TOPSOIL, RIPPING, AND HERBICIDES INFLUENCE TREE SURVIVAL AND GROWTH ON COAL MINESOIL AFTER NINE YEARS[1]

by

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Abstract. On reclaimed coal surface mines trees are stressed by soil compaction, herbaceous competition, and animal damage. We tested treatments to modify soils and herbaceous competition in a split-split-plot experiment on calcareous minesoils in southeastern Ohio. We measured tree survival and growth as affected by minesoil surface (standard graded topsoil, ripped topsoil, graded overburden) and herbicide applications (type, rate, and frequency). 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 into a grass/legume ground cover seeded 18 months earlier. 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). After nine years, only green ash (95%) and black pine (48%) had adequate survival. Silver maple (16%), alder (7%), Virginia pine (6%) and white pine (<1%) had low survival by the fifth year. Black pine survived better ($p=0.07$) on standard topsoil (60%) than on graded overburden (37%) and was 43% taller on both topsoils (165 or 168 cm total height) than on graded overburden (116 cm). Green ash height varied significantly on all soil surfaces (172 cm on ripped topsoil, 136 cm on standard topsoil, 102 cm on graded overburden). Survival on herbicide treated plots was greater than on untreated controls only for Virginia pine sprayed with Princep or Oust and for silver maple sprayed with Stomp, but both species had less than 25% survival even when treated by these herbicides. Green ash survival decreased with both rates of Oust and with increasing frequency of Oust. Green ash height was increased an average of 19% by either rate of Dowpon or Surflan. Longer term tree growth was benefited more by topsoil replacement and ripping than by herbicide treatments.

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 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

Mined lands reclaimed according to the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87) are commonly topsoiled and seeded with an herbaceous cover. Trees planted on these sites suffer from various stresses including poor soil physical conditions, competition from the planted ground covers, and animal damage (Ashby 1990). In this paper we evaluate treatments to modify soil properties and herbaceous competition on calcareous minesoils in southeastern Ohio.

Topsoil replacement generally provides suitable soil chemical conditions but is associated with soil compaction from equipment traffic. Elimination of topsoiling does not guarantee good soil physical conditions if overburden is still graded extensively. Various deep tillage or ripping techniques have been used to ameliorate compaction on topsoiled (Cleveland and Kjelgren 1994) and non-topsoiled sites (Ashby 1995; Torbert and Burger 1996). Our experiment tested a ripping procedure that was less intensive than those described in these papers.

Control of herbaceous competition can be achieved by planting a tree-compatible ground cover (Torbert and Burger 1990), by mechanical treatments such

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as scalping, or by spraying herbicides. In Indiana, survival and height of black walnut (Juglans nigra L.) and northern red oak (Quercus rubra L.) after 12 years were increased strongly by spraying herbicides (amizine and dalapon) during the first two years (Chaney et al. 1995). Even when improved by herbicides, growth of both species was poor primarily due to soil compaction. Ringe et al. (1984), Ringe and Graves (1985), and Graves and Ringe (1993) described the effects of mechanical scalping and 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 eight years, tree survival and height were not improved by any of the treatments compared to the untreated controls. Our experiment also tested a variety of herbicide materials.

We evaluated survival and growth of six tree species as affected by topsoil replacement, topsoil ripping, type and rate of herbicide, and frequency of herbicide application. This paper describes longer-term (nine year) effects of these practices. It indicates the relative benefits of topsoil replacement versus herbicide applications. Third-year results were described by Kost et al. (1992).

Methods

The experiment was a split-split-plot design testing three soil surfaces, 12 herbicide material and rate combinations, and two frequencies of herbicide application, with four replications. Each of six tree species was studied as a separate experiment. The study area is on Central Ohio Coal Company's Muskingum Mine, 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. Two replications were on a generally level (2-6% slope) area facing northeast and two were in a steep valley (21% slope) facing southwest.

Reclaimed soil surfaces consisted of graded gray cast overburden without topsoil, graded cast overburden with 30 cm of replaced topsoil (standard topsoil), and a standard topsoil surface that was ripped to a 30 cm depth after topsoil grading (ripped topsoil). Topsoil was ripped at a 30 cm spacing with a multiple shank device attached to a rubber-tired road grader. Topsoiled areas are classified as Morristown silty clay loam, and graded overburden without topsoil as Morristown channery silty clay loam. These are loamy-skeletal, mixed (calcareous), mesic Typic Udorthents (Waters and Roth 1990). Main soil surface plots measured 40 m (a few varied from 26-48 m) by 34 m.

