CROPPING SYSTEM EFFECTS ON PHOSPHORUS RESPONSE OF CORN[1]

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Today's corn producer performs less tillage than in the past and predictions indicate that even less will be done in the future. Changes in management practices involving different tillage and residue incorporation practices alter the dynamics of organic matter turnover in soil and may influence the supply of plant nutrients. To maximize efficiency, it is critical that information be available to guide fertilizer management adjustments for specific tillage and rotation systems. A tremendous amount of research on this aspect has been conducted on N management, but less research has been conducted with respect to P management. Studies carried out in South Dakota (Fixen, et al., 1987) indicated that no till (NT) systems may require a lower P soil test level for maximum economic yield than plowed systems. They reported that where annual P applications were broadcast, the soil test P level required for 95% of maximum corn yield was 15 lbs/A lower in NT than in chisel or moldboard plow (MP) systems.

The "fallow syndrome" is a phenomenon that has been recognized in the northwestern corn belt for many years. Past experiences have shown that severe early growth problems due to P deficiency of corn occur when this crop is planted in a field that has been fallowed the year before. A study conducted in southeastern South Dakota showed that soybeans likely experience a similar growth problem but to a lesser degree than corn (Fixen et al., 1984). The question remains as to what specific effect fallowing has on P nutrition. Mycorrhizal (a beneficial root fungus) association and labile organic P could be the two possible factors involved.

With these factors in mind, a study was initiated in 1986 with the following objectives: To determine the influence of tillage and previous crop on

1. soil P availability to corn;
2. labile inorganic, labile organic and soil solution P fractions;
3. and on mycorrhizal infection levels of corn.

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METHODS

A field study was conducted on a Viborg silty clay loam (Heplustoll) soil in southeastern South Dakota. These soils are deep, friable, moderately well-drained soils developed in a silty cap over glacial till. The study was laid out in a split-plot randomized block design with four replications. Five different cropping systems namely MP corn-fallow, MP corn-barley, MP continuous corn, ridge plant (RP) corn-soybean, and RP continuous corn were established in 1986. Each plot was split and soil test levels of 24 lbs/A and 89 lbs/A were established by applying 0 and 520 lbs P_2O_5/A as CSP. Along with the P treatments, 20 lbs Zn/A were also applied. The study area was planted with Pioneer 3475 on April 23 in 1987 and May 2nd in 1988, at the seeding rate of 24,500 seeds/A. A split application of liquid nitrogen as 28-0-0 was made at the rate of 75 lbs N/A at emergence and another 75 lbs N/A at lay-by stage. In the RP system 6-8" ridges were built during final cultivation (corn 18" tall). Corsoy 79 soybeans and Bowman barley were used in rotations.

Parameters measured were early dry matter production and P uptake, date of silking, grain yield, grain moisture and stover yield. Soil and root samples were collected periodically at different growth stages of corn (V2, V6, V12, R1 and R4) from all treatments. Soil samples taken at depth increments of 0-2", 2-4" and 4-6" were analyzed by Bray and Kurtz No. 1 P (Bray and Kurtz, 1945), mineralizable organic P (0.5 N $NaHCO_3$ extractable organic P; Bowman, 1986), soil solution P (Aslyng, 1954) and soil solution organic P - 0.01M $CaCl_2$ extractable organic P. Root samples were estimated for mycorrhizal infection rate using the grid intersection method (Giovannetti and Mosse, 1980) after clearing the roots and staining them with trypan blue (Phillips and Hayman, 1970). Corn yield was determined by hand harvesting of 20 foot of the center two rows.

Since the 1987 and 1988 growing season were quite different, key weather parameters for the experiment site are given in Table 1 and Table 2.

Table 1. Growing season temperature date at SE site.

