THE POTENTIAL FOR USING WILDFLOWER SPECIES TO INCREASE NATURAL HABITAT IN CONTOUR SURFACE MINE RECLAMATION

by

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Abstract. While non-native herbaceous species are commonly used for mine reclamation, these species have low wildlife and aesthetic value and may inhibit long-term succession. The goal of this study was to determine the suitability of wildflowers for surface mine reclamation in the Appalachian mountains. A seed mixture composed of native and naturalized wildflower species was compared to the standard revegetation mixture by testing greenhouse germination rates of all species in both mine spoils and potting soil and establishing field plots at reclamation sites in southwestern Virginia. In May 1993, two 9-m^2 (97-ft^2) plots were seeded with each revegetation mixture on four slopes with different aspects. Vegetation cover and composition were recorded in all plots during the 1993 and 1994 field seasons. Wildflower species had germination rates ranging from 0-52%. In field studies, all but 2 of the 14 species of wildflowers seeded became established in study plots, while only 4 of the 8 species in the standard mixture were recorded. Cover was highly variable among plots on different aspects seeded with the same mixture. In most cases, total vegetative cover did not differ significantly between plots seeded with different mixtures. Some native and naturalized wildflower species appear to have potential for use in mine reclamation and could be included with standard revegetation mixtures in order to provide more native diversity. However, further research is necessary due to a number of factors confounding these results, including the low seeding rates used, drought conditions during the 1993 field season, and problems with regrowth of previous vegetation.

Additional Key Words: biodiversity, restoration.

Introduction

Large areas of land in the Appalachian region of United States have been disturbed by coal surface mining. According to the Office of Surface Mining, in Virginia alone nearly 50,000 ha (123,000 acres) have been disturbed by mining since passage of the Surface Mining Control

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[1]Paper presented at the National Meeting of the American Society for Surface Mine Reclamation, Knoxville, Tennessee, May 19-25, 1996.

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[3]The authors thank Ken Hyer for field assistance. For assistance on various aspects of the project, the help of Robert Lyons, Eric Smith, and Tom Wieboldt is greatly appreciated. Funds were provided by the Mobil and Du Pont Education in Aid programs and the Virginia Tech Graduate Student Assembly. Penn Virginia provided lodging for researchers.

Proceedings America Society of Mining and Reclamation, 1996 pp 453-461
DOI: 10.21000/JASMR96010453

and Reclamation Act (1977). The majority of these areas was revegetated using a few non-native grasses and legumes, including red top, Kentucky-31 tall fescue, orchard grass, clover, sweet clover, and birdsfoot trefoil. While these species provide rapid cover for erosion control and are inexpensive to seed, they provide little wildlife value and may inhibit long-term succession (Brenner et al. 1984; Burger and Torbert 1990; Hughes 1992).

In recent years, interest has increased in using wildflowers to revegetate disturbed areas such as landfills and roadsides. Wildflowers not only improve the aesthetic quality of an area, but they provide nectar and forage resources for wildlife and allow for the establishment of later successional plant species (Luken 1990). The goal of this project was to test the potential for using a number of native and naturalized wildflower and grass species for mine reclamation.

Site Description

This research was performed in Wise County, Virginia. The sites are located on the Powell River Project research area (PRP), an approximately 700-ha (1700-acre) area, about 125 ha (310 acre) of which have been mined. The PRP is a cooperative research program administered by Virginia Tech. The pre-mining soil in this area is comprised of acidic and infertile sandstones, siltsones, and shales (Daniels and Amos 1985).

The areas where test plots were located had been seeded prior to initiation of the experiment. North and south facing aspects were seeded in spring 1992; cover was predominantly birdsfoot trefoil, Kentucky 31-tall fescue, and perennial rye (*Lolium perenne*) at the initiation of the study. East and west facing slopes were seeded a few months before the start of the experiment and annual rye was just beginning to emerge.

