

ESTABLISHMENT OF NATIVE PLANT SPECIES FROM FOREST TOPSOIL SEEDBANKS ON A BORROW AREA IN KENTUCKY ¹

by

Gary L. Wade

and

Ralph L. Thompson ²

Abstract. The seed banks in forest topsoils were used to introduce native species to an unreclaimed, xeric borrow area in eastern Kentucky. The results of using eight treatments are reported: (1) 1 cm topsoil + mulch, (2) 1 cm topsoil tilled into the substrate + mulch, (3) 2 cm topsoil + mulch, (4) 1 cm topsoil without mulch, (5) 4 cm topsoil in strips covering 25% of the area + mulch, (6) 1 cm topsoil + a grass-legume reclamation mix + mulch, (7) the reclamation mix + mulch without topsoil, and (8) mulch without topsoil or reclamation mix. The seed bank produced 90 species from 34 families including seven tree species, seven shrubs, 16 graminoids, and 50 forbs. Forest topsoil use introduced 57 native or naturalized species during the first growing season and 82 species were present during the second growing season. Average ground cover of native species totaled only about 5% after ten weeks of the first growing season. Wheat and timothy seed contained in the hay mulch increased mean ground cover to over 70%. The reclamation mix produced 96% cover during the first year and it completely suppressed establishment of native species during the first two years. Different methods of topsoil use without the reclamation mix did not significantly affect the number of native species established in the first and second growing seasons, cover in the first growing season, the number of species increase in the second year, or the number of established trees and shrubs.

Additional key words: Reclamation, revegetation



¹ Paper presented at the 1990 Mining and Reclamation Conference and Exhibition, Charleston, West Virginia, April 23-26, 1990.

² Gary L. Wade is Botanist, Northeastern Forest Experiment Station, USDA Forest Service, Berea, KY 40403; Ralph L. Thompson is Associate Professor of Biology, Biology Department, Berea College, Berea, KY 40404.



Introduction

Drastic land disturbances such as surface mines, road banks, quarries, and construction projects with fills or borrow areas produce significant areas requiring revegetation and reclamation. Techniques for simple revegetation of these areas are well developed, but exotic and monotonous, highly competitive plant communities are the frequent result. Also, establishment and succession of desirable communities of native species may be slowed by current revegetation practices (Brenner 1984). Communities of native species can be established with commercially available seed and planting stock, but such materials tend to be expensive, and propagules of many native species are often not available.

Topsoil seed banks have been used effectively to introduce native species on reclaimed mined lands in the western United States (Beauchamp et al. 1975, Howard and Samuel 1979, Iverson and Wali 1982). However, the amount of cover produced by the seed bank species has been less than that obtained with exotic reclamation species. DePuit (1984) has synthesized some potentially successful strategies for enhancing vegetation and species diversity on reclaimed mined lands using topsoil seed banks.

Use of topsoil seed banks to introduce native species to reclaimed land has been successful in Australia. Tacey (1979) used the top 5 cm of topsoil to introduce native species of jarrah (Eucalyptus marginata) forest to mined lands in Western Australia. Dominance-diversity curves in reestablished vegetation approached the log-normality distribution found in more diverse communities after four years (Tacey and Glossop 1980). Topsoil seed banks have been used to reestablish many high dune forest and coastal wetland species after surface mining on the Australian east coast (Brooks 1988).

In the United Kingdom, chopped turf from old mined sites has been used to introduce native species to newly mined sites. A 30 cm layer of topsoil was also successful in native species introduction, but a "few millimeters thick" and "small molehill" amounts were not effective (Wathern and Gilbert 1978, Gilbert and Wathern 1980).

Farmer et al. (1982) and Wade (1986) found that seed banks in eastern United States deciduous forests produced many native species in pioneer communities with high biomass and cover when forest topsoils were spread 2.5 to 5.0 cm thick over mine spoils in 1.3 m² microplots. Moreover, the growing conditions in these last two studies were optimal because of supplemental irrigation.

Quality of the seed bank is important for species introductions. Quality can be influenced by source soil types, vegetation, disturbance history, aspect, and season of collection. A soil may contain several types of seed banks that range from transient to persistent based on seed-dormancy characteristics of its component species. Different types of seed banks may be able to exploit certain types of disturbances at only certain times of the year (Grime 1981).

