EFFECTIVENESS OF TREATMENTS TO ESTABLISH TREES ON MINELANDS DURING DROUGHT AND WET YEARS[1]

Merlyn M. Larson, David A. Kost, and John P. Vimmerstedt[2]

Abstract: In two studies, green ash (Fraxinus pennsylvanica) and white pine (Pinus strobus) were planted on three minesoils (graded topsoil, ripped topsoil, and gray cast overburden). Mixtures of grasses and/or legumes were seeded at different times in relation to tree planting. In the first study, tree planting was followed by several weeks of drought; in the second study, precipitation was above average for the first two growing seasons following planting. In the drought year, survival of green ash was influenced by minesoil type, herbaceous mixture, and time of seeding in relation to tree planting. Among minesoils, ash survival on ripped topsoil was 28% above that on graded topsoil in one seeding treatment, but mean survival was highest (87%) on cast overburden. Seeding grasses the fall before planting resulted in poor ash survival (40% to 47%) compared with seeding at time of planting (82% to 85%). Ash survived well (81% to 94%) on legume-seeded plots owing, in part, to slow early development of legumes the first season. When tree planting was followed by two wet seasons, survival at 4 and 5 yr ranged from very good to excellent, with much smaller differences between treatments. Total height of ash trees on cast overburden averaged 31% less than that of trees on topsoil. Mean height of ash on legume-seeded subplots was 75 cm, compared with 58 cm on grass subplots, although herbaceous biomass was greater on legume subplots. The three minesoils proved unsuitable for white pine.

Additional Key Words: minesoils, ripping, cast overburden, green ash, white pine, herbaceous competition.

Introduction

Minelands that have been topsoiled and seeded with herbaceous species are often hostile sites for planted tree seedlings. Not only are surface soils compacted during grading and spreading of topsoil, but many herbaceous species severely compete with planted trees for moisture and nutrients.

Various treatments and modifications of reclamation practices can be employed to mitigate the effects of soil compaction and herbaceous competition. Some commonly used measures to enhance tree establishment are to reduce the density of compacted soils by ripping, reduce herbaceous cover in selected areas by mechanical or chemical means, and use herbaceous species that are less competitive with trees.

Success in tree planting requires adequate precipitation after planting. Drought is a common cause of planting failures, and the ultimate objective of all the above-mentioned treatments is to increase availability of soil moisture to trees during dry periods.

Reported here are results of two field studies designed to investigate tree seedling survival and growth on three different minesoils, each seeded with various grasses and/or legume mixtures either prior to or at time of tree planting. In the first study, trees planted in April were subjected to a record drought lasting about 10 weeks. Results of this study, now terminated, were reported earlier (Larson and Vimmerstedt 1990). In a

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[2]Merlyn M. Larson, Professor, David A. Kost, Senior Research Associate, and John P. Vimmerstedt, Associate Professor, The Ohio State University, School of Natural Resources, Wooster, OH, USA. Salaries and research support were provided by cooperative agreement with the American Electric Power Service Co. and by State and Federal funds appropriated to the Ohio Agricultural Research and Development Center, The Ohio State University; Manuscript number 223-93 of the Ohio Agricultural Research and Development Center.

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second study of similar design installed on the same area, precipitation following tree planting was above average during the first two growing seasons. Preliminary results of this on-going study were reported by Larson et al. (1993). The two studies allowed us to evaluate the effectiveness of various treatments to enhance seedling establishment during both drought and wet years.

Soil Materials

Plots were established on a recently mined area of the Muskingum Mine, Central Ohio Coal Co., located 5 km south of Cumberland, OH. Soil materials and treatments included the following: (1) topsoiled (25 to 30 cm deep), standard graded in accordance with current practice, (2) topsoiled, graded, and then ripped to 30 cm deep to reduce soil compaction, and (3) gray cast overburden, leveled after mining. Each soil material was applied to one of three plots (each 30.5 m by 40.2 m) in each of six blocks.

The chemical and physical properties of topsoil and gray cast overburden on the Muskingum Mine are given in table 1. Cast overburden has higher cation exchange capacity, more exchangeable potassium, calcium, and magnesium, but lower phosphorus than topsoil. Also, cast overburden has less clay, more sand, and a higher rock content than topsoil. pH of both soils was neutral.

