EFFECTS OF PHOSPHATIC AMENDMENTS ON YIELD AND ELEMENTAL COMPOSITION OF CORN GROWN ON ACID MINESOILS[1]

by

J. C. Sencindiver and D.K. Bhumbla[2]

Abstract. Greenhouse experiments were conducted to evaluate the growth and chemical composition of three crops of corn grown on limed and unlimed minesoils amended with phosphatic clay, rock phosphate, and monocalcium phosphate. Application rates of phosphatic clay and rock phosphate were 288 and 576 mg P kg^{-1}. Phosphatic clay also was added at 1152 mg P kg^{-1}. Monocalcium phosphate was added at 50 mg P kg^{-1}, and a control had no phosphate amendment. Corn yields were higher on phosphatic clay-treated minesoils than on minesoils treated with rock phosphate or monocalcium phosphate. Yields were generally no better for the highest application rate than they were for the middle rate of phosphatic clay. Phosphatic clay improved the uptake of macronutrients by corn growing on both limed and unlimed minesoils. Concentrations of calcium and phosphorus were significantly higher in tissues of plants grown on phosphatic-clay treated minesoils than on minesoils with other treatments. Tissue concentrations of manganese decreased with increasing levels of phosphatic amendments.

Additional Key Words: rock phosphate, phosphatic clay, abandoned mine lands, amendments.

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[2] J. C. Sencindiver is Associate Professor of Soil Science and D. K. Bhumbla is a Research Assistant, Division of Plant and Soil Sciences, West Virginia University, Morgantown, WV 26506-6108.

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Table 1 -- Chemical and physical properties of minesoils and phosphatic clay used in greenhouse experiments.

Properties	Units	Materials		
		Sandstone Minesoil	Shale Minesoil	Phosphatic Clay
pH	--	4.03	3.74	7.5
Organic Carbon	%	0.05	1.01	0.3
CEC	meq/100 g	8.50	9.51	37.6
Exchangable Cations	meq/100 g			
Ca^{++}		3.54	1.02	17.4
Mg^{++}		0.79	0.52	10.2
K^{+}		0.05	0.15	0.3
Al^{+++}		1.63	4.00	ND
Extractable Metals	ppm			
Zn		2.24	8.54	6.0
Cu		0.44	3.56	2.7
Mn		57.20	42.60	1.0
Fe		28.50	60.10	57.7
Particle Size Distribution	%			
sand		68.50	22.60	8.1
silt		21.60	55.70	17.2
clay		9.90	21.70	74.6
Total Elements	%			
S		0.54	0.03	--
P		--	--	2.4
Lime Requirement	mg/1000 mg	2.50	12.50	--

Greenhouse Study

Greenhouse experiments were conducted in a randomized complete block design with three replications of seven treatments. Three weeks before the initiation of the experiment, 2.5 kg of soil were allocated to each of 84 polyethylene-lined plastic pots. Soil in one-half of the pots from each site was treated with $Ca(OH)_2$ to meet the lime grown on the same soils, and plant and soil samples were obtained in the same manner as described for the first crop. Both second and third crops received additions of N, K and Zn fertilizers at the levels applied to the first crop. No data for the second or third crops are presented in this paper, but they were presented in an earlier report (Bhumbla and Sencindiver, 1989).

Plant Analyses

Calcium, Mg, K, P, Zn, and Mn concentrations in plant tissue were determined by the following method: 1.0 g of ground plant tissue was digested with a mixture of HNO_3 and $HClO_4$ (3:1) in a tall 200-ml beaker in a perchloric acid hood. The digested residue was dissolved in 50 ml of 0.1 N HCl. Phosphorus was determined by the molybdivanadophosphoric acid method outlined by Kitson and Mellon (1944). Optical density was read at 470 mu. Calcium, Mg, K, Zn, and Mn were determined with a Perkin Elmer model 5000 atomic absorption spectrophotometer.

Results and Discussion

Plant Dry Matter Yield

In phosphate-treated unlimed sandstone minesoil, the highest yields were recorded for the phosphatic clay treatments (Table 3). Among the phosphate treatments, monocalcium phosphate had the lowest yield. Phosphatic clay increased the yield of the first corn crop by over seven times the yield of the control. The application of phosphatic clay at the first level produced significantly higher dry matter than that produced by rock phosphate.

When sandstone minesoil was limed, but had no phosphorus added, the yield of the first corn crop increased from 1.5 g pot^{-1} to 1.76 g pot^{-1} (Table 3). The yield increase

Table 3 -- Effect of phosphate treatments on dry matter yields of corn crops grown on limed and unlimed sandstone and shale minesoils.

	Sandstone		Shale	
Phosphate Treatments	Unlimed Corn Crop 1	Limed Corn Crop 1	Unlimed Corn Crop 1	Limed Corn Crop 1
	g pot^{-1}			
Control	1.50	1.76	1.70	2.60
Monocalcium phosphate	5.80	9.70	8.30	9.60
Rock phosphate - 1	8.50	2.70	9.90	8.70
Rock phosphate - 2	10.20	3.40	12.50	8.50
Phosphatic clay - 1	10.60	6.70	13.20	8.33
Phosphatic clay - 2	11.10	8.00	13.90	10.20
Phosphatic clay - 3	11.60	10.60	14.90	10.40
LSD (0.05)	0.75	0.97	0.75	2.17

Table 5 -- Effect of phosphate treatments on concentrations of phosphorus in plant tissue of corn grown on limed and unlimed shale and sandstone minesoils.

	Sandstone		Shale	
Phosphate Treatments	Unlimed Corn Crop 1	Limed Corn Crop 1	Unlimed Corn Crop 1	Limed Corn Crop 1
	---g kg^{-1}---			
Control	1.20	2.40	1.20	1.80
Monocalcium phosphate	2.25	1.80	3.60	4.65
Rock phosphate - 1	3.30	3.06	4.65	4.20
Rock phosphate - 2	3.45	3.30	5.25	3.90
Phosphatic clay - 1	3.45	2.55	4.35	3.30
Phosphatic clay - 2	3.75	2.85	3.70	3.60
Phosphatic clay - 3	3.90	2.55	3.90	3.90
LSD (0.05)	0.17	0.32	0.45	0.62

kg^{-1} (Table 5), the corresponding crop yield increase was 11.5 g (Table 3).

Manganese and Zinc. Manganese concentrations decreased with increases of phosphatic amendments (Table 6). The lowest plant tissue manganese concentrations were observed in phosphatic clay-treated soils. Phosphorus fertilizers are reported to increase the level of soil-solution manganese in most soils, probably because of acidic reaction of dissolved superphosphate or because of acidity produced by the nitrification of ammonium phosphate (Heintze, 1969). The decreased soil pH associated with high phosphorus rates was considered to be responsible for increased manganese uptake (Smilde, 1973).

There were two important reasons for the observed manganese depression by the phosphatic amendments. The amendments used in the present study had tribasic phosphates, so the applied phosphatic amendments were a sink for hydrogen ions. Soil solution concentrations of Mn^{2+}, as well as exchangeable Mn^{2+}, are governed by the solubilities of manganese oxides such as Mn_2O_3 and MnO_2 (Adams, 1980). Manganese from its (+4) and (+3) oxidation state can be reduced to (+2) oxidation state by ferrous ions (Jaurequi and Reisenauer, 1982). In the present study manganese reduction was controlled effectively by reducing the rate of ferrous iron production from pyrite oxidation. The formation of insoluble manganese phosphates was also responsible for the observed decrease in manganese concentration in plants with increasing phosphorus application.

There were significant differences in zinc concentrations in tissue of plants grown on minesoils (Table 7). The classic phosphorus-zinc interaction was observed. Increasing levels of phosphorus resulted in decreasing zinc concentrations in plant tissues. Similar observations of the phosphorus-zinc interaction have been reported by other researchers (Stukenholtz et al., 1966).

Conclusions

Phosphatic clay has potential for amending acid minesoils for revegetation purposes. Corn yields were higher on phosphatic clay-treated minesoils than on the same minesoils treated with rock phosphate or monocalcium phosphate. Yields were generally no better for the highest level (4.8% by weight) than they were for the second level (2.4% by weight) of phosphatic clay treatments. Phosphatic clay is a better amendment for unlimed than limed minesoils. Liming of both sandstone and shale minesoils prior to application of phosphatic clay or rock phosphate generally reduced yields.

Phosphatic clay improved the uptake of macronutrients of plants growing on both minesoils. Concentrations of Ca and P were significantly higher in the tissue of plants grown on the phosphatic clay-treated minesoils than on minesoils with other treatments.

When compared to the control, phosphate treatments significantly reduced the plant concentrations of Mn and Zn. However, differences between phosphatic clay treatments and other phosphate treatments were not always significant.

It appears that the second level of phosphatic clay additions (2.4% by weight) would be the most practical application. This application rate of phosphatic clay was generally better than an equivalent rate (based upon phosphorus content) of rock phosphate.

The overall conclusion of this study is that phosphatic clay is a better revegetation amendment on acid minesoils than rock phosphate. Differences between the effects of rock phosphate and phosphatic clay are related to surface area. All particles of phosphatic clay are less than 2 mm in diameter and 75% of those particles are less than 0.002 mm. The rock phosphate was ground to less than 60 mesh (0.25 mm), but most of the material was sand size (> 0.05 mm). Since this study was conducted in a greenhouse, these results need to be confirmed in a field experiment before they can be recommended for use in revegetation of mined lands.

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