Methods

Seed Selection and Preparation

The standard seed mixture consisted of species commonly used for mine reclamation in the region (Table 1). A list of native and naturalized wildflowers and grasses that would be tolerant of open canopy and drought conditions was compiled based on information provided by local horticulturalists and naturalists and a number of regional floras (Wofford 1993; Harvill et al. 1992; Radford et al. 1968). The preliminary wildflower species list was reduced to species for which seeds could be obtained from wildflower seed companies in the United States (Table 1).

Germination Studies

In March 1993, germination tests were conducted on seeds from different sources to determine germination rates. One hundred seeds of each species from both the standard and wildflower species mixtures were sown in two soil types in 0.093-m^2 (1-ft^2) flats in greenhouses. Soil types included a control potting soil (a 3:1:1 mixture of peat, perlite, and vermiculite), and soil collected from the top 5 cm of areas adjacent to the experiment plots. Seeds in each flat were watered daily, and the number of germinating seeds was counted every 3 to 4 days for approximately 30 days.

Site Preparation

In April 1993, two 10 x 5-m (33' x 15') plots were marked on each of four aspects, north, south, east, and west, on shallow slopes of reclaimed mine sites at the PRP. Two 9-m^2 sub-plots were marked in each of the plots with a space of 0.5 m (1.6-ft) separating the sub-plots. Permanent sub-plots of 1-m^2 (11-ft^2) were marked at the center of each 9-m^2 sub-plot for cover surveys. In

total, each mixture was seeded in eight sub-plots at each site.

The standard revegetation mixture from hydroseeding conducted the previous year began to emerge in March. In April, plots were sprayed with a glyphosate herbicide (Roundup®, Monsanto) to eradicate preexisting vegetation. Roundup® is a topically applied, systemic herbicide that kills nonwoody plants; however, it does not affect seed viability. A 0.5% solution of concentrate was mixed with water on site, and plots were sprayed using a backpack sprayer. Each block was sprayed twice, with an interval of 12 days between sprayings. All vegetation soon displayed symptoms of chlorosis and died within 14 days of spraying.

In May, each 9-m^2 sub-plot was seeded with either the standard or wildflower revegetation mixture. Seed mixtures were preweighed for each sub-plot, with seeding densities for the wildflower mixture calculated according to standard specifications from national wildflower seed companies. Most companies recommended sowing 100-120 seeds per 0.093 m^2 (1 ft^2) to provide maximum coverage of disturbed areas. Pure live seeds estimates were not used because they were not available from all companies. Grasses were seeded at a density of 270 gm/ha (0.25 lb/acre) for each species. One species, showy evening primrose, was only seeded on north and south facing aspects because of a shortage of seed. Seed amounts in the standard mixture were determined differently because the donated seeds had arrived premixed. An estimation of the number of seeds was made based on the number of seeds commonly found per gram of each species and then multiplied by the number of seeds needed to complement the number of seeds being seeded in the wildflower mixture. A total of approximately 11610 seeds were mixed with 500 g (1 lb) coarse construction sand and spread by hand broadcasting on each 9-m^2 sub-plot.

Table 1. Percent germination of 100 seeds of each species in the standard reclamation and wildflower mixture in potting soil and mine soil.

Scientific name[1]	% Germination PS[2]	MS
STANDARD MIX		
Annual rye	87	93
Birdsfoot trefoil	65	62
Clover	64	71
Foxtail millet	62	50
Kentucky-31 tall fescue	69	63
Orchard grass	85	67
Red top	64	71
Sweet clover	69	57
WILDFLOWER MIX		
Annual sunflower	4	4
Bergemont	49	0
Big bluestem	29	37
Black-eyed susan	57	28
Catchfly	78	52
Cornflower	70	28
Dame's rocket	60	0
Lance-leaved coreopsis	51	48
Little bluestem	14	33
New England Aster	55	14
Perennial lupine	37	17
Plains coreopsis	71	38
Showy evening primrose	53	11
Stiff goldenrod	57	0

[1]Common names and addresses of seed suppliers listed in Appendix 1
[2]PS = potting soil; MS = mine soil

No fertilizers nor irrigation was applied to plots.