After final grading in 1987, 8-32-16 fertilizer was applied at 448 kg/ha. The site also was seeded with annual ryegrass (Lolium multiflorum)and fertilized with 112 kg/ha ammonium nitrate to stimulate growth and help reduce soil erosion before the first study was established in autumn 1987.

Precipitation

Annual precipitation in southeast Ohio averages 907 mm with about 432 mm occurring during April through August (NOAA 1989). In 1988 (the drought year), a severe drought began after the trees were planted on the study area in April. The April through June precipitation was 151 mm, which was 51% below normal based on long-term records of a nearby meteorological station at Cambridge, OH. The drought continued 2 more weeks until mid-July, during which time a rain gage was installed on the study area. Precipitation was

Table 1. Chemical and physical properties of topsoil and gray cast overburden on the Muskingum Mine.

	Topsoil	Overburden
Available nutrients, kg/ha:		
Phosphorus	16	13
Potassium	285	377
Calcium	5,824	14,380
Magnesium	877	1,157
pH	7.0	7.0
Cation Exchange Capacity cmol/kg	17	37
Extractable Na+ µg/ml	22	968
Particle-size analysis, %:		
Sand	28	36
Silt	40	41
Clay	32	23
Rock content >4mm %	18	30

abundant from late July through August (243 mm) and ended the drought.

For the 2 wet years, the April through August precipitation totaled 768 mm (77% above normal for the Cambridge area) in 1989, and 611 mm (41% above normal) in 1990, 320 mm in 1991, 528 mm in 1992, and 451 mm in 1993.

Seeding Herbaceous Species and Tree Planting

Each plot was divided into subplots (each 6.7 m by 12.4 m), which received one of three herbaceous seedings (grasses, legumes, or grass-legume mixture)(table 2) applied either the autumn before tree planting or at time of planting in the spring. In addition to these six treatments, one adjacent subplot was left unseeded but planted with trees. The grass-legume mixture at 56 kg/ha is the standard species and rate used by the Central Ohio Coal Co.

One-half of each subplot was planted with 1-yr-old green ash (Fraxinus pennsylvanica) seedlings, and the other one-half was planted with 2-yr-old white pine (Pinus strobus) seedlings. Each species was planted in three rows of five trees each, with two of the three rows sprayed in strips 60 cm wide with simazine at 4.5 kg/ha 3 weeks after planting to reduce competition from seeded herbaceous species. Spacing was 1.2 m between trees and 2.4 m between rows. Spacing was maintained in ripped subplots without regard to the location of the rips. In total, 1,890 green ash and 1,890 white pine seedlings were planted on 126 subplots during March 1988. Tree survival counts were made in mid-August 1988, at which time the first study was terminated.

The second study was started on the same area in late August 1988. The plots were sprayed with glyphosate at 3.5 L/ha to remove existing vegetation and prepare the site for seeding herbaceous mixtures. Plots were again divided into subplots, and each received one of the seven treatments described above. Three additional treatments were added in which trees were planted 1 yr after subplots were seeded with one of the three herbaceous types in the spring (i.e., seeded in March 1989 and planted with trees in March 1990). In total, 1,890 green ash and 1,890 white pine seedlings were planted during March 1989, and an additional 1,080 trees of each species were planted in March 1990.

Table 2. Species and seeding rates of 3 herbaceous mixtures used on the study subplots.

Grass species	Kg/ha
Orchardgrass (Dactylis glomerata)	13.4
Timothy (Phleum pratense)	11.2
Perennial ryegrass (Lolium perenne)	9.0
Kentucky bluegrass (Poa pratensis)	5.6
Total grass species	39.2
Legume species	
Ranger alfalfa (Medicago sativa)	5.6
Birdsfoot trefoil (Lotus corniculatus)	5.6
Mammoth red clover (Trifolium pratense)	5.6
Total legume species	16.8
Grass-legume mixture	
Total of the above species	56.0

Since application of simazine damaged green ash in the first study, results reported here are based only on data of trees planted in untreated strips. In the second study, application of herbicide was without significant effect on trees, and these data are combined in the tables.

Measurement of Herbaceous Vegetation

The quadrat method was used to measure both cover (defined as the ground area within the canopy of a plant or group of plants expressed as a percentage of the total area of the quadrat) and above ground biomass.

