 0030-0950/79/0006-0274/$1.50/0

GROWTH PERFORMANCES AND MYCORRHIZAE OF NATIVE AND EXOTIC HARDWOODS ON BITUMINOUS STRIPMINE SPOILS[1]

WILLIAM C. SHUFFSTALL[2] and RICHARD J. MEDVE, Department of Biology, Slippery Rock State College, Slippery Rock, PA 16057

Abstract. Growth parameters and mycorrhizal characteristics were compared for 10 hardwood species that naturally invade bituminous stripmine spoil and 4 exotic hardwoods that are commonly planted on reclaimed stripmine spoils in western Pennsylvania. *Sassafras albidum*, *Acer rubrum*, *Populus tremuloides*, *Crataegus* spp., and *Robinia pseudoacacia* grew better on bituminous spoils than on non-spoil sites. Invaders with the best total growth performances on stripmine spoils were *Aralia spinosa*, *Rhus glabra*, *Populus tremuloides*, *Robinia pseudoacacia*, and *Acer rubrum*. These 5 natural invaders, which are not usually planted on stripmine spoil, exceeded selected growth characteristics of 4 exotic species commonly planted on bituminous stripmine spoil. All species had mycorrhizae under all conditions studied, but type or percent of mycorrhizae were not related to success as a pioneer species on stripmine spoil.

OHIO J. SCI. 79(6): 274, 1979

Reclaimed bituminous stripmined land in Pennsylvania has been revegetated with grasses, legumes, trees, shrubs, or combinations of these plants. For areas reforested with hardwoods, selected species are usually characterized by high survival rates and rapid growth. Some naturally invading hardwood species possess these characteristics, but are usually not used in reforestation of bituminous spoils.

Quaking aspen (*Populus tremuloides* Michx.), black locust (*Robinia pseudoacacia* L.), red maple (*Acer rubrum* L.), large tooth aspen (*Populus grandidentata* Michx.), black cherry (*Prunus serotina* Ehrh.), and hawthorn (*Crataegus* spp.) are some of the common hardwoods that are found as natural invaders on stripmine spoils in western Pennsylvania. Medve (1973) reported quaking aspen, black locust, and red maple to have the highest importance values for hardwoods invading reclaimed bituminous stripmine spoils in Moraine State Park, Pa. Czapowskyj (1970) also found black locust to grow well on stripmine spoil while Davis (1971) reported black locust to be a very good species for erosion control.

Exotic hardwood species are often planted on reclaimed stripmine spoils. European alder (*Alnus glutinosa* (L.) Jaertn.) has been used as an early cover crop and was reported to have a good survival rate with rapid growth on stripmine spoils (Dale 1963). Hybrid poplar (*Populus* sp.) grew rapidly on stripmine spoils having a pH greater than 4.0 and showed value for erosion control (Davis 1971).

The importance of mycorrhizae to stripmine invaders has not been clearly elucidated. Arbuscular mycorrhizae have been found on some trees growing on anthracite and bituminous spoils (Daft and Hacskaylo 1976). Schramm (1966) found that early ectomycorrhizae formation appeared to be necessary for seedling survival of a number of hardwood and conifer species growing on anthracite spoils. Mycorrhizae are thought to increase the tolerance of trees to the adverse conditions of stripmine spoils (Marx 1975). The present study compares selected growth and mycorrhizal characteristics for hardwood species invading stripmine spoils and non-stripmine sites and exotic

[1]Manuscript received 23 August 1978 and in revised form 16 February 1979 (#78-49).

[2]Present address: Cooperative Extension Service, Colorado State University, Burlington, CO 80807.

hardwood species often planted on stripmine spoils.

METHODS AND MATERIALS

Ten hardwood species that naturally invade stripmine spoils and 4 exotic hardwood species that are commonly planted on reclaimed stripmine spoils were selected for study. These 14 plant species were found growing on 13 sites in Butler County, Pennsylvania.

Reclaimed stripmined areas were either returned to the approximate original contour or terrace backfilled. Reclamation occurred from 1967–1969. No topsoil was returned to the reclaimed spoil and no fertilizer was added.

