Soybean Response to Poultry Litter and Inorganic Fertilizer

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Poultry litter application to fields that will be cropped to legumes is desirable because legumes biologically fix N_2 gas from the atmosphere, allowing manures to be applied at rates needed only to satisfy crop P and/or K requirements. The need to export the nutrients in poultry litter from western Arkansas to areas of intensive cropping and fertilizer use plus recent increases in commercial fertilizer prices have increased interest in using poultry litter as an alternative to P and K fertilizers. Soybean [*Glycine max* (L.) Merr.] yield has responded favorably to poultry litter in Mississippi (Adeli et al., 2005). Initial research in Arkansas comparing soybean yield response to poultry litter and commercial fertilizers (Slaton, unpublished data) has shown mixed results. Trials established at the Rice Research Extension Center (Dewitt silt loam) and Northeast Research Extension Center (Sharkey-Steele complex) showed no yield benefit from poultry litter or equivalent P and K rates from commercial fertilizers on soils that had high soil-test K and medium or lower soil-test P. However, several trials established on silt loam soils west of Crowley's Ridge have shown significant yield increases from poultry litter that were sometimes greater than yields produced with equivalent rates of P and K fertilizer.

Our primary research objective was to evaluate soybean yield and leaf nutrient concentration responses to poultry litter compared to various inorganic fertilizer combinations. The overall goals of this research were to determine the availability of P and K in poultry litter and establish whether poultry litter provided any potential yield benefits above those provided by adequate rates of commercial fertilizers.

PROCEDURES

Trials were established at three sites in 2008, including a Calhoun silt loam at the Pine Tree Branch Station (PTBS) and two grower fields in Poinsett County (Poinsett-1 and Poinsett-2) with each having soil mapped as a Hillemann silt loam. Soybean (PTBS) and rice (Poinsett-1 and Poinsett-2) were grown in the research areas during 2007. At the PTBS, the research site was tilled shallowly, study boundaries were flagged, soil samples were collected, treatments were applied, and soybean was seeded. At the two grower fields, the growers kept fertilizer applied to the surrounding field off of the research area, performed tillage, planted soybean, and we then collected soil samples and applied the treatments to the soil surface about 1 day before the soybean emerged. At each site a composite soil sample was collected to a depth of 4 inches from each replicate's (n=6 per site) unfertilized control before fertilizer application. Soil samples were oven-dried, crushed to pass a 2-mm sieve, and analyzed for soil pH (1:2 soil weight: water volume ratio); soil organic C; and total N by combustion; Mehlich-3 extractable nutrients were determined by inductively coupled plasma spectroscopy (ICPS). Selected mean soil chemical properties are listed in Table 1. Granular B fertilizer (1.0 lb B/acre) was broadcast just before or after planting at all sites to insure B was not yield limiting.

Poultry litter was obtained in fall 2007 directly from a poultry house at the University of Arkansas Savoy Poultry Production facility. Broilers had been grown for 18 months before litter removal. Three subsamples of litter were analyzed for total nutrient content and showed litter averaged 3.35% total N, 1.47% P, 3.06% K, 20.3% moisture and had a mean pH of 8.7. Poultry litter treatments were weighed for each site to provide the equivalent of 70 (low rate) and 140 (high rate) lb P_2O_5/acre, and stored in sealed plastic bags until litter was applied. The 'Low' and 'High' P_2O_5 poultry litter rates corresponded to 2080 and 4159 lb moist litter/acre and supplied 76 and 152 lb K_2O/acre, respectively.

Inorganic-fertilizer treatments were prepared to provide the same equivalent amount of total P_2O_5/acre as poultry litter or a similar amount of plant-available N (PAN) as the low and high poultry litter rates. The PAN of poultry litter was estimated to be 67% of its total N content. When inorganic-N fertilizer was added with P and K fertilizers or applied by itself, 'Super Urea' (Agrotain International, St. Louis, Mo.) was used as the N source and applied at 47 and 93 lb N/acre for the low and high rates, respectively. Super Urea was used because it contains both a urease and nitrification inhibitor, which would help reduce fertilizer-N losses.