	Temperature (°F)							
	1987				1988			
Month	Average		Departure from 35 yr avg		Average		Departure from 36 yr avg	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
April	67.5	38.1	+6.4	+2.5	59.8	30.0	-1.3	-5.5
May	77.2	53.5	+4.1	+6.1	79.3	52.6	+6.0	+5.1
June	85.0	59.2	+2.7	+2.1	87.7	63.1	+7.2	+5.9
July	85.5	64.3	-1.9	+2.3	87.0	62.5	-0.4	+0.5
August	79.9	57.1	-5.3	-2.0	87.8	61.5	+2.6	+2.3

Source: SE Farm, Ag. Experiment Station, SDSU, SD

Table 2. Growing season precipitation at SE site.

Month	Precipitation (inches) 1987 Total	1987 Dep from 35 yr avg	1988 Total	1988 Dep from 36 yr avg
April	0.50	-1.98	2.58	+0.10
May	3.15	-0.32	2.04	-1.39
June	3.58	-0.62	1.45	-2.68
July	4.75	+1.59	0.83	-2.27
August	1.42	-1.49	5.24	+2.26
April-Aug	13.40	-2.82	12.14	-3.98

Source: SE Farm, Ag. Experiment Station, SDSU, SD.

RESULTS AND DISCUSSION

Early Growth Response

Substantial early growth response to P was observed in nearly all cropping systems at the six leaf stage in 1987 and 1988 (Table 3). Relative early growth responses averaged over both years were 367%, 91%, 56%, 5% and 26% for the plowed corn-fallow, plowed corn-barley, plowed corn-corn, ridge tilled corn-soybean and ridge tilled corn-corn systems, respectively. In the ridge plant system, the response was lower than in the moldboard system. The ranking of early dry matter response agreed with the theoretical expectations based on mycorrhizal relationships (Table 4). Early growth responses to P were inversely related to mycorrhizal infection (Fig. 1). Mycorrhizal infection was highest in the RP system when compared to MP and within MP system the fallow-corn rotation had the lowest percentage of infection. The physical disturbance of the intensely tilled system and lack of potential host plants in the corn-fallow system could be reasons for low infection rates in this system. The role of mycorrhizae in improving P nutrition of plants has been reported by many researchers (Kahn, 1972; Sanders et al., 1975; Kucey and Paul, 1980; Reid, 1984). Most of the beneficial aspects of mycorrhizae in mineral uptake are those related to increases in surface area effective in ion absorbtion; which is an important factor influencing plant response to P fertilizer.

Table 3. Early growth response of corn to P as effected by cropping systems, 1987-1988.

Tillage System	Previous Crop	Early Growth Response 1987	1988	Avg.
			%†	
Moldboard	Fallow	384	350	367
Moldboard	Barley	119	62	91
Moldboard	Corn	53	59	56
Ridge plant	Soybean	8	2	5
Ridge plant	Corn	23	29	26

† Dry matter production at 6-leaf stage expressed as: $(P_{520} - P_0)/P_0 \times 100$

FIG. 1 MYCORRHIZAL INFECTION VS

EARLY GROWTH RESPONSE OF CORN TO P(V6)

