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PHOSPHORUS SOURCES

Phosphorus Availability of Monocalcium and Diammonium Phosphates in Calcareous Soils

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Monocalcium phosphate monohydrate and diammonium phosphate were applied to calcareous soils and evaluated as phosphorus sources for oats by a short-term growth technique in the greenhouse. Soils were chosen on the basis of low available phosphorus and pH above 7. Several soil types which occur extensively in Minnesota were used. Monocalcium phosphate monohydrate and diammonium phosphate (−20-mesh) applied to calcareous soils by mixed placement were not found to be significantly different as phosphorus sources for oats. Phosphorus yield of oats grown on either treated or untreated soil did not show an inverse relationship to calcium carbonate equivalence. When the carbonates present as dolomite were subtracted from total carbonates, greatest phosphorus uptake by oats was from two soils with 0.2 and 4.0% calcium carbonate. There was no quantitative relationship between plant uptake of phosphorus and calcium carbonate equivalence of soils having between 9 and 24% calcium carbonate.

MONOCALCIUM phosphate (MCP) and diammonium phosphate (DAP) have been widely used as phosphorus (P) fertilizers. Ensminger (*6*) concluded, on the basis of 358 location-year experiments, that MCP and DAP applied with dolomitic lime were equally satisfactory as phosphorus sources for cotton. Beaton and Nielsen (*7*), comparing MCP and DAP on two calcareous soils, found that MCP increased yield of alfalfa more than DAP, while DAP increased per cent phosphorus more than MCP. There was no significant difference between MCP and DAP as indicated by total phosphorus yield. Bouldin and Sample (*3*) reported that MCP was superior to DAP as a phosphorus source for oats grown on a calcareous soil. The purpose of this study was to compare MCP and DAP further as phosphorus sources when applied to a larger number of calcareous soils.

Procedure

Bulk soil samples were taken from the plow layer of seven calcareous Minnesota soils, air-dried, screened, and thoroughly mixed.

Reagent grade $Ca(H_2PO_4)_2 \cdot H_2O$ (MCP) and $(NH_4)_2HPO_4$ (DAP) were used as the sources of P. They were passed through a 20-mesh sieve, washed in acetone, and placed in a calcium chloride desiccator.

Fertilizer salts were added to soils in three ways: mixed, banded, and spot-placed. When mixed placement was used, 1000 grams of soil and a given amount of fertilizer were placed in an end-over-end divider-type mixer and allowed to mix for at least 20 minutes. The soil-fertilizer mixture was then divided into five portions of 200 grams each and placed in 12-ounce wax-lined Dixie cups. For band placement fertilizer was mixed with 0.1 gram of pure 40-mesh quartz sand. The fertilizer-sand mixture was then placed in a circular band (5.5 cm. in diameter) $^1/_2$ inch below the surface of the soil. For spot application the fertilizer was placed in a single spot $^1/_2$ inch below the surface of the soil.

The soils were watered to $^1/_3$-atm. moisture content and maintained at this level for 2 weeks. After the incubation period the surface of the soils was leveled and available P determined using the short-term method of Stanford and DeMent (*14*). Oats used as the test crop were grown in sand culture for 14 days. The cultures were then placed on the surface of the test soils and allowed to grow for 9 days. Then the plants were clipped at the sand surface, dried, weighed, and per cent P was determined colorimetrically using the vanado-molybdophosphoric yellow color method in a nitric acid system (*7*).

Chemical determinations were made on soils treated in the same way as those used in plant uptake studies. Two replicates were prepared and sealed in polyethylene bags for 2 weeks. Samples were air-dried, ground, and analyzed in duplicate for available P by the Bray No. 1 (soil to solution ratio of 1 to 50), Morgan, sodium bicarbonate, and water-soluble methods (*2*, *4*, *11*, *12*). Phosphate content of the solutions was determined colorimetrically by the molybdenum blue method of Dickman and Bray (*5*). Boric acid was added to the Bray No. 1 extracts to reduce fluoride interference.

