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ORGANIC AMENDMENTS COMPARED TO TOPSOIL REPLACEMENT FOR THE RECLAMATION OF PRIME FARMLAND

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ABSTRACT

The incorporation of organic amendments into reconstructed stripmine spoil may provide an alternative to topsoil replacement. This method may offer an extra advantage when the topsoil on the premined land is thin or eroded. The objective of this study was to determine the effects of incorporating various organic amendments in the surface spoil of stripmined prime farmland compared to topsoil replacement on corn (*Zea mays* L.) performance. This research was conducted on severely compacted spoils at Peabody Coal's Will Scarlet Mine near Stonefort, Williamson County, Illinois. Four manure rates (0, 50, 100 and 200 Mg ha^{-1}), a green manure crop (rye cereal, *Secale cereale* L.), and hairy vetch (*Vicia villosa* L.), and a sod crop (tall fescue, *Festuca arundinacea* (Schreb.) were incorporated into strip mine spoil.

All of the organic amendments increased organic matter content of spoil material, however, they only had a slight affect on soil bulk densities at the 0-30 cm depth. Corn leaf tissue analyses indicated that adequate amounts of nutrients were obtained by the corn from the amended spoil. The addition of the organic amendments into the strip mine spoil gave as good or better corn yields than topsoil replacement. Corn production on organically amended spoil offers a possible alternative to topsoil replacement on some strip mine prime farmland.

INTRODUCTION

The federal government enacted The Federal Surface Mining Control and Reclamation Act in 1977. This law sets forth specific guidelines for the reclamation of prime farmland. The law requires the separation and replacement of A, B, and C soil horizons in the reclamation process. The B and C-horizons may be combined if it can be shown together they are equal to or more favorable for plant growth than the segregated B-horizon.

Horizontal replacement of topsoil is required by the law. Generally, it's purpose is to provide favorable environmental conditions for crop growth by preserving soil organic matter. This provision is appropriate in areas where a thick topsoil layer is present. However, southern Illinois, Indiana, and western Kentucky have characteristically thin-layered A-horizons developed under forest vegetation which are quite low in organic matter. Dense clay pans have resulted from accumulative leaching from the A-horizon to the B-horizon. These clay pans restrict water penetration, drainage, aeration, and root penetration. Also, the pre-mine fields are sometimes sloping and moderately to highly eroded often with little topsoil remaining. A possible alternative to topsoiling may be the incorporation of various organic amendments to improve crop production and reduce reclamation costs. Many coal companies have cattle operations as part of their reclamation program. This offers an inexpensive and readily available source of organic matter. As an alternative, the incorporation of a grass/legume sod or green manure crop could provide a valuable source of organic matter.

Research work conducted by Barnhisel (1977) raised a question regarding the recommendation of topsoiling. The physical and chemical properties found in the available topsoil material may be less desirable than certain geologic materials found in the lower profile. Carter et al. (1973) observed that Illinois spoils contained more available nutrients than the topsoil except for nitrogen, but lacked organic matter. McFee et al. (1981) indicated that additional knowledge is required on mine overburden properties, placement, and plant growth potential. Although topsoil is required by law, the best plant growth medium may be other overburden strata that could be placed near the surface more efficiently and economically. Various combinations of substratum and B-horizon materials as subsurface rooting media were evaluated by McSweeney et al. (1981). Their findings suggest that in southern Illinois selective subsurface blending would produce a better soil than segregation and replacement of the B-horizon from mined soils. Area with problems in the B-horizon can be identified by soil survey interpretation.

One means of adding organic matter to mine spoils is the growing of a grass/legume sod building crop or a green manure crop, thus improving the soil's physical character. Carter et al. (1973) reported that the decomposition of forage residue contributes to organic matter accumulation. Above ground vegetation will improve soil structure thus reducing erosion and increasing infiltration. Johnston et al. (1942) observed that the growth of sod crops improved soil aggregation. Grandt (1978) noted that newly mined land should not be planted to row crops but seeded to a grass/legume mixture first to allow the soil to set properly. During this time, the soil's biological, physical, and chemical aspects will stabilize, thus allowing for the successful future cultivation of row crops.

