut, white ash, and American elm are well suited as crop trees when healthy but are subject to special considerations due to their susceptibility to pests as described in text.

[c] Growth Rate: mod = moderate.

[d] Soil pH range: Trees are grouped by soil pH suitable for the species. L = low (pH<5); M = medium (pH 5-7); H = high (pH>7).

[e] Climate Suitability. C = does well in cool climates, including northern Appalachia and at higher elevations (>3000 ft) in central and southern Appalachia; W = does well in warm climates, including Appalachia's southern region and parts of central Appalachia, If neither C nor W is specified, the species does well throughout the region.