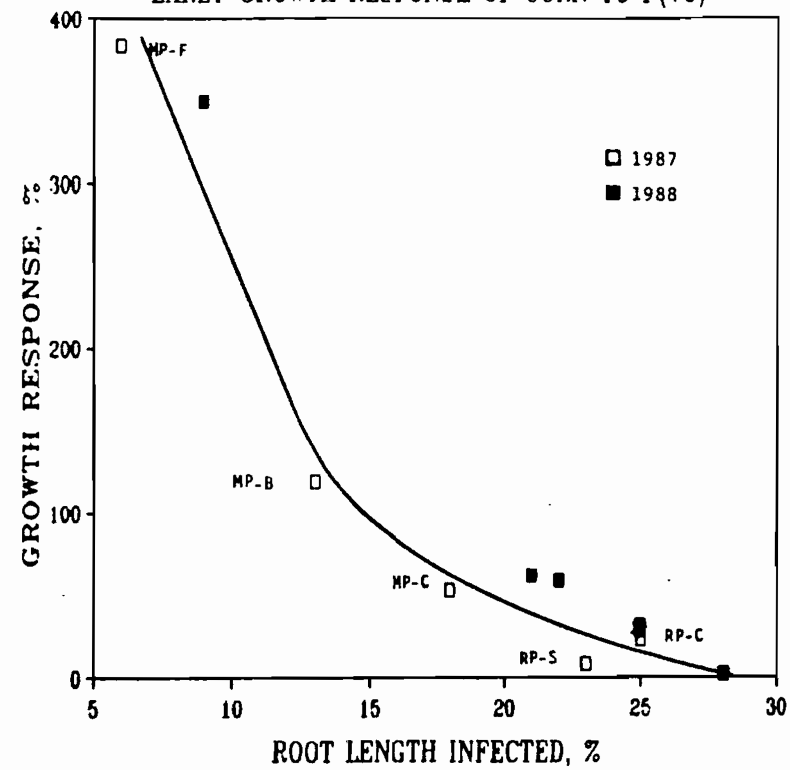


Table 4. Influence of residual P on mycorrhizal infection of corn in five cropping systems, 1987-1988.

Tillage	Previous Crop	Mycorrhizal Infection at V6				Mycorrhizal Infection at R1			
		1987[1]		1988		1987		1988	
		P_0	P_{520}	P_0	P_{520}	P_0	P_{520}	P_0	P_{520}
		%[2]				%			
Moldboard	Fallow	6	-	9	2	19	-	21	10
Moldboard	Barley	13	-	21	7	32	-	29	14
Moldboard	Corn	18	-	22	10	40	-	31	15
Ridge plant	Soybean	23	-	28	13	50	-	43	20
Ridge plant	Corn	25	-	25	11	51	-	42	16
	$LSD_{.10}$	5.1		4.1		3.2		6.3	

[1] Applied in the fall of 1985.
[2] % of root length infected.

Grain Yield Response

The grain yield responses to P in 1987 (Table 5) were 29 bu/A, 7 bu/A, 31 bu/A, -4 bu/A and 21 bu/A for MP corn-fallow, corn-barley, corn-corn, and RP corn-soybean, corn-corn rotations, respectively (LSD .10 = 18). Grain yield did not follow the trend observed in early dry matter production. There were significant yield responses to P observed for corn following fallow and continuous corn in the MP system and in continuous corn in the RP system. Although there was a tremendous early growth response to P observed for different crop rotations and tillage systems, the crop appeared to catch up later in the season thus not reflecting the same pattern in the grain yield. In 1988, over all yield (Table 5) was drastically reduced due to the severe drought conditions experienced during the growing season (growing season precipitation for months of May, June and July were 2.04", 1.45", and .83" which were -1.39", -2.68", -2.27" below the 36 year average for the experiment site - Table 2). Therefore, no significant P effects could be detected (P and P X System effects were NS at the 0.30 level). However, the system averages over high and low P for the above rotations were 58 bu/A, 36 bu/A, 25 bu/A, 42 bu/A and 33 bu/A. These differences were likely caused by variations in water use by previous crops and by water conservation in the RP systems.

Table 5. Influence of cropping system and P on corn grain yield, 1987-1988.

Tillage	Previous Crop	Grain Yield 1987 P_0	1987 P_{520}	Response	1988 P_0	1988 P_{520}	Avg.
Moldboard	Fallow	141	170	29	63	53	58
Moldboard	Barley	153	160	7	39	33	36
Moldboard	Corn	127	158	31	31	19	25
Ridge plant	Soybean	179	175	-4	39	45	41
Ridge plant	Corn	135	156	21	28	38	33
	$LSD_{.10}$			18			8

Effect on P Fractions

The influence of cropping systems on Bray P from check plots for the years 1987 and 1988 are presented in Table 6. Amongst the five systems Bray P was highest in RP corn-soybean system (18.1 ppm and 15.4 ppm) and was lowest in MP corn-corn system (10.7 ppm and 8.6 ppm) for the years of 1987 and 1988. As expected Bray P in all systems was lower in 1988 when compared to 1987. The seasonal changes in Bray P averaged over the systems for both years are given in Fig. 2. There was a noticeable drop in Bray P over time in both years in the high P plots. The drop in Bray P over time in check plots was considerably less. The data for soil solution inorganic P was not ready for this paper. Therefore, this fraction would not be discussed here.

