EFFECTS OF COAL MINESOIL SURFACE AND HERBICIDE APPLICATIONS ON EARLY TREE SURVIVAL AND GROWTH[1]

by

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Abstract. Factors affecting tree establishment on calcareous coal minesoil surfaces (standard graded topsoil, graded and ripped topsoil, levelled gray cast overburden) are being evaluated in southeastern Ohio. Green ash (*Fraxinus pennsylvanica* Marsh.), silver maple (*Acer saccharinum* L.), European alder (*Alnus glutinosa* (L.) Gaertn.), black pine (*Pinus nigra* Arnold), eastern white pine (*P. strobus* L.), and Virginia pine (*P. virginiana* Mill.) were planted in spring 1989 into a grass/legume ground cover seeded in fall 1987. Dowpon M (dalapon), Poast (sethoxydim), Oust (sulfometuron methyl), Princep 4L (simazine), Stomp (pendimethalin), and Surflan A.S. (oryzalin) herbicides were applied over the trees at two rates (except Stomp) and two frequencies (first year only, two consecutive years) for all species except Virginia pine (first year applications only). Except for Virginia pine (24%), first-year overall survival was generally high, varying from 73% for white pine to 98% for green ash. Following a drought in 1991, overall survival of white pine (3%), European alder (14%), and silver maple (41%) declined sharply from 1990 levels, but that of black pine (62%) or green ash (97%) did not. All species tended to survive better on topsoil than on graded cast overburden. Black pine had the greatest range in percent survival: 73 on standard topsoil, 58 on ripped topsoil, and 56 on cast overburden. Black pine, silver maple, and green ash had greater total height on standard topsoil (35, 30, and 51 cm, respectively) and ripped topsoil (36, 32, and 61 cm) than on cast overburden (31, 21, and 41 cm). Survival on herbicide treated plots was greater than on untreated controls only for white pine (Princep 4L-9.4 l/ha) and Virginia pine (Princep 4L-9.4 l/ha; Oust-0.14 or 0.28 kg/ha). Survival of both species was unacceptably low (7-18%) even when improved by these herbicides. Green ash and European alder survival decreased with both rates of Oust and with increasing frequency of Oust. Green ash height was increased by either rate of Dowpon, Poast, or Surflan. The general lack of herbicide effects on tree survival and growth was due in part to

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abundant precipitation, 77% and 41% greater than normal for April-August, during the first two years of the study.

Additional Key Words: Fraxinus pennsylvanica Marsh., Acer saccharinum L., Alnus glutinosa (L.) Gaertn., Pinus nigra Arnold, Pinus strobus L., Pinus virginiana Mill., graded topsoil, ripped topsoil, graded cast overburden, herbicide rate, herbicide frequency, Dowpon M (dalapon), Poast (sethoxydim), Oust (sulfometuron methyl), Princep 4L (simazine), Stomp (pendimethalin), Surflan A.S. (oryzalin), animal damage.

Introduction

Forest production was the dominant post-mining land use on Central Ohio Coal Company's Muskingum Mine prior to 1972. Passage of the Ohio Surface Mining and Reclamation Law in that year resulted in a great decline in tree planting, with a corresponding increase in acreage reclaimed to grasslands. The amount of land reclaimed to grassland was approaching 4000 hectares by 1980 (Smith 1980) and has increased to about 8000 hectares today. Because of a continuing interest in tree planting, the Ohio Agricultural Research and Development Center and the American Electric Power Service Corporation (Central Ohio Coal Company) established a set of research plots in 1987 to study tree establishment and growth under current mining regulations and with alternative resoiling materials. Several of the ten studies that have been installed focus on the effects of ground cover management on tree establishment.

Establishment of ground cover as required by federal and state reclamation regulations has several beneficial effects, including control of erosion and initiation of nutrient cycling through organic matter accumulation. Adverse effects of ground cover on tree establishment have, however, been well documented (Vogel 1980, Philo et al 1983). Adequate tree survival on minesoils with vigorous ground cover is often dependent upon vegetation control with herbicides (Raisanen 1982, Andersen et al 1989). Selection of an appropriate ground cover may allow tree establishment without the use of herbicides (Torbert and Burger 1990).