Non-stripmine areas were selected because of their proximity to the stripmine study sites. All non-stripmine areas were located on agricultural fields that were fallow for 2–20 years, supported vigorously growing shrub communities and appeared to be good quality sites.

The growth characteristics studied for each species were late leaf length, amount of stem extension growth, number of leaf primordia, number of leaf scars, and mycorrhizal characteristics. Trees selected for sampling varied in age from approximately 6–12 years old. Late leaf measurements were made in August 1976. Amount of stem extension growth was obtained in October 1976 by measuring the distance from the previous year's terminal bud scale scars to the tip of the terminal bud. Leaf scar data were also collected in October 1976. The number of leaf scars between the previous year's terminal bud scale scars and the terminal bud were counted.

In March 1976, 25 terminal buds were collected and used for the leaf primordia study. Ten buds of each species were randomly selected and used for the leaf primordia study. In April 1977, non-woody roots were collected from specimens growing on spoil material and non-stripmine soil. Roots were washed in water, fixed in FAA, embedded in paraffin, sectioned, and stained with safranin and fast green. At least 100 randomly selected root sections of each species were observed for the presence of mycorrhizae.

Based on the number of leaf scars and number of leaf primordia, each species was classified as having determinate or indeterminate extension growth. The t-test for a significant difference between independent means was used to determine significant differences in late leaf length, amount of extension growth, number of leaf primordia, and number of leaf scars for the indigenous species growing on stripmine spoil and on non-spoil.

A comparative growth index (CGI) was calculated for each indigenous species by summing the ratios of on and off stripmine spoil mean values for late leaf length, leaf primordia, and leaf scars. This sum was multiplied by 100 and divided by 3. The CGI was used to compare the growth of a plant species found on stripmine spoil to that on non-stripmine soil. A CGI greater than 100 would indicate better growth on spoil than on non-spoil.

RESULTS

Late leaf length, extension growth, and number of leaf scars on spoil and non-spoil were significantly different for 6, 5, and 4 indigenous species respectively. Number of leaf primordia showed no significant

TABLE 1

Mean Values for Selected Growth Characteristics for Invading Species on Bituminous Stripmine Spoil and Non-Stripmine Soil.

Species	Area	Late Leaf Length (mm)	Extension Growth (mm)	No. Leaf Scars	No. Leaf Primordia
Red Maple	Non spoil	83± 23**	182± 83**	11±3**	6±0**
	Spoil	177± 33*	218±138	11±3	6±0
Hercules' club	Non-spoil	695±122	764±202	14±2	8±1
	Spoil	534± 82*	374±126*	12±1*	9±1
Flowering dogwood	Non-spoil	98± 18	104± 67	5±1	4±0
	Spoil	73± 21*	95± 71	6±1	5±0
Hawthorn	Non-spoil	63± 15	175± 81	11±4	10±3
	Spoil	64± 8	171± 67	13±4	9±3
Large tooth aspen	Non-spoil	93± 22	222±140	12±3	8±2
	Spoil	123± 29*	93± 65*	9±2*	8±2
Quaking aspen	Non-spoil	67± 21	218±118	14±5	9±2
	Spoil	65± 21	329±107	15±1	8±2
Black cherry	Non-spoil	97± 15	167± 93	12±4	16±2
	Spoil	121± 26*	69± 41*	8±3*	14±1
Smooth sumac	Non-spoil	224± 40	221± 55	14±1	12±1
	Spoil	173± 43*	179± 55*	15±3	12±1
Black locust	Non-spoil	175± 44	287±150	12±4	5±1
	Spoil	165± 44	280±108	14±4	8±1
Sassafras	Non-spoil	73± 41	63± 21	18±3	12±1
	Spoil	53± 32	181±107*	15±1*	10±1

*Significant $P<0.01$.
**Mean±SD.

difference for any of the indigenous species (table 1). Large tooth aspen, Hercules' club, (*Aralia spinosa* L.), and black cherry had three parameters which were significantly different on spoil and non-spoil. Hercules' club, however, was the only species for which all three parameters were significantly less on spoil material. Except for black cherry, all of the indigenous species had indeterminate extension growth.

