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Organic and Inorganic Amendments Affect Vegetation Growth on an Acidic Minesoil

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Abstract

Organic amendments can be included in minesoil revegetation treatments to produce high-density ground covers or increase the yield of pasture and forage crops. They may provide an alternative to the "topsoiling" requirements under current surface-mining laws and regulations. In this study, shredded hardwood bark, composted municipal waste, and a tannery waste were applied to an acidic minesoil. Supplemental inorganic amendments including fertilizer, agricultural lime, and an alkaline waste from an SO_2 scrubber system were applied alone and in combination with the organic amendments. Treatment comparisons were based on vegetation response and chemical and physical characteristics of the minesoil after treatment. Organic amendments are not required for establishing vegetation though some reduced the time required to produce an acceptable cover. Site characteristics, land use objectives, and the availability of organic materials determine the appropriate amendment for a specific site.

Introduction

Nutrient availability, microbiological activity, and moisture efficiency are directly and indirectly affected by the organic matter in a soil. Organic matter is an important component of productive forest soils. Many of the less productive forest soils in the coal-producing regions of the Appalachians have relatively low percentages of organic matter. Fresh minesoils generally are deficient or lacking in this valuable component.

Previous research has been concerned with the use of organic materials as amendments for toxic spoils where other treatments have failed. The use of sewage sludge, manure, and composted municipal waste has been successful to some degree in revegetating toxic spoils (Sopper and Kardos 1972; Sopper et al. 1974; Sutton 1973; Lejcher and Kunkle 1974; Scanlon et al. 1973).

The successful revegetation of thousands of acres of nontoxic minesoil with inorganic fertilizer (with or without lime) demonstrates that organic amendments are not essential. However, it is believed that a high-density herbaceous cover can be produced in less time and that yields of pasture and forage crops will be higher when organic amendments are used. It has been suggested that organic amendments provide an alternative to the "topsoiling" requirements under current surface-mining laws and regulations.

In this study, shredded hardwood bark, composted municipal waste, and tannery waste were applied and disced into an acidic minesoil. We compared vegetation response and chemical and physical characteristics of the minesoil after these organic amendments had been applied. Fertilizer, agricultural lime, and an alkaline waste from an SO_2 scrubber system were evaluated as supplemental amendments.

Figure 1.—Estes aerospreader applying municipal waste.

Materials and Methods

The three organic amendments, shredded hardwood bark, composted municipal waste, and tannery waste, represent a wide range of physical properties and chemical composition. Shredded hardwood bark is a waste product from sawmills using debarkers. The bark is processed by passing it through a shredding machine that reduces the bark fragments to a more uniform size. Bark from many species of Appalachian hardwoods may be included but the oaks probably represent the greatest volume.

Composted municipal waste contains all materials commonly found in municipal garbage, including glass and plastics. A process that includes shredding, grinding, and composting produces a granular product. The composting process minimizes or eliminates pathogenic hazards. Potential plant and animal toxicities are controlled by excluding industrial wastes.

Tannery waste contains the organic residues and the chemical effluents from a tannery. This effluent is discharged into settling ponds to allow the solids to settle. It is an alkaline material with a high moisture content and the consistency of fresh manure.

Shredded hardwood bark was applied at a rate equivalent to 30 to 40 cubic yards per acre, composted municipal waste at 7 to 10 tons per acre, and tannery waste at 7 to 10 tons per acre, air-dried weight. The bark and the municipal waste were applied with an Estes[1] aerospreader (Fig. 1). The tannery waste was spread by hand; however, a conventional manure spreader would be more efficient for spreading tannery waste on large acreages.