Quadrat size was 70.7 by 70.7 cm. Plant samples were taken in August 1989 and in June of 1990, 1992, and 1993 from 180 subplots. Areas between rows of trees were sampled. Within the quadrat, vegetation was clipped level to the soil surface, placed in paper bags, dried to constant weight at 60° C, and weighed.

Measurement of Trees and Data Analysis

Survival and total height of trees were measured each year. The study design was a randomized split-plot design with six blocks, and the experimental unit was a single five-tree row. Analysis of variance was in accordance with standard procedures for this design (Steel and Torrie 1960). Survival data were subjected to arc sin transformation.

Results

Survival of White Pine

Mean survival of white pine in the first study was only 19% at the end of the drought season. In the second study, survival after 2 wet years was 36%, but few pines were alive at the end of the third year on any subplot regardless of treatment. These minesoils clearly are not suited to white pine, partly due to high soil pH and salinity (table 1). Thus, the results that follow are only for green ash.

Effects of Treatments - Drought Year

In the first study (drought year), the benefits of ripping topsoil to reduce soil compaction were mixed. Ripping increased green ash survival 28% above that of trees on graded topsoil but only when both seeding and tree planting were carried out in the spring (table 3). Ripping was without benefit to trees planted on unseeded subplots or subplots seeded the previous fall. When the three minesoils were seeded the fall before planting, ash survived best on cast overburden at 83%, compared with 58% for trees on graded topsoil and 47% on ripped topsoil (table 3). Ash survival on unseeded subplots averaged 88%, with differences between minesoils not significant.

Seeding grasses or grass-legume mixture the fall before planting resulted in low ash survival (40% to 47%), compared with seeding only legumes (94% survival) or seeding at time of tree planting (81% to 85% survival)(table 4).

Effects of Treatments - Wet Years

In the second (wet years) study, differences in green ash survival among the minesoil and herbaceous seeding treatments were relatively small. Ash survival 4 to 5 yr after planting generally exceeded 90% for all treatments (tables 3 and 4). One exception was that trees planted on cast overburden and seeded the previous spring had 85% survival, which was 9% to 14% lower survival than trees in other treatments (table 3).

Table 3. Percent survival of green ash when planting was followed by a drought (1st study) or by 2 wet years (2nd study) on 3 minesoil types seeded either before tree planting or at time of planting with herbaceous species, or unseeded.[1]

	Time of herbaceous seeding and tree planting			
Seeding time	Autumn	Spring	Spring	Unseeded
Planting time	Spring	Spring	Spring+1	Spring
	1ST STUDY - DROUGHT YEAR			
	Year 1	Year 1		Year 1
Minesoil type:				
Topsoiled, graded	58 c	66 bc	---	87 a
Topsoiled, ripped	47 c	94 a	---	83 ab
Cast overburden	83 ab	84 ab	---	93 a
	2ND STUDY - WET YEARS			
	Year 5	Year 5	Year 4	Year 5
Minesoil type:				
Topsoiled, graded	99 a	99 a	97 a	98 a
Topsoiled, ripped	98 a	99 a	96 a	98 a
Cast overburden	98 a	94 ab	85 b	97 a

[1] 1st study terminated at end of 1st (1988) growing season; in 2nd study, subplots were seeded in autumn 1988 and spring 1989, trees planted in 1989 (spring) and 1990 (spring+1); survival measured in autumn 1993. Within each study, any 2 survival values not followed by a common letter are significantly different at P=0.05.

Although survival of green ash on cast overburden was generally very good, mean height was only 49.3 cm, which is 31% less than that of trees on topsoil. However, 30.5% of the trees on cast overburden showed visible signs of deer browsing, compared with only 12% for trees on graded or ripped topsoil. Tallest trees were found on subplots in ripped and graded topsoil (86.8 cm and 82.2 cm, respectively) that were seeded with legumes (table 5).

In general, mean tree heights were greatest on subplots seeded with legumes, and heights declined in order from subplots seeded with legumes to grass-legume mix to unseeded to grasses (tables 5 and 6). Browsing of trees for the three seeded herbaceous types was similar, but trees planted in 1990 were more heavily browsed (23.6%) than trees planted in 1989 (15.4%).