Vegetation Measurements and Analyses

The plots were monitored biweekly between late May and early September in 1993 and 1994. On each sampling date, percent cover and species richness of planted species were recorded in the 1 m^2 at the center of sub-plot. Percent cover and composition of naturally invading species were also recorded, but these data are not presented here.

Results of species richness and cover measurements were combined for north and south aspects, as well as east and west aspects, as results were similar. Species richness values include observations from the entire field season, while cover measurements from mid-August are reported.

Soil Analyses

In May 1993 and August 1994, composite soil samples were taken from each experimental plot. All analyses were done by the Virginia Tech Soil Testing Laboratory.

Results

Germination rates for species in the standard mixture were all ≥50% and were similar in both potting and mine soils (Table 1). Germination rates for species in the wildflower mixture were mostly ≥50% in potting soil but ≤50% in mine soils. Germination rates for species in the wildflower mixture were lower in mine soils for all species except the two grasses, little bluestem and big bluestem. One species, annual sunflower, had a 4% germination rate in both potting and landfill soil.

In the field experiments, species richness was significantly higher in wildflower plots in all cases except east and west plots in 1993 (Table 2). However, this would be expected as more wildflower species were planted. The percent of seeded species that germinated was also higher in wildflower plots. This difference was statistically significant on north and south facing plots in 1993 (Table 2).

Only four of eight species in the standard reclamation mixture became established, and one species, foxtail millet, was only observed in two plots in year 1 (Table 3). Dominant species in standard mixture plots in both 1993 and 1994 were birdsfoot trefoil and clover. Twelve of fourteen species in the wildflower mixture became established (Table 3). Only stiff goldenrod and little bluestem were not recorded in experimental plots. Lance-leaved coreopsis, plains coreopsis, and black-eyed Susan were widespread in both years. Two annuals, cornflower, and catchfly, were common in year 1, but were rarely observed in the year 2. Big bluestem, New England aster, Dame's Rocket and bergemont were not observed in year 1, but became established in year 2.

Total cover of planted species for both seed mixtures was low in both years, but increased from 1993 to 1994 (Table 4). Cover was much higher in north and south plots than in east and west plots, which may be due to reoccurrence of previously established vegetation on north and south plots. In 1994, cover levels were significantly higher in north and south plots seeded with the standard reclamation mixture. However, these plots were dominated by birdsfoot trefoil, which partially regrew from plants seeded before the study.

Soil pH, nitrate, and organic matter levels were much lower on east and west facing slopes at the time of seeding, while phosphorus, potassium, and calcium levels were similar (Table 5). None of these variables changed greatly within the 15-month study period. Seed mixture did not have a significant effect on any of the variables measured.

Discussion

Results of field studies suggest that a number of native and naturalized wildflower species have potential for revegetating mined areas, despite the many obstacles to establishing vegetation on these sites, such as low pH, soil compaction, elevated surface temperatures, water stress, and low nutrients. All but two of the wildflower and native grass species became established in experimental plots. Cover levels were similar in areas seeded with the standard reclamation and wildflower mixtures.

Table 2. Mean species richness and percent of seeded species that germinated for standard and wildflower mixtures in 1993 and 1994.

Year	Aspect	Species richness[1] Standard	Wildflower	p[2]	% of species germinating Standard	Wildflower	p
1993	North/south	2.3 ± 0.5	6.0 ± 0.8	***	28 ± 7	39 ± 4	*
	East/west	2.0 ± 0.0	4.0 ± 2.0	NS	25 ± 1	31 ± 16	NS
1994	North/south	2.3 ± 1.0	6.0 ± 1.4	**	29 ± 12	43 ± 10	NS
	East/west	2.3 ± 1.0	6.0 ± 1.4	**	31 ± 13	46 ± 10	NS

[1]Mean ± standard deviation

[2]NS = $p>0.05$, *$p<0.05$, **$p<0.01$, ***$p<0.001$

Table 3. Frequency and cover measurements for standard reclamation and wildflower species seeded on mine sites.