At the PTBS, Armor 47G7 soybean was drill seeded on 21 May into plots that were 13-ft wide and 20-ft long and contained 10 soybean rows spaced 15 inches apart. The drill provided some incorporation of surface-applied fertilizers and poultry litter, which were applied before seeding. Soybean was drilled into conventionally tilled seedbeds at Poinsett-1 (Asgrow 5501) and Poinsett-2 (UA4805) with soybean rows spaced 7-inches apart on 31 and 24 May, respectively, by the cooperating farmers. Individual plots were 10-ft wide and 25-ft long.

Trifoliate leaves (15) were collected from each plot at the R2 growth stage, dried to a constant moisture, ground to pass a 1-mm sieve, digested, and analyzed for elemental concentrations by ICPS. An 18-to 22-ft long section from the middle rows of each plot was harvested with a plot combine. Soybean moisture was adjusted to 13% for final yield calculations. Each experiment was a randomized complete block design with treatments structured as 2 (rate) × 4 (nutrient source) factorial plus a no fertilizer control. Each treatment was replicated six times per site. Analysis of variance was conducted with the PROC GLM procedure in SAS v9.1 (SAS Institute, Inc., Cary, N.C.) using a split-plot treatment structure where site-year was the whole plot and the rate × source factorial was the subplot. When appropriate, mean separations were performed using Fisher's Protected Least Significant Difference method at a significance level of 0.10.

RESULTS AND DISCUSSION

The University of Arkansas soil-test guidelines for soybean showed that soil-test K (Table 1) was 'Medium' (<91-130 ppm) at the PTBS and Poinsett-1 and 'Optimum' at Poinsett-2. Soil-test P was 'Very Low' at Poinsett-1, 'Low' at PTBS, and 'Optimum' at Poinsett-2. Recommended fertilizer rates would have ranged from 0 to 100 lb P_2O_5/acre to 0 to 60 lb K_2O/acre.

Soybean yields were affected significantly by all three main effects (site, nutrient source, and rate) and the interaction between nutrient rate and source. Soybean yields, averaged across nutrient sources and rates, were in order of decreasing yield Poinsett-1 (70 bu/acre, LSD = 2 bu/acre) > Poinsett-2 (67 bu/acre) > PTBS (64 bu/acre). Soybean yields, averaged across sites, receiving no fertilizer or N only produced equal yields that were significantly lower than yields of soybean receiving poultry litter or PK fertilizers (Table 2). Soybean receiving low and high rates of NPK fertilizer produced equal yields that were similar to low rates of PK and poultry litter. However, soybean yields increased significantly when PK and poultry litter were applied at high rates. Soybean receiving the high rate of poultry litter produced the greatest overall yield.

Trifoliate leaf K concentrations were affected by the source × rate (Table 2) and site × rate interactions (Table 3). Trifoliate leaves of soybean receiving no fertilizer (or litter) and N only contained low and similar K concentrations that were lower than soybean receiving P and K at low and high rates (Table 2). Soybean receiving low rates of PK, NPK, and poultry litter had similar trifoliate leaf K concentrations that were always lower than soybean that received the high rate of fertilizer or litter. In general, the site × nutrient rate interaction showed that trifoliate leaf K concentrations responded differently to nutrient rate among sites (Table 3). At the PTBS and Poinsett-2, leaf K concentrations increased with each increment of nutrient addition. At Poinsett-1, leaf K concentrations of soybean receiving the low and high nutrient rates were similar and greater than the K concentration of soybean receiving no fertilizer or poultry litter.

Trifoliate leaf P concentrations of soybean were affected by the site × nutrient rate (Table 3) and site × nutrient source interactions (Table 4). At the PTBS and Poinsett-1, trifoliate leaf P concentrations remained constant regardless of the nutrient rate applied. At Poinsett-2, the high nutrient rate increased leaf P concentrations above the values of the low rate and control (None), which were similar (Table 3). The site × nutrient source interaction also showed that trifoliate leaf P concentrations changed significantly only at Poinsett-2 among nutrient sources (Table 4).

PRACTICAL APPLICATION

Trials to evaluate soybean response to poultry litter showed that soybean yields were increased similarly by P and K fertilizers and poultry litter applied at rates that supplied 70 lb P_2O_5 and 76 lb K_2O/acre. However, application of poultry litter at a rate that supplied 140 lb P_2O_5 and 152 lb K_2O/acre produced greater yields than an equivalent rate of P and K fertilizers. Trifoliate leaf P and K concentrations suggest that fertilizer and poultry litter applied at equal P and K rates provide similar amounts of plant-available P and K to soybean. Thus, all of the P and K in poultry litter should be considered as plant available.

Application of N with P and K fertilizers showed no benefit on soybean yield or nutrient uptake, but the lack of response to N does not rule out the possibility that soybean may be responding to the N in poultry litter. Poultry litter may provide greater N availability later in the growing season (i.e., after blooming when the demand for N by soybean is greatest) than inorganic-N fertilizer applied at planting. Tissue analysis results showed that other essential elements (e.g., B, Zn, Cu, etc.) were present in sufficient amounts and should not have been yield limiting. Further investigations should include a time of poultry litter application (i.e., several months before planting) treatment to better evaluate whether slowly available N is contributing to improved soybean yields. Furthermore, it should be noted that poultry litter does not always increase soybean yields above that of inorganic fertilizers. Reasons why relatively high rates (2 ton/acre) of poultry litter appeared to stimulate soybean yields on some soils are not known. Research evaluating soybean response to poultry litter will be continued in 2009.

ACKNOWLEDGMENT

Research was funded by Arkansas Soybean Check-off Funds and administered by Arkansas Soybean Research and Promotion Board. The University of Arkansas Division of Agriculture also provided support.

LITERATURE CITED

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Table 1. Selected soil chemical property means (*n* = 6) of poultry litter fertilization trials conducted at three sites during 2008.

	Soil	Total soil		Mehlich-3-extractable nutrients										
Site	pH	C	N	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
		(%)		(ppm)										
PTBS	8.2	1.43	0.12	17	105	2574	375	10	25	228	310	3.0	1.3	0.4
Poinsett-1	8.1	1.21	0.11	6	103	3734	474	76	98	469	211	5.9	0.4	0.2
Poinsett-2	7.8	1.29	0.12	40	135	3539	398	26	133	478	114	11.8	0.6	0.8

Table 2. Soybean seed yield and trifoliate leaf K concentration at the R2 stage responses to the nutrient source × application rate interaction, averaged across three silt loam soil sites in 2008.

	Yield		Tissue K	
Fertilizer source	Low rate	High rate	Low rate	High rate
	(bu/acre)		(% K)	
No fertilizer control	61		1.21	
N only	62	61	1.21	1.15
PK	68	72	1.45	1.58
NPK	69	68	1.45	1.60
Poultry litter	70	76	1.45	1.63
LSD0.10	3.2		0.059	
P-value	0.0248		0.0004	

Table 3. Soybean trifoliate leaf P and K concentrations, averaged across nutrient sources, at the R2 growth stage as affected by the site and nutrient rate interaction.

	Potassium			Phosphorus		
Site	None	Low	High	None	Low	High
	(% K)			(% P)		
PTBS	1.21	1.33	1.45	0.32	0.31	0.32
Poinsett-1	1.13	1.33	1.32	0.27	0.27	0.27
Poinsett-2	1.29	1.50	1.71	0.33	0.33	0.36
LSD0.10[z]	0.066			0.011		
LSD0.10[y]	0.238			0.049		
P-value	0.0001			0.0089		

[z] LSD0.10 to compare nutrient rate means within a site.
[y] LSD0.10 to compare any two means.

Table 4. Trifoliate-leaf P concentrations, averaged across nutrient addition rates, at the R2 growth stage of soybean at the R2 stage response to K-fertilizer rate at three sites during 2008.

Fertilizer source	PTBS	Poinsett-1	Poinsett-2
	(% P)		
None	0.32	0.27	0.33
N only	0.31	0.27	0.32
PK	0.32	0.26	0.35
NPK	0.32	0.28	0.35
Poultry litter	0.32	0.27	0.36
LSD0.10[z]	0.015		
LSD0.10[y]	0.066		
P-value	0.0031		

[z] LSD0.10 to compare nutrient rate means within a site.
[y] LSD0.10 to compare any two means.