In the second (wet years) study, timing of seeding herbaceous species in relation to planting had little effect on tree height after 4 and 5 yr (table 6). In fact, seeding legumes the fall prior to tree planting resulted in taller trees (88.7 cm) than when subplots were seeded at time of planting (79.4 cm) or unseeded (72.5 cm). Even trees on subplots seeded with legumes 1 full yr prior to planting were slightly taller than trees of the same age on unseeded subplots.

Table 4. Percent survival of green ash when planting was followed by a drought (1st study) or by 2 wet yr (2nd study) on subplots seeded with legumes, grasses, or grass-legume mixtures either prior to or at time of tree planting.[1]

	Time of herbaceous seeding and tree planting		
Seeding time....................	Autumn	Spring	Spring
Planting time..................	Spring	Spring	Spring+1
	1ST STUDY - DROUGHT YEAR		
	Year 1	Year 1	
Seeded Species:			
Legumes (3 species)......	94 a	81 a	---
Grasses (4 species)........	47 b	82 a	---
Grass-legume mix..........	40 b	85 a	---
	2ND STUDY - WET YEARS		
	Year 5	Year 5	Year 4
Seeded Species:			
Legumes (3 species)......	99 a	98 ab	94 ab
Grasses (4 species)........	99 a	96 ab	91 b
Grass-legume mix..........	98 ab	97 ab	94 ab

[1] 1st study terminated at end of 1st (1988) growing season; subplots in 2nd study seeded in autumn 1988 and spring 1989, trees planted in 1989 (spring) and 1990 (spring+1), survival measured in autumn 1993. Within each study, any 2 survival values not followed by a common letters are significantly different at P=0.05.

Table 5. Total height(cm) of green ash trees planted on 3 minesoil types in subplots seeded with legumes, grass-legume (G/L) mixtures, grasses, or unseeded.[1]

	Seeded herbaceous species			
Minesoil type	Legumes	G/L Mix	Grasses	Unseeded
Topsoiled, Graded..........	82.2 a	74.8 b	68.3 c	70.0 bc
Topsoiled, Ripped..........	86.8 a	69.8 bc	60.1 d	69.1 bc
Cast Overburden............	56.4 de	49.6 ef	46.1 f	45.3 f
Herbaceous mean...........	75.1	64.7	58.2	61.5

[1] Tree heights measured in fall 1993; data of trees planted in 1989 and 1990 combined for the analysis; means followed by 1 or more common letters are not significantly different at P=0.05.

Table 6. Total height (cm) of green ash trees planted in subplots seeded with legumes, grass-legume (G/L) mix, or grasses either prior to or at time of planting, or in unseeded subplots.[1]

Seeding time	Planting time	Seeded herbaceous species			
		Legumes	G/L mix	Grasses	Unseeded
Autumn 1988	Spring 1989............	88.7 a	74.1 bc	64.7 d	---
Spring 1989	Spring 1989...........	79.4 b	69.0 cd	64.4 d	---
Spring 1989	Spring 1990...........	57.3 a	51.0 ab	45.4 b	---
Unseeded	Spring 1989...........	---	---	---	72.5 bc
Unseeded	Spring 1990...........	---	---	---	50.4 ab

[1] Heights measured in fall 1993, trees planted in spring 1989 completed 5 growing seasons, trees planted in spring 1990 completed 4 growing seasons. Within each planting year, heights not followed by 1 or more common letters are significantly different at P=0.05.

Herbaceous Cover and Biomass

The amount of herbaceous cover 4 to 5 years after seeding on subplots was not related to minesoil type or time of seeding treatments, nor does soil erosion appear to be excessive on any minesoil-herbaceous treatment combination. The amount of fertilizer applied to the subplots was significantly reduced in order to keep herbaceous competition at a low level, and yet meet the minimum standard of 30% ground cover required by Federal law. For the three herbaceous types, above ground biomass was 29% higher for subplots seeded with legumes than for subplots seeded with grasses. Biomass on legume-seeded subplots averaged 183.8 g per 0.5 m^2, and these also had the highest estimated total ground cover at 39.3%, of which 36.3% was legume cover (table 7).