Many reclamation/revegetation projects occur on sites where stressful conditions of high temperatures, low fertility, and low available water potential exist. Large quantities of topsoils for large-scale projects can be difficult to obtain without disturbance to other areas on an unacceptable scale. The borrow area of Cowbell Hollow provided an opportunity to investigate: (1) what methods of application of minimal amounts of forest topsoil would establish pioneer communities from the contained seed bank, (2) whether exotic reclamation ground cover species would inhibit the invasion and establishment of desired native successional species, and (3) which species could be established after two growing seasons.

Materials and Methods

The study area is a 7.0 ha borrow area within the Red Lick Watershed Control Basin below Cowbell Hollow Reservoir in the Berea College Forest, Madison County, Kentucky. The forest topsoils and part of the subsoils were removed for use as fill in a large earthen dam in 1985. The original soils were classified as Shelocta gravely silt loams (Newton et al. 1973) . only the very strongly acid subsoils remain with a depth of approximately 30 cm over sandstone and shale. Three study areas were established on a broad second terrace above Red Lick Creek below a long east-facing slope with an open southern exposure. The site can be classified as xeric because of its exposure and shallow soil parent materials, although water from upper slope positions sometimes reaches the plots during and after high precipitation events.

In March 1986, the borrow area was chisel-plowed to a depth of 25 cm and 10-10-10 fertilizer was applied at a rate of 1210 kg ha⁻¹ . Three study areas were subdivided into eight 3 m x 3 m plots in line with a 1 m buffer strip separating the plots. Forest topsoil to a depth of about 15 cm was collected from a nearby undisturbed Virginia pine-red maple (Pinus virginiana-Acer rubrum) stand using a farm tractor with a front-mounted end loader and deposited adjacent to two of the study areas. Topsoil was similarly collected for use in a third area from an adjacent American beech-white oak (Fagus grandifolia-Quercus alba) stand.

The study was laid out as four independent experiments to study 1) effectiveness of topsoil for introducing native species, 2) effect of the reclamation species on native species, 3) effects of different methods of topsoil use, and 4) effects of mulch., Eight treatment plots were randomly assigned and replicated once in each of three blocks in the barrow area. Treatments were as follows:

- T1. 1 cm topsoil plus mulch.
- T2. 1 cm topsoil lightly tilled into soil with a rototiller plus mulch.
- T3. 2 cm topsoil plus mulch.
- T4. 1 cm topsoil minus mulch.
- T5. 1 cm topsoil equivalent applied in two strips 4 cm deep across the plot plus mulch.
- T6. 1 cm topsoil plus a reclamation species mix plus mulch.
- T7. No topsoil, reclamation species mix only plus mulch.
- T8. No topsoil, no reclamation mix, mulch only.

The required amounts of topsoils were spread April 4 on each plot by filling buckets with the appropriate volumes of topsoil, transferring the soil to the plot, and raking it evenly or stripping it over the surface. The reclamation species mix was seeded on April 9. It consisted of Japanese lespedeza (Lespedeza striata) seeded at 9 kg ha Korean lespedeza (Lespedeza stipulacea) at 8 kg ha⁻¹, white clover (Trifolium repens) at 5 kg ha⁻¹ perennial ryegrass (Lolium perenne mixed with Italian ryegrass (L. multiflorum) at 9 kg ha⁻¹ orchard grass (Dactylis glomerata) at 11 kg ha⁻¹ and timothy (Phleum pratense) at 4 kg ha⁻¹ . A common wheat (Triticum aestivum) hay mulch was spread at the rate of 2 t ha⁻¹ on the day of seeding. The surrounding borrow area was reclaimed at the same time in the same manner as the reclamation mix only plots but tall fescue (Festuca arundinacea) and red clover (Trifolium pratense) were added in some areas. Plots in which reclamation species were not desired

were covered with plastic sheeting during the short time that seed was broadcast near the experimental areas.

Vegetation development was monitored and species presence in each plot was recorded at three to four week intervals. Cover after ten weeks was determined on June 20, 1986, using a pindrop method through a 20 point frame placed at random five times in each plot. Woody species were counted in each plot in late September, 1986. Vegetation development was recorded at various times using black and white or color photography. Nomenclature for all species follows Strausbaugh and Core (1978).