FIG. 2 SEASONAL CHANGES IN BRAY P

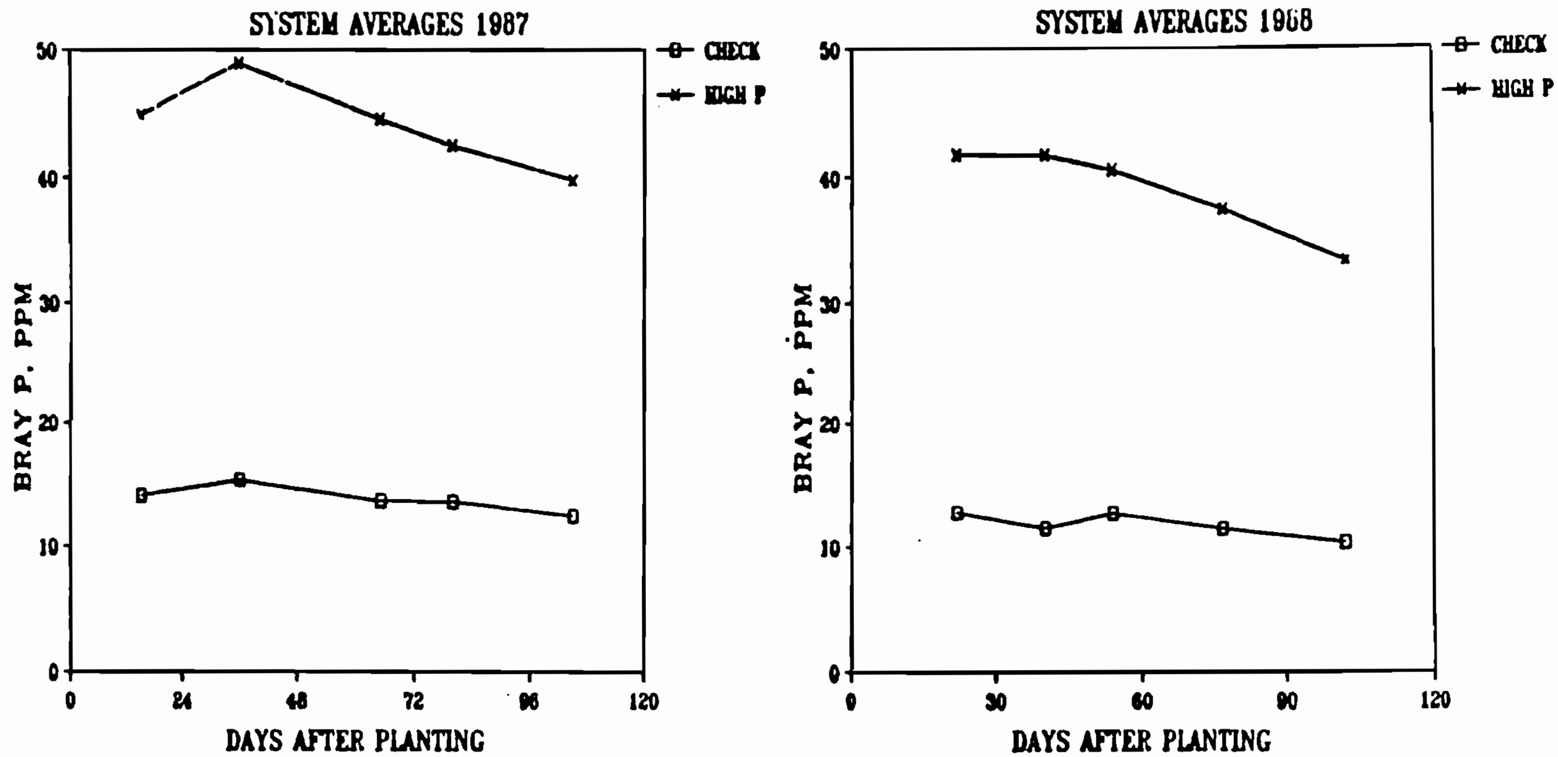


Table 6. Influence of cropping systems on the seasonal average of Bray and Kurtz P in the check plots.

Tillage	Previous Crop	Year 1987	1988
		Bray P, ppm	
Moldboard	Fallow	14.7	12.9
Moldboard	Barley	12.8	10.7
Moldboard	Corn	10.7	8.6
Ridge plant	Soybean	18.1	15.4
Ridge plant	Corn	13.1	11.4
	$LSD_{.10}$	3.3	4.7

The effect of cropping systems on mineralizable P in check plots is given in Table 7. In both years, the mineralizable P was highest in RP corn-soybean rotation and was followed by the MP corn-barley rotation. The lowest mineralizable P was found in the MP corn-corn rotation. It is interesting to note that the grain yield responses in 1987 were inversely related to mineralizable P at all planting times (Table 7 and Fig. 3). Mineralizable P appear to play an important role in determining grain yield response in these systems.

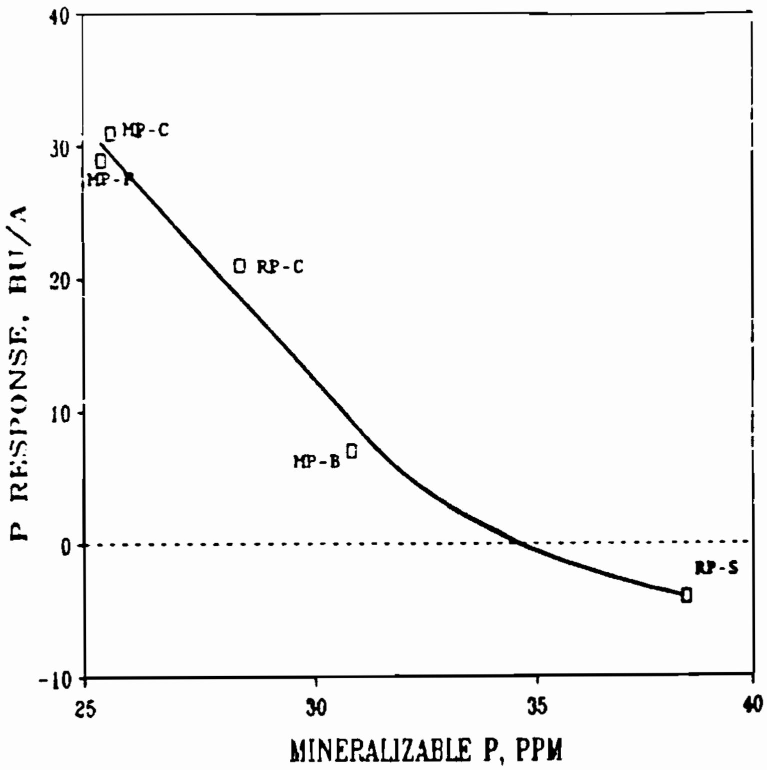
All P fractions (Bray P and mineralizable P) measured and mycorrhizal infection rates were highest in RP corn-soybean rotation making it a favorable rotation for P management.

Table 7. Influence of cropping systems on the seasonal average of mineralizable P in the check plots.

Tillage	Previous Crop	Year 1987	1988
		Mineralizable P, ppm	
Moldboard	Fallow	25.4	30.8
Moldboard	Barley	30.8	35.4
Moldboard	Corn	25.6	27.6
Ridge plant	Soybean	38.4	36.1
Ridge plant	Corn	28.4	31.8
	$LSD_{.10}$	5.3	8.8

FIG. 3 YIELD RESPONSE VS MINERALIZABLE P

AVERAGED OVER TIME, 1987



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