A split-plot experimental design was selected for this study. Each of the organic amendments and an untreated control were randomly as-

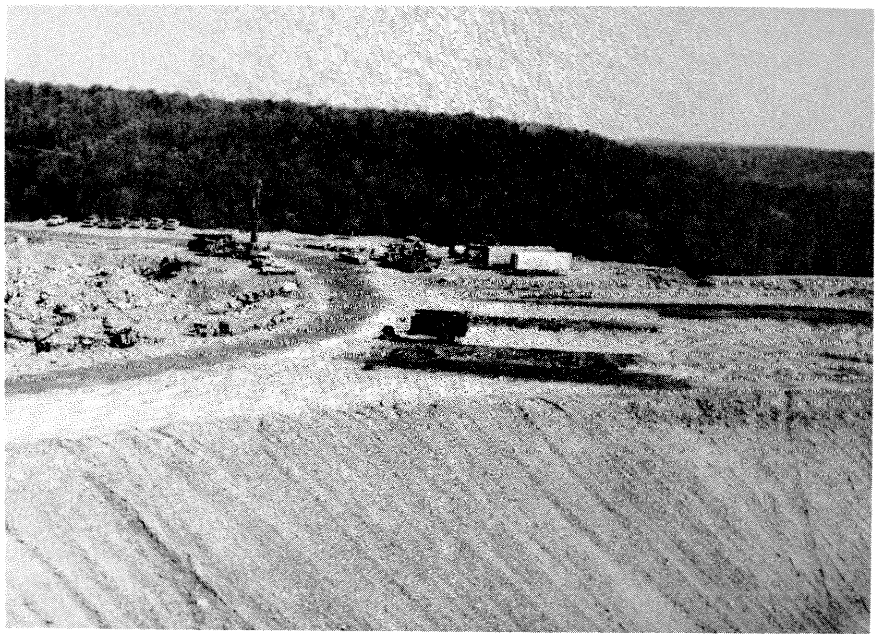
[1] The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

signed to one plot in each of three blocks. Each block had one common side with another block. The plots were subdivided into four subplots. Three inorganic amendment treatments were randomly assigned to three subplots. The fourth subplot was not treated with inorganic amendments. Diammonium phosphate fertilizer (18-46-0) was applied at a rate of 300 pounds per acre alone, and in combination with lime and scrubber waste. Agricultural limestone, the second inorganic amendment, represents a treatment often recommended for acidic minesoils. The third inorganic amendment, scrubber waste, was a waste product from an SO_2 scrubbing system for a coal-burning electric generating plant. In this system, limestone is used to remove SO_2 and other pollutants. The limestone must be replenished periodically and the residual material represents a large volume of industrial waste. It was included in the study to determine its potential for mined-land reclamation. The limestone and scrubber waste had similar calcium carbonate equivalents and both were applied at a rate of 3 tons per acre.

The study area is located on a relatively flat bench on a surface mine in Randolph County, West Virginia (Fig. 2). A coarse-textured shale and sandstone overburden was top-dressed with 4 to 6 inches of soil. The top-dressing was a mixture of the B and C horizons from a forest soil. Little or no A horizon was found at this site. This procedure is typical of many mining operations in West Virginia. Laboratory analyses of this top-dressing showed that pH ranged from 3.7 to 4.4 and that there was a deficiency of phosphorus. The soil texture was sandy loam to sandy clay loam.

The organic and inorganic amendments were applied, the plots were disced, and the following seed mixture was sowed:

Figure 2.—The study area after municipal waste and shredded bark had been applied.



Species	*Pounds per acre*
"K-31" tall fescue	10
Orchardgrass	5
Red clover	3
Alsike clover	2
Kobe lespedeza	5
Birdsfoot trefoil	5
Crownvetch	3

The study was established in May 1977. During the first three growing seasons, vegetative yield was determined by clipping a 4 ft^2 quadrat within each subplot. The green weight of all living plants was used to compare vegetation response to treatments.

Prior to the third clipping, the percent ground cover within each quadrat was estimated. The percentage of the total ground cover contributed by legumes was then estimated. These two estimates were used to obtain the percentage of each quadrat covered by legumes.

At the end of the first growing season, the bulk density of the surface 6 inches was determined by the rubber-balloon method. Water-holding capacity and total pore space were determined by conventional laboratory methods for soil particles 2 mm or less in size.