Data were analyzed on a Data General MV-7800 computer using the SYSTAT statistical program package of Wilkinson (1988). Data for numbers of native species, number of trees and number of shrubs were log transformed ($n=\log(n+1)$) to reduce positive skewness, but data for other variables did not require this procedure. Comparisons of treatment means of vegetation variables were made using one-way analysis of variance (ANOVA) and Fisher's (protected) LSD (Steel and Torrie 1980). Independent variables tested by ANOVA were 1) use of topsoil, 2) use of reclamation mix, 3) use of mulch, and 4) method of topsoil use. Topsoil source was not considered as a variable. We decided a priori to make multiple comparisons of vegetation variables only among certain treatments as follows:

Absolute effectiveness of topsoil on vegetation variables:

T1 vs. T8,

Effects of reclamation mix on vegetation variables linked to topsoil:

T1 vs. T6 vs. T7

Effects of different methods of topsoil use on vegetation variables:

T1 vs. T2 vs. T3 vs. T5

Effects of mulch on vegetation variables:

T1 vs. T4

Significance level for all statistical tests was $\alpha = 0.05$. Analysis of variance tables are presented in Appendix 1.

Rainfall amounts were measured and recorded at the Northeastern Forest Experiment Station, Forestry Sciences Laboratory, about 3 km from the study site.

Results and Discussion

This study revealed that small quantities of forest topsoils and their seed banks can be used successfully to introduce native species to borrow areas. However, the most obvious differences in plots were linked to use of the reclamation species mix and the hay mulch at ten weeks after establishment and afterwards. Where the reclamation mix was employed, an aggressive cover of planted grasses dominated the plots with lesser amounts of annual legumes. Where mulch was employed without the reclamation mix, the plots were dominated

by wheat and timothy. Scattered native species were established in all topsoiled plots that did not have the seeded reclamation mix.

Forest topsoils significantly increased the number of native or naturalized plant species in the plots during the first and second growing seasons (one-way ANOVA of Treatment 1 and Treatment 8 data, $\alpha = 0.05$) (Table 1). Most of these species were few in number and occurred in only a few plots. In all topsoiled plots, 57 native species were found during the first growing season. The mean number of native or naturalized species per topsoiled plot without the reclamation mix was 11 with a range of 6 to 20. During the second year, a total of 87 species were documented with a mean of 19 and a range of 7 to 27 native or naturalized species per topsoiled plot. Some species found the first year were not present during the second growing season. Nonplanted native or naturalized species totaled 90 taxa from 34 families present in either or both years (Table 2). This number of established species is comparable to the 199 species found in a greenhouse study of eight Appalachian forest seed banks (Dobberpuhl 1981), 134 species from three Appalachian forest topsoils spread over mine spoils (Farmer et al. 1982), and 84 species in one forest topsoil seed bank spread on mine spoil in irrigated, microplots (Wade 1986, 1989).

Native species composition of topsoiled plots was characteristic of the early seral stages of secondary forest succession, but species composition and frequency were not comparable to the standing forests (intermediate or late seral stages) of the topsoil donor sites.

Topsoiling resulted in a significantly greater increase in the mean number of species in the plots (ANOVA of Treatment 1 and Treatment 8 data, $\alpha = 0.05$) (Table 1). This may have been because additional dormant seed in the applied soils did not germinate until the second year. Other possibilities are that invaders were more successfully established after modification of environmental factors, or the presence of symbiotic soil microflora, especially mycorrhizal fungi. Farmer et al. (1982) observed that many native species from forest topsoil seed banks on newly exposed mine spoils had endomycorrhizal associates. Korean and Japanese lespedezas in the reclamation mix were observed to be growing more luxuriantly on and near the topsoil strips used in Treatment 5 than in the rest of the plots. This may have been because of native strains of Rhizobium spp. in the topsoils. Although the amounts of added forest soils were small, fertility factors might also have been influential in facilitating greater establishment of native species on topsoils.

Topsoil application significantly increased the number of shrubs but not the number of trees (ANOVA of Treatment 1 and Treatment 8 data, $\alpha = 0.05$) (Table 1). A total of seven tree species and seven shrub or woody vine species were present in all topsoiled plots (Table 2) with a mean total number of woody stems equivalent to 11,000 ha. Of the trees, black locust (Robinia pseudoacacia) was the most numerous and fastest growing species and it was more frequent in the plots that received topsoil from the Virginia pine-red maple stand.

Native species from the seed bank did not provide a significant amount of ground cover in the plots after two weeks in the first growing season (ANOVA of Treatment 1 and Treatment 8 data, $\alpha = 0.05$) (Table 1). Mean cover of native species in all topsoiled plots was 5 percent, but this was highly variable. The pin drop method of cover estimation is conservative since the fine pins as used in this study frequently drop through the canopies of some plants without actually touching leaves or stems. The amount of cover produced by seed bank species alone would not have met the standards for mined-land reclamation in the United

States. Other forest topsoil seed bank studies in the eastern United States have produced acceptable cover during the first growing season under optimal growing conditions (Farmer et al. 1982; Wade 1986, 1989).