The beneficial effects of organic matter applications in the form of animal manures have been studied. Hafez (1974) found that beef and dairy cattle manures on mine spoils had decreased the bulk density with each increasing rate of manure and the percentage moisture holding capacity increased proportionately. There was an improvement of soil structure through a higher degree of soil particle aggregation. Meek et al. (1982) evaluated the long-term effect of manure application rates (0-540 t ha^{-1}) on the various soil chemical and physical properties. Manure increased the soil organic matter 1.0-1.2 percent and about 30 percent of the organic matter which was applied remained five years later. Organic matter was an important factor contributing to increases in water intake rates.

Weathered soils with limiting chemical and physical properties in the subsoil horizon may be improved agronomically by mixing deeper strata with the limiting horizon (Stucky et al., 1986). However, compaction can have an adverse effect on the reconstructed profiles. Compaction destroys soil structure, increases soil strength and the size and the amount of macro — pore space. This pore volume is important in water infiltration and movement through the soil (Chong et al., 1986). McSweeney et al., 1987 reported that the lack of pore space restricts proper root development and proliferation thus restricting growth. Schroeder and Halvorson, 1988 noted that net soil water depletion was less in reclaimed soil profiles than on the undisturbed soil profiles. It was also observed that soil water depletion within the reclaimed soil was affected by topsoil thickness and spoil texture through effects on available water at planting and soil strength effects on root penetration.

The purpose of this study was to evaluate the effects of incorporating organic amendments into a mixture of unconsolidated overburden from surface mined prime farmland compared to topsoil replacement on corn (*Zea mays* L.) performance.

MATERIALS AND METHODS

Research Site

A field study was conducted at Peabody Coal's Will Scarlet Mine near Stonefort, Williamson County, Illinois. The research site, classified as Pit 16, was mined in October, 1977. The rooting media consisted of a mixture of 1.2-1.5 m of loess and 9-15 m of glacial till. Coarse fragments such as gravel or stones were not present on this spoil. An unmined Ava silt loam soil (Ava fine silty, mixed, mesic Typic Fragiudalf) near the research site was used as the experimental control. It had been in tall fescue (*Festuca arundinacea* (Schreb.) for five years prior to the initiation of this study.

Treatments

The following treatments were employed:

1. Unamended spoil.
2. Replacement of topsoil as required by law over the spoil to a depth of 30 cm.
3. Winter green manure crop of rye cereal (*Secale cereale* L.) and hairy vetch (*Vicia villosa* L.) planted annually each fall.
4. 50 Mg ha^{-1} animal manure (dry weight) incorporated into the surface spoil once.
5. 100 Mg ha^{-1} animal manure incorporated into the surface spoil once.
6. 200 Mg ha^{-1} animal manure incorporated into the surface spoil once.
7. One year old sod crop (planted in 1979) of tall fescue and planted to corn (*Zea mays* L.) in the Spring of 1980.
8. Two year old sod (planted in 1979) and planted to corn in the spring of 1981.

9. Three year old sod (planted in 1979) and planted to corn in the spring of 1982.
10. Unmined Ava silt loam soil (control).

Seedbed Preparation

The animal manure (horse) was applied only once at the beginning of the study and was incorporated into the surface spoil by chiselplowing and disking in the spring of 1979 prior to planting to a depth of about 20 cm. The nutrient analysis of one metric ton of manure was .7 kg of N, .22 kg P and .51 kg K. The sod and green manure crops were planted in the fall of 1978. The green manure crop was disked and plowed under each spring prior corn planting. All sites were limed and fertilized according to soil test requirements. The spoil site received an initial application of 90 kg ha^{-1} N, 90 kg ha^{-1} P, and 112 kg ha^{-1} of K in the fall of 1978. The unmined site received an application of 90 kg ha^{-1} N and 90 kg ha^{-1} of P. Both sites received 12.5 Mg ha^{-1} of limestone in the fall of 1978. Starter fertilizer at the rate of 5 kg N, 11 kg P, and 21 kg K ha^{-1} was applied each year at planting.

