Soybean Response to Phosphorus Fertilization Following Rice in the Rotation

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RESEARCH PROBLEM AND BACKGROUND INFORMATION

In Arkansas, fertilizer guidelines for irrigated-soybean [*Glycine max* (L.) Merr.] grown on loessial soils recommend the application of P fertilizer when Mehlich 3 soil-test P (1:7 extraction ratio) is ≤40 lb P/acre (20 mg P/kg). Although soybean is not considered highly responsive to P fertilization, crops following flood-irrigated rice in the rotation often require P because the P is less available following extended periods of flooding (Brandon and Mikkelsen, 1979; Griffin and Brandon, 1983). However, P deficiency of soybean is not commonly observed in Arkansas even when following rice in the rotation. In this report we present three years of soybean response data from a long-term experiment, initiated in 1998, investigating rice and soybean response to P fertilization application rate and frequency. The overall objectives of this study were to 1) determine soil-test P response to P fertilization rate and frequency, and 2) document rice and soybean growth and yield responses to P fertilization when grown in rotation.

PROCEDURES

In 2002, soybean was grown for the third year on the same plots established in 1998 on a Calloway silt loam (pH =7.8) at the Pine Tree Branch Station (PTBS) near Colt, AR, and a DeWitt silt loam (pH = 5.2) at the Rice Research and Extension Center (RREC), near Stuttgart, AR. Soybean had previously been grown in these same plots in 1998 and 2000 and rice was grown previous to soybean in 1999 and 2001. Each year a composite soil sample was taken in February or early March from each plot to a depth of 4 inches and extracted with Mehlich 3 (1:7 extraction ratio) for soil nutrient concentrations, including P (Table 1).

In 2002, at the PTBS, 'Caviness' soybean was drilled (15-inch rows) into the undisturbed rice stubble from the previous year using a no-till drill on 30 May 2002. At the RREC, Caviness soybean was drilled (15-inch rows) into a conventionally tilled seedbed on 22 May 2002. Before soybean emergence, P was broadcast applied to the soil surface at rates of 0, 20, 40, 80, and 120 lb P_2O_5/acre on plots that received annual applications of P fertilizer (Annual: both soybean and rice crops receive P); and on plots that received P only when seeded to soybean (Soybean: no P applied when rice is grown). A third set of plots receive P fertilizer only when cropped to rice (Rice: no P applied when soybean is grown). Specific management information on studies conducted in 1998 and 2000 were described by Slaton et al. (1999, 2001). At the R2 growth stage, whole-plant samples were taken from a 3-ft row section for total dry-matter accumulation and analysis for tissue-P concentration (data not shown). Potassium fertilizer (0-0-60) was also applied to ensure that K was not a yield-limiting factor. Boron (1 lb B/acre, preplant soil application as Solubor) was also applied at the PTBS in 2002. At maturity, soybeans at both locations were harvested by combine. Soybean yields were adjusted to a uniform moisture content of 13% for statistical analysis. The treatments were arranged as a randomized complete block, 3 (frequency of application; Annual, Soybean, and Rice) × 4 (P application rate) factorial with an unfertilized control (0 lb P_2O_5/acre and None) and four replications. Yield data from each location were analyzed separately. Analysis of variance procedures were conducted with the PROC GLM procedure in SAS. Mean separations were performed by Fisher's protected least significant difference (LSD) method at a significance level of 0.05

or 0.10. Soil-test P means were plotted and subjected to simple linear regression to describe soil-test P response to annual P fertilizer rates.

RESULTS AND DISCUSSION

Grain Yield Response

Soybean yield responses to P fertilization during 1998, 2000, and 2002 are presented in Tables 2 and 3. The interaction between P rate and frequency of P fertilizer application has not significantly affected yields at either location since the study was initiated. In 1998, the frequency of P fertilization was not a treatment factor since it was the first year of the study. At the PTBS, soybean yield generally increased when P rates ^{3}40 lb P_2O_5/acre were first applied in 1998 (Table 2), but significant yield increases due to P-application rate, averaged across frequencies of application, have not reccurred. At the RREC, significant soybean yield responses have not occurred, but the data show a trend for increased yields due to P application during each year.