There do not appear to be many studies that have evaluated a spectrum of herbicides for tree establishment on minesoils. Ringe et al. (1984) and Ringe and Graves (1985) described the effects of glyphosate (Roundup) alone and in combination with atrazine 4L, napropamide 50WP (Devrinol), diphenamid 90W (Enide), oxadiazon 2G (Ronstar), and oryzalin 4L (Surflan) on survival and height growth of European alder and Virginia pine planted into a four-year old ground cover in eastern Kentucky. After two years, only survival of European alder treated with glyphosate plus atrazine 4L was significantly greater than that of untreated controls.

The purpose of the present study is to evaluate survival and growth of several tree species as affected by minesoil surface and by type, rate, and frequency of herbicide application.

Methods

The experiment was a split-split-split-block design testing three soil surfaces, six tree species, 12 herbicide-rate combinations, and two frequencies of herbicide application, with four replications. The study area, located on Central Ohio Coal Company's Muskingum Mine, is 5 km south of Cumberland in Noble County, Ohio. The area was mined using pan scrapers to remove and stockpile the topsoil, followed by draglines to uncover the Meigs Creek No. 9 coal seam. Reconstructed soil surfaces consisted of graded gray cast overburden without topsoil, graded cast overburden with 30 cm of replaced topsoil (standard topsoil), and a similarly-constructed topsoil surface that was ripped to 30 cm depth after topsoil grading (ripped topsoil). Two replications were on a generally level (2-6% slope) area facing northeast and two were in a steep valley (21% slope) facing southwest. Main soil surface plots measured 40 m (a few varied from 26-48 m) by 34 m.

Topsoil was a mixture from the upper layer of several soil complexes dominated by the Gilpin (fine-loamy, mixed, mesic Typic Hapludult), Westmore (fine-silty, mixed, mesic Typic Hapludalf), and Guernsey (fine, mixed, mesic Aquic Hapludalf) series. These soils were severely eroded prior to mining, with the upper 18 cm being primarily subsoil. The gray cast overburden is predominately gray shale and limestone but contains some sandstone. Physical and chemical properties of the two soils are listed in Table 1.

Plots were fertilized in August, 1987 with 448 kg/ha of 8-32-16 (N-P-K) fertilizer and 112 kg/ha ammonium nitrate (34% N), and then seeded (kg/ha) with a mixture containing orchardgrass-Dactylis glomerata L. (6.7), timothy-Phleum pratense L. (11.2), perennial ryegrass-Lolium perenne L. (9.0), Kentucky bluegrass-Poa pratensis L. (5.6), Mammoth red clover-Trifolium pratense L. (5.6), Empire birdsfoot trefoil-Lotus corniculatus L. (5.6), and wheat-Triticum aestivum L. (1.3 hectoliters/ha). Plots were mulched with hay after seeding.

Bare-root tree seedlings (European alder, green ash, silver maple, black pine, Virginia pine, white pine) were hand planted at 1.8 m by 0.6 m spacing in three-row sub-blocks in March-April, 1989. Dead Virginia pine were replaced in March, 1990. Planting stock for hardwoods and conifers was one and two years old, respectively. Trees were obtained from state nurseries in Zanesville, Ohio (all hardwoods); Marietta, Ohio (black pine); Vallonia, Indiana (white pine); and Lakin, West Virginia (Virginia pine). Each species was graded and pruned to a relatively uniform stem caliper and height before planting.

Herbicides were applied in 0.75 m wide bands over the trees using backpack sprayers in April-May, 1989 and 1990. Each tree species subplot on each soil surface was divided into 24 sub-sub-subplots (8 sub-sub-subplots/row) for herbicide treatments. These subplots, which contained from four to eight trees because of differences in widths of main plots, were the experimental units for all measurements.

Herbicide-rate combinations are listed in Table 2. Herbicides were tested at two frequencies (first year only, two consecutive years) for all species except Virginia pine (first year applications only), with all except Stomp tested at two rates. Dowpon M and Poast control established grasses only. Oust both prevents establishment of and controls established annual and perennial grasses and forbs. The other three herbicides primarily prevent the establishment of many grasses and forbs. The experimental use of these herbicides does not imply that they have been registered for this use, nor does mention of trade names constitute endorsement of these products.

Tree survival and effects of herbicides on trees and ground cover were measured in late-June 1989 and 1990. Trees (except Virginia pine) were evaluated for types and extent of damage symptoms. Grasses and forbs were evaluated separately for effectiveness of herbicide control. Tree survival was also measured in October 1989 and 1990 and in August 1991, with total height (nearest cm) measured on the last date.