Experimental Design

The experiment consisted of ten treatments completely randomized. Each treatment consisted of a plot 9 m by 22 m divided into four quadrants so plant and soil samples could be sampled. True replication was not possible due to the nature and size of the equipment used to add the topsoil. The experimental site originally had a uniform soil free of any gradients such as slope or fertility.

Data was analyzed using the System for Applied Statistics (SAS) program (Barr et al., 1979). A one way analysis of Variance and Duncan's Multiple Range Test were used to identify and separate significant differences among treatments.

Planting

Pioneer 3184 corn was planted in rows 75 cm apart using a hand corn planter. Two or three seeds were planted in hills 30 cm apart within rows, and corn was later thinned to one plant per 30 cm of row for a plant population of 43,500 plants per hectare. The corn was planted in 1979, 1980, 1981, and 1982. However, in 1980 there was a severe drought and therefore no corn yield data was obtained.

Weeds were controlled by use of Lasso (Alachlor) at 2.7 1/ha^{-1} (1.4 kg ha^{-1} a.i.) and Aatrex (Atrazine) at 5.0 1/ha^{-1} (2.5 kg ha^{-1} a.i.).

Corn Tissue Analysis

Corn leaf tissue samples were obtained 26 July 1979. A composite of 20 leaves was taken from each treatment within every sample. Sampling was done after tasseling by taking the first leaf below and opposite the corn ear. Samples were dried, ground in a Wiley Mill with a 2 mm screen. The nitrogen (N) content was determined by the standard Kjeldahl procedure using one half of each sample. Remaining samples were sent to a private laboratory to determine phosphorus, potassium, calcium, magnesium, sulfur, boron, copper, iron, magnesium, and zinc.

Harvest

An area 10 m^2 (2 rows 6.7 m long) from each of four replicates within each treatment was hand harvested. Corn was shelled, weighed, and tested for moisture content and yields were adjusted to a standard 15.5 percent moisture content.

Soil Analysis

Soil organic matter was determined for all treatments from samples taken early each spring at the 0-30 cm depth. Soil samples were air-dried, ground through a 10 mesh sieve, and analyzed using the Wakley-Black Organic Carbon Method (Allison, 1965).

Undisturbed surface soil cores were taken to 30 cm depth before seedbed preparation in the spring of 1979, 1981, and 1982 with an Uhland soil sampler to ascertain bulk densities for each replicate on all treatments. Subsurface (greater than 30 cm) cores were collected prior to the 1982 growing season only. Because it was assumed that the unamended spoil represented a uniform soil material, two sampling sites per treatment were used. Soil moisture percentages were determined to observe soil water depletion by the corn.

RESULTS AND DISCUSSION

The soil organic matter content in the 0-30 cm depth varied widely among treatments (Table 1). The replaced topsoil had a lower initial organic matter content (1.47%) than the unmined Ava soil (2.24%). The replaced topsoil was obtained from a sloping area which previously had some soil erosion, whereas, the unmined Ava soil site was level with little or no erosion. After cropping the control site which had previously been in a tall fescue sod for five years, soil organic matter decreased and then tended to stabilize somewhat. The lowest organic matter level on the mined soil was observed on the unamended spoil. Organic matter percentages tended to increase with increasing manure rates, however, they generally declined somewhat each year following the one time application of manure. There was a slight upward trend in organic matter content from one year sod (four years in cultivation) to the fourth year sod which had not been cultivated. With each additional year that the sod crop was cultivated, the organic amendments from incorporation underwent further decomposition.

In 1983, generally there was a slight increase in the soil organic matter percentages of the treatments over 1982. This may be attributed to the larger supply of fresh organic residues incorporated from the previous year.

Bulk densities were determined for all treatments for the 0-30 cm depth (Table 2). The various organic amendments had only a slight effect on soil bulk densities for all mined spoil treatments. Although the organic matter levels for the manure amended treatments decreased somewhat with time, the bulk densities stabilized at about the same levels. The green manure and sod treatments tended to increase in organic matter content and decreased in bulk density over time. Increased organic matter levels were attributed to yearly additions of plant residues incorporated along with the impact of rooting in the spoil from the grasses and legumes grown which improved soil structure and decreased bulk densities.

Subsurface bulk densities for the mined spoil treatments and the unmined Ava were also obtained (Table 3). Bulk densities varied slightly from 1.71 g/cc to 1.75 g/cc on the mined spoil. This was much higher than on the unmined Ava soil which ranged from 1.48 g/cc to 1.52 g/cc. These higher bulk densities severely restricted root penetration and impeded water movement.

Leaf tissue analyses of corn grown on amended spoil of mined prime farmland are presented in Table 4. It appears from the corn tissue analyses that plant nutrients were not a limiting factor in grain production on any treatment (Vitosh et al. 1973). These results suggest that there were adequate amounts of available nutrients in the spoil which were taken up by the corn.

Corn grain yields are given for 1979, 1981 and 1982 in Table 5. There was a severe drought in 1980 resulting in the loss of the entire crop. In 1979, corn grain yields were increased significantly over the unamended spoil by incorporating animal manure into the surface spoil. Grain yields on the 100 and 200 Mg ha^{-1} animal manure treatments were comparable to the unmined Ava silt loam treatment. Grain yields on the unamended spoil in 1979 were comparable to the topsoil replacement treatment. During this cropping season, however, the corn on the topsoil replacement treatment grew off faster than on the unamended spoil and encountered a severe dry spell at pollination. This resulted in lower grain yields on the replaced topsoil treatment. In subsequent years, there were no real differences in yield between these two treatments probably due to the fact that fresh organic residues were being added each year to the unamended spoil. The green manure treatment gave the lowest corn grain yield in 1979.

The organic amended treatments (animal manure, green manure and sod) gave higher corn grain yields than the topsoil replacement in both 1981 and 1982. This difference may be due to the potentially higher productivity of the amended spoil material. Pollination of the corn on the topsoil replacement treatment was also earlier than that on the organically amended spoil treatment when moisture conditions were more favorable.

Soil moisture percentages indicated that the rooting depth of the corn in the mined spoil was limited to the depth of chiseling (30-40 cm). The rooting depth of the unmined Ava soil was approximately 75 cm, the depth of the impermeable fragipan which accounts for some of the yield differences.

Organically amended spoil may provide a more favorable rooting medium for corn production than unamended spoil. While spoils generally lack nitrogen because of the loss of topsoil with its organic matter, this deficiency may be rectified with the addition of organic amendments (Fail and Wochok, 1977). The addition of manures to soils may also increase water intake (Hafez 1974 and Meek et al. 1982).

CONCLUSION

When bulk densities and compaction problems can be minimized through improved reclamation techniques, organic amendments and a mixture of B and C-horizons in lieu of topsoil replacement may provide a possible alternative to the segregation and replacement of A, B, and C soil horizons in the reclamation of mined prime farmland. However, crop production may be less than on unmined soil.

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Table 1. Mean percentages of soil organic matter for the 0-30 cm depth for all treatments on mined prime farmland in 1979, 1981, 1982, and 1983.

	Organic Matter			
Treatment	1979	1981	1982	1983
	%			
Unamended Spoil	0.38a*	0.31a	0.30a	0.40a
Green Manure	0.48a	0.37a	0.44a	0.81cde
50 Mg ha^{-1} Manure	0.97b	0.48a	0.37a	0.76bc
100 Mg ha^{-1} Manure	1.29c	0.88b	0.71ab	0.93e
200 Mg ha^{-1} Manure	1.96d	1.58c	1.23c	1.23f
1 Year Sod	—	0.49a	0.43a	0.71b
2 Year Sod	—	0.67ab	0.54a	0.73b
3 Year Sod	—	—	0.77b	0.76bc
4 Year Sod		—	—	0.91cde
Topsoil Replacement	1.47c	1.33c	1.35c	1.29f
Unmined Ava Soil	2.24	1.53	1.57	1.66

*Means in the same column followed by similar letters are not significantly different at the 0.05 level according to Duncan's Multiple Range Test.

Table 2. Mean soil bulk densities for the 0-30 cm depth for all treatments on mined prime farmland in 1979, 1981, 1982.

Treatment	Bulk Density		
	1979	1981	1982
	.... g/cc		
Unamended Spoil	1.60a*	1.54a	1.50ab
Green Manure	1.56a	1.47a	1.48abc
50 Mg ha^{-1} Manure	1.54a	1.50a	1.54a
100 Mg ha^{-1} Manure	1.40b	1.49a	1.47abc
200 Mg ha^{-1} Manure	1.32b	1.49a	1.48abc
1 Year Sod	—	1.48a	1.47abc
2 Year Sod	—	1.43a	1.42cd
3 Year Sod	—	—	1.44bc
Topsoil Replacement		1.45a	1.42cd
Unmined Ava Soil	1.32	1.33	1.35

*Means in the same column followed by similar letters are not significantly different at the 0.05 level according to Duncan's Multiple Range Test.

Table 3. Mean soil bulk densities 30-120 cm depths for all treatments on mined prime farmland in 1982.

Surface — mined Site		Unmined Ava Soil	
Depth cm	Bulk Density g/cc	Depth cm	Bulk Density g/cc
30-60	1.71	20-75	1.48
60-90	1.75	75-120	1.52
90-120	1.72		

Table 4. Leaf tissue analyses of corn grown on amended spoil of mined prime farmland (26 July, 1979).

Treatment	N	P	K	Ca	Mg	B	Cu	Fe	Mn	Zn
	%					ppm				
Unamended Spoil	2.74ab*	.26a	2.60b	.31b	.25abc	10.0a	20.0bc	121.3a	60.5b	33.0ab
Green Manure	2.53bc	.26a	2.37b	.31b	.26ab	9.3a	21.0ab	158.5a	79.3ab	39.5a
50 Mg ha^{-1} Manure	2.73ab	.24a	2.63b	.33b	.22cd	7.7a	19.5bc	123.7a	80.5ab	32.7ab
100 Mg ha^{-1} Manure	2.49c	.26a	3.05a	.32b	.18de	9.7a	17.0d	134.0a	59.3b	27.0c
200 Mg ha^{-1} Manure	2.60abc	.27a	2.59b	.35b	.15e	10.0a	18.7c	137.0a	53.7b	28.0c
Topsoil Replacement	2.74ab	.24a	1.91c	.34b	.29a	8.0a	21.0ab	132.3a	102.5a	27.3c
Unmined Ava Soil	2.77	.26	1.95	.48	.24	7.5	22.3	133.0	56.7	29.3

*Means in the same column followed by similar letters are not significantly different at the 0.05 level according to Duncan's Multiple Range Test.

Table 5. Mean corn yields (15.5% moisture) for all treatments on mined prime farmland in 1979, 1981, 1982.

Treatment	Corn Grain Yield		
	1979	1981	1982
	.... kg/ha^{-1}		
Unamended Spoil	6,892b*	5,666bcd	5,644bcd
Green Manure	5,941c	7,094a	6,368ab
50 Mg ha^{-1} Manure	7,374b	6,822abc	4,967cd
100 Mg ha^{-1} Manure	8,257a	7,424a	6,693ab
200 Mg ha^{-1} Manure	8,649a	6,794abc	6,717abc
1 Year Sod	—	6,576abc	7,065ab
2 Year Sod	—	5,305cd	7,673a
3 Year Sod	—	—	6,868ab
Topsoil Replacement	6,852b	4,724d	4,254d
Unmined Ava Soil	8,245	9,496	7,124

*Means in the same column followed by similar letters are not significantly different at the 0.05 level according to Duncan's Multiple Range Test.