Phosphorus Fertilization and Previous Crop Effects on Nutrient Uptake and Grain Yield of Wheat

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RESEARCH PROBLEM

Fertilizer recommendations based on routine soil test information require constant correlation and calibration to ensure that accurate and economic guidelines are provided to growers. Soft red winter wheat (*Triticum aestivum* L.) grown in Arkansas commonly exhibits P deficiency symptoms in January and February when soils are cold and wet. A number of factors including the crop grown preceding wheat in the rotation can influence the P nutrition and fertilizer requirements of wheat. The objective of this study was to evaluate the effect of P fertilization on wheat growth, P uptake, and grain yield on two soils when following different crops in the rotation. Ultimately, the goal of this project is to develop a database on Mehlich 3-extractable soil P and wheat response to P fertilization.

BACKGROUND INFORMATION

In Arkansas, the crop grown before seeding soft red winter wheat is perceived to affect wheat growth, nutrition, and grain yield. Rice (*Oryza sativa* L.), soybean [*Glycine max* (L.) Merr.], grain sorghum [*Sorghum bicolor* (L.) Moensch], and corn (*Zea mays* L.) are the most common crops grown preceding wheat. Previous research has shown that wheat following flood-irrigated rice generally requires P fertilizer to produce maximum grain yields (Wells et al., 1989; DeLong et al., 2001). University of Arkansas fertilizer recommendations are currently based on soil nutrient concentrations from a modified Mehlich 3 extraction procedure (1:7 extraction ration rather than 1:10), but we are considering changing to the published 1:10 extraction ratio to be consistent with other laboratories that use this extraction procedure. Therefore, efforts are underway to collect correlation and calibration data for a number of crops, including wheat, to refine fertilizer recommendations when this change is made.

PROCEDURES

Studies were established in the fall of 2001 at the Cotton Branch Experiment Station (CBES), Marianna, AR, on a Calloway (fine-silty, mixed, active, thermic Aquic Fraglossudalfs) silt loam and the Rice Research and Extension Center (RREC), Stuttgart, AR, on a Dewitt (fine, smectitic, thermic Typic Albaqualfs) silt loam. The treatment factors were soft red winter wheat cultivar ('NK9663' and 'P26R24') and P fertilizer rate (0, 25, 50, 75, and 100 lb P_2O_5/acre applied as triple super phosphate). At each site, two separate studies were established with wheat seeded following different summer crops. At the CBES wheat followed sorghum and soybean and at the RREC wheat followed rice and soybean.

Wheat was seeded into conventional tilled seedbeds at the CBES on 1 November 2001 and the RREC on 26 October 2001 at 100 lb/acre. Before P fertilizer was applied, soil samples were collected to a depth of 15 cm in the unfertilized control plots and extracted with Mehlich 3 (1:10 extraction ratio and analyzed by ICAP) for P and other soil nutrient concentrations (Table 1). Phosphorus fertilizer treatments were applied to the soil surface 7 to 10 days after seeding. Fall N, 45 lb N/acre as urea, was applied to wheat that followed rice and grain sorghum in the rotation. Spring N was applied at the rate of 60 lb N/acre as ammonium sulfate at Feekes scale 5 and 60 lb N/acre as urea at Feekes scale 7. Whole plant samples for total dry-matter accumulation were collected from a 3-linear ft row at Feekes scale 5 (tillering), 10.1 (heading), and 11.4 (maturity). Samples were oven-dried at 60°C to a constant weight, weighed,

ground, digested and analyzed for nutrient concentrations. Total P uptake was calculated by multiplying wheat dry matter/acre by wheat tissue P concentration. Only total P uptake at Feekes growth scale 10.1 is reported. At maturity, a small plot combine was used to harvest wheat for grain-yield determination. Grain yields were adjusted to a uniform 12% moisture content for statistical analysis. The treatments were arranged as a randomized complete block, 2 (cultivar) × 5 (P rate) factorial design with 4 replications. Each location and previous crop were analyzed separately.

RESULTS AND DISCUSSION

The interaction between cultivar and P fertilizer rate was not significant at any study site. At both locations, wheat cultivar P26R24 produced numerically or significantly higher grain yields than NK9663, regardless of the previous crop (Table 2). Application of P fertilizer resulted in numerical grain-yield increases at both locations, regardless of the previous crop. Significant grain-yield increases from P fertilizer rate, averaged across cultivars, occurred only at the RREC when wheat followed rice in the rotation. Application of 50 lb P_2O_5/acre significantly increased grain yields compared to the untreated check. Based on current soil-test guidelines for P, P fertilizer would have been recommended for wheat grown at the RREC, but not at the CBES. Although wheat yields between previous crops were not statistically compared at each location, grain yields were numerically higher following soybean compared to rice and sorghum, indicating the previous crop has a significant impact on wheat grain yields. Grain yields were also numerically higher at the CBES compared to the RREC. Although wet field conditions and abnormally cool February temperatures did apparently injure wheat in these studies, the conditions may have limited grain yield potential and potential responses to P fertilization.

At Feekes scale 5, wheat following soybean at the CBES showed prominent P deficiency symptoms, but P-deficiency symptoms were not observed after Feekes scale 7. In contrast, wheat plants at the same growth stage at the CBES following sorghum showed no or few P-deficiency symptoms. Wheat following soybean had lower P tissue concentrations (data not shown), but lower total dry-matter accumulation (data not shown) than wheat following sorghum, which diluted the tissue P and may have contributed to the expression of P-deficiency symptoms. Increased wheat growth after soybean at both locations may also be associated with the relative availability of soil N, P, or both N and P as influenced by previous crop residues or management practices. Also, wheat at the RREC did not exhibit pronounced P deficiency symptoms despite having the lowest soil-test P.

Total P uptake at Feekes scale 10.1 was statistically equal between the two cultivars, averaged across P application rates, in all four studies (data not shown). At Feekes scale 10.1, total P uptake was not affected by P fertilizer rate for wheat following sorghum at the CBES (Table 3). When wheat followed soybean at the CBES or followed soybean and rice at the RREC, P fertilizer rate significantly ($P<0.10$) affected dry-matter accumulation (Table 3). Application of 50 lb P_2O_5/acre significantly increased P uptake compared to the unfertilized control in all three studies. When wheat followed rice at the RREC, the P fertilizer rates that significantly increased total P uptake also significantly increased wheat grain yields (Table 2).

Although previous crops and locations were not compared, P uptake was numerically higher at the CBES than the RREC and at the RREC the P uptake was greater when wheat followed soybean (Table 3). The crop rotations and soil chemical properties are different between these two sites. At the CBES, Mehlich 3 P was much higher than at the RREC (Table 1). The flood irrigation used for rice production at the RREC decreases P availability and soil test P, which partially explains why wheat following rice consistently requires P fertilization to maximize grain yields.

PRACTICAL APPLICATIONS

Current soil test P guidelines for wheat recommend P fertilization of wheat when Mehlich 3 P (1:7 ratio) is <50 mg P/kg (100 lb P/acre), which corresponds to approximately 70 mg P/kg (140 lb P/acre) (Baker et al., 2002). Based on the converted critical soil test P for wheat the recommendations correctly predicted wheat-yield response to P fertilization at only one (RREC wheat following rice) of four locations. Additional data are needed to accurately correlate and calibrate wheat-yield response to Mehlich 3 soil P and P fertilizer rate. The data also support observations that P fertilizer recommendations should be calibrated for soil-test P and the

previous crop to provide wheat growers with accurate fertilizer recommendations for soft red winter wheat grown in various cropping systems in Arkansas.

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Table 1. Selected soil chemical properties before P fertilization of a Calloway silt loam at the Cotton Branch Experiment Station (CBES) and a Dewitt silt loam at the Rice Research and Extension Center (RREC) in 2001-2002.

	Soil test values			
Location - previous crop	pH[z]	P[y]	Ca[y]	Mg[y]
	--------- (Mehlich 3 mg kg^{-1}) ---------			
CBES - sorghum	7.2	54	1,228	145
CBES - soybean	6.7	53	855	118
RREC - rice	6.3	9	1,034	136
RREC - soybean	6.4	14	1,054	148

[z] Soil pH measured in 1:2 soil weight: water volume mixture by glass electrode.
[y] Extraction ratio was 1:10 soil weight:Mehlich 3 solution volume.

Table 2. Wheat grain yields by cultivar, averaged across P rates, and P rates, averaged across cultivars, for previous crops grain sorghum, soybean, and rice at the CBES and RREC in 2002.

	Grain yield at maturity			
Cultivar or	CBES		RREC	
P fertilizer	Sorghum	Soybean	Rice	Soybean
(lb P_2O_5/A)	---------- (bu/acre) ----------			
Cultivar				
NK9663	60.1	67.9	46.4	52.0
P26R24	68.9	71.2	47.7	57.3
$LSD_{(0.05)}$	2.2	2.4	NS[z]	4.8
P-value	0.01	0.01	0.57	0.03
P fertilizer rate				
0	62.8	68.3	39.9	51.8
25	65.8	69.8	44.4	57.5
50	65.6	68.5	51.4	55.3
75	63.9	69.8	49.9	52.3
100	64.7	71.4	50.1	55.8
$LSD_{(0.10)}$	NS	NS	7.1	NS
P-value	0.44	0.49	0.0509	0.57

[z] NS = not significant.

Table 3. Total P uptake by wheat as affected by P rate, averaged across cultivars, at Feekes scale 10.1 (Heading) for previous crops grain sorghum, soybean, and rice at the CBES and RREC in 2002.

	Total P uptake at Feekes Scale 10.1			
	CBES		RREC	
P fertilizer rate	Sorghum	Soybean	Rice	Soybean
(lb P_2O_5/A)	(lb P/acre)			
0	34.5	24.7	5.4	11.0
25	31.6	27.3	6.0	11.8
50	32.2	33.7	7.0	12.9
75	41.4	34.9	8.4	16.3
100	33.6	36.4	8.4	13.2
$LSD_{(0.10)}$	NS[z]	8.0	1.6	3.0
P-value	0.2594	0.0779	0.0053	0.0519

[z] NS = not significant.