Premining soils included 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 replaced topsoil is a mixture from the upper horizons of these premining soils. The gray cast overburden is predominately gray shale and limestone but contains some sandstone. Physical and chemical properties of the reclaimed soils are listed in Table 1. In an adjacent study (Kost et al. 1998), available water retention (33 to 1500 kPa) by the <2mm fraction did not differ significantly for topsoil (119 g/kg) and overburden (102 g/kg). The greater fraction of soil-sized (<2 mm) particles in topsoil than overburden (Table 1) indicates greater water retention in topsoil if particles >2mm retained negligible water. Electrical conductivity (1:2 soil/water mixture) was 4.08 dS/m for fresh overburden and 0.40 dS/m for topsoil, indicating high soluble salts in overburden. Conductivity of overburden decreased to 1.15 dS/m in an adjacent study after 5 years of weathering and leaching.

Plots were fertilized in August 1987 with 448 kg/ha of 8-32-16 (N-P-K) fertilizer and 112 kg/ha ammonium nitrate, 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 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 species 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). Seedlings of each species were graded and pruned to a relatively uniform stem caliper and height before planting. We selected green ash and black pine because of their tolerance of calcareous soils, European alder for its N fixing ability, white pine for its productivity on native soils, and Virginia pine as a third pine species. We would have preferred to use sycamore (Platanus occidentalis L.) because it grew well on older minesoils on the Muskingum Mine. Sycamore stock was not available so we substituted silver maple.

Table 1. Physical and chemical characteristics of soils in the topsoiling-ripping-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
Extractable Nutrients[2], kg/ha		
P	31	5
K	231	416
Ca	6014	11797
Mg	577	1691
Cation Exhange Capacity, cmol p+/kg	15.7	32.7
Organic Matter, %	0.9	0.8

[1] < 2 mm fraction analyzed by hydrometer method
[2] P by Bray-1 extraction; K, Ca, and Mg by ammonium acetate (1 mole/L) extraction

Table 2. Rates of herbicide products and active ingredients

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

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

Herbicides (Table 2) were applied in 0.75 m wide bands over the trees using backpack sprayers in April-May, 1989 and 1990. For each tree species, each main soil surface plot contained three tree rows and each row was split into four subplots for herbicide type and rate treatments. Each herbicide type and rate treatment, including the untreated control, was assigned randomly to one of the 12 subplots. Each subplot was divided into two sub-subplots to accommodate two frequencies of herbicide application (first year only, two consecutive years). Virginia pine only received first year applications because of poor survival. These sub-subplots contained from four to eight trees because of differences in widths of main plots.

All herbicides except Stomp were tested at two rates (Table 2). Dowpon M and Poast control established grasses only. Oust both prevents establishment of and controls established annual and perennial grasses and forbs (non-grass herbaceous plants). 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.

In June 1989 the effects of the herbicides in controlling herbaceous plants were estimated separately for grasses and forbs. We used a rating scale of 1 (no control by the herbicide), 1.5 (some or slight control), 2 (moderate control), 2.5 (extensive control but some herbaceous plants present), and 3 (complete control). Ratings were assigned by comparing vegetation in the treated sub-subplot with the vegetation on either side of the sub-subplot. If there were no grasses present in the adjacent vegetation, it was assumed that grasses were absent from the sub-subplot before herbicide treatment, so no rating was given to grasses for that sub-subplot. A similar procedure was used for forbs.

Tree survival was measured in late summer or early fall of 1989, 1990, 1991, 1993, and 1997. Total height (nearest cm) of each live tree was measured on the last three dates. For each sub-subplot, mean survival percentage was based on the number of trees planted in the sub-subplot and mean height was based on the number of live trees in the sub-subplot. These sub-subplot means were used in analysis of variance calculations.

Data for each tree species were subjected to a separate analysis of variance using the ANOVA or GLM procedures of SAS (SAS Institute Inc.,1987). Differences among means were tested with the LSD or 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

Overall Tree Survival

After nine growing seasons, overall survival was: white pine (<1%), Virginia pine (6%), European alder (7%), silver maple (16%), black pine (48%), and green ash (95%). Most of the tree mortality had occurred during the first five years. Silver maple (24% survival after five years) and black pine (53% after five years) had the most mortality in the last four years.

Soil Surface Effects on Tree Survival and Growth

Survival of silver maple (p=0.35), black pine (p=0.07), and Virginia pine (p=0.11) all tended to be greater on the topsoils than on graded overburden (Table 3). Green ash had excellent survival on all soil surfaces (Table 3). Black pine was 43% taller on both topsoil surfaces than on graded overburden (Table 4). Green ash on ripped topsoil was 26% taller than on standard topsoil and 69% taller than on graded overburden (Table 4). Height of silver maple (Table 4) was affected by severe rabbit cutting and deer browsing.