The reclamation mix species effectively eliminated wheat and timothy from the mulch and the native species in the topsoil (Table 3). ANOVA and Fisher's (protected) LSD of vegetation variable means from Treatment 1 (1 cm topsoil plus mulch), Treatment 6 (1 cm topsoil plus mulch and reclamation mix significantly ($\alpha = 0.05$) reduced the number of native species during the first two growing seasons, the number of trees, and the number of shrubs (Table 1). Cover of reclamation species was significantly higher than cover of wheat and timothy from the mulch. There were no significant differences in the amount of native species cover because of the low but highly variable numbers of native species in topsoiled plots. The increase in native species between the first and second years was significantly less in plots containing the reclamation mix. This suggests that the reclamation mix community could retard plant succession.

Table 1. Effects of various factors on vegetation variables in Cowbell Hollow plots. Within each factor group, means followed by the same letter are not significantly different, ANOVA followed by LSD where appropriate, $\alpha = 0.05$.

Factor	Treat.	Year 1 Native Species	Year 2 Native Species	Incr. Native Species	Number Trees	Number Shrubs	% Cover	% Cover Native
Topsoil	T1	8.7a	22.0a	13.3a	11.3a	3.7a	71.3a	4.0a
	T8	0.7b	5.0b	4.3b	0.7a	0.0b	76.0a	0.3a
Rec Mix	T1	8.7a	22.0a	13.3a	11.3a	3.7a	71.3b	4.0a
	T6	0.3b	3.3b	3.0b	0.0b	0.3b	100.0a	0.0a
	T7	0.3b	3.0b	2.7b	0.3b	0.0b	96.3a	0.0a
Topsoil Method	T1	8.7a	22.0a	13.3a	11.3a	3.7a	71.3a	4.0a
	T2	8.3a	14.7a	6.3a	2.0a	0.3a	72.3a	7.0a
	T3	11.0a	20.0a	9.0a	15.0a	3.7a	81.0a	5.3a
	T5	8.7a	18.0a	9.3a	5.3a	2.7a	66.0a	5.0a
Mulch	T1	8.7a	22.0a	13.3a	11.3a	3.7a	71.3a	4.0a
	T4	16.0a	19.0a	3.0b	16.0a	4.3a	9.0b	4.7a

Table 2. Frequency of species occurrence in plots of each treatment in 1986 and 1987.

SPECIES	T1		T2		T3		T4		T5		T6		T7		T8	
	TS		TS til		TS 2x		TS-mul		TSstri		TS+RM		RMonly		No TSRM	
	86	87	86	87	86	87	86	87	86	87	86	87	86	87	86	87
<u>Acalypha gracilens</u> Gray	.3		.3		.3		.6		.3							
<u>Acalypha rhomboidea</u> Raf.		.7				.7										
<u>Acer rubrum</u> L.		.7		.7				.3	.7		.3			.3		
<u>Agrostis perennans</u> (Walt.) Tuckerm.								.3								
<u>Aster pilosus</u> Willd.						.7			.3							
* <u>Bromus japonicus</u> Thunb.														.3		.3
* <u>Cardamine hirsuta</u> L.		.3														
<u>Carex digitalis</u> Willd.		.3		.3					.3							
* <u>Cerastium viscosum</u> L.		.3														
<u>Chenopodium album</u> L.														.3		
* <u>Chrysanthemum leucanthemum</u> L.			.3													
* <u>Cirsium arvense</u> L.				.7		.7			.3							
* <u>Cirsium vulgare</u> (Savi) Ten.			.3	.3												
<u>Cyperus esculentus</u> L.									.3							
* <u>Dactylis glomerata</u> L.				.3		.3					.3			.3		.3
<u>Danthonia spicata</u> L.								.3								
<u>Desmodium paniculatum</u> (L.) DC.	.3															
* <u>Digitaria ischaemum</u> (Schreb.) Muhl.			.3		.3			.3								
* <u>Digitaria sanguinalis</u> L.		.3	.3													
<u>Diodia teres</u> Walt.								.3								
<u>Eragrostis spectabilis</u> (Pursh) Steud.		.3														

Table 2. Frequency of species occurrence in plots of each treatment in 1986 and 1987. (continued)