After three growing seasons, a sample was collected of the surface 6 inches of minesoil in each subplot to compare selected chemical characteristics. Specific conductance and pH were determined by conventional methods in which a spoil and distilled water mixture are used. Available phosphorus was determined by the Bray No. 1 extractant solution. The titration method developed by Yuan was used to determine exchangeable acidity and aluminum. Available calcium, magnesium, and potassium were determined by atomic absorption methods.

Results

Vegetation Response

The green weights of all plant materials removed from each quadrat at each clipping date were used to compare vegetative response to the organic and inorganic treatments. Analysis of variance and Duncan's multiple range test were used to analyze the data.

During the first growing season, there was no significant difference in yield between plots treated with the organic amendments or in interactions between the organic and inorganic amendments. The inorganic amendments significantly influenced vegetation growth. Plots treated with lime and fertilizer and scrubber waste and fertilizer produced the highest yield (Table 1). There was no significant difference between these treatments. The plots treated with lime and fertilizer had significantly higher yields than plots treated with fertilizer alone.

After two growing seasons, there was a significant difference in yield between plots treated with organic amendments. Neither the inorganic amendments nor the interaction between organic and inorganic amendments significantly affected yield. The yields were highest on plots treated with municipal and tannery waste. Both treatments had significantly higher yields than the shredded bark treatment or the control, but there were no significant differences between treatments. The shredded bark plots had significantly higher yields than the control plots.

During the third growing season, both organic and inorganic amendments significantly affected yields and there was a significant difference in yield between replications. The interaction between organic and inorganic amendments was not significant. The municipal waste treatment had significantly higher yields than all other organic amendments and the control plots. Yields following the tannery waste treatment were higher than those for the shredded bark treatment or the control. There was no significant difference in yield between the shredded bark treatment and the control.

Plots treated with lime and fertilizer and scrubber waste and fertilizer had significantly higher yields than fertilizer alone or the control. Although there was no significant difference in yield between the lime and fertilizer and scrubber waste and fertilizer plots, the lime and fertilizer treatment had consistently higher yields than the scrubber waste fertilizer treatment.

There were significant differences in yield between replications during the third growing season. Chemical characteristics of the minesoil showed the replication with the lowest yield had significantly lower exchangeable aluminum and available phosphorus. Although not statistically significant, the replication with the lowest yield also had the highest median pH and mean specific conductance. Exchangeable acidity and available potassium were low and there was no consistent trend for calcium or magnesium.

Species composition is an important consideration in treatment comparisons. The species of grasses and legumes in the mixture have a range of tolerances to toxic ions, nutrient requirements, and compatability with associated

Table 1.—Average green weight yield for three growing seasons

Inorganic amendment	Organic amendment											
	Control			Shredded bark			Composted waste			Tannery waste		
	Growing season			Growing season			Growing season			Growing season		
	1	2	3	1	2	3	1	2	3	1	2	3
	Thousand pounds per acre											
Control	[a]	[a]	0.4	[a]	0.1	1.3	0.4	1.1	5.5	0.4	2.3	4.4
Fertilizer	[a]	[a]	.5	0.3	.9	1.8	.9	1.5	7.2	.8	2.1	4.7
Lime + Fertilizer	0.2	1.5	7.2	1.0	1.8	7.4	1.2	2.0	9.0	1.3	1.8	9.1
Scrubber waste + fertilizer	.3	1.2	7.1	1.1	1.9	6.0	.9	2.2	7.7	.9	2.0	5.3

[a] Average is less than 100 pounds per acre.

plants. These treatments may affect each of these tolerance factors directly or indirectly. The legumes are more responsive to toxicities, nutrient availability, and competition than many grass species. Therefore, the percentage of the ground cover contributed by legumes was related to the treatments. Each of the organic amendments when used alone increased the percentage of legumes on the plots (Table 2). The use of fertilizer with the organic amendments resulted in a slight increase in the percentage of legumes. The addition of lime or scrubber waste and fertilizer created conditions that allowed the legumes to dominate the cover. This occurred for all organic amendments as well as the control.