Based on the difference in average height for the fifth (unpublished data) and ninth years, green ash height growth averaged 10 cm/yr on graded overburden, 15 cm/yr on standard topsoil, and 20 cm/yr on ripped topsoil. Similar calculations for black pine yield average height growth of 19 cm/yr on graded overburden, 28 cm/yr on standard topsoil, and 29 cm/yr on ripped topsoil. The calculations for green ash are probably as accurate as if height growth of individual trees was averaged, because green ash had little mortality between the fifth and ninth year. The calculations for black pine may be slightly high if the trees that died since the fifth year were below average in height at the fifth year.

Effectiveness of Herbicides for Control of Herbaceous Plants

Both rates of Oust provided good control of both grasses and forbs as indicated by high ratings for effectiveness of control of grasses and forbs (Table 5). Oust sub-subplots could be recognized easily in the field because they were usually barren of herbaceous vegetation. Ratings for Dowpon and Poast, which are only supposed to be effective against grasses, indicate that these materials were effective in controlling grasses

Table 3. Tree survival after 9 years as affected by soil surface, herbicide material and rate, and frequency of herbicide application.

	Alder	Green ash	Silver maple	Black pine	Virginia pine
	---------------------------------------	----------	----%----	----------	---------------------------------------
Soil Surface					
Standard topsoil	4[1]	95	15	60	9
Ripped topsoil	11	95	24	47	10
Graded overburden	5	94	8	37	1
Herbicide (Rate)[2]					
None	10ab	96a	12bc	51	5bc
Dowpon (11.2)	4ab	98a	22ab	47	0c
Dowpon (16.8)	4ab	99a	21ab	41	1c
Poast (1.8)	3b	99a	15abc	46	4bc
Poast (2.9)	5ab	98a	16abc	45	9ab
Surflan (7.0)	13a	96a	13abc	47	4bc
Surflan (11.7)	13a	98a	18abc	54	4bc
Princep (4.7)	9ab	98a	21ab	48	8ab
Princep (9.4)	9ab	98a	10bc	55	12a
Oust (0.14)	1b	85b	6c	52	13a
Oust (0.28)	0b	76c	10bc	39	15a
Stomp (7.0)	9ab	95a	24a	51	3bc
Herbicide Frequency					
1st year only	7	96a	17	49	NA[3]
2 consec. years	6	93b	14	47	NA

[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).
[3]NA = not applicable

Table 4. Tree height after 9 years as affected by soil surface, herbicide material and rate, and frequency of herbicide application.

	Alder	Green ash	Silver maple	Black pine	Virginia pine
	--------------------------------------cm--------------------------------------				
Soil Surface					
Standard topsoil	233[1]	136b	57a	165a	164
Ripped topsoil	239	172a	64a	168a	202
Graded overburden	190	102c	41b	116b	170
Herbicide (Rate)[2]					
None	224	127cd	50	169	208a
Dowpon (11.2)	185	154a	60	141	----
Dowpon (16.8)	245	153a	62	136	169abc
Poast (1.8)	206	131c	59	150	163abc
Poast (2.9)	157	144abc	51	145	191ab
Surflan (7.0)	241	150a	56	145	146bc
Surflan (11.7)	229	149ab	53	152	181ab
Princep (4.7)	268	134bc	50	155	179ab
Princep (9.4)	193	139abc	62	160	188ab
Oust (0.14)	210	114d	56	148	205a
Oust (0.28)	-----	114d	49	152	198ab
Stomp (7.0)	231	132c	54	157	118c
Herbicide Frequency					
1st year only	222	137	58	155	NA[3]
2 consec. years	229	136	54	155	NA

[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).
[3]NA = not applicable

Table 5. Effectiveness rating[1] of herbicide treatments for controlling grasses and forbs (non-grasses) in tree species plots.[2]