The frequency of P application did not show a consistent statistically significant effect on soybean yields at either location in 2000 (Table 3). Significant ($P < 0.10$) yield responses to P-application frequency, averaged across P rates, were noted at both locations during 2002. Although soybean yields among P rates were statistically significant at the PTBS in 2002, the unfertilized control (None) produced yields equal to all other P-application rates. At the RREC, soybean yields were statistically similar among the unfertilized control (None) and treatments receiving P every other year (Rice or Soybean). Annual application of P fertilizer produced significantly higher yields than the unfertilized control (None) or application every other year.

Soil Test P Response to P Fertilization

The relationship between P fertilizer rates applied annually and Mehlich 3-extractable P (1:7 extraction ratio) for two silt loam soils used for rice and soybean production is shown in Fig. 1. After two complete soybean-rice rotation cycles (4 years), annual P rates >120 lb P_2O_5/acre for the alkaline Calloway silt loam (PTBS) and ~56 lb P_2O_5/acre for the acidic DeWitt silt loam (RREC) were needed to maintain the initial soil test P concentrations measured in 1998. The relationship suggests that annual P-fertilizer rates above the rate of P removed by harvested rice and soybean seed are required to maintain the soil-test P on these silt loam soils used for rice and soybean production. Although these data do not indicate the soil-test P response to P-fertilizer rate in rotations not involving rice, the flooded-irrigated system used for rice production likely results in fixation of soil- and fertilizer-P. This theory is supported by the trends in annual soil-test P measured following each crop (Fig. 2). Figure 2 shows the absolute difference in soil-test P between years. For example, the absolute difference in 1999 was calculated by subtracting the initial soil-test P (from samples taken before P-fertilizer application in 1998) from the soil-test P measured in February 1999 (after soybean was fertilized and produced in 1998). Soil-test P in samples taken following soybean in the rotation increased in both 1999 and 2001 *(Note: The year indicates the year soil sample was taken after soybean grown during the previous year)* at the PTBS and in 1999 at the RREC. In contrast, soil-test P declined following rice in the rotation at the PTBS in 2000 and 2002 and at the RREC in 2000. Apparently the P fixed after flood removal is not extractable, at least for several months, with the Mehlich 3 method.

PRACTICAL APPLICATIONS

The lack of soybean yield responses to P-fertilization at the PTBS and RREC suggests that P is not a major yield-limiting factor at these two locations. Soybeans grown in the unfertilized control plots have not exhibited visual P-deficiency symptoms after P removal, without replacement via fertilization, by four harvested crops (two complete 1:1 soybean-rice rotations). Although P has been reported to limit the yield of soybean and other crops grown following rice in the rotation, dramatic differences in soybean yields among P-fertilizer treatments have not yet been observed in this study. Phosphorus fertilization has also not consistently and significantly affected rice yields during this study either. Despite annual application of P fertilizer, soils used for rice and soybean production commonly have very low to medium soil-test P but may not require routine P fertilization to maximize yields. Growers should not be concerned about low soil-test P for soils used for rice and soybean production since this is likely a result of the alternating anaerobic-aerobic conditions of this crop rotation. Most soils apparently have adequate plant-available P to sustain high rice and soybean yields, especially when current recommendations are followed. Phosphorus fertilization guidelines using the Mehlich 3 extractant require further research to establish whether a good correlation exists between Mehlich 3-extractable P and the yield of soybean grown on the silt loam soils following rice in the rotation.

ACKNOWLEDGMENTS

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Table 1. Selected soil chemical properties of the unfertilized controls (samples taken in February 2002 to a depth of 4 inches) for two long-term P fertilization studies conducted at the Pine Tree Branch Station (PTBS) and the Rice Research and Extension Center (RREC). Soil-test nutrient concentrations in mg/kg can be converted to lb P/acre by multiplying each × 2.

	Mehlich 3 (1:7 extraction ratio) soil-test concentrations									
Site	pH	P	K	Ca	Mg	S	Fe	Mn	Zn	B
		(mg/kg)								
PTBS	7.8	10	116	1779	386	11	204	116	4.4	0.5
RREC	5.2	6	146	632	92	13	258	102	0.6	0.5

Table 2. Soybean yield response to P-fertilizer application rate, averaged across P application frequency, at the Pine Tree Branch Station (PTBS) and the Rice Research and Extension Center (RREC) during 2002.