Data for each tree species were subjected to a separate analysis of

Table 1. Physical and chemical characteristics of soils in Herbicide Study on the Muskingum Mine.

	Topsoil	Cast Overburden
Sieve Analysis, %		
> 4 mm	18	38
2 - 4 mm	8	13
< 2 mm	74	49
Particle-size Analysis[1], %		
Sand	33	36
Silt	38	40
Clay	29	23
pH	6.8	7.4
Available Nutrients, kg/ha		
Phosphorus (Bray 1)	31	5
Potassium	231	416
Calcium	6014	11797
Magnesium	577	1691
Cation Exchange Cap., cmol p+/kg	15.7	32.7
Organic Matter, %	0.9	0.8

[1]< 2 mm fraction

Table 2. Herbicide type-rate combinations.

Herbicide	Rate of Product[1]	Active Ingredient	Rate of Active Ingredient
			(kg/ha)
Dowpon M	11.2	Dalapon (74%)	8.29
"	16.8	" "	12.43
Poast	1.8	Sethoxydim (20%)	0.322
"	2.9	" "	0.537
Oust	0.14	Sulfometuron methyl (75%)	0.105
"	0.28	" "	0.21
Princep 4L	4.7	Simazine (42%)	2.24
" "	9.4	" "	4.48
Surflan A.S.	7.0	Oryzalin (40%)	3.36
"	11.7	" "	5.6
Stomp	7.0	Pendimethalin (42%)	3.36

[1]Rates are l/ha for all herbicides except Dowpon M and Oust (kg/ha).

variance using the ANOVA or GLM (appropriate if data are missing) procedures of SAS (SAS Institute Inc.,1987). Differences among means were tested with Duncan's multiple range test at the p=0.05 probability level. Survival percentages were transformed with the arcsine-square root function before analysis.

Results

Ground Cover Establishment

The wheat nurse crop grew well in early spring, 1988. Permanent ground cover establishment was hindered by the drought that year, during which the period mid-May through mid-July was very dry. We measured percent live vegetative cover and aboveground biomass (using 0.5 m^2 quadrats) in other studies on this site but not in the herbicide study. Data from an earthworm introduction study and a forest versus grassland ecosystems study are listed in Table 3. In the ecosystems study, aboveground biomass on graded cast overburden was only 25% of that on standard topsoil in October 1988; biomass levels on the two surfaces were similar in 1989. Cover and biomass in both studies increased from 1989 to 1990 and then decreased during the drought in 1991. Legumes, including volunteer sweetclover (Melilotus officinalis Lam.) were relatively more abundant on cast overburden than topsoil. All plots of the herbicide study had volunteer tall fescue (Festuca arundinacea Schreb.) from seed in the mulch.

Overall Tree Survival

Except for Virginia pine (24%), overall survival of all tree species in October 1989 was greater than 70%, varying from 73% for white pine to 98% for green ash. In 1990 Virginia pine survival was only 20% despite replacement of dead seedlings that spring. Survival of green ash (98%) and silver maple (95%) were stable, while European alder (87%), black pine (76%), and white pine (64%) decreased slightly from 1989 levels. Following a drought in 1991, overall survivals of silver maple (41%), European alder (14%), and white pine (3%) declined sharply, but those of green ash (97%) or black pine (62%) did not. Black pine tended to survive better on the steep southwest facing slope (75%) than on the relatively level, northeast facing slope (49%). Unless otherwise noted, the statistically significant results that follow are based upon 1991 data.

Soil Surface Effects on Tree Survival and Growth

All tree species tended to survive and grow better on topsoil than on graded cast overburden (Tables 4-9). Black pine had the greatest range in percent survival and survived better on standard topsoil than on ripped topsoil or cast overburden (Table 7). Black pine and silver maple (Table 6) had greater total height on standard topsoil and ripped topsoil than on cast overburden. Green ash (Table 5) had greater height on ripped topsoil than on standard topsoil, which, in turn, was greater than on cast overburden. Height of silver maple and European alder was influenced by stem dieback during the drought. Height of all species, especially silver maple, was affected by rabbit and deer cutting or browsing.

Herbicide Effects on Tree Survival and Growth

Herbicide applications resulted in greater overall survival over untreated controls only for white pine and Virginia pine. Both species survived better with Princep 4L at 9.4 l/ha (Tables 8,9). Virginia pine survival was also improved by both rates of Oust. Survival of both species was so low, however, that they can not be recommended for planting on these calcareous materials regardless of herbicide treatment. Virginia pine's responses to the herbicides should not

Table 3. Live canopy cover and aboveground biomass in two studies (Earthworm Introduction, Forest vs Grassland Ecosystems) on sampling dates as affected by soil surfaces.[1]

Earthworm Introduction

	Live Canopy Cover			Aboveground Live Biomass		
	Aug. '89	July '90	July '91	Aug. '89	July '90	July '91
	%			kg/ha		
Standard topsoil	45	70	40	1816	3932	2892
Ripped topsoil	43	76	40	2092	4164	2630
Gray cast overburden	52	63	40	2814	3764	2664

Forest vs Grassland Ecosystems

	Live Canopy Cover				Aboveground Live Biomass			
	Oct.'88	July'89	June'90	June'91	Oct.'88	July'89	June'90	June'91
	%				kg/ha			
Standard topsoil	65*	74	78	61	1576*	2978	3784	2644**
Gray cast overburden	33	60	71	56	400	3466	3610	1742

[1]Means of 24 samples from locations not receiving herbicide applications.
*,**Significant differences between soil surfaces on the same sampling date at $p = 0.05$ and $p = 0.01$, respectively.

Table 4. European alder survival and height as influenced by soil surface and herbicide treatments.

	Survival 1990 (Year 2)	Survival 1991 (Year 3)	Height 1991 (Year 3)
Soil Surface	---------%---------		cm
Standard topsoil	94.9 a[1]	9.5	77.9
Ripped topsoil	89.8 a	20.9	102.6
Gray cast overburden	75.3 b	12.1	57.3
Herbicide (Rate)[2]			
Princep (9.4)	97.2 a	16.8 ab	
Stomp (7.0)	96.7 a	20.0 ab	
Dowpon (11.2)	96.0 a	10.3 ab	
Poast (2.9)	95.4 a	12.8 ab	
Princep (4.7)	93.5 a	16.9 ab	
Dowpon (16.8)	93.3 a	11.9 ab	
Surflan (7.0)	92.2 a	18.7 ab	
Poast (1.8)	91.7 a	11.8 bc	
Surflan (11.7)	91.7 a	24.0 a	
Control	89.2 a	24.6 ab	
Oust (0.14)	60.2 b	0.6 d	
Oust (0.28)	42.8 c	1.8 cd	
Herbicide Frequency			
1st year	88.7a	14.5	
2 years	84.6b	13.8	

[1] Within a column and factor, means followed by no letters or by a common letter are not significantly different at p = 0.05 using Duncan's multiple range test.

[2] Rates are l/ha for all herbicides except Dowpon and Oust (kg/ha).

Table 5. Green ash survival and height as influenced by soil surface and herbicide treatments.

	Survival		Height
	1990 (Year 2)	1991 (Year 3)	1991 (Year 3)
Soil Surface	---------%--------		cm
Standard topsoil	98.8	98.7 a[1]	50.9 b
Ripped topsoil	97.5	97.2 ab	60.9 a
Gray cast overburden	98.0	95.0 b	41.1 c
Herbicide (Rate)[2]			
Dowpon (11.2)	100 a	99.5 a	66.1 a
Poast (2.9)	100 a	100 a	56.4 bcd
Princep (4.7)	100 a	99.5 a	49.0 de
Dowpon (16.8)	100 a	100 a	62.1 ab
Control	99.6 a	96.4a	45.2 e
Surflan (7.0)	99.5 a	98.5 a	55.2 bcd
Surflan (11.7)	99.5 a	100 a	56.0 bcd
Princep (9.4)	98.9 a	98.6 a	50.6 cde
Poast (1.8)	98.9 a	100 a	57.2 bc
Stomp (7.0)	98.0 a	97.0 a	47.2 de
Oust (0.14)	92.1 b	87.7 b	35.2 f
Oust (0.28)	90.8 b	86.6 b	30.1 f
Herbicide Frequency			
1st year	99.1a	98.4a	50.6
2 years	97.1b	95.5b	51.1

[1] Within a column and factor, means followed by no letters or by a common letter are not significantly different at p = 0.05 using Duncan's multiple range test.

[2] Rates are l/ha for all herbicides except Dowpon and Oust (kg/ha).

Table 6. Silver maple survival and height as influenced by soil surface and herbicide treatments.

	Survival 1990 (Year 2)	Survival 1991 (Year 3)	Height 1991 (Year 3)
Soil Surface	---------%--------		cm
Standard topsoil	95.1	42.9	29.9 a[1]
Ripped topsoil	96.2	43.8	31.6 a
Gray cast overburden	93.1	35.2	20.8 b
Herbicide (Rate)[2]			
Princep (4.7)	99.1 a	48.7	29.2
Dowpon (16.8)	98.0 a	52.0	26.9
Dowpon (11.2)	98.0 a	48.5	28.8
Control	97.6 a	39.2	26.2
Poast (1.8)	97.1 a	41.0	31.2
Poast (2.9)	96.9 ab	40.2	31.0
Princep (9.4)	96.6 ab	38.1	26.7
Surflan (11.7)	95.7 abc	39.8	30.0
Surflan (7.0)	94.9 abc	40.7	31.3
Oust (0.14)	90.4 bc	29.5	21.1
Stomp (7.0)	89.0 cd	39.9	29.2
Oust (0.28)	84.3 d	30.1	21.3
Herbicide Frequency			
1st year	94.7	41.4	27.9
2 years	94.9	39.9	27.8

[1] Within a column and factor, means followed by no letters or by a common letter are not significantly different at p = 0.05 using Duncan's multiple range test.

[2] Rates are l/ha for all herbicides except Dowpon and Oust (kg/ha).

Table 7. Black pine survival and height as influenced by soil surface and herbicide treatments.

	Survival		Height
	1990 (Year 2)	1991 (Year 3)	1991 (Year 3)
Soil Surface	---------%--------		cm
Standard topsoil	82.7 a[1]	73.0 a	35.4 a
Ripped topsoil	76.9 ab	57.8 b	36.2 a
Gray cast overburden	67.8 b	55.6 b	30.7 b
Herbicide (Rate)[2]			
Control	83.9	69.6	36.0 a
Poast (2.9)	79.7	58.4	36.0 a
Princep (9.4)	78.2	70.0	34.9 ab
Dowpon (11.2)	78.2	57.9	33.4 ab
Oust (0.14)	77.8	65.5	31.6 b
Princep (4.7)	77.2	61.8	36.6 a
Stomp (7.0)	77.1	67.8	34.6 ab
Surflan (11.7)	75.6	68.8	33.2 ab
Oust (0.28)	73.1	51.3	31.3 b
Poast (1.8)	72.1	57.6	35.5 ab
Surflan (7.0)	71.7	59.6	36.2 a
Dowpon (16.8)	65.1	57.1	30.7 b
Herbicide Frequency			
1st year	75.0	62.4	34.4
2 years	76.6	61.9	33.9

[1] Within a column and factor, means followed by no letters or by a common letter are not significantly different at $p = 0.05$ using Duncan's multiple range test.

[2] Rates are l/ha for all herbicides except Dowpon and Oust (kg/ha).

Table 8. White pine survival as influenced by soil surface and herbicide treatments.

	Survival	
	1990 (Year 2)	1991 (Year 3)
Soil Surface	---------%--------	
Standard topsoil	78.9 a[1]	5.8
Ripped topsoil	63.4 b	2.1
Gray cast overburden	51.0 c	0.7
Herbicide (Rate)[2]		
Princep (9.4)	72.9 a	6.6 a
Princep (4.7)	70.5 ab	1.8 ab
Control	70.4 abc	0.7 b
Surflan (11.7)	68.5 abc	0.7 b
Stomp (7.0)	66.4 abcd	3.8 ab
Oust (0.14)	66.0 abcd	1.9 ab
Poast (2.9)	64.3 abcd	3.0 ab
Surflan (7.0)	63.7 abcd	3.9 ab
Dowpon (11.2)	63.4 abcd	4.4 ab
Oust (0.28)	57.9 bcd	4.5 ab
Poast (1.8)	57.1 cd	1.4 ab
Dowpon (16.8)	52.2 d	1.8 ab
Herbicide Frequency		
1st year	64.4	3.2
2 years	64.5	2.5

[1] Within a column and factor, means followed by no letters or by a common letter are not significantly different at $p = 0.05$ using Duncan's multiple range test.

[2] Rates are l/ha for all herbicides except Dowpon and Oust (kg/ha).

Table 9. Virginia pine survival and height as influenced by soil surface and herbicide treatments.

	Survival 1990 (Year 2)	Survival 1991 (Year 3)	Height 1991 (Year 3)
Soil Surface	---------%--------		cm
Standard topsoil	24.6 a[1]	13.5	35.2
Ripped topsoil	26.9 a	14.9	41.6
Gray cast overburden	7.3 b	3.8	
Herbicide (Rate)[2]			
Oust (0.14)	32.5 a	18.3 a	
Oust (0.28)	27.3 ab	17.9 ab	
Stomp (7.0)	23.0 abc	10.2 abc	
Princep (4.7)	22.6 abc	10.2 abc	
Princep (9.4)	22.2 abc	17.0 ab	
Surflan (11.7)	20.6 abcd	8.1 abc	
Poast (2.9)	19.9 bcd	12.6 abc	
Poast (1.8)	19.4 bcde	9.8 abc	
Control	16.2 cde	7.5 c	
Surflan (7.0)	14.1 cde	8.0 bc	
Dowpon (11.2)	10.6 de	5.2 c	
Dowpon (16.8)	6.6 e	3.9 c	

[1] Within a column and factor, means followed by no letters or by a common letter are not significantly different at $p = 0.05$ using Duncan's multiple range test.

[2] Rates are l/ha for all herbicides except Dowpon and Oust (kg/ha).

be compared to those of the other species because Virginia pine was replanted after herbicide applications were completed. Both rates of Oust caused decreases in survival for European alder and green ash (Tables 4,5).

There were no significant survival differences between rates for the five herbicides tested at two rates. Black pine showed the largest changes in percent survival as herbicide rates changed. Although black pine survival tended to increase with an increase in rate of Princep or Surflan (Table 7), the changes did not represent an increase over survival of control seedlings. Increasing the rate of Oust caused a substantial, but statistically insignificant, decrease in black pine survival. Silver maple survival decreased as the rate of Princep increased (Table 6).

Survival of European alder and black pine in 1990 and silver maple in 1991 exhibited significant (p=0.05) interactions of soil surface with herbicide type-rate. The interaction for alder was due in part to greater survival on graded cast overburden for the Stomp (97%), Princep 4L-9.4 l/ha (92%), and Dowpon M-16.8 kg/ha (91%) treatments versus control (68%). A component of the interaction for black pine was lower survival for the high rate of Surflan on graded cast overburden versus the other soil surfaces. The interaction for silver maple resulted from decreased survival for Poast-1.8 l/ha, Stomp, and Surflan-7.0 l/ha on cast overburden and for Oust-0.14 kg/ha on standard topsoil.

Frequency of herbicide application had few significant effects on tree survival. Survival of European alder (1990 only) and green ash (both 1990 and 1991) decreased when herbicides were applied for two consecutive years (Tables 4,5). The main effect of herbicide frequency for green ash resulted from a significant (p=0.01) interaction of herbicide type with frequency. Survival was 8-19% lower when both rates of Oust were applied for two years instead of one. For all other herbicides there was very little variation (mostly 0 but up to 4%) in green ash survival with frequency of application.

Only green ash, black pine, and silver maple had sufficient survival for an analysis of herbicide type and frequency effects on height. Green ash had greater height when sprayed with either rate of Dowpon M, Poast, or Surflan (Table 5). Seedlings treated with Dowpon M at 11.2 kg/ha were 46% taller than untreated controls. Both rates of Oust caused a decrease in green ash height (Table 5). Green ash height showed a significant (p=0.05) interaction of herbicide type with frequency. Responses contributing to the interaction included decreases for both rates of Oust, but increases for both rates of Dowpon, as frequency of application increased.

Black pine height was not improved by herbicide application. Both rates of Oust and the high rate of Dowpon M caused decreases in height of black pine (Table 7). There were no significant herbicide effects on silver maple height. Seedlings treated with Poast or Surflan tended to be taller, but those treated with Oust tended to be smaller, than the controls (Table 6).

Several herbicides caused significant increases in percentages of trees showing damage symptoms in June 1989. For black pine, 70-80% of trees sprayed with Dowpon were damaged, versus 3% for untreated controls. Percentages of white pine rated as damaged by the high rate of Oust (41%), low rate of Dowpon (74%), and high rate of Dowpon (92%) were greater than for the controls (23%). Ten percent of untreated green ash were rated as damaged, versus 31% and 36% for the high rates of Princep and Oust, respectively. The value of 19% for green ash damaged by the low rate of Princep was relatively high but not statistically significant. The two rates of Oust damaged 27 to 28% of silver maple and 83 to 92% of European alder, versus 16% and 33% for untreated controls, respectively.

Discussion

Effects of the 1991 drought on survival of the various tree species were similar in this and other studies on the Muskingum Mine. Green ash and black pine were very drought tolerant two years after planting. In earlier plantings, black pine had better first-year survival than green ash or white pine after the drought in 1988 (unpublished data).

The general absence of beneficial herbicide effects upon tree survival was probably due to abundant precipitation during the first two years of the study. Because rainfall for April-August in 1989 and 1990 was 77% and 41% greater than normal, respectively, it is unlikely that ground cover competition for moisture was a factor influencing tree survival. Other studies or demonstrations have shown varied effects of herbicide treatments on tree survival during years of abundant rainfall. Carlson (1979) and Schoenholtz and Burger (1984) found no increase in first-year survival when ground cover was controlled with paraquat or Roundup. In contrast, Raisanen (1982) observed increases (not statistically tested) in first-year survival for a variety of species when treated with a mixture of Amitrol-T and simazine. Competition for soil moisture in the present study would have been severe during the drought of 1991. Among the four species showing greatly decreased survival in 1991, only white pine and Virginia pine were benefited by herbicides.

It is generally recommended that trees be planted before or concurrently with ground cover, or that ground cover be controlled with herbicides if tree planting must be delayed (Vogel 1980). In this study herbicides did not improve survival of green ash, silver maple, European alder, or black pine planted into a ground cover seeded a year earlier. Inhibition of ground cover development by the drought of 1988 probably reduced the ground cover competitiveness at time of tree planting. In substitute ground cover measurements (Table 3), aboveground biomass was similar to, but percent cover less, than that reported by Andersen et al (1983) for a minesite in Indiana. In their study, ground cover control with herbicides resulted in significantly better survival of red oak (Quercus rubra L.) and black walnut (Juglans nigra L.) after seven years. First- and second-year survival of red oak and black walnut but not green ash was improved by a mixture of Roundup and Princep when trees were planted in a one-year old ground cover in Illinois (Ashby et al 1988). In another ongoing study on the Muskingum Mine, green ash establishment during the drought of 1988 was best when planted concurrently with ground cover (Larson and Vimmerstedt 1990). Application of Princep 4L caused a decrease in green ash survival during that drought.

We did not observe an improvement in tree survival by applying herbicides for two consecutive years. Green ash did tend to be taller with two years of Dowpon treatment. On topsoiled minesoils in Illinois and Indiana, tulip tree (Liriodendron tulipifera L.), white oak (Quercus alba L.), and white pine but not autumn olive (Elaeagnus umbellata Thunb.), black walnut, or European alder tended to survive better with two years of herbicide treatment (Parr 1982). Black walnut planted on mined (Philo et al 1983) and unmined (Bey and Williams 1976) lands grew taller with increasing years of herbicide weed control.

Increased height for green ash was the strongest beneficial response to herbicides in this study. Greater green ash height for Dowpon and Poast, which control grasses only, indicates that grasses were the dominant source of competition.

Summary and Conclusions

Among the species planted in this study, green ash and black pine showed the most potential for reclamation of these calcareous minesoils. European alder and silver maple survived well during the years of abundant rainfall but were affected strongly by the drought. Silver maple also suffers from excessive animal damage.

Ground cover control with herbicides generally did not increase tree survival during two wet years followed by a droughty year. It must be emphasized that the absence of beneficial herbicide effects on tree survival can not be extrapolated to other rainfall regimes. Oust should not be applied over trees at the rates used in this study. Results with Virginia pine indicate that Oust may be beneficial if applied before trees are planted. Height of green ash, but not black pine, responded strongly to herbicide application. Use of herbicides to increase tree growth but not survival is probably not a cost-effective reclamation practice.

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