Birdsfoot trefoil dominated the legume cover but red clover and crownvetch contributed on many plots. Alsike clover and Kobe lespedeza were not present after three growing seasons though they were included in the seed mixture. Crownvetch was found on all plots treated with lime or scrubber waste, and on plots treated with tannery waste and fertilizer.

Physical Properties

One year after treatment, bulk density, total pore space, and moisture-holding capacity were determined for selected treatment combinations. No samples were collected on plots treated with fertilizer alone, or in combination with the organic amendments.

There was no significant difference between treatments for bulk density or total pore space (Table 3). Analyses of the moisture-holding capacity show that subplots treated with scrubber waste had significantly lower moisture-holding capacity than the untreated control or the plots treated with lime. There was no significant differences in water-holding capacity between the organic amendments.

Table 2.—Percentage of ground cover provided by legumes at the end of the third growing season

Inorganic amendment	Organic amendment			
	Control	Shredded bark	Composted waste	Tannery waste
	Percent			
Control	26	34	47	40
Fertilizer	21	36	53	52[a]
Lime + fertilizer	80[a]	68[a]	80[a]	62[a]
Scrubber waste + fertilizer	63[a]	68[a]	67[a]	58[a]

[a] Crownvetch found on one or more subplots.

Table 3.—Physical properties of mine soils 1 year after treatment

Treatment	Bulk density	Pore space	Moisture-holding capacity
	(g/cc)	*Percent*	
Control			
Control	1.45	54.7	8.7
Lime + fertilizer	1.38	59.2	9.7
Scrubber waste + fertilizer	1.34	60.5	8.5
Mean	1.39	58.1	8.9
Shredded bark			
Control	1.30	62.6	10.6
Lime + fertilizer	1.14	69.5	10.7
Scrubber waste + fertilizer	1.27	62.5	8.2
Mean	1.24	64.9	9.8
Municipal waste			
Control	1.22	69.7	10.1
Lime + fertilizer	1.07	67.5	10.0
Scrubber waste + fertilizer	1.22	65.2	9.4
Mean	1.17	67.5	9.8
Tannery waste			
Control	1.22	65.8	11.5
Lime + fertilizer	1.27	61.5	10.4
Scrubber waste + fertilizer	1.18	64.9	9.9
Mean	1.22	64.1	10.6

Chemical Properties

At the end of the third growing season, samples were collected from each subplot to assess the chemical characteristics of the minesoils. Parameters included were pH, specific conductance, exchangeable acidity, exchangeable aluminum, and available phosphorus, potassium, calcium, and magnesium. All data was analyzed by analysis of variance and Duncan's multiple range test.

Minesoil pH and specific conductance were significantly influenced by the organic amendments but not by the inorganic amendments (Table 4). The tannery waste treatment resulted in significantly higher values for both variables than all other treatments. Minesoils on the control plots had the lowest pH values. There was no significant difference in specific conductance between the control and shredded bark and municipal waste treatments.

Both organic and inorganic amendments reduced exchangeable acidity and exchangeable aluminum. Tannery waste treatments had significantly lower levels than all other treatments. All organic amendment treatments were lower than the control. Lime and scrubber waste significantly reduced exchangeable acidity and exchangeable aluminum, but there was no significant difference between these treatments.

The analyses show the tannery waste treatment and the untreated control had significantly higher levels of phosphorus than the bark or composted municipal waste treatments. The low levels of phosphorus on the bark and municipal waste plots may reflect a interaction between the organic amendment and the available phosphorus. The inorganic amendments did not affect phosphorus levels. There were highly significant differences in available phosphorus between replications; replication means ranged from 38.4 to 9.7 ppm.

There were no significant differences in potassium between plots treated with organic or inorganic amendments.