Calcium carbonate equivalence and per cent dolomite were determined by the manometric technique outlined by Skinner, Halstead, and Brydon (*13*).

Experimental Results

Some chemical characteristics of the soils under study were determined (Table I). These data show that the Clyde soil has a higher level of organic matter than the other soils. Bearden and McIntosh soils contain less calcium carbonate than others in this group.

Effect of Fertilizer Placement on Phosphorus Uptake by Oats. The objective of this study was to evaluate the short-term technique using various fertilizer placements. MCP and DAP were applied mixed, banded, or spot-placed at rates of 50 and 100 p.p.2m. P (parts per 2,000,000 P) or as 114.5 and 229 p.p.2m. P_2O_5, respectively, to Bearden, Clyde, and McIntosh soils. The results from all soils were averaged.

The results shown in Figure 1 indicate that under these conditions MCP and DAP were not different as phosphorus sources for oats.

At both rates of application mixed placement increased phosphorus uptake more than band placement, which was

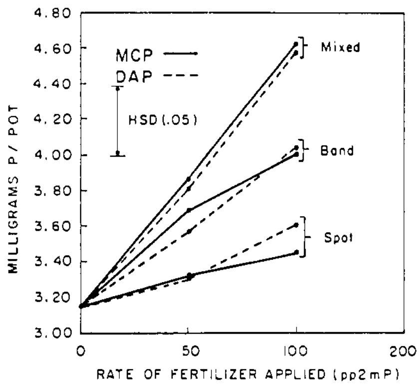

Figure 1. Phosphorus yield in oats as affected by rate and placement of fertilizer applied to Bearden, Clyde, and McIntosh soils

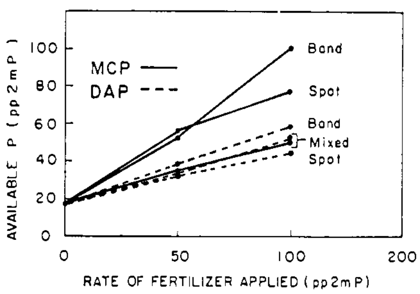

Figure 2. Sodium bicarbonate–extractable phosphorus as affected by rate and displacement of MCP and DAP applied to Bearden, Clyde, and McIntosh soils

better than spot placement, whether MCP or DAP was used at the source of phosphorus (Figure 1).

The fertilized Bearden, Clyde, and McIntosh soils were extracted with sodium bicarbonate to determine available phosphorus. Results in Figure 2, averaged over soils, indicate that MCP applied either as a spot or as a band was more available than DAP. When MCP and DAP were applied mixed, they were equally soluble in sodium bicarbonate. The method of application of DAP had little effect on the level of available phosphorus as indicated by sodium bicarbonate extraction.

Available phosphorus values found by sodium bicarbonate extraction were higher when MCP was applied as either a band or spot (Figure 2). The opposite effect was indicated by plant uptake data (Figure 1). We attribute the lower uptake of phosphorus by oats from spot and band treatments to limited root development and the short time available for uptake.

The data presented in Figure 1 show that the effect of rate of application of MCP and DAP on phosphorus uptake was larger when the materials were applied by mixed placement than by band or spot placement. To maximize the sensitivity of the method to differences between MCP and DAP, the fertilizers were applied by mixed placement in the following experiments.

