Use of Alternative Topsoil Materials in Surface Mine Reclamation

by

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Introduction

Some of the soils at mining sites in West Virginia have properties that make them less than ideal for mined land topsoil. Some of these soils are shallow, some are clayey, some are infertile, some are acid (pH < 5.0), and some have all of these properties. Therefore, when these materials are saved and used as topsoils on mined lands, they often require large applications of lime and fertilizer.

Some operators have begun to use crushed sandstone or other materials from the coal overburdens as topsoil substitutes. Generally, these materials have been analyzed in a laboratory, but plant growth studies, other than the establishment of vegetation at the mine site, have not been initiated.

These potential topsoil substitutes should be studied to determine which ones will or will not adequately support vegetation. Other information that is needed includes treatments that are necessary to obtain optimum plant growth and long-term plant-soil relationships. It is a well known fact that some overburden materials appear to have excess neutralizers in the fresh, unweathered state but become acidic after a certain period of time.

Since the growth of vegetation is such an important part of the total reclamation of a mine site, it is important that all topsoil materials be evaluated for their plant growth potential.

The purpose of this study was to evaluate the establishment and growth of vegetation on four soil materials: (1) spoil, (2) original soil, (3) crushed sandstone and (4) a mixture of crushed sandstone and original soil.

Methodology

As originally proposed the topsoil substitute study was to be a field experiment with plots established by procedures normally used in materials handling and vegetation establishment by the surface mine operator. Due to problems which prevented the establishment of plots at the mine site, an alternative study design was implemented to evaluate the topsoiling materials. This design involved the construction of minesoil profiles within cylindrical containers which were placed outdoors at the WVU Plant Sciences Farm at Morgantown, WV. The minesoil profiles included the following:

1. Spoil only (36 inches deep)
2. Spoil with a covering of crushed sandstone at depths of 6, 12 and 18 inches.
3. Spoil with a covering of stockpiled topsoil at depths of 6, 12 and 18 inches.
4. Spoil with a covering of a 1:1 mixture of crushed sandstone and topsoil at depths of 6, 12, and 18 inches.

Each treatment was replicated three times and incorporated into a randomized complete block design. Ammonium nitrate, triple superphosphate, and potassium chloride were added at a rate equivalent to 672 kg/ha (600 lbs. per acre) of 10-20-10. Lime was added where needed at rates recommended by the WVU Soil Testing Laboratory according to a lime requirement determination. Fertilizer and lime were incorporated into the surface of the soil to a depth of 6 inches. On June 16, 1983, all soils were seeded at a rate equivalent to 22.4 kg/ha (20 lb. per acre) of KY-31 tall fescue (Festuca arundinacea Schreb) and 16.8 kg/ha (15 lb per acre) of Empire birdsfoot trefoil (Lotus corniculatus L.). Hay mulch was applied at 4.5 to 5.5 metric tons per hectare (2 to 2.5 tons per acre). Germination of both species occurred within seven days after the containers were seeded and mulched. Growth observations were made and temperature and rainfall parameters were monitored throughout the growing season. In September of 1983 all treatments were photographed, individuals of both seeded species were counted and average vegetation heights were recorded.

Results

Material Characterization: An array of physical and chemical analyses were performed on composite samples to characterize the spoil, topsoil, sandstone and the sand stone- topsoil mixture (Tables I-VI). Selected chemical analyses have been performed on samples representing the topsoiling materials in each container to observe variability and to evaluate plant-soil relationship at a later date. A summary of dominant soil properties for each material follows.

Spoil: This material is dominated by low chroma, grey sandstone, over 50 percent of which is composed of fragments greater than 2 mm, but less than 10 em. The fine earth fraction has a sandy loam texture and a low moisture retention difference. Chemically, this material is in an unweathered state, moderately high in total sulfur, but with a high neutralization potential yielding a net excess of neutralizers. The spoil has a 100 percent base saturation, neutral pH and relatively high concentrations of Fe, Mn, Cu and Zn.

Topsoil: The stockpiled topsoil is relatively free of large coarse fragments, has a loam texture, and a medium moisture retention difference. Chemically, this material is highly weathered, having low total sulfur and low neutralization potential. The topsoil is acid with a low pH and an extremely low base saturation with exchangeable aluminum dominating the cation exchange capacity. This material has a projected lime requirement of 12.3 metric tons per hectare (5-5 tons per acre) to bring the soil pH up to 6.4. Concentrations of extractable Fe, Mn, Cu and Zn are similar to the spoil.