	Effectiveness Rating for Grasses					Effectiveness Rating for Forbs				
	Alder	Green ash	Silver maple	Black pine	White pine	Alder	Green ash	Silver maple	Black pine	White pine
Herbicide (Rate)[3]										
None	1.1	1.2	1.3	1.2	1.0	1.0	1.1	1.2	1.0	1.0
Dowpon (11.2)	1.9	2.0	2.2	2.2	1.5	1.2	1.6	1.3	1.5	1.6
Dowpon (16.8)	2.2	2.2	2.1	2.4	2.2	1.8	1.6	1.4	1.6	1.5
Poast (1.8)	2.1	2.1	2.1	1.8	2.3	----	1.1	1.0	1.1	1.5
Poast (2.9)	2.4	2.3	2.5	2.3	2.2	1.1	1.2	1.2	1.1	1.2
Surflan (7.0)	1.6	1.5	1.7	1.5	1.2	1.1	1.2	1.6	1.2	1.2
Surflan (11.7)	1.7	1.6	1.5	1.5	1.8	1.2	1.1	1.2	1.2	1.5
Princep (4.7)	1.5	1.6	1.4	1.5	1.1	----	1.0	1.4	1.1	1.4
Princep (9.4)	1.5	1.8	1.7	1.5	1.6	1.2	1.3	1.6	1.6	1.3
Oust (0.14)	2.5	2.6	2.6	2.6	2.4	----	2.2	2.2	2.4	2.2
Oust (0.28)	2.9	2.8	2.8	2.8	2.6	----	2.6	3.0	2.6	2.5
Stomp (7.0)	1.2	1.6	1.2	1.2	1.0	----	1.2	1.1	1.0	1.1
LSD (p = 0.05)	0.4	0.3	0.3	0.3	0.4	0.3	0.4	0.4	0.3	0.4

[1]Effectiveness rating scale: 1.0 = no control of vegetation; 1.5 = some or slight control; 2.0 = moderate control; 2.5 = extensive control but some herbaceous plants present; 3.0 = complete control

[2]Herbicides were applied in April or May 1989 and plots rated in June 1989.

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

Table 6. Heights of green ash and black pine after 9 years on each soil surface with no herbicide treatment and with the herbicide treatment producing greatest height (best herbicide).

Species/Soil Surface	No Herbicide	Best Herbicide
	----cm----	----------cm-----------
Green Ash		
Standard topsoil	127 ± 2[1]	164 ± 22 (Dowpon-16.8)[2]
Ripped topsoil	174 ± 20	193 ± 22 (Surflan-7.0)
Graded overburden	81 ± 10	120 ± 19 (Dowpon-11.2)
Black Pine		
Standard topsoil	188 ± 26	174 ± 34 (Surflan-7.0)
Ripped topsoil	198 ± 36	195 ± 12 (Princep-9.4)
Graded overburden	116 ± 31	131 ± 20 (Stomp-7.0)

[1]Mean ± 1 SE

[2]Herbicide type and rate. Rate in L/ha for all herbicides except Dowpon (kg/ha).

(Table 5). Stomp was notable in having low ratings for control of both grasses and forbs.

Herbicide Effects on Tree Survival and Growth

After nine growing seasons, herbicide applications resulted in greater survival over untreated controls only for Virginia pine and silver maple. Virginia pine survival was improved by both rates of Oust and by the high rate of Princep 4L, and silver maple survival was improved by Stomp (Table 3). Survival of both species is unacceptably low even with the improvement due to herbicide. Virginia pine's responses to the herbicides should not 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 green ash (Table 3).

Green ash survival decreased as the rate of Oust increased (Table 3). There were no other significant effects of herbicide rate on survival. Survival tended to decrease for silver maple as the rate of Princep increased, and for black pine as the rate of Oust increased (Table 3).

Frequency of herbicide application only had a significant effect on ash survival, which decreased when herbicides were applied for two consecutive years (Table 3). The main effect of herbicide frequency for green ash resulted from a significant ($p=0.0001$) interaction of herbicide type with frequency. Ash survival was 11% lower (90% vs 79%) for the low rate of Oust and 35% lower (94% vs 59%) for the high rate of Oust when applied for two years instead of one. For all other herbicides there was little variation (0.2% to 6.0%) in green ash survival with frequency of application.

Only green ash and Virginia pine showed significant growth effects from the herbicide treatments. Compared to untreated seedlings, green ash varied from 17% to 21% taller when sprayed with either rate of Dowpon M or Surflan, and 10% shorter when sprayed with either rate of Oust (Table 4). Virginia pine was shorter when sprayed with Stomp or the low rate of Surflan (Table 4). As frequency of herbicide application increased, green ash height tended to decrease for the low rate of Oust (14 cm decrease) and low rate of Princep (7 cm decrease) but increase for both rates of Dowpon (9 cm increase).

Although there were no significant interactions of soil surface and herbicide type-rate affecting tree height, means for soil surfaces in Table 4 are influenced by detrimental effects of some herbicides, such as Oust on green ash. Table 6 gives heights of green ash and black pine on each soil surface with no herbicide treatment and with the treatment producing greatest height (best herbicide). Tree growth on graded overburden with the best herbicide clearly did not surpass growth on topsoils without herbicide, so use of herbicides on graded overburden can not substitute for topsoil replacement.

Discussion

Topsoil replacement increased survival of black pine and growth of both green ash and black pine. Ripping the topsoil improved growth of green ash but not black pine. Similar results occurred in another study (P fertilizer) on the same experimental area (Kost et al. 1998) except that topsoil ripping did not improve growth of either species. The reasons for better tree growth on topsoil probably include more suitable (lower) soil pH, lower soluble salts, and greater water holding capacity.

Ash height on ripped topsoil (172 cm) was near the low end of heights (168-282 cm) for similar-aged trees on ungraded calcareous overburden in Ohio (Finn 1958). In southern Illinois after 8 years, ash was 309 cm tall when 20 cm of topsoil was replaced over 100 cm of subsoil and 115 cm tall on graded overburden without topsoil (Ashby 1990). Thus in our study ash growth on graded overburden (102 cm) was poor but comparable to that in southern Illinois. Ash growth on ripped topsoil was inferior to that on ungraded overburden in Ohio or on topsoil in Illinois. In our study, black pine grew well on the topsoils, with average growth for the last four years (28-29 cm/yr) approaching the 30 cm/yr rate that this species shows on a variety of unmined sites (Van Haverbeke 1990). The close within-row spacing has probably affected growth rates of both species. Aboveground competition among the closely planted trees seems more intense in the black pine, with suppressed individuals occurring commonly.

Early results of this study showed that herbicides generally did not benefit tree survival when a year of below normal rainfall followed two years of above normal rainfall (Kost et al. 1992). During the third year, rainfall for May through July totaled 109 mm, which was 65% below normal. Survival of silver maple, alder, and white pine declined sharply during the dry third year regardless of herbicide treatment. Apparently tree survival during the third year was influenced more by each species' ability to withstand severe moisture deficits than by effects of herbicide treatments in reducing herbaceous competition for moisture.

Several significant effects of herbicides that were present after three years have persisted through the ninth year. Beneficial effects of Oust and Princep on Virginia pine survival, and of Dowpon and Surflan on green ash growth, were already present after three years. Reductions in survival and growth of green ash due to Oust have also persisted. Oust had caused significant decreases in survival of alder and silver maple by the second year (Kost et al. 1992), but these effects did not persist as survival of both species continued to decline regardless of herbicide treatment. Oust gave excellent control of herbaceous vegetation but damaged any hardwoods that were starting to leaf out when applied in early spring. Treating green ash with Poast increased ash height after five years (unpublished data) but not nine years. The beneficial effect of Stomp on silver maple seen after nine years was not significant after five years (unpublished data).

We did not observe an improvement in tree survival by applying herbicides for two consecutive years. It might be expected that trees that had been sprayed during the second year would have survived better during the dry third year because there had been less time for competing vegetation to redevelop. In terms of tree growth, an additional year of herbicide treatment that came several years after the first year might be more beneficial than two consecutive years of treatment. If the first year of herbicide treatment was successful in controlling vegetative competition, a consecutive year of treatment would give little benefit but treatment several years later might control competition that had developed later. Green ash did tend to be taller with two years of Dowpon treatment.

Increased height for green ash was the strongest beneficial response to herbicides in this study. In southern Illinois, herbicide treatment (Amitrole-T with Princep) increased eighth-year heights 33% for green ash, 77% for black walnut, and 115% for northern red oak (Ashby 1990).

Summary and Conclusions

After nine years only green ash and black pine are established successfully on these calcareous minesoils. European alder and silver maple survived well during the first two years with abundant rainfall but were affected strongly by a third-year drought. Silver maple also suffers from excessive animal damage. Although Virginia pine survived poorly presumably because of the high soil pH, the trees that survived on topsoil grew as well as the best black pine. White pine shows no promise on these soils.

Grading overburden without topsoil replacement does not yield good tree growth. Green ash survived well on graded overburden, but growth of ash and black pine were much better on topsoil. Ripping the topsoil only benefited green ash growth. In retrospect, we should have tried ripping the graded overburden for comparison with topsoil replacement.

There were no practical improvements in long-term tree survival as a result of herbicide applications. If rainfall had been below normal rather than above normal during the first two years of the study, there may have been greater beneficial herbicide effects on tree survival. Oust should not be applied over hardwoods in early spring because any trees that are even beginning to leaf out will be damaged. Results with Virginia pine indicate that Oust may be beneficial if applied before trees are planted. Although height of green ash was increased by some herbicides, longer-term growth of all species was benefited more by topsoil replacement than by herbicides.

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