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Wayne E. Sabbe Arkansas Soil Fertility Studies 2009

Nathan A. Slaton
University of Arkansas, Fayetteville

Wayne E.Sabbe
ARKANSAS
SOIL FERTILITY STUDIES
• 2009 •

Nathan A. Slaton, Editor

UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE

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WAYNE E. SABBE ARKANSAS SOIL FERTILITY STUDIES – 2009 –

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SUMMARY

Rapid technological changes in crop management and production require that the research efforts also be presented in an expeditious manner. The contributions of soil fertility and fertilizers are major production factors in all Arkansas crops. The studies described within will allow producers to compare their practices with the university's research efforts. Additionally, soil test data and fertilizer sales are presented to allow comparisons among years, crops, and other areas within Arkansas.

INTRODUCTION

The 2009 Soil Fertility Studies include research reports on numerous Arkansas commodities and several disciplines. For more information on any topic, please contact the author(s). Also included is a summary of soil test data from samples submitted during 2008. This set of data includes information for counties, soil associations, physiographic areas, and selected cropping systems.

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Mention of a trade name is for facilitating communication only. It does not imply any endorsement of a particular product by the authors or the University of Arkansas Division of Agriculture, or exclusion of any other product that may perform similarly.

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Soil Test and Fertilizer Sales Data: Summary for the 2008 Growing Season

R.E. DeLong, S.D. Carroll, N.A. Slaton, M. Mozaffari, and C. Herron

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Soil test data from samples submitted to the University of Arkansas Division of Agriculture Soil Testing and Research Laboratory in Marianna between 1 January 2008 and 31 December 2008 were categorized according to geographic area (GA), county, soil association number (SAN), and selected cropping systems. The GA and SAN were derived from the General Soil Map, State of Arkansas (Base 4-R-38034, USDA, and University of Arkansas Agricultural Experiment Station, Fayetteville, Ark., December, 1982). Descriptive statistics of the soil-test data were calculated for categorical ranges for pH, phosphorus (P), potassium (K), and zinc (Zn). Soil pH and Mehlich-3 extractable (analyzed using inductively coupled plasma spectroscopy, ICAP) soil nutrient (i.e., P, K, Zn, etc.) concentrations indicate the relative level of soil fertility.

RESULTS AND DISCUSSION

Crop Acreage and Soil Sampling Intensity

Between 1 January 2008 and 31 December 2008, 120,408 soil samples were analyzed by the Soil Testing and Research Laboratory in Marianna. After removing standard and check soils measured for quality assurance (10,080), the total number of client samples was 110,328. A total of 56,884 soil samples, representing a total of 1,532,805 acres averaging 27 acres/sample, had complete data for county, total acres, and soil pH, P, K, and Zn. The difference of 52,029 samples between the total samples and samples with reported acreage were designated as grid samples conducted on row crops (49,470) or special or research samples (2,559). Soil samples from the Bottom Lands and Terraces and Loessial Plains, primarily row-crop areas, represented 56% of the total samples and 82% of the total acreage (Table 1). The average number of acres represented by each soil sample ranged from 1 to 81 acres/sample (Table 2). Clients from Craighead (30,520); Clay (Corning and Piggott offices, 7,914); Crittenden (6,119); Lawrence (5,057); Lee (4,503); Washington (3,479); and Arkansas (Stuttgart and De Witt offices, 3,305) counties submitted the most soil samples for analyses. Sample numbers from Craighead county increased almost 9× this year due to three clients submitting 88% of its samples. Sample numbers submitted by clients in Washington County have increased by more than 100% from previous years, which is likely due to regulations concerning P and its relation to water quality in northwest Arkansas.

Soil association numbers show that most samples were taken from row-crop and pasture production areas (Table 3). The soil associations having the most samples submitted were 44 (Calloway-Henry-Grenada-Calhoun), 4 (Captina-Nixa-Tonti), 22 (Foley-Jackport-Crowley), 45 (Crowley-Stuttgart), 24 (Sharkey-Alligator-Tunica), 32 (Rilla-Hebert), and 25 (Dundee-Bosket-Dubbs). However, the soil associations representing the largest acreage were 44, 24, 45, 32, 23 (Kobel), 25, and 22 which represented 26, 17, 12, 6, 5, 5, and 4% of the total sampled acreage, respectively. Crop codes indicate that land used for i) row crop production accounted for 86% of the sampled acreage and 58% of submitted samples, ii) hay and pasture production accounted for 13% of the sampled acreage and 21% of submitted samples, and iii) home lawns and gardens accounted for <1% of sampled acreage and 16% of the submitted samples (Table 4).

Soil Test Data

Information in Tables 5, 6, and 7 pertains to the fertility status of Arkansas soils as categorized by GA, county, and the crop grown prior to collecting soil samples, respectively. The soil-test levels and median (Md) values relate to the potential fertility of a soil, but not necessarily to the productivity of the soil. The median is the value that has an equal number of higher and lower observations and thus is a better overall indicator of a soil's fertility status than a mean value. Therefore, it is not practical to compare soil-test values among SAN without knowledge of factors such as location, topography, and cropping system. Likewise, soil-test values among counties cannot be realistically compared without knowledge of the SAN and a profile of the local agricultural production systems. Soil-test data for cropping systems can be carefully compared; however, the specific agricultural production systems often indicate past fertilization practices or may be unique to certain soils that would influence the current soil-test values. For example, soils used for cotton production have a history of intensive fertilization. Similarly, rice is commonly grown on soils with low P and K concentrations, which may be an artifact of the management practices (i.e., flooded soil conditions) used rather than routine fertilization practices. The pH of most soils in Arkansas ranges from 5.5 to 6.5, however, the predominant soil pH range varies among GA (Table 5), county (Table 6), and last crop produced (Table 7).