Crushed Sandstone This material has been mechanically crushed and is free of large coarse fragments. The soil texture is a sandy loam and the moisture retention difference is low. The sandstone is in an unweathered state, with a neutralization potential exceeding maximum potential acidity as projected from total sulfur. The crushed sandstone has a 100 percent base saturation and a neutral pH. Extractable Mn concentration is noticeably lower in this material when compared to the topsoil and spoil. Extractable Fe and Cu concentrations are similar to the other materials and Zn appears somewhat higher.

Sandstone-Topsoil Mixture: This mixture of materials expresses properties which tend to compromise the differences in properties of the two parent materials. The soil texture is a sandy loam, with somewhat more clay than the sandy loam texture of the crushed sandstone, and this is reflected by the increased moisture retention difference of the 1:1 mixture over the sandstone. Chemically, this mixture has not had an opportunity to come to equilibrium with its components at the time of sampling. However, the chemical characteristics of the material tend to reflect a moderating influence of both components. The alkaline nature of the sandstone effectively eliminated the exchangeable aluminum of the topsoil and increased the base saturation to over 70 percent and the pH to over 5.0. This material has about 11.2 metric tons per hectare (5 tons per acre) excess neutralizers. Extractable Fe is slightly higher in the mixture than in either of the parent materials, while extractable Zn and Mn are lower in the mixture than in the sandstone and topsoil respectively.

Vegetation Progress: At the end of the first three months seeded vegetation was established in all containers. All treatments involving the spoil, sandstone and the 1:1 mixture of sandstone and topsoil were approaching what can be considered a successful establishment of cover with a desirable botanical composition of grasses and legumes. The factor of depth does not appear to have had a noticeable effect at this time. All of the treatments involving the topsoil material have shown less ground cover, lower number of individual plants, lower average vegetation height, and a lower percentage of legumes than the other materials involved (Tables VII and VIII).

After adding fertilizer and amending the topsoil with the recommended amount of lime, two possible sources of stress could be expected to account for differences in vegetation establishment among the various treatments. One is the possibility of water stress during periods of low rainfall. Although this past summer was quite dry, no wilting or loss of plant tissue was observed during dry periods on any of the treatments. Moisture retention difference, an indication of the available water holding capacity of a soil, does not exhibit any association with yield observations.

The other possible source of soil related stress could be expected from soil chemical constraints which may not have been ameliorated by the addition of lime and an N-P-K fertilizer. Future analysis of the harvested plant material should provide additional information regarding plant-soil relationships.

A small greenhouse demonstration in which the four topsoiling materials were seeded without any chemical or organic amendments has revealed that none of the materials are capable of supporting acceptable growth without such amendments. The topsoil failed to support any plant establishment, whereas the other materials have managed to maintain a very diminative growth of individuals which exhibited severe morphological symptoms of N and P deficiency.

TABLE I
Means of Acid-Base Accounting Analyses for
AMDTAC Topsoil Substitute Study

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AMDTAC Topsoil Substitute Study

Material	Fizz	pH	%S	MPA*	N.P.*
Spoil	2.0	7.4	0.302	9.42	30.90
Sandstone	0.0	7.5	0.056	1.75	11.44
Topsoil	0.0	4.4	0.002	0.07	0.28
1:1 mixture	0.0	5.1	0.088	2.76	7.23

*Neutralization Potential and Maximum Potential Acidity (%S x 31.25) are expressed as tons of $CaCO_3$ per 1000 tons of material.

TABLE II

Means of Exchangeable Cation
Analyses for AMDTAC Topsoil Substitute Study

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Means of Exchangeable Cation
Analyses for AMDTAC Topsoil Substitute Study

Material	Exch. Bases			Exch. Acidity		CEC	% Base Saturation
	Exch. Ca+2	Exch. Mg+2	Exch. K+1	Exch. Al+3	Exch. H+		
	meq per 100g						
Spoil	12.50	0.96	0.12	0.0	0.1	2.92	95
Sandstone	2.56	0.80	0.90	0.0	0.1	2.08	96
Topsoil	0.28	0.20	0.09	3.3	0.7	6.79	8
1:1 Mixture	2.62	0.72	0.11	0.1	0.3	4.50	74