Table I. Chemical Characteristics of Experimental Soils

Soil Type	pH	Organic Matter, %	$CaCO_3$ Equiv., %	Dolomite, %	Calcite, %
Bearden clay loam	7.8	4.2	10.2	62	38
Clyde muck	7.8	26.2	17.8	tr	100
Harpster clay loam	7.9	7.0	23.2	1	99
Hegne clay loam	8.0	3.5	12.9	35	65
McIntosh loam	7.8	4.2	1.0	81	19
Ulen sandy loam	8.4	3.4	12.8	tr	100
Webster clay loam	7.8	6.8	12.7	tr	100

Table II. Effect of Soils and Materials on Phosphorus Yield in Oat Tissue and Phosphorus Extracted by Various Chemicals

Soils	Fertilizer at 100 p.p.2m. P	Plant Uptake, Mg. P/Pot			Available P, p.p.2m. P			
		Expt. 1	Expt. 2	Expt. 3	Bray No. 1	Morgan	Sodium bicarbonate	Water-soluble
Bearden	None	2.10	3.43	2.87	72	53	35	6
	MCP	2.56	4.73	4.26	136	109	74	25
	DAP	2.86	5.06	4.33	134	110	74	22
Clyde	None	1.62	2.52	1.76	13	8	28	tr
	MCP	1.96	3.62	2.36	39	14	61	tr
	DAP	1.98	3.73	2.43	30	12	59	tr
Harpster	None	1.75		2.07	8	35	29	tr
	MCP	2.18		3.20	8	78	73	7
	DAP	2.10		3.26	11	76	67	5
Hegne	None	1.74		1.92	25	12	15	tr
	MCP	2.91		3.39	84	52	55	3
	DAP	2.70		3.38	84	52	58	2
McIntosh	None	1.73	3.08	1.96	33	12	16	2
	MCP	2.91	4.82	3.54	91	51	63	21
	DAP	2.70	5.00	4.22	93	53	55	18
Ulen	None	1.59	2.23	1.67	6	10	10	tr
	MCP	1.96	3.07	2.75	17	36	60	tr
	DAP	1.93	3.17	3.60	23	37	52	tr
Webster	None	1.73		1.81	22	29	13	tr
	MCP	2.03		3.00	59	70	54	3
	DAP	2.03		3.32	57	68	49	2
LSD	(0.05)	0.31	0.57	0.37	13	5	7	2

Effect of Application Rate on Phosphorus Uptake. MCP and DAP were passed through a 20-mesh screen, then applied by mixing to Bearden, McIntosh, Ulen, and Clyde soils at rates of 50, 100, and 200 p.p.2m. P.

Figure 3 *A* shows average phosphorus uptake by oats in all soils as affected by rate of application of MCP and DAP. MCP and DAP had an equal effect on phosphorus uptake at all the rates of phosphorus used (Figure 3 *A*). Phosphorus uptake by oats was significantly different between 0 to 50, 50 to 100, and 100 to 200 p.p.2m. P rates of MCP or DAP application to all soils.

Uptake of phosphorus by oats was dependent upon soil type. It was greater from treated or untreated Bearden and McIntosh soils than from Clyde and Ulen soils (Figure 3 *B*).

Comparison of MCP and DAP by Plant Uptake and Chemical Extraction. On the basis of the two previous experiments, MCP and DAP were more extensively studied. They were applied by mixed placement at a rate of 100 p.p.2m. P to seven calcareous soils. Both fertilizer materials had been screened so that the particle size was less than 20-mesh. When MCP or DAP is placed in moist soil, it will dissolve rapidly and within 2 weeks move into the surrounding soil. When water-soluble materials, such as MCP and DAP (particle sizes less than 20-mesh), are applied with mixed placement to soils containing calcium carbonates, it is probable that the properties of the soil will have a dominant effect on the nature of the reaction products formed. In this experiment these conditions were met. Short-term uptake of phosphorus by oats and chemical extractions for available phosphorus support the contention that the reaction products were similar (Table II).