	PTBS			RREC		
P application rate	1998	2000	2002	1998	2000	2002
(lb P_2O_5/acre)	(bu/acre)					
0	36.9	39.3	49.8	20.5	47.1	48.8
20	37.7	44.8	51.4	26.2	47.7	52.7
40	43.9	41.8	45.8	22.9	49.8	53.8
80	39.3	44.7	48.0	26.7	49.5	56.6
120	42.2	40.6	47.7	24.1	50.6	58.6
P-value	0.0423	0.1825	0.3843	0.4211	0.5057	0.1562
LSD (0.10)	4.4	NS	NS	NS	NS	NS

Table 3. Soybean yield response to P fertilizer application frequency, averaged across P application rates, at the Pine Tree Branch Station (PTBS) and the Rice Research and Extension Center (RREC) during 2000 and 2002. (Note: 1998 was the first year of the study and only P application rate was a treatment factor).

	PTBS		RREC	
P application frequency	2000	2002	2000	2002
	(bu/acre)			
None	39.3	49.8	47.1	48.8
Rice	44.1	48.1	49.7	53.6
Soybean	41.9	51.2	50.0	53.6
Annual	43.0	45.7	48.6	58.7
P-value	0.5438	0.0949	0.6866	0.0826
LSD (0.10)	NS	5.7	NS	5.0

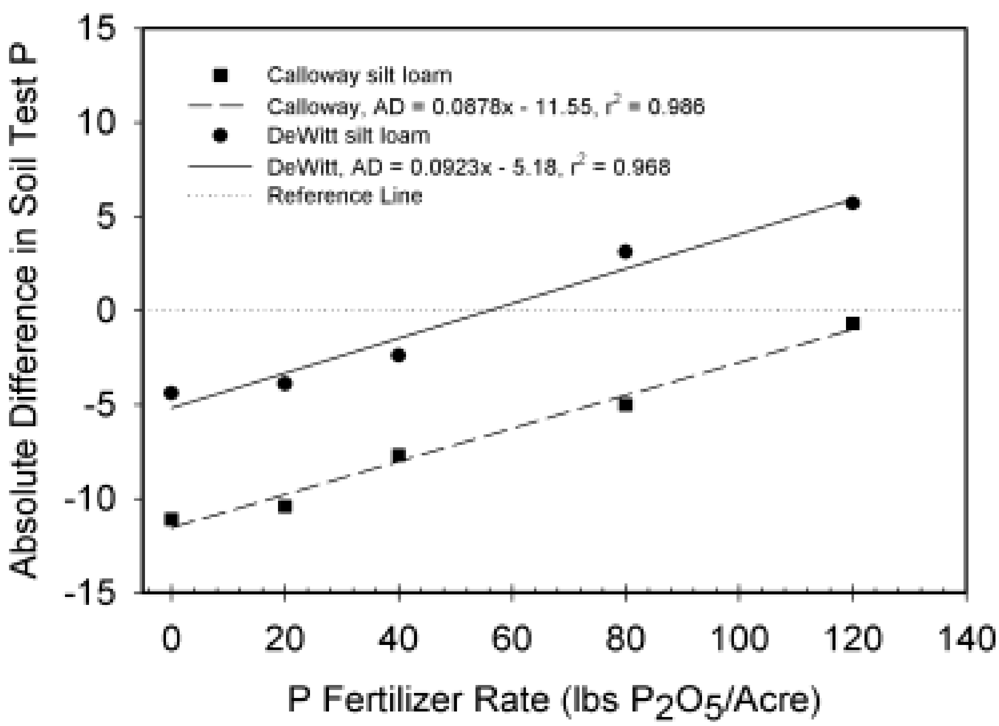

Fig. 1. The relationship between annual P fertilizer rate and the absolute difference of Mehlich 3 (1:7 extraction ratio) extractable soil P after two complete soybean-rice rotation cycles on a Calloway silt loam at the PTBS and a DeWitt silt loam at the RREC. Graphed values indicate the net increase or decrease in soil-test P between the initial 1998 values and those measured in February 2002. The dotted horizontal line (at 0 absolute difference) marks the point of no change in soil-test P concentration after four years. Data points below the dotted line indicate a net decrease and points above the dotted line indicate a net increase in soil-test P.