TABLE III

Means of DTPA Extractable Fe, Mn,
Cu and Zn for AMDTAC Topsoil Substitute Study

TABLE III

Means of DTPA Extractable Fe, Mn, Cu and Zn for AMDTAC Topsoil Substitute Study

Material	Fe	Mn	Cu	Zn
	ppm			
Spoil	29.81	10.59	0.80	1.61
Sandstone	18.67	3.72	0.64	4.16
Topsoil	16.69	13.76	0.84	0.82
1:1 mixture	20.71	9.49	0.58	0.78

TABLE IV
Organic Carbon and Total Nitrogen Analyses of Topsoiling Materials for AMDTAC Topsoil Substitute Study

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Organic Carbon and Total Nitrogen Analyses of Topsoiling Materials for AMDTAC Topsoil Substitute Study

Material	% Total N	% Organic Carbon
Spoil	0.052	0.59
Sandstone	0.041	0.29
Topsoil	0.038	0.16
1:1 mixture	0.035	0.28

TABLE V
Moisture Retention and Moisture Retention Difference (MRD) of Topsoiling Materials for AMDTAC Topsoil Substitute Study

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Moisture Retention and Moisture Retention Difference (MRD) of Topsoiling Materials for AMDTAC Topsoil Substitute Study

Material	1/3 bar	4 bars	15 bars	1/3 bar-15 bars (MRD)
	% moisture			
Spoil	11	7	3	8
Sandstone	9	5	2	7
Topsoil	22	14	7	15
1:1 mixture	15	9	5	10

TABLE VI

Soil Texture of Topsoiling Materials for AMDTAC
Topsoil Substitute Study

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Soil Texture of Topsoiling Materials for AMDTAC Topsoil Substitute Study

Material	% sand	% silt	% clay	Textural Class
Spoil	68.7	19.2	12.1	Sandy Loam
Sandstone	75.3	16.2	8.5	Sandy Loam
Topsoil	37.8	42.6	19.6	Loam
1:1 mixture	61.8	25.2	13.0	Sandy Loam

TABLE VII

Species Stem Count*, Sept. 8, 1983,
AMDTAC Topsoil Substitute Study

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Species Stem Count*, Sept. 8, 1983,
AMDTAC Topsoil Substitute Study

Treatment Material	Treatment Depth	Vegetation type	Block 1	Block 2	Block 3	Treatment mean
Spoil	36 in.	Fescue	41	66	75	61
		Trefoil	52	37	43	44
Sandstone	6 in.	Fescue	46	75	81	67
		Trefoil	38	31	47	39
Sandstone	12 in.	Fescue	74	87	93	85
		Trefoil	50	44	27	40
Sandstone	18 in.	Fescue	70	79	94	81
		Trefoil	51	29	34	38
Topsoil	6 in.	Fescue	49	41	37	42
		Trefoil	3	8	8	6
Topsoil	12 in.	Fescue	38	51	74	54
		Trefoil	6	4	15	8
Topsoil	18 in.	Fescue	37	45	53	45
		Trefoil	5	1	13	6
1:1 Mixture	6 in.	Fescue	66	91	78	78
		Trefoil	37	34	48	40
1:1 Mixture	12 in.	Fescue	62	60	96	73
		Trefoil	52	13	58	41
1:1 Mixture	18 in.	Fescue	63	61	66	63
		Trefoil	30	57	23	37

*Number of stems greater than three inches in length

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TABLE VIII
Average Vegetation Height, Sept. 30, 1983
AMDTAC Topsoil Substitute Study

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Average Vegetation Height, Sept. 30, 1983
AMDTAC Topsoil Substitute Study

Treatment Material	Depth	Block 1	Block 2	Block 3	Treatment mean
		--------Height in inches-------			
Spoil	36 in.	5.0	4.0	5.0	4.7
Sandstone	6 in.	4.0	4.0	4.0	4.0
Sandstone	12 in.	5.5	4.5	5.5	5.2
Sandstone	18 in.	4.5	4.0	5.0	4.5
Topsoil	6 in.	3.5	2.5	3.5	3.2
Topsoil	12 in.	4.0	3.5	5.0	3.0
Topsoil	18 in.	3.5	2.5	4.0	3.3
1:1 mixture	6 in.	4.0	4.0	5.0	4.3
1:1 mixture	12 in.	3.0	3.0	6.0	4.7
1:1 mixture	18 in.	5.5	4.5	5.0	5.0