The CGI values show that 5 indigenous species, sassafras (*Sassafras albidum* (Nutt.) Nees.), red maple, quaking aspen, hawthorn, and black locust, grew better on spoil than on non-spoil. The CGI values for flowering dogwood (*Cornus Florida* L.), smooth sumac (*Rhus glabra* L.), large tooth aspen, black cherry, and Hercules' club show these species to grow better on non-spoil than on stripmine spoil (table 2).

TABLE 2

Comparative growth index of indigenous species on bituminous stripmine spoil and non-stripmine soil.

Species	Comparative Growth Index*
Sassafras	148
Red maple	144
Quaking aspen	118
Hawthorn	106
Black locust	103
Flowering dogwood	95
Smooth sumac	88
Large tooth aspen	83
Black cherry	78
Hercules' club	70

*Values>100 indicate better growth on bituminous stripmine spoil than on non-stripmine sites.

Mycorrhizae were found on all the indigenous species, both on and off stripmine spoil (table 3). Five species (red maple, sassafras, hawthorn, flowering dogwood, and Hercules' club) had endomycorrhizae on and off stripmine spoil. Quaking aspen, large tooth aspen, smooth sumac, and black locust had ectomycorrhizae on and off stripmine spoil. Black cherry had endomycorrhizae on undisturbed soil and ectomycorrhizae on stripmine spoil.

Six of the indigenous species had at least 50% mycorrhizae in root sections sampled on and off stripmine spoil (table 3). The percent mycorrhizae for red maple, hawthorn, and Hercules' club varied at least 34%. Black locust had a low percentage of mycorrhizae on both sites.

For the exotic species, European white birch (*Betula pendula* Roth.) had the lowest values for all growth parameters except number of leaf primordia (table 4). European alder had the greatest number of leaf primoridia. Hybrid poplar had the largest late leaf length and number of leaf scars. The mean number of embryonic leaves, late leaf length, and leaf primordia for the indigenous species were greater than the mean values for any of the exotics. Hybrid poplar, autumn olive (*Eleagnus umbellata* Thunb.), and the indigenous species with the best growth characteristics had indeterminate extension growth. Although European alder had determinate extension growth, it produced more leaf primordia than hybrid poplar and autumn olive. European white birch and hybrid poplar had ectomycorrhizae while autumn olive and European alder had endomycorrhizae (table 4). All of the exotic species except autumn olive had mycorrhizal percentages greater than 50%.

DISCUSSION

Reclaimed stripmine spoils have physical characteristics that are usually detrimental to plant growth (Marx 1975), but growth indices for sassafras, red maple, quaking aspen, hawthorn, and black locust show that these indigenous species grew better on stripmine spoil than on non-spoil (table 2). Red maple, black locust, and quaking aspen are the most common invaders found on bituminous stripmine spoil while sassafras and hawthorn are limited (Medve 1973).

The CGI values of flowering dogwood, smooth sumac, large tooth aspen, hercules' club, and black cherry indicated poorer growth on stripmine spoil than on non-spoil for these species. Large tooth aspen and, to a lesser degree, black cherry, are found with regularity as bituminous stripmine invaders (Medve 1973).

Hercules' club, smooth sumac, black locust, red maple, and quaking aspen

TABLE 3

Type and Percent Mycorrhizae of Indigenous Species Growing on Stripmine Spoil and Non-Stripmine Soil.