Table 7 contains soil-test concentration ranges and the median concentrations for each of the cropping system categories. Soil-test concentration ranges, from low to high concentrations, can be categorized into soil-test levels of 'Very Low', 'Low', 'Medium', 'Optimum', and 'Above Optimum'. Among row crops, the lowest median concentrations of P and K occur in soils used for the production of rice and soybean, whereas soils used for cotton production have the highest median concentrations of P and K. The highest median concentrations of Zn occur in soils used for non-row-crops (e.g., home garden and ornamental). Fertilizer tonnage sold by county (Table 8) and by fertilizer nutrient, formulation, and use (Table 9) illustrates the wide use of inorganic fertilizer predominantly in row-crop production areas. However, fertilizer tonnage does not account for the use of fresh animal manures or other by-products as a source of nutrients that may be applied to the land. Only processed manures or biosolids (e.g., pelleted poultry litter) are quantified in fertilizer tonnage data under the category of 'Organic'.

PRACTICAL APPLICATIONS

The data presented, or more specific data, can be used in county- or commodity-specific educational programs on soil fertility and fertilization practices. Comparisons of annual soil-test information can also document trends in fertilization practices or areas where nutrient management issues may need to be addressed. Of the soil samples submitted in 2008, 84% of the samples and 99% of the represented acreage had commercial agricultural/farm crop codes. Likewise, 97% of the fertilizer and soil amendment tonnage sold was categorized for Farm Use. Fertilizer and soil amendment tonnage for on-farm use was sold, in decreasing order, as N (55%), multi-nutrient (27%), miscellaneous (9%), K (6%), and P (<2%). Five counties in eastern Arkansas (Arkansas, Mississippi, Poinsett, Craighead, and Clay counties) accounted for 33% of the total fertilizer sold.

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Financial support for routine soil testing services offered to Arkansas citizens is provided by a proportion of Fertilizer Tonnage Fees. The University of Arkansas Division of Agriculture also provided support.

Table 1. Sample number and total acreage by geographic area for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2008 through 31 December 2008.

Geographic area	Acres sampled	No. of samples	Acres/ sample
Ozark Highlands - Cherty Limestone and Dolomite	101,204	8,298	12
Ozark Highlands - Sandstone and Limestone	9,003	455	20
Boston Mountains	23,850	2,304	10
Arkansas Valley and Ridges	43,008	3,857	11
Ouachita Mountains	25,876	2,992	9
Bottom Lands and Terraces	642,449	17,655	36
Coastal Plain	41,926	3,678	11
Loessial Plains	560,281	11,431	49
Loessial Hills	14,189	1,189	12
Blackland Prairie	1,021	157	7

Table 2. Sample number and total acreage by county for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2008 through 31 December 2008.

County	Acres sampled	No. of samples	Acres/ sample	County	Acres sampled	No. of samples	Acres/ sample
Arkansas, De Witt	93,909	1,673	56	Lee	219,551	4,503	49
Arkansas, Stuttgart	58,404	1,632	36	Lincoln	2,787	131	21
Ashley	8,798	596	15	Little River	5,501	171	32
Baxter	2,464	434	6	Logan, Booneville	1,478	184	8
Benton	9,582	1,439	7	Logan, Paris	6,064	411	15
Boone	12,852	728	18	Lonoke	83,034	2,546	33
Bradley	639	88	7	Madison	9,361	504	19
Calhoun	153	46	3	Marion	5,194	206	25
Carroll	15,196	765	20	Miller	1,553	162	10
Chicot	21,564	398	54	Mississippi	30,484	2,156	14
Clark	2,786	322	9	Monroe	214,841	2,647	81
Clay, Corning	16,239	2,954	6	Montgomery	5,810	365	16
Clay, Piggott	17,435	4,960	4	Nevada	705	62	11
Cleburne	5,432	488	11	Newton	2,748	169	16
Cleveland	8,236	306	27	Ouachita	1,552	221	7
Columbia	1,541	225	7	Perry	1,409	127	11
Conway	9,947	358	28	Phillips	13,448	556	24
Craighead	76,887	30,520	3	Pike	5,562	298	19
Crawford	7,029	410	17	Poinsett	60,504	2,395	25
Crittenden	35,361	6,119	6	Polk	3,639	331	11
Cross	75,276	1,633	46	Pope	7,645	540	14
Dallas	404	68	6	Prairie, Des Arc	20,161	418	48
Desha	24,333	1,644	15	Prairie, De Valls Bluff	17,977	439	41
Drew	3,934	621	6	Pulaski	4,628	1,109	4
Faulkner	3,856	551	7	Randolph	17,268	2,296	8
Franklin, Charleston	196	14	14	Saline	912	360	3
Franklin, Ozark	4,847	315	15	Scott	3,970	214	19
Fulton	2,925	305	10	Searcy	3,127	225	14
Garland	1,571	1,154	1	Sebastian	5,131	661	8
Grant	375	143	3	Sevier	6,262	288	22
Greene	33,441	2,048	16	Sharp	5,857	364	16
Hempstead	5,134	298	17	St. Francis	3,289	1,672	2
Hot Spring	2,353	325	7	Stone	2,130	195	11
Howard	9,287	459	20	Union	820	251	3
Independence	9,053	491	18	Van Buren	1,271	159	8
Izard	4,179	312	13	Washington	40,725	3,479	12
Jackson	17,438	2,742	6	White	13,302	1,397	10
Jefferson	39,696	1,262	32	Woodruff	10,921	638	17
Johnson	2,255	267	9	Yell, Danville	7,977	452	18
Lafayette	5,644	214	26	Yell, Dardanelle	948	80	12
Lawrence	32,608	5,057	7				

Table 3. Sample number, total acreage by soil association number (SAN), average acreage per sample, and median soil pH and Mehlich-3 extractable P and K values by soil association for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2008 through 31 December 2008.