Scientific name	Number of plots[1] 1993	1994	Cover ranking[2] 1993	1994
STANDARD MIX				
Annual rye	-	-	-	-
Birdsfoot trefoil	8	8	3	4
Clover	8	4	3	1
Foxtail millet	2	1	-	-
Kentucky-31 tall fescue	-	-	-	-
Orchard grass	-	-	-	-
Red top	-[3]	-	-	-
Sweet clover	1	4	1	2
WILDFLOWER MIX				
Annual sunflower	6	-	1	-
Bergemont	-	5	-	2
Big bluestem	-	7	-	1
Black-eyed susan	8	8	1	2
Catchfly	3	-	1	-
Cornflower	6	1	2	1
Dame's rocket	6	2	1	1
Lance-leaved coreopsis	8	7	1	2
Little bluestem	-	-	-	-
New England Aster	-	4	-	2
Perennial lupine	3	2	1	1
Plains coreopsis	8	5	1	1
Showy evening primrose[4]	4	2	-	-
Stiff goldenrod	-	-	-	-

[1]Number of plots out of a total of eight in which each species was recorded

[2]Average cover of each species in mid-August using ranking system: 0-1% = 1, 1-5% = 2, 5-10% = 3, >10% = 4

[3]Represents no appearance of the species within the experimental plot

[4]Only seeded in four plots on north and south facing slopes

Table 4. Mean percent cover of standard and wildflower mixtures in 1993 and 1994.

Year	Aspect	Standard Mix[1]	Wildflower Mix	p
1993	North/south	16 ± 3	11 ± 3	NS
	East/west	1 ± 1	2 ± 3	NS
1994	North/south	4 ± 4	11 ± 5	NS
	East/west	49 ± 19	17 ± 5	*

[1]Mean ± standard seviation
[2]NS = $p>0.05$, *$p<0.05$

Table 5. Soil nutrients in experimental plots in 1993 and 1994.[1]

Aspect	Year	pH	P	K	Ca	NO_3-N	OM (%)
North	93	7.2	39	98	624	13	2.1
	94	7.3 ± 0.2	48 ± 2	88 ± 12	756 ± 57	10 ± 3	--
South	93	6.7	27	95	456	15	2.1
	94	6.9 ±0.5	24 ± 7	79 ± 5	504 ± 84	5.8 ± 1.3	--
East	93	5.0	19	98	252	3	1.0
	94	5.1 ± 0.1	16 ± 4	98 ± 35	285 ± 34	3.0 ± 0.0	--
West	93	5.0	48	98	468	3	1.2
	94	5.0 ± 0.1	39 ± 5	91 ± 12	387 ± 33	3.0 ± 0	--

[1]Samples from different sub-plots were composited before sampling in 1993. Sub-plots were analyzed separately in 1994. Values for 1994 are means ± standard deviation. All values except pH and OM are in mg/kg.

A number of annuals and perennials became established in year 1 which provide erosion control and attract pollinators, while a few additional perennials were observed in year 2.

While most wildflower species became established, overall cover values were quite low, ranging from 0-23% in plots seeded with the wildflower mixture. These cover levels provide minimal erosion control and are well below the 90% required by law. However, cover in plots seeded with the standard reclamation mixture were also low, ranging from 0-60%. There are a number of explanations for the low cover values. First, the extremely warm and dry conditions in Virginia during summer 1993 likely inhibited seed germination and seedling survival and growth. Total rainfall was 165 mm (0.65 in) below normal (the second lowest water year on record) and mean temperature was 2.4°C above normal. Second, the seeding rate used, approximately 39 kg/ha (35 lb/acre), may be considered too low for some mine reclamation conditions (Bradshaw 1980). The seeding rate used was chosen according to specifications of the seed suppliers. As results of the germination test show, germination rates may be reduced on soils from mined areas and higher seeding rates may need to be used.

Seeding on previously vegetated areas clearly confounded interpretation of results. First, on areas that were previously seeded, cover and species richness levels of the mixtures seeded for this study were higher than on open areas. The higher establishment rate may be due to more favorable soil conditions on these sites, including higher pH, nitrate, and organic matter. It may also be due to shade provided by dead vegetation. In addition, dead vegetation may prevent seeds from washing away during heavy rainfall. Second, as some of the prior vegetation regrew after being treated with herbicide, it is impossible to make accurate comparisons of cover between the two seeding mixtures.

In this study, results of greenhouse germination tests contradicted those of field studies. In the germination tests, most species in the standard reclamation mixed showed similar germination rates in potting and mine soil, while most species in the wildflower mixture showed lower germination rates in the mine soil. Conversely, more species from the wildflower mixture became established in field tests. One species, annual sunflower, had very low germination rates in both soils, but became widely established in field studies. Little bluestem, one of the two species that showed higher germination in mine than potting soils, was not observed in field studies. These results suggest that greenhouse germination studies are not a good indicator of the response of many species under field conditions.

While a number of native and naturalized herbaceous species show potential for mine reclamation, widespread use of these species may be limited by cost and seed availability. The cost of wildflower seed mixtures is approximately $55/kg ($25/lb) while reclamation seed mixtures normally cost around $22/kg ($10/lb). However, individual wildflower species range greatly in price, as do the number of seeds per pound. For instance, black-eyed Susan costs $44/kg ($20/lb) which contains 1,700,000 seeds, while lupine costs $49/kg ($22/lb) which contains only 21,300 seeds. A few of the cheaper species, such as plains coreopsis, lance-leaved coreopsis, plains coreopsis, big bluestem and black-eyed Susan, could be included in a standard reclamation mixture without elevating the price greatly. An associated problem is that seeds of many native species are not available commercially in large quantities. Presumably, if demand for these species increases, they will become more widely available.

Future Research

A number of areas of research would be useful to better evaluate the potential of native and naturalized wildflower species for mine reclamation. First, research is necessary on mixtures of species including both non-native species commonly used for reclamation and wildflower species. Using such a mixture would likely provide sufficient cover while increasing wildlife value. Second, experiments should be done using different seeding rates to determine ideal seeding rates for mine soils. Third, combining mulch with the seeding mixtures should be tested as it may elevate germination and survival rates in a similar manner to the dead vegetation on the plots in this study. Finally, more information is needed on the effect of the different seeding mixtures on long-term ecosystem succession.

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Appendix 1. Species scientific names and seed suppliers.

Common Name	Scientific Name	Seed Provider
STANDARD MIX		
Annual rye	*Secale cereale*	1
Birdsfoot trefoil	*Lotus corniculatus*	1
Clover	*Trifolium* spp.	1
Foxtail millet	*Setaria italica*	1
Kentucky 31-tall fescue	*Festuca arundinacea*	1
Orchard grass	*Dactylis glomerata*	1
Red top	*Agrostis alba*	1
Sweetclover	*Melilotus* spp.	1
WILDFLOWER MIX		
Annual sunflower	*Helianthus annuus*	2
Bergemont	*Monarda fistulosa*	3
Big bluestem	*Andropogon gerardii*	2
Black-eyed susan	*Rudbeckia hirta*	4
Catchfly	*Silene armeria*	2
Cornflower	*Centaurea cyanus*	4
Dame's rocket	*Hesperis matronalis*	4
Lance-leaved coreopsis	*Coreopsis lanceolata*	4
Little bluestem	*Schizachrium scoparius*	3
New England aster	*Aster novae-angliae*	2
Perennial lupine	*Lupinis perennis*	4
Plains coreopsis	*C. tinctoria*	4
Showy evening primrose	*Oenothera speciosa*	5
Stiff goldenrod	*Solidago rigida*	5

[1]Country Boy
1811 Gate City Hwy.
Bristol, TN 24201

[2]Applewood Seed Co.
5380 Vivian St
Arvada, CO 80002

[3]Prairie Nursery
P. O. Box 306
Westfield, WI 53946

[4]Lofts
P. O. Box 146
Bound Brook, NY 08805

[5]S&S Seeds
P. O. Box 1275
Carpenteria, CA 93013