Table 4.—Minesoil chemical characteristics 3 years after treatment

Treatment	Median pH	Specific conductance	Exchangeable—		Available—			
			acidity	aluminum	P	K	Ca	Mg
		(mmho/cm)	(meq/100g)		(ppm)			
Control	3.9							
Control		0.060	3.8	3.0	31	43	84	26
Fertilizer		.088	2.5	2.2	31	43	68	50
Lime + fertilizer		.031	2.4	2.1	52	41	338	47
Scrubber waste + fertilizer		.058	2.5	2.1	36	44	338	35
Mean		.059	2.8	2.4	37	43	207	33
Shredded bark	3.9							
Control		.036	2.4	2.2	9	37	556	48
Fertilizer		.028	2.3	2.1	41	19	61	8
Lime + fertilizer		.092	0.7	0.6	15	35	465	65
Scrubber waste + fertilizer		.062	.6	.4	14	99	666	66
Mean		.055	1.5	1.3	20	47	437	47
Municipal waste	4.2							
Control		.079	3.2	2.4	12	40	159	20
Fertilizer		.034	1.8	1.6	7	30	185	15
Lime + fertilizer		.079	.5	.4	17	35	753	27
Scrubber waste + fertilizer		.046	1.3	1.0	16	28	419	15
Mean		.060	1.5	1.4	13	33	379	19
Tannery waste	4.8							
Control		.281	.2	.1	32	52	2290	136
Fertilizer		.162	.8	.8	17	29	1364	227
Lime + fertilizer		.208	.7	.7	39	65	831	103
Scrubber waste + fertilizer		.158	.2	[a]	65	40	1447	56
Mean		.202	.5	.4	38	46	1483	130

[a] Indicates a trace.

The tannery waste treatment greatly increased calcium and magnesium levels, but there was no significant difference between the other two organic amendment treatments or the control. The lime and scrubber waste treatments significantly increased calcium but not magnesium.

Discussions

The results of this study indicate that several organic and inorganic amendment options may be useful in establishing an herbaceous cover on acidic minesoil. The primary advantages are more rapid establishment of an effective cover and higher yields of pasture and forage crops.

The time required to establish an effective cover is an important consideration on many mine sites. Therefore, the time required to produce an effective ground cover—1,000 pounds of green forage per acre—provides a basis for reviewing the treatment options.

An effective ground cover cannot be established on this minesoil without organic or inorganic amendments. Acidity and exchangeable aluminum are believed to be contributing factors. The addition of 300 pounds of diammonium phosphate fertilizer alone did not increase yields. However, when fertilizer and lime or scrubber waste were used, an effective cover developed during the second growing season. These treatments also are favorable for legume growth.

When composted municipal waste or tannery waste were used, an effective cover developed in the second growing season without the benefit of fertilizer, lime, or scrubber waste. Shredded hardwood bark was less effective and required 3 years. These organic amendments reduced active acidity, exchangeable acidity, and exchangeable aluminum.

The use of fertilizer with the three organic amendments did not appreciably reduce the length of time required to produce an effective cover. It did increase yields when used with shredded bark and composted municipal waste.

Where lime and fertilizer were used with the organic amendments, an effective cover with a high percentage of legumes developed in the first growing season. Scrubber waste with fertilizer and the organic amendments were less effective than lime but an effective cover was produced in the first or second growing season.

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Errata Sheet -- Research Paper NE-502

Change "Composted waste" to "Municipal waste" in box headings in Tables 1 and 2.

Plass, William T. Organic and inorganic amendments affect vegetation growth on an acidic minesoil. Broomall, PA: Northeast. For. Exp. Stn.; 1982; USDA For. Serv. Res. Pap. NE 502. 7 p.

Shredded hardwood bark, composted municipal waste, and a tannery waste were applied to an acidic minesoil. Supplemental inorganic amendments including fertilizer, agricultural lime, and an alkaline waste from an SO_2 scrubber system were applied alone and in combination with the organic amendments. Treatment comparisons were based on vegetation response and chemical and physical characteristics of the minesoil after treatment. Organic amendments are not required for establishing vegetation, though some reduced the time required to produce an acceptable cover.

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Keywords: Bark mulch; composted municipal waste; tannery waste; grasses; legumes

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