Phosphorus content of oats and available phosphorus in soils are shown in Table II. In all cases phosphorus yield in oats grown on soils treated with MCP or DAP was greater than on untreated soils and was greater on McIntosh and Bearden soils than on other soils. This difference could be explained partly on the basis of differential phosphorus fixation due to carbonates present in these soils. Data in Table I show that the calcium carbonate equivalence of the McIntosh soil is only 1%, while in other soils it was from 10 to 24%. However, if the car-

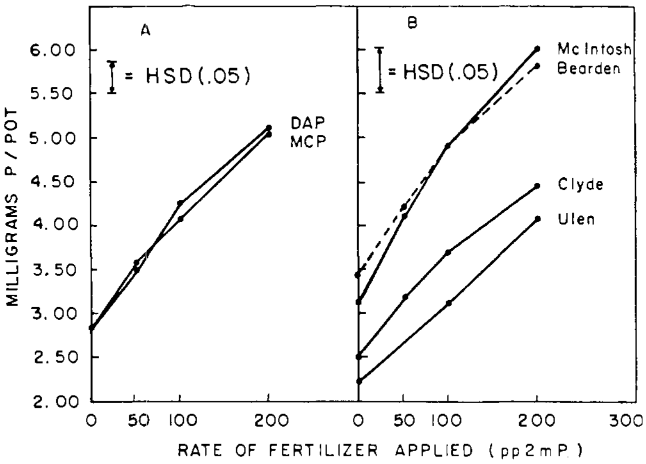

Figure 3. Phosphorus yield in oat tissue

A. As affected by P application rate in Bearden, Clyde, McIntosh, and Ulen soils
B. As affected by rate of application of MCP and DAP to soils

bonate present as dolomite is considered relatively inactive in the fixation of phosphorus, as indicated by MacIntire, Shaw, and Shuey (*8–10*), the soils may be divided into two groups. The McIntosh and Bearden soils contained 0.2 and 4% calcium carbonate, respectively; other soils from 9 to 24%. This may be the reason why water-soluble phosphorus values were higher on fertilized Bearden and McIntosh soils (Table II).

In all cases MCP and DAP were equally effective as phosphorus sources for oats grown on five of the seven soils, but in one experiment, phosphorus uptake by oats on the McIntosh and Ulen soils was greater with DAP than MCP. In greenhouse trials 1 and 2 no differences between MCP and DAP were shown (Table II). Available phosphorus as determined by extraction using Bray, Morgan, sodium bicarbonate, or water-soluble phosphorus methods did not indicate DAP to be more soluble than MCP on any of the soils. In fact, the sodium bicarbonate extraction indicated a higher level of available phosphorus in MCP than DAP-fertilized McIntosh and Ulen soils (Table II). On the McIntosh soil water-soluble phosphorus was also slightly higher with MCP than with DAP. There is no apparent reason why DAP should supply more phosphorus to oats than MCP in this one experiment.

Bouldin and Sample (*3*) compared MCP and DAP applied to the soil as a single pellet. They found a larger uptake of phosphorus when the Webster soil was treated with MCP than DAP, as shown by measurement of integrated water-soluble phosphorus around the fertilizer pellet. Sodium bicarbonate estimates of available phosphorus were higher when MCP was applied as a band or spot than DAP (Figure 2), but no differences were shown in plant uptake studies (Figure 1). Results presented in Table II were obtained in a system where MCP and DAP (−20 mesh) were intimately mixed with the soil. Chemical extractions for available phosphorus showed no differences between MCP and DAP.

One would expect phosphorus availability to be influenced more by fertilizer than soil properties when applied as a single spot, but that soil properties (carbonates) would dominate when the fertilizer was applied by mixed placement. Results obtained in this study show that when MCP and DAP were applied to the soil by mixing, phosphorus was equally available from both sources. This is in agreement with the results of other workers who examined these materials on calcareous soils or in the presence of lime (*1, 3, 6*).

Results from three greenhouse trials run at different times (reported in Table II) show that the absolute values for phosphorus uptake varied between trials, but that the phosphorus uptake pattern as affected by soils and fertilizer was the same in all three trials. Short-term studies of phosphorus uptake by oats and chemical extractions for available phosphorus indicated that MCP and DAP (−20 mesh) applied to calcareous soils by mixed placement were equally good phosphorus fertilizers. Since results of plant studies are in agreement with chemical extraction data, we feel this conclusion is valid.

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