Species	Area collected	Type mycorrhiza	% Mycorrhizae
Red maple	Non-spoil	Endo.	89
	Spoil	Endo.	55
Hercules' club	Non-spoil	Endo.	50
	Spoil	Endo.	15
Flowering dogwood	Non-spoil	Endo.	84
	Spoil	Endo.	95
Hawthorn	Non-spoil	Endo.	25
	Spoil	Endo.	90
Large tooth aspen	Non-spoil	Ecto.	97
	Spoil	Ecto.	98
Quaking aspen	Non-spoil	Ecto.	86
	Spoil	Ecto.	95
Black cherry	Non-spoil	Endo.	26
	Spoil	Ecto.	15
Smooth sumac	Non-spoil	Ecto.	56
	Spoil	Ecto.	70
Black locust	Non-spoil	Ecto.	10
	Spoil	Ecto	11
Sassafras	Non-spoil	Endo.	90
	Spoil	Endo.	85

showed the greatest overall growth on stripmine spoil, but hercules' club and smooth sumac had low CGI values, indicating that they are sensitive to conditions found on stripmine spoil.

Number of leaf primordia was not significantly different on and off stripmine spoil for any species (table 1), indicating that this parameter is very stable. Extension growth and late leaf length were significantly different on and off stripmine spoil for several species and appear to be greatly affected by the different conditions encountered on spoil and non-spoil (table 1).

Red maple, quaking aspen, and large tooth aspen were previously described as having indeterminate extension growth (Marks 1975). This characteristic enables the plant to continue leaf production beyond those found as primordia in the winter bud, and it is advantageous for invading species. Except for black cherry, all indigenous species had indeterminate extension growth. Two of the 4 exotic species, however, had determinate extension growth.

Endomycorrhizae were found on red maple, sassafras, hawthorn, flowering dogwood, and hercules' club on stripmine

TABLE 4

Mean Values for Growth and Mycorrhizal Characteristics of Exotic and Indigenous Species Found on Bituminous Stripmine Spoils.

Species	Leaf Length (mm)	Amount Extension Growth (mm)	No. Leaf Scars	No. Leaf Primordia	Type Mycorrhiza	% Mycorrhizae
European white birch	39	87	6	7	Ecto.	94
Hybrid poplar	95	196	13	10	Ecto.	65
Autumn olive	73	296	12	4	Endo.	27
European alder	64	233	12	12	Endo.	91
*5 Ind. Sp. with best growth characteristics	196	262	14	9		49

*2 with endomycorrhiza, 3 with ectomycorrhiza.

spoil and non-spoil. Ectomycorrhizae were found on quaking aspen, black locust, smooth sumac, and large tooth aspen on and off stripmine spoil (table 3). These mycorrhizae types are consistent with those reported by Marx (1975), Schramm (1966), Daft and Hacskaylo (1976), Medve *et al* (1977), and Henry (1933).

Marx (1975) reported that tree species normally having one type of mycorrhiza may under certain conditions have another type. This occurrence could explain the different types of mycorrhizae found for black cherry on and off spoil.

A higher percentage of mycorrhizae did not always result in increased growth. Red maple, hercules' club, and black cherry had a greater percentage of mycorrhizae on non-spoil than on spoil (table 3), and red maple grew better on spoil (table 2). Flowering dogwood, hawthorn, and smooth sumac had a greater percentage of mycorrhizae on spoil than on non-spoil (table 3), but only flowering dogwood and hawthorn grew better on spoil (table 2). No correlation was evident between type and/or percent mycorrhizae and growth characteristics on or off spoil.

A low percentage of mycorrhizae (table 3) and increased growth on stripmine spoil (table 2) for black locust support studies previously reported by Medve *et al* (1977). Nitrogen fixing ability of plants such as black locust may reduce the occurrence of mycorrhizae (Schramm 1966). Nitrogen fixing European alder, however, was found to have 91% of its non-woody roots endomycorrhizal (table 4), suggesting that some nitrogen-fixing species can become heavily mycorrhizal.

Stripmines used in this study did not have the topsoil replaced. Shale and other coarse spoil materials comprised the rooting medium and were expected to show an initial dearth of mycorrhizal fungi (Schramm 1966). Windblown basidiospores, however, could account for the presence of ectomycorrhizal inoculum. Spores of the endomycorrhizal symbionts could be introduced to the area by rodents (Trappe and Maser 1976) or wasps and birds (McIlveen and Cole 1976). Although ectomycorrhizal inoculum would appear to be more easily disseminated, both types of mycorrhizae were represented by indigenous plant species on reclaimed spoils.

Exotic species do have attributes which make them valuable in reforestation of stripmine spoils. European alder has good survival and growth on spoils with pH as low as 3.4 (Funk and Dale 1963). Certain clones of hybrid poplar survive well and make rapid growth on spoils with pH as low as 4.0 (Finn 1958, Czapowskyj 1970). The hybrid poplar is also a valuable erosion controlling species (Davis 1971). Autumn olive fixes nitrogen (Schramm 1966), has good survival on stripmine spoils, and produces food and cover for wildlife (Plass 1975). European white birch was reported as the best surviving species on extremely acid spoils (Davis 1971).

Indigenous species with the greatest growth measurements exceeded the best growth characteristics of most of the exotic species. Number of leaf scars and leaf primordia for hybrid poplar, extension growth of autumn olive, and number of leaf primordia for european alder were the only parameters of the exotic species within 10% of the parameter values for the indigenous species with the best growth characteristics (table 4). Some indigenous species appear to have growth characteristics that make them more suitable for bituminous stripmine revegetation than the presently used exotics. Black locust is planted in a number of states. Red maple, quaking aspen, and sassafras, however, are not usually planted on bituminous stripmine spoils, but show excellent potential for reforestation.

LITERATURE CITED

Czapowskyj, M. M. 1970 Experimental planting of 14 tree species on Pennsylvania's anthracite stripmine spoils. U.S. Forest Serv. Northeast. States Expt. Sta. Res. Note 155, 18 pp.

Dale, M. E. 1963 Interplant alder to increase growth in stripmine plantations. U.S. Forest Serv. Expt. Sta. Res. Note 14, 4 pp.

Davis, G. (Ed. Chairman). 1971 A Guide for Revegetating Bituminous Strip-mine Spoils in Pennsylvania. 46 pp.

Daft, M. J. and E. Hacskaylo 1976 Arbuscular mycorrhizas in the anthracite and bituminous coal wastes of Pennsylvania. J. Appl. Ecol. 13: 523–531.

Finn, R. F. 1958 Ten years of strip-mine forestation research in Ohio. U.S. Forest Serv. Central States Expt. Sta. Res. Notes 153, 38 pp.

Funk, D. T. and M. E. Dale 1961 European alder. A promising tree for strip-mine planting. U.S. Forest Serv. Central States Expt. Sta. Res. Note 151, 2 pp.

Henry, L. K. 1933 Mycorrhizas of trees and shrubs. Bot. Gaz. 94: 791–800.

Marks, P. L. 1975 On the relationship between extension growth and successional status of deciduous trees of the north-eastern United States. Bull. Torrey Bot. Club 102: 172–177.

Marx, D. 1975 Mycorrhizae and establishment of trees on stripmined land. Ohio J. Sci. 75: 288–297.

McIlveen, H. W. and D. H. Cole Jr. 1976 Spore dispersal of Endogonaceae by worms, ants, wasps, and birds. Canadian J. Bot. 54: 1486–1489.

Medve, R. J. 1973 Tree seedling survival on reclaimed bituminous stripmine spoils in Moraine State Park, Pennsylvania. Proc. Pa. Acad. Sci. 47: 129–132.

———, F. M. Hoffman and T. W. Gaither 1977 The effects of mycorrhizal-forming amendments on the revegetation of bituminous stripmine spoils. Bull. Torrey Bot. Club. 104(3): 218–225.

Plass, W. T. 1975 An evaluation of trees and shrubs for planting surface-mine spoils. U.S. Forest Serv. Northeast. States Expt. Sta. Res. Note 317, 8 pp.

Schramm, J. R. 1966 Plant colonization studies on black wastes from anthracite mining in Pennsylvania. Trans. Amer. Phil. Soc. 56: 1–194.

Trappe, J. M. and C. Maser 1976 Germination of spores of *Glomus macrocarpus* (Endogonaceae) after passage through a rodent digestive tract. Mycologia 58: 433–436.