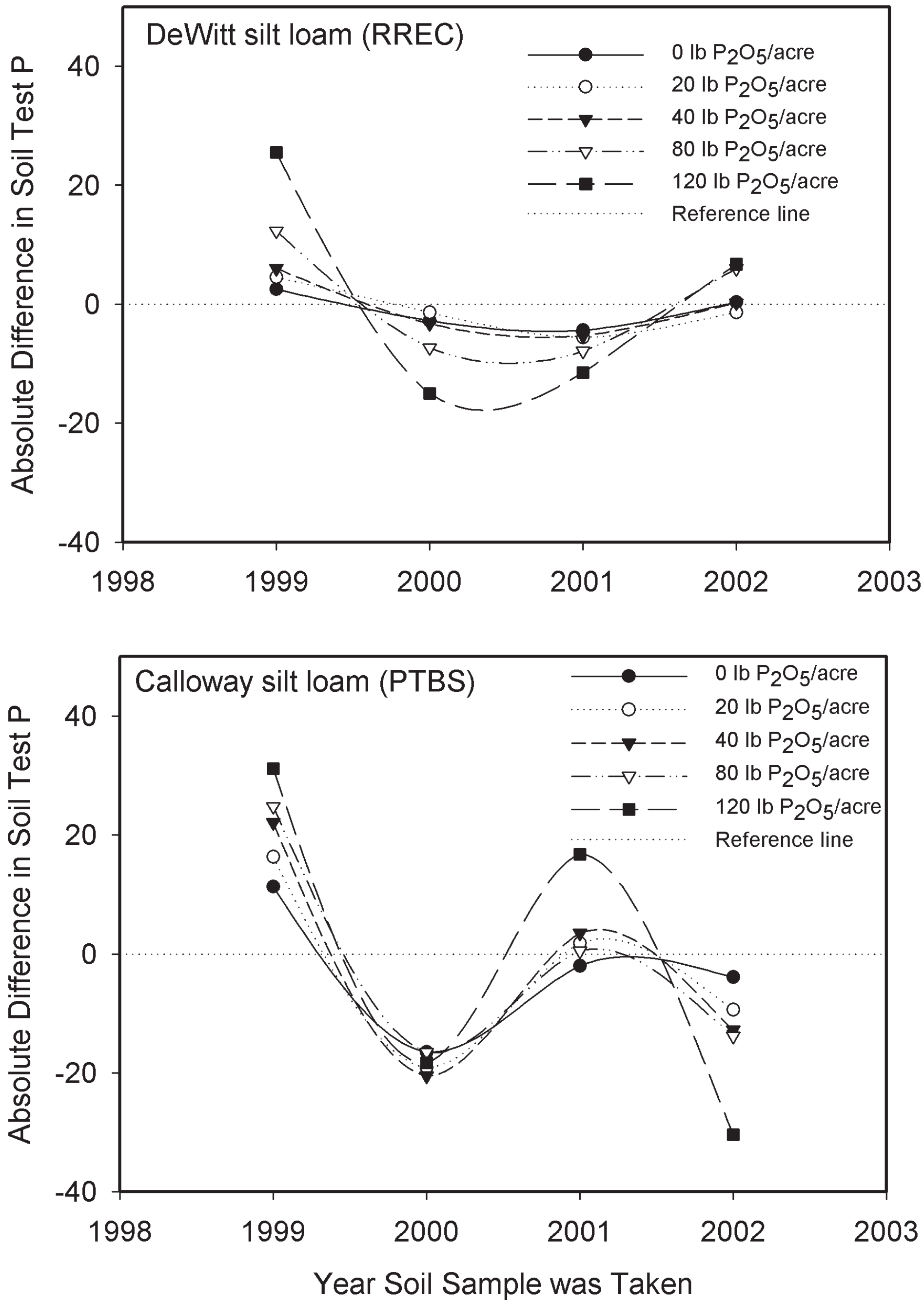

Fig. 2. Annual fluctuations in soil-test P, by annual P application rate, represented as the absolute differences between soil-test P of two consecutive years (e.g., 1999-1998, 2000-1999, etc.). Note: Soybean was grown in 1998 and 2000 and rice was grown in 1999 and 2001. Year, on the x-axis, denotes the year that the soil sample was taken with the previous year soil-test P subtracted to give the absolute difference.