	T1	T2	T3	T4	T5	T6	T7	T8
SPECIES	TS	TS t1l	TS 2x	TS-mul	TSstri	TS+RM	RMonly	No TSM
	86	87	86	87	86	87	86	87
* <u>Medicago lupulina</u> L.	.3	.3	.3	.3	.7	1.	.7	
* <u>Microstegium vinineum</u> (Trin.) A. Camus				.3				
<u>Panicum clandestinum</u> L.				.3				
<u>Panicum commutatum</u> Schultes			.7	.3				
<u>Panicum dichotomum</u> L.			.3	.3				
<u>Panicum lanuginosum</u> Ell.		.3	.3	.7	.3	.7		
<u>Panicum polyanthes</u> Schultes				.3				
<u>Paronychia fastigiata</u> (Raf.) Fernald	.3	.3	.3					
* <u>Phleum pratense</u> L.	.7	.7	.7	.7	.3	.3	.3	.3
<u>Physalis heterophylla</u> Nees.				.3				
<u>Phytolacca americana</u> L.	.7	.7	.7	1.	.7	.7	.7	.3
<u>Pinus virginiana</u> Mill.		.3		.3		.3		.3
<u>Plantago rugelii</u> Dcne.			.3	.3	.7			.3
<u>Platanus occidentalis</u> L.				.3	.3			
* <u>Poa compressa</u> L.				.3				
<u>Polygonatum biflorum</u> (Walt.) Elliott		.3		.3		.3		
<u>Polygonum scandens</u> L.	1.	.7	.3	.3	.7	.7	.7	.3
<u>Populus deltoides</u> Marsh.					.3			
<u>Potentilla norvegica</u> L. Ann.						.3		
* <u>Potentilla recta</u> L. Per.			.3			.3		
<u>Potentilla simplex</u> Michx.						.3		
<u>Rhus copallina</u> L.	.3	1.		.7	.3	1.	.7	.7
<u>Rhus glabra</u> L.	.7	.7	.3	.3	.3	.7	.3	.3
<u>Robinia pseudoacacia</u> L.	.7	.7	.7	.7	1.	1.	1.	.3
<u>Rubus allegheniensis</u> T. C. Porter		.3	.3	.3	.3	.7	.3	.3
* <u>Rumex crispus</u> L.			.3	.3		.3	.3	.3
<u>Sassafras albidum</u> (Nutt.) Nees			.3	.3	.3	.3	.7	.3
<u>Scutellaria leonardii</u> Epling		.3	.3		.3	.3		
* <u>Sida spinosa</u> L.		.7	.3		.3			
<u>Smilax glauca</u> Walt.						.3	.3	
<u>Smilax bona-nox</u> L.							.3	
<u>Solanum carolinense</u> L.		.3	.7	.3	.3			
<u>Solanum nigrum</u> L.	.3	.3		.3		.3	.3	
<u>Solidago canadensis</u> L.	.3	.3			.3	.3		
* <u>Sonchus asper</u> (L.) Hill.			.3	.3				
* <u>Sonchus oleraceus</u> L.		.7	.3	.3	.3	.3	.3	
* <u>Taraxacum officinale</u> Weber.	.3	.3	.7	.3	.3	.7	1.	.3
* <u>Trifolium campestre</u> Schreb.		.3						

Table 2. Frequency of species occurrence in plots of each treatment in 1986 and 1987. (continued)

SPECIES	T1		T2		T3		T4		T5		T6		T7		T8	
	TS		TS til		TS 2x		TS-mul		TSstri		TS+RM		RMonly		No TSRM	
	86	87	86	87	86	87	86	87	86	87	86	87	86	87	86	87
+* <i>Trifolium pratense</i> L.	.3		.3		.3				.3							
+* <i>Trifolium repens</i> L.		.3			.3	.7		.3	.3	.3						
+* <i>Triticum aestivum</i> L.	1.	1.	1.	1.	1.	1.		.7	1.	1.	1.	1.	.7	.7	1.	.7
+ <i>Verbascum blattaria</i> L.										.3						
+ <i>Verbascum thapsus</i> L.			.3	.3		.3	.3									
+ <i>Veronica arvensis</i> L.	.3															
<i>Viola affinis</i> Le Conte.					.3	.7										
<i>Vitis aestivalis</i> Michx.	.3						.3	.3								

* Planted in reclamation mix plots and in the surrounding area.

+ Naturalized species.

Table 3. Mean number of native species present per plot in the first and second years, total number of trees, total number of shrubs, percent cover (at 10 weeks), and percent cover by native or naturalized species, planted grasses, planted legumes, and wheat. Standard deviations are in parentheses.

	TREATMENT							
	TS 1 cm	TS 1 cm Tilled	TS 2 cm	TS no mulch	TS strip	TS + RecMix	RecMix only	no TS or RecMix
# native spp. year 1	8.7 (3.8)	8.3 (2.1)	11.0 (4.4)	16.0 (6.1)	8.7 (4.6)	0.3 (0.6)	0.3 (0.6)	0.7 (0.6)
# native spp. year 2	22.0 (2.0)	14.7 (7.1)	20.0 (9.6)	19.0 (8.5)	18.0 (3.5)	3.3 (2.5)	3.0 (2.7)	5.0 (1.7)
2nd year ssp. increase	13.3 (4.0)	6.3 (5.0)	9.0 (7.2)	3.0 (3.5)	9.3 (4.2)	3.0 (3.0)	2.7 (2.9)	4.3 (2.1)
# trees	11.3 (12.9)	2.0 (1.0)	15.0 (19.1)	16.0 (19.2)	5.3 (3.5)	0.0 (0.0)	0.3 (0.6)	0.7 (0.6)
# shrubs	3.7 (3.1)	0.3 (0.6)	3.7 (3.1)	4.3 (3.5)	2.7 (2.5)	0.3 (0.6)	0.0 (0.0)	0.0 (0.0)
% cover	71.3 (11.7)	72.3 (25.7)	81.0 (12.3)	9.0 (9.8)	66.0 (6.6)	100.0 (0.0)	96.3 (4.0)	76.0 (4.6)
% cover native species	4.0 (5.3)	7.0 (3.0)	5.3 (4.0)	4.7 (2.3)	5.0 (8.7)	0.0 (0.0)	0.0 (0.0)	0.3 (0.6)
% cover planted grasses	4.0 (6.9)	0.7 (1.2)	0.0 (0.0)	0.0 (0.0)	0.7 (1.2)	100.0 (0.0)	96.3 (4.0)	0.0 (0.0)
% cover planted legumes	0.3 (0.6)	0.3 (0.6)	0.7 (1.2)	0.0 (0.0)	0.7 (1.2)	7.3 (5.8)	6.0 (2.6)	0.0 (0.0)
% cover wheat	60.7 (12.2)	68.3 (32.3)	75.7 (19.0)	5.0 (7.8)	52.0 (9.5)	7.3 (5.1)	4.3 (5.9)	75.7 (4.5)

Comparisons of different methods of topsoil use: 1 cm, 1 cm tilled into the substrate, 2 cm, and a 1 cm equivalent piled in deeper strips, showed no significant differences among methods of topsoil use for any vegetation variables (ANOVA, $\alpha = 0.05$) (Table 1).

Use of mulch resulted in a significantly greater increase in native species and cover (ANOVA of Treatment 1 and Treatment 4 data, $\alpha = 0.05$) (Table 1). The cover difference was largely because of wheat and timothy from seed input with the mulch. Greater increase in native species in mulched plots probably occurred because mulch conserved soil moisture, lowered

surface temperatures, provided a trapping effect on wind-blown seeds, and reduced erosion. Mulch did not significantly affect the number of native species in the first two years, cover in the first year, or the total number of trees or shrubs. These results suggest that with seed-free straw mulches a light seeding of wheat or timothy may be desirable to provide additional cover in the first growing season of native species introduced via seed banks.

Native species were established during a severe drought on an exposed site with shallow soils and without protective cover except the hay mulch. Total precipitation was 0.7 and 1.9 standard deviations below normal in 1986 and 1987, respectively. Water deficits during most months of the growing seasons were even greater (Table 4). While the wheat and timothy from the mulch provided some shading and amelioration of surface temperatures, they were also competitors for soil water.

In a study using a forest topsoil seed bank spread over two surface-mine spoils, the number and biomass of established native species was significantly reduced when a reclamation mix of Italian ryegrass (*Lolium multiflorum*), perennial ryegrass (*L. perenne*), tall fescue (*Festuca arundinacea*), weeping lovegrass (*Eragrostis curvula*), and sericea lespedeza (*Lespedeza cuneata*) was seeded into the forest topsoil, but the native species were not eliminated (Wade 1986, 1989). Ground cover developed fastest in the reclamation mix and slowest in the seed bank community, but there were no significant differences in ground cover 16 weeks after establishment. Doerr and Redente (1983) also observed that a mixture of seeded grasses repressed native forb biomass production in Colorado. The lower cover and populations of native species in the Cowbell Hollow borrow area may be attributed to the harsher environmental conditions, especially drought, low soil moisture, and possibly a reduced number of propagules in the smaller amount of forest topsoil used.

Conclusions

Forest topsoil seed banks can be used to introduce a variety of native species under harsh environmental conditions to drastically disturbed lands such as borrow areas. Many of the species contained in forest topsoil seed banks are not available from seed suppliers. For the reclamationist interested in native species establishment, topsoil seed banks provide a low cost, easily available propagule source for the revegetation of disturbed sites for enhancement of wildlife or forest habitats.

The coemployment of common, aggressive herbaceous ground cover species can significantly reduce success of native species establishment from forest topsoils. The reclamation species mix effectively eliminated all species from the forest topsoil seed banks during the first year; 82 were present during the second year. Different methods of forest topsoil use did not significantly affect results. Effects of hay mulch were not significant except that presence of mulch significantly enhanced native species establishment during the second year.

Table 4. Growing season and yearly precipitation (mm) at Berea, Kentucky, for 1986, 1987, and the 1951-1980 mean and standard deviation (Conner et al. 1981).

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year Total
1986	110	71	29	67	45	102	86	156	1043
1987	90	73	49	58	73	82	32	11	813
mean	85	122	115	106	109	122	102	95	1193
s.d.	56	56	61	48	48	55	61	60	201

Literature Cited

- Beauchamp, H., R. Lang, and M. May. 1975. Topsoil as a seed source for reseeding strip mine spoils. Wyo. Agr. Exp. Sta. Res. J. 90, Univ. Wyo., Laramie, WY.
- Brenner, F. J. 1984. Restoration of natural ecosystems on surface coal mine lands in the northeastern United States. p. 211-255. In: T. N. Veziroglu (ed.) The Biosphere: Problems and Solutions. Elsevier Science Publishers B. V., Amsterdam.
- Brooks, D. R. 1988. Rehabilitation following heavy mineral sands mining in Australia. p. 129-147. In: Environmental Workshop--1988 Proceedings, Volume I. Darwin, September 1988. Australian Mining Industry Council, Dickson ACT.
- Conner, G., T. Boyer, and L. Dilgard. 1981. Climate of Berea Kentucky. Climatology of Kentucky Series. Kentucky Climate Center, Department of Geology and Geography, Western Kentucky University, Bowling Green.
- Dobberpuhl, J. M. 1981. Seed banks of forest soils in East Tennessee. M. S. Thesis, The University of Tennessee, Knoxville.
- DePuit, E. J. 1984. Potential topsoil strategies for enhancement of vegetation diversity on mined lands. Minerals and the Environment 6:115-120.
- Doerr, T. B., and E. F. Redente. 1983. Seeded plant community changes on intensively disturbed soils as affected by cultural practices. Reclam. Reveg. Res. 2:13-24.
- Farmer, R. E., Jr., M. Cunningham, and M. A. Barnhill. 1982. First-year development of plant communities originating from forest topsoils placed on southern Appalachian minesoils. J. Appl. Ecol. 19:282-294.
- Gilbert, O. L., and P. Wathern. 1980. The creation of flower-rich swards on mineral workings. Reclamation Review 3:217-221.
- Grime, J. P. 1981. The role of seed dormancy in vegetation dynamics. Ann. Appl. Ecol. 98: 555-558.
- Howard, G. S., and M. J. Samuel. 1979. The value of fresh-stripped topsoil as a seed source of useful plants for surface mine revegetation. J. Range Manage. 32:76-77.

Iverson, L. R., and M. L. Wali. 1982. Buried, viable seeds and their relation to revegetation after surface mining. *J. Range Manage.* 35:648-652.

Newton, J. H., H. P. McDonald, D. G. Preston, A. J. Richardson, and R. P. Sims. 1973. Soil survey of Madison County, Kentucky. USDA Soil Conservation Service, Washington, DC.

Steele, R. G. D., and J. H. Torrie. 1980. *Principles and Procedures of Statistics*, 2nd Ed. McGraw-Hill Book Company, New York.

Strausbaugh, P. D., and E. L. Core. 1978. *Flora of West Virginia*, Second Ed. Seneca Books, Inc., Grantsville, West Virginia. 1079 p.

Tacey, W. H. 1979. Landscaping and revegetation practices used in rehabilitation after bauxite mining in Western Australia. *Reclamation Review* 2:123-132.

Tacey, W. H., and B. L. Glossop. 1980. Assessment of topsoil handling techniques for rehabilitation of sites mined for bauxite within the jarrah forest of Western Australia. *J. of Appl. Ecol.* 17:195-201.

Wade, G. L. 1986. Forest topsoil seed banks for introducing native species in eastern surface-mine reclamation. p. 155-164. In: *New Horizons for Mined Land Reclamation: 1986 National Meeting of the American Society for Surface mining and Reclamation*; Jackson, MS: March 17-20; American Society for Surface Mining and Reclamation, Princeton, WV.

Wade, G. L. 1989. Grass competition and establishment of native species from forest soil seed banks. *Landscape and Urban Planning* 17:135-149.

Wathern, P., and O. L. Gilbert. 1978. Artificial diversification of grassland with native herbs. *J. Environ. Manage.* 7:29-42.

Wilkinson, L. 1988. *SYSTAT: The System for*

Appendix 1. Analysis of variance tables for effects of topsoil use, reclamation mix, method of topsoil use, and mulch.

Source	SS	DF	MS	F	Sig.	Data
$\log_{10}$ number of species, 1st year						
topsoil	4.643	1	4.643	31.437	**	T1 T8
error	0.591	4	0.148			
rec mix	7.924	2	3.962	26.090	**	T1 T6 T7
error	0.911	6	0.152			
method	0.122	3	0.041	0.324	ns	T1 T2 T3 T5
error	1.004	8	0.125			
mulch	0.470	1	0.470	3.054	ns	T1 T4
error	0.615	4	0.154			
$\log_{10}$ number of species, 2nd year						
topsoil	2.830	1	2.830	50.541	**	T1 T8
error	0.224	4	0.056			
rec mix	6.779	2	3.389	12.552	**	T1 T6 T7
error	1.620	6	0.270			
method	0.330	3	0.110	0.687	ns	T1 T2 T3 T5
error	1.281	8	0.160			
mulch	0.065	1	0.065	0.549	ns	T1 T4
error	0.473	4	0.118			

Appendix 1. Analysis of variance tables for effects of topsoil use, reclamation mix, method of topsoil use, and mulch. (continued)

Source	SS	DF	MS	F	Sig.	Data
species increase						
topsoil	121.500	1	121.500	11.758	*	T1 T8
error	41.333	4	10.333			
rec mix	220.667	2	110.333	9.832	*	T1 T6 T7
error	67.333	6	11.222			
method	75.000	3	25.000	0.901	ns	T1 T2 T3 T5
error	222.000	8	27.750			
mulch	160.167	1	160.167	11.306	*	T1 T4
error	56.667	4	14.167			
log ₁₀ number of trees						
topsoil	4.090	1	4.090	5.893	ns	T1 T8
error	2.776	4	0.694			
rec mix	8.064	2	4.032	8.713	*	T1 T6 T7
error	2.776	6	0.463			
method	2.622	3	0.874	1.108	ns	T1 T2 T3 T5
error	6.308	8	0.789			
mulch	1.014	1	0.104	0.080	ns	T1 T4
error	5.181	4	1.295			
log ₁₀ number of shrubs						
topsoil	2.883	1	2.883	12.000	*	T1 T8
error	0.961	4	0.240			
recmix	3.3310	2	1.655	7.750	*	T1 T6 T7
error	1.281	6	0.214			
method	2.677	3	0.892	1.781	ns	T1 T2 T3 T5
error	4.008	8	0.501			
mulch	0.019	1	0.019	0.037	ns	T1 T4
error	2.110	4	0.528			
cover (percent)						
topsoil	32.667	1	32.667	0.413	ns	T1 T8
error	316.667	4	79.167			
rec mix	1460.007	2	730.003	14.252	**	T1 T6 T7
error	307.33	6	51.222			
method	347.333	3	115.778	0.468	ns	T1 T2 T3 T5
error	1979.333	8	247.417			
mulch	5828.167	1	5828.167	49.743	**	T1 T4
error	468.667	4	117.167			
native species cover (percent)						
topsoil	20.167	1	20.167	1.424	ns	T1 T8
error	56.667	4	14.167			
rec mix	31.947	2	15.973	1.711	ns	T1 T6 T7
error	56.00	6	9.333			
method	14.00	3	4.667	0.145	ns	T1 T2 T3 T5
error	256.667	8	32.083			
mulch	0.667	1	0.667	0.040	ns	T1 T4
error	66.667	4	16.667			