Table 7. Estimated total cover and legume cover, and above ground biomass of subplots seeded with 3 herbaceous types.[1]

Seeded Herbaceous Type	Total cover %	Legume cover %	Above ground biomass g per 0.5 m^2
Legumes..	39.3 a	14.3 a	183.8 a
Grass/Legume Mix..........................	37.9 a	13.9 a	162.1 b
Grasses...	31.5 b	10.7 a	142.4 c

[1] Measured in early summer 1993; cover estimates based on living plant material above ground; data of subplots seeded in 1989 and 1990 combined; Within each column, any 2 means not followed by a common letter are significant at P=0.05.

Discussion

These results, combined with those of other research, provide a good understanding of the effects of minesoils, herbaceous species, and timing of seeding of herbaceous species on initial establishment of tree seedlings during wet and dry growing seasons.

Survival of White Pine and Green Ash

White pine failed on these minesoils, even when planting was followed by wet growing seasons. Both topsoil and cast overburden, with pH of 7.0, are probably too alkaline for this species. Torbert et al. (1989) noted that white pine grown in soils with pH above 6.5 become chlorotic and stunted.

When tree planting is followed by drought, initial survival of green ash may be better on cast overburden than on topsoiled areas because the seeded herbaceous species appeared to be slow to develop on cast overburden (Larson et al. 1993). Grass species seeded in the fall were first to become established the following spring, and newly planted trees suffered high mortality, whereas legumes seeded the previous fall or grasses seeded at time of planting were much less competitive with trees.

Treatments to enhance establishment of green ash were not needed during wet years. Tree survival was excellent on all minesoils, and seeding herbaceous species did not reduce survival except when grasses were seeded a full year before tree planting. In Illinois, green ash performed better on areas seeded with a grass-legume mixture at time of planting than on areas seeded the previous year (Ashby et al. 1988).

Other research has shown that green ash planted on ungraded spoil in 1947 survived and grew better on plots seeded only with sweetclover (Melilotus officinalis) than on plots seeded with a mixture of lespedeza (Lespedeza cuneata) and orchardgrass (Dactylis glomerata)(Larson and Vimmerstedt 1983). Vogel (1980) reported reduced survival when trees were planted in dense stands of legumes, although growth of surviving trees was later increased. Olah (1988) suggests that 1 yr of herbaceous vegetation be incorporated into the soil before tree planting. The commonly recommended practice is to delay seeding herbaceous species until the same time or after trees are planted (Vogel 1980, Ashby et al. 1988).

Ripping to reduce topsoil compaction did not consistently benefit ash survival in the drought year. It is possible that the ripping operation was not uniformly applied to plots, but this was not measured. The influence of compaction may yet appear in future measurements. In Illinois, black walnut (Juglans nigra) planted on ripped minesoil had 58% greater root depth and 89% greater lateral root spread in the second year than trees planted on graded soils that were not ripped (Philo et al. 1982). There is abundant evidence of detrimental effects of compaction and the importance of good physical properties of replaced topsoil (Andersen et al. 1989, Ashby et al. 1988, Chong et al. 1986, Davidson et al. 1984, Kolar et al. 1981, Pope 1989, Vogel 1981).

Height Growth of Green Ash

Although ash trees survived well on cast overburden, height growth was inhibited the very first year (Larson, et al. 1993) and continues to lag behind that of trees on topsoil after 5 yr. Trees on cast overburden have been somewhat more heavily deer browsed than trees on topsoil, although the reason for this is not apparent.

Seeding legumes instead of grasses improved height growth of ash trees on all minesoils, including cast overburden. After 5 yr, subplots originally seeded with legumes had about one-third of the total cover in legumes. Legumes have also successfully invaded subplots seeded with grasses. The fact that low amounts of fertilizer were used, and tree heights were greatest in legume-seeded subplots suggest that soil nitrogen deficiency may be a primary growth limiting factor. Others have suggested that nitrogen-fixing trees and shrubs be planted on overburden mixtures without topsoil (Wade et al. 1985).

Cast Overburden as a Resoiling Material

This research suggests that cast overburden is a suitable alternative resoiling material during both wet and dry years if a suitable tree species such as green ash is planted, and the seeded mixtures contain mostly legume species that do not aggressively compete with trees. Cast overburden sustained herbaceous cover as well as topsoil except during the first growing season (Larson et al. 1993). However, additional measures to increase tree growth may be needed if the trees are to be harvested within a normal rotation period.

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