SAN	Soil association	Acres sampled	No. of samples	Acres/ sample	Median pH	Median P	Median K
1.	Clarksville-Nixa-Noark	17,085	1,038	17	6.0	60	135
2.	Gepp-Doniphan-Gassville-Agnos	8,398	976	9	6.3	63	143
3.	Arkana-Moko	21,153	1,151	18	6.1	87	140
4.	Captina-Nixa-Tonti	51,224	4,935	10	6.1	106	149
5.	Captina-Doniphan-Gepp	2,484	121	21	6.2	43	115
6.	Eden-Newnata-Moko	860	77	11	5.6	63	127
7.	Estate-Portia-Moko	2,471	90	28	6.2	86	123
8.	Brockwell-Boden-Portia	6,532	365	18	6.1	66	99
9.	Linker-Mountainburg-Sidon	6,797	587	12	6.0	57	111
10.	Enders-Nella-Mountainburg-Steprock	17,053	1,717	10	5.9	91	114
11.	Falkner-Wrightsville	570	25	23	5.6	46	91
12.	Leadvale-Taft	15,309	1,726	9	5.8	62	115
13.	Enders-Mountainburg-Nella-Steprock	5,682	330	17	5.7	47	90
14.	Spadra-Guthrie-Pickwick	3,075	205	15	5.7	38	112
15.	Linker-Mountainburg	18,372	1,571	12	5.8	69	114
16.	Carnasaw-Pirum-Clebit	9,974	1,232	8	5.7	86	107
17.	Kenn-Ceda-Avilla	4,879	372	13	5.6	84	96
18.	Carnasaw-Sherwood-Bismarck	6,401	1,103	6	5.7	111	120
19.	Carnasaw-Bismarck	692	58	12	5.4	105	144
20.	Leadvale-Taft	2,734	110	25	5.3	37	94
21.	Spadra-Pickwick	1,196	117	10	5.5	61	103
22.	Foley-Jackport-Crowley	63,500	4,467	14	6.3	40	119
23.	Kobel	71,980	1,218	59	6.4	38	122
24.	Sharkey-Alligator-Tunica	252,397	3,273	77	6.2	42	257
25.	Dundee-Bosket-Dubbs	71,670	2,117	34	6.4	63	156
26.	Amagon-Dundee	40,254	1,507	27	6.1	66	174
27.	Sharkey-Steele	11,051	329	34	6.0	65	204
28.	Commerce-Sharkey-Crevasse-Robinsonville	11,538	319	36	6.4	54	187
29.	Perry-Portland	23,527	952	25	6.1	46	181
30.	Crevasse-Bruno-Oklared	291	15	19	6.2	117	178
31.	Roxana-Dardanelle-Bruno-Roellen	6,216	282	22	5.9	82	127
32.	Rilla-Hebert	80,409	2,874	28	6.3	51	143
33.	Billyhaw-Perry	2,804	81	35	6.7	54	315
34.	Severn-Oklared	5,429	93	58	6.2	78	159
35.	Adaton	181	11	17	6.0	300	123
36.	Wrightsville-Louin-Acadia	1,118	91	12	6.2	56	105
37.	Muskogee-Wrightsville-McKamie	84	26	3	5.9	97	114
38.	Amy-Smithton-Pheba	1,325	169	8	5.6	53	87
39.	Darco-Briley-Smithdale	71	17	4	5.2	162	68
40.	Pheba-Amy-Savannah	1,224	185	7	5.5	67	72
41.	Smithdale-Sacul-Savannah-Saffell	16,293	1,431	11	5.5	101	100
42.	Sacul-Smithdale-Sawyer	14,541	1,327	11	5.6	55	102
43.	Guyton-Ouachita-Sardis	8,472	549	15	5.5	65	108
44.	Calloway-Henry-Grenada-Calhoun	378,648	7,852	48	6.5	34	106
45.	Crowley-Stuttgart	181,633	3,579	51	6.4	30	103
46.	Loring	2,386	143	17	5.9	32	92
47.	Loring-Memphis	10,712	1,003	11	6.0	37	114
48.	Brandon	1,091	43	25	6.0	34	91
49.	Oktibbeha-Sumter	1,021	157	7	5.8	74	122

Table 4. Sample number and total acreage by previous crop for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2008 through 31 December 2008.

Crop	Acres sampled	No. of samples	Acres/ sample
Corn	166,634	2,710	62
Cotton	114,501	4,037	28
Grain sorghum, non-irrigated	3,146	99	32
Grain sorghum, irrigated	33,220	764	44
Rice	149,505	3,511	43
Soybean	696,144	13,726	51
Wheat	22,525	691	33
Cool-season grass hay	16,458	829	20
Native Warm-season grass hay	3,816	279	14
Warm-season grass hay	41,263	2,131	19
Pasture, all categories	114,475	6,018	19
Home garden	4,050	3,276	1
Home lawn	4,346	3,963	1
Small fruit	1,008	450	2
Ornamental	2,697	1,807	2

Table 5. Soil test data (% of sampled acres) and median (Md) values by geographic area for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2008 through 31 December 2008.

Geographic area	Soil pH[z]						Mehlich-3 soil P[y] (ppm)						Mehlich-3 soil K[y] (ppm)						Mehlich-3 soil Zn[y] (ppm)					
	<5.4	5.4-5.7	5.8-6.2	6.3-6.9	>6.9	Md[x]	<16	16-25	26-35	36-50	>50	Md	<61	61-90	91-130	131-175	>175	Md	<1.6	1.6-3.0	3.1-4.0	4.1-8.0	>8.0	Md
	---(% of sampled acreage) ---						--(% of sampled acreage) --					(ppm)	-- (% of sampled acreage)---					(ppm)	---- (% of sampled acreage) ----					(ppm)
Ozark Highlands - Cherty Limestone and Dolomite	14	17	26	26	17	6.1	5	6	8	12	69	88	11	13	20	19	37	145	2	11	9	29	49	8.1
Ozark Highlands - Sandstone and Limestone	15	17	26	30	12	6.1	9	12	8	11	60	69	17	22	26	13	22	105	6	23	12	32	27	4.8
Boston Mountains	22	19	23	26	10	5.9	6	8	7	12	67	81	17	19	23	15	26	114	4	17	9	28	42	6.7
Arkansas Valley & Ridges	29	20	22	21	8	5.8	12	13	9	10	56	61	15	21	24	17	23	112	4	16	11	27	42	6.4
Ouachita Mountains	31	25	23	15	6	5.7	7	6	7	10	70	91	19	19	23	17	22	110	3	12	10	28	47	7.3
Bottom Lands & Terraces	9	14	26	35	16	6.3	5	11	14	23	47	48	4	12	22	21	41	156	4	23	18	41	14	4.3
Coastal Plain	38	22	19	15	6	5.6	13	11	7	10	59	72	25	21	18	13	23	99	7	19	11	24	39	5.9
Loessial Plains	11	11	20	30	28	6.4	13	23	20	19	25	32	9	27	32	17	15	105	7	27	17	32	17	4.0
Loessial Hills	23	16	24	24	13	6.0	17	17	15	15	36	36	15	22	26	17	20	110	7	28	16	26	23	4.0
Blackland Prairie	32	17	15	16	20	5.8	11	10	12	10	57	74	17	19	19	11	34	122	6	16	10	29	39	6.4
Average	22	18	22	24	14	6.0	10	12	11	13	53	65	15	20	23	16	26	118	5	19	12	30	34	5.8

[z] Analysis by electrode in 1:2 soil weight:deionized water volume.
[y] Analysis by ICAP in 1:10 soil weight:Mehlich-3 volume.
[x] Md = median.

Table 6. Soil test data (% of sampled acres) and median (Md) values by county for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2008 through 31 December 2008.

	Soil pH[z]						Mehlich-3 soil P[y] (ppm)						Mehlich-3 soil K[y] (ppm)						Mehlich-3 soil Zn[y] (ppm)					
County	<5.4	5.4-5.7	5.8-6.2	6.3-6.9	>6.9	Md[x]	<16	16-25	26-35	36-50	>50	Md	<61	61-90	91-130	131-175	>175	Md	<1.6	1.6-3.0	3.1-4.0	4.1-8.0	>8.0	Md
	---(% of sampled acreage) ---						--(% of sampled acreage) --					(ppm)	-- (% of sampled acreage)---					(ppm)	---- (% of sampled acreage) ----					(ppm)
Arkansas, DeWitt	8	15	28	44	6.9	14	28	26	19	13	28	8	36	41	11	4	95	8	17	15	44	16	4.7	
Arkansas, Stuttgart	10	12	21	35	22	6.4	16	25	21	18	20	29	4	32	31	13	20	105	8	23	20	37	12	4.0
Ashley	13	10	22	30	25	6.3	10	13	12	17	48	49	11	18	19	21	31	136	15	29	16	27	13	3.4
Baxter	8	9	15	21	47	6.9	5	7	9	10	69	89	7	14	21	23	35	147	1	7	6	22	64	10.3
Benton	17	17	27	25	14	6.0	2	3	5	11	79	107	7	9	17	25	42	163	1	5	9	33	52	8.6
Boone	13	20	28	28	11	6.1	5	10	10	14	61	61	13	14	15	17	41	146	6	18	11	30	35	5.6
Bradley	23	16	10	24	27	6.3	13	5	1	5	76	181	23	10	11	18	38	137	7	8	8	18	59	11.5
Calhoun	33	22	17	20	8	5.6	0	4	7	15	74	70	9	22	33	17	19	108	7	24	15	20	34	4.6
Carroll	7	19	34	25	15	6.1	2	4	9	14	71	98	11	12	15	16	46	162	1	6	7	28	58	10.0
Chicot	11	12	26	35	16	6.3	8	18	26	21	27	34	8	8	14	13	57	216	5	27	20	32	16	4.0
Clark	39	18	19	15	9	5.6	18	10	6	9	57	74	21	26	20	12	21	93	10	23	12	26	29	4.7
Clay, Corning	8	18	29	31	14	6.2	12	22	22	21	23	33	10	30	40	16	4	100	2	15	13	42	28	5.6
Clay, Piggott	8	13	27	38	14	6.3	3	6	9	19	63	60	3	12	26	25	34	146	6	29	19	35	11	3.8
Cleburne	37	20	19	18	6	5.6	10	14	12	13	51	54	21	23	23	14	19	101	7	26	13	24	30	4.3
Cleveland	18	27	28	20	7	5.8	13	14	10	17	46	46	5	11	14	14	56	193	3	26	23	27	21	3.9
Columbia	32	22	25	14	7	5.7	10	8	5	6	71	105	17	29	15	19	20	101	10	9	6	21	54	9.2
Conway	42	14	20	17	7	5.6	11	12	12	15	50	52	18	22	23	15	22	105	7	22	10	24	37	5.5
Craighead	10	11	20	32	27	6.4	9	13	14	19	45	47	9	15	21	19	36	141	3	20	17	40	20	4.7
Crawford	16	19	22	27	16	6.1	6	10	11	12	61	69	1	18	25	17	28	125	3	12	14	38	33	5.9
Crittenden	11	11	22	30	26	6.4	1	8	12	22	57	55	2	5	15	20	58	195	3	18	17	48	14	4.7
Cross	6	7	13	28	46	6.9	8	22	24	22	24	34	14	35	28	11	12	91	5	26	18	36	15	4.2
Dallas	49	21	18	7	5	5.4	29	16	7	10	38	29	47	25	19	3	6	61	24	24	9	24	19	3.2
Desha	6	13	32	39	10	6.2	2	7	9	22	60	57	1	5	15	24	55	187	4	23	19	40	14	4.2
Drew	54	11	11	20	4	5.2	40	11	6	9	34	24	24	23	22	12	19	93	5	29	17	27	22	4.0
Faulkner	38	15	20	19	8	5.7	17	15	11	10	47	45	15	27	27	15	16	101	9	26	12	23	30	4.2
Franklin, Charleston	29	14	14	21	22	5.9	14	14	7	7	58	64	0	14	14	29	43	147	0	14	0	36	50	7.1
Franklin, Ozark	24	30	24	15	7	5.7	6	12	10	9	63	75	10	20	29	18	23	117	2	14	9	30	45	6.8
Fulton	22	22	25	22	9	5.8	11	10	13	13	53	59	9	16	22	15	38	142	2	21	19	37	21	4.7
Garland	25	22	28	19	6	5.8	2	4	7	12	75	91	10	19	28	19	24	119	1	9	11	34	45	7.0
Grant	36	15	17	21	11	5.7	16	11	11	8	54	55	29	20	23	13	15	92	9	25	13	19	34	4.4
Greene	10	12	30	37	11	6.2	12	18	18	20	32	37	10	22	27	17	24	115	7	31	21	32	9	3.6
Hempstead	33	22	19	15	11	5.7	9	11	6	11	63	74	22	19	19	12	28	108	5	13	14	23	45	7.4
Hot Spring	35	22	24	16	3	5.6	10	15	11	15	49	50	20	26	20	12	22	96	6	22	12	30	30	4.8
Howard	31	27	21	13	8	5.6	5	6	3	5	81	239	14	12	16	17	41	155	3	7	4	15	71	14.1
Independence	15	18	26	31	10	6.1	9	16	13	15	47	47	14	19	26	17	24	115	4	26	15	31	24	4.6
Izard	21	23	26	22	8	5.9	8	7	7	12	66	73	21	22	24	14	29	101	9	20	11	28	32	4.9
Jackson	10	15	26	37	12	6.2	3	9	13	19	56	57	2	14	27	29	28	141	5	28	19	31	17	3.9
Jefferson	13	11	23	39	14	6.3	6	8	12	32	42	46	7	15	33	18	27	124	7	30	18	27	18	3.7
Johnson	30	18	23	22	7	5.8	14	15	12	10	49	50	17	25	23	16	19	103	4	11	14	32	39	6.3
Lafayette	19	26	18	18	19	5.9	4	7	4	8	77	98	7	9	20	15	49	160	5	9	12	33	41	6.6
Lawrence	11	15	27	34	13	6.2	25	23	19	16	17	26	8	27	28	18	19	108	3	28	23	34	12	3.8
Lee	13	18	28	31	10	6.1	1	6	16	29	48	49	1	6	17	18	58	195	7	32	16	37	8	3.7
Lincoln	21	18	16	25	20	6.1	11	12	11	14	52	54	8	17	28	12	35	125	5	23	18	34	20	4.3
Little River	29	14	10	22	25	6.1	16	8	11	10	55	57	16	21	24	9	30	108	8	16	14	30	32	5.0

continued

Table 6. Continued.

County	Soil pH[z]						Mehlich-3 soil P[y] (ppm)						Mehlich-3 soil K[y] (ppm)						Mehlich-3 soil Zn[y] (ppm)					
	<5.4	5.4-5.7	5.8-6.2	6.3-6.9	>6.9	Md	<16	16-25	26-35	36-50	>50	Md	<61	61-90	91-130	131-175	>175	Md	<1.6	1.6-3.0	3.1-4.0	4.1-8.0	>8.0	Md
	---(% of sampled acreage) ---						--(% of sampled acreage) --					(ppm)	-- (% of sampled acreage)---					(ppm)	---- (% of sampled acreage) ----					(ppm)
Logan, Booneville	24	25	21	27	3	5.8	21	17	16	21	25	31	20	29	33	8	10	89	9	34	15	26	16	3.2
Logan, Paris	20	38	33	8	1	5.7	4	3	6	8	14	128	18	19	16	10	37	120	0	5	6	20	69	11.5
Lonoke	20	19	30	27	4	6.0	15	23	19	20	23	31	11	27	34	16	12	103	13	40	18	21	8	2.9
Madison	26	26	25	19	4	5.7	5	5	7	10	73	93	13	18	20	18	31	128	4	16	11	29	40	6.5
Marion	12	21	23	25	19	6.1	6	9	10	16	59	67	13	12	22	14	39	135	2	14	8	36	40	6.5
Miller	35	15	23	19	8	5.7	10	14	11	9	56	63	24	20	17	17	22	103	3	20	15	25	37	5.3
Mississippi	14	16	25	33	12	6.2	0	1	3	16	80	70	1	2	9	26	62	198	0	9	17	60	14	5.1
Monroe	12	14	21	28	25	6.3	22	21	16	19	22	30	5	16	30	25	24	129	4	31	20	33	12	3.7
Montgomery	27	29	22	19	3	5.7	3	5	4	9	79	140	25	26	18	17	14	90	1	13	11	26	49	7.9
Nevada	45	24	18	8	5	5.4	8	15	11	11	55	63	27	24	13	19	17	88	2	21	15	27	35	5.7
Newton	17	25	24	25	9	6.0	2	11	8	14	65	61	19	17	15	17	32	125	5	19	17	26	33	4.9
Ouachita	53	6	14	11	6	5.3	14	12	7	13	54	59	38	29	20	7	6	73	6	26	12	26	30	4.8
Perry	35	24	26	12	3	5.6	10	15	6	6	63	91	25	14	19	6	36	110	8	20	4	24	44	6.7
Phillips	10	10	21	45	14	6.4	1	6	11	18	64	62	1	8	35	29	27	140	4	23	18	40	15	4.3
Pike	39	24	24	13	0	5.5	10	12	5	7	66	96	49	16	15	8	12	61	6	22	9	21	42	6.0
Poinsett	3	7	15	36	39	6.8	13	24	21	19	23	31	10	38	28	12	12	93	4	17	11	32	36	5.8
Polk	48	24	14	11	3	5.4	6	9	9	10	66	85	28	16	20	17	19	104	9	17	12	22	40	5.8
Pope	26	19	23	23	9	5.8	8	8	5	10	69	104	16	18	25	15	26	115	2	12	8	25	53	8.4
Prairie, Des Arc	10	10	22	37	21	6.4	15	36	22	16	11	25	8	44	35	8	5	89	6	23	13	35	23	4.7
Prairie, De Valls Bluff	10	12	24	26	28	6.3	15	40	22	14	9	24	13	36	35	12	4	92	9	36	19	28	8	3.4
Pulaski	28	14	18	24	16	6.0	10	10	8	11	61	70	14	22	25	18	21	112	5	13	8	23	51	8.2
Randolph	6	12	18	34	30	6.5	11	19	20	22	28	36	9	23	30	19	19	112	3	19	17	43	18	4.8
Saline	41	14	12	18	15	5.6	12	10	11	13	54	62	29	25	23	12	11	84	6	23	11	26	34	5.3
Scott	27	23	25	21	4	5.7	12	17	10	10	51	50	31	17	19	10	23	93	4	22	15	29	30	5.0
Searcy	29	22	17	26	6	5.7	7	10	8	12	63	61	15	21	28	16	20	112	6	31	15	26	22	4.0
Sebastian	25	17	23	18	17	5.9	12	9	8	9	62	73	10	17	24	21	28	127	1	4	6	27	62	10.8
Sevier	45	30	17	5	3	5.4	9	12	7	9	63	90	30	14	17	14	25	108	4	16	10	32	38	6.0
Sharp	11	15	24	32	18	6.2	10	12	9	10	59	67	18	19	25	16	22	113	7	23	12	30	28	4.7
St. Francis	15	16	26	32	11	6.1	2	9	13	27	49	51	1	5	15	21	58	193	5	29	18	32	16	3.9
Stone	28	18	20	15	19	5.8	9	9	5	11	66	83	19	23	20	12	26	107	4	17	11	28	40	6.0
Union	45	19	15	14	7	5.4	20	8	6	5	61	75	38	18	19	14	11	81	10	18	6	18	48	7.9
Van Buren	26	33	20	8	13	5.6	6	6	4	21	63	64	20	24	24	11	21	101	6	14	9	38	33	5.7
Washington	13	16	25	28	18	6.2	4	5	8	10	73	107	10	13	22	19	36	141	1	8	7	27	57	9.9
White	22	15	21	31	11	6.1	8	13	9	12	58	65	17	22	24	16	21	109	5	17	11	26	41	6.3
Woodruff	9	16	23	33	19	6.3	18	31	20	19	12	26	25	33	22	14	6	82	13	36	24	19	8	3.1
Yell, Danville	41	31	15	11	2	5.5	23	12	6	6	53	60	24	19	20	17	20	101	6	14	7	25	48	7.6
Yell, Dardanelle	19	28	30	14	9	5.8	6	11	15	8	60	71	1	24	28	9	38	129	1	4	5	39	51	8.1
Average	23	18	23	24	12	6.0	10	12	11	14	53	65	15	20	23	16	26	120	5	20	13	30	32	5.8

[z] Analysis by electrode in 1:2 soil weight:deionized water volume.
[y] Analysis by ICAP in 1:10 soil weight:Mehlich-3 volume.
[x] Md = median.

Table 7. Soil test data (% of sampled acres) and median (Md) values by previous crop for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2008 through 31 December 2008.

	Soil pH[z]						Mehlich-3 soil P[y] (ppm)						Mehlich-3 soil K[y] (ppm)						Mehlich-3 soil Zn[y] (ppm)					
Geographic area	<5.4	5.4-5.7	5.8-6.2	6.3-6.9	>6.9	Md[x]	<16	16-25	26-35	36-50	>50	Md	<61	61-90	91-130	131-175	>175	Md	<1.6	1.6-3.0	3.1-4.0	4.1-8.0	>8.0	Md
	---(% of sampled acreage) ---						--(% of sampled acreage) --					(ppm)	-- (% of sampled acreage)---					(ppm)	---- (% of sampled acreage) ----					(ppm)
Corn	6	10	25	42	17	6.4	2	8	15	28	47	49	3	12	29	20	36	141	5	24	18	41	12	4.2
Cotton	8	13	27	42	10	6.3	0	2	5	16	77	69	0	3	16	30	51	176	4	22	19	43	12	4.3
Grain sorghum, non-irrigated	24	27	18	13	18	5.7	8	21	17	16	38	43	28	15	8	16	33	126	6	44	11	27	12	3.0
Grain sorghum, irrigated	12	22	30	30	6	6.0	4	16	23	27	30	39	7	14	19	13	47	168	7	33	17	37	6	3.6
Rice	9	13	20	32	26	6.4	18	26	21	18	17	28	10	23	24	13	30	117	5	26	19	37	13	4.0
Soybean	8	12	23	32	25	6.4	11	21	21	24	23	34	6	24	30	16	24	114	5	25	18	39	13	4.2
Wheat	24	18	27	21	10	5.9	8	14	14	21	43	46	7	14	31	25	23	129	11	34	20	27	8	3.3
Cool-season grass hay	22	21	31	23	3	5.9	6	9	10	15	60	62	23	19	18	16	24	111	6	22	17	27	28	4.5
Native Warm-season grass hay	39	28	19	9	5	5.5	17	14	10	18	41	43	25	30	17	13	15	86	10	26	16	26	22	4.0
Warm-season grass hay	30	22	25	19	4	5.7	11	10	9	9	61	82	25	21	21	13	20	96	6	18	10	25	41	6.3
Pasture, all categories	28	25	26	17	4	5.7	9	11	8	11	61	70	18	18	19	15	30	120	5	18	11	28	38	6.0
Home garden	12	11	17	28	32	6.5	4	4	4	6	82	160	6	12	18	17	47	168	2	7	5	18	68	13.5
Home lawn	30	17	22	20	11	5.8	6	8	9	22	55	67	8	16	28	24	24	128	2	12	12	38	36	6.4
Small fruit	32	14	22	20	12	5.8	6	8	11	14	61	75	12	20	26	18	24	116	5	15	8	28	44	6.9
Ornamental	14	10	16	27	33	6.5	7	7	7	9	70	100	9	18	24	20	29	129	2	6	4	21	67	12.3
Average	20	18	23	25	14	6.0	8	12	12	17	51	65	13	17	22	18	30	128	5	22	14	31	28	5.8

[z] Analysis by electrode in 1:2 soil weight:deionized water volume.
[y] Analysis by ICAP in 1:10 soil weight:Mehlich-3 volume.
[x] Md = median.

Table 8. Fertilizer tonnage sold in each Arkansas county from 1 July 2008 through 30 June 2009[z].

County	Fertilizer sold	County	Fertilizer sold
	(tons)		(tons)
Arkansas	73,271	Lee	19,103
Ashley	14,502	Lincoln	11,611
Baxter	1,054	Little River	3,178
Benton	10,174	Logan	2,358
Boone	1,504	Lonoke	42,368
Bradley	297	Madison	2,788
Calhoun	120	Marion	604
Carroll	1,123	Miller	7,852
Chicot	26,037	Mississippi	71,233
Clark	592	Monroe	32,247
Clay	46,640	Montgomery	195
Cleburne	1,223	Nevada	450
Cleveland	7	Newton	416
Columbia	185	Ouachita	80
Conway	4,052	Perry	424
Craighead	48,284	Phillips	44,146
Crawford	3,004	Pike	1,132
Crittenden	13,562	Poinsett	63,826
Cross	29,794	Polk	1,953
Dallas	540	Pope	1,417
Desha	31,074	Prairie	23,008
Drew	7,450	Pulaski	21,748
Faulkner	2,705	Randolph	16,602
Franklin	799	Saline	1,030
Fulton	1,148	Scott	249
Garland	582	Searcy	918
Grant	2,290	Sebastian	1,592
Greene	29,061	Sevier	478
Hempstead	2,390	Sharp	488
Hot Spring	480	St. Francis	42,747
Howard	774	Stone	1,033
Independence	7,140	Union	1,459
Izard	1,111	Van Buren	4,532
Jackson	22,154	Washington	2,492
Jefferson	19,882	White	18,718
Johnson	536	Woodruff	27,993
Lafayette	5,863	Yell	551
Lawrence	28,601		

[z] Arkansas Distribution of Fertilizer Sales by County July 1, 2008 to June 30, 2009, Arkansas State Plant Board, Division of Feed and Fertilizer, Little Rock, Ark., and University of Arkansas Division of Agriculture, Arkansas Agricultural Experiment Station, Fayetteville, Ark.

Table 9. Fertilizer nutrient, formulation, and use category sold in Arkansas from 1 July 2008 through 30 June 2009[z].

	Container			Use		
Fertilizer	Bag	Bulk	Liquid	Farm	Non-farm	Totals
	---------- (tons) ----------					
Multi-nutrient	40,134	196,042	12,515	235,035	13,656	248,691
Nitrogen	10,117	435,546	55,457	499,041	2,079	501,120
Phosphate	1,036	13,569	645	15,164	86	15,250
Potash	2,225	47,683	2,093	51,827	175	52,002
Organic	19	108	0	109	18	127
Micronutrient	5,397	1,634	775	3,810	3,995	7,805
Lime	456	3,400	0	3,777	79	3,856
Miscellaneous	10,527	66,575	7,298	75,697	8,702	84,399
Totals	69,910	764,558	78,781	884,460	28,789	913,249

[z] Arkansas Distribution of Fertilizer Sales By Counties 1 July 2008 to 30 June 2009, Arkansas State Plant Board, Division of Feed and Fertilizer, Little Rock, Ark., and University of Arkansas Division of Agriculture, Arkansas Agricultural Experiment Station, Fayetteville, Ark.

Crop Response to Poultry Manure and Biosolids in Two Leveled Soils

M. Mozaffari

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Row-crop farmers in eastern Arkansas and other regions level land to create a gentle and uniform slope across a field to increase irrigation water use efficiency. After land leveling, soil productivity may be reduced by the extensive soil manipulation, which often requires that organic amendments be applied to aid in restoring soil productivity (Brye et al., 2004). Growers in eastern Arkansas have traditionally used fresh poultry litter (FPL) to restore soil productivity after land leveling, but FPL is not always readily available or the existing equipment may not be suitable for its application. Municipal biosolids have high organic matter content, contain N and other plant nutrients, and have been successfully used for mine land reclamation (Sopper, 1992). A type of pelleted biosolids has recently become available in eastern Arkansas and is being marketed under the trade name of Top Choice Organic® (TCO). Information on the potential effectiveness of TCO for restoring the productivity of precision leveled fields will be beneficial for Arkansas growers who may be interested in alternatives to FPL. Therefore, the objective of this research was to evaluate corn (*Zea mays* L.) and cotton (*Gossypium hirsutumn* L.) response to FPL, pelleted poultry litter (PPL), and TCO in combination with synthetic fertilizers on two leveled soils in eastern Arkansas.

PROCEDURES

Two separate irrigated field experiments, one each for corn and cotton, were conducted at the Lon Mann Cotton Research Station in Marianna, Ark., during 2008. The corn experiment was located on a Calloway silt loam and the cotton experiment was located on a Loring silt loam. Both fields had been precision leveled by removing the top 3 to 8 inches of soil from areas of higher elevation and depositing it in areas of lower elevation. A composite soil sample was collected from the 0- to 6-inch depth of each replication (n = 5) of each experiment before applying any soil amendments. Soil samples were dried, crushed, and soil NO_3-N was extracted with 0.025 *M* aluminum sulfate and measured with a specific ion electrode (Donahue, 1992). Other soil nutrients were extracted with Mehlich-3 solution and the concentrations of elements in the extract were measured by inductively coupled plasma atomic emission spectroscopy. Soil particle size analysis was performed by the hydrometer method (Arshad et al., 1996).

Pelleted poultry litter was purchased from a local fertilizer dealer and TCO was provided by MANNCO Fertilizer Company (http://manncofertilizer.com/products.html). Fresh poultry litter was obtained from a baling facility in northwest Arkansas. Sub-samples of FPL, PPL, and TCO were analyzed by the University of Arkansas Agricultural Diagnostic Laboratory using standard methods (Table 2; Peters et al., 2003).

The corn experiment was a randomized complete block design with three organic soil amendments (FPL, PPL, TCO) each applied at three rates (500, 1,000, and 2,000 lb/acre) plus 100 lb N/acre as urea (urea-N, 46% N) and compared to a treatment of 100 lb N/acre as urea and a no N control. Muriate of potash (0-0-60), triple superphosphate (0-46-0) and $ZnSO_4$ were broadcast applied to supply 120 lb K_2O, 46 lb P_2O_5, 6.7 lb Zn, and 5 lb S/acre on 15 April to all treatments except the no N control. The no N control received no soil amendment or fertilizer. All soil amendments were hand-applied and incorporated with a Do-all on April 15. Each plot was 25-ft long and 10-ft wide allowing for four rows of corn planted in 30-inch wide rows. Corn cultivar 'Pioneer 32B29' was planted on 22 April and emerged on 29 April. Corn plants in the center 2-rows of each plot were harvested with a plot combine on 17 September and grain yields were adjusted to 15.5% moisture content. At harvest, grain subsamples were collected and analyzed for total N using the Kjeldahl method. Grain N uptake was calculated by multiplying grain yield by N concentration.

The experimental design for cotton was a randomized complete block where FPL, PPL, and TCO were each applied at two rates (1,000 and 2,000 lb/acre) plus 50 lb N/acre as urea (urea-N) and compared to cotton fertilized with 50 lb N/acre as urea and a control that received no fertilizer or organic amendment. The same organic N amendment sources for the corn experiment were used for cotton research. All cotton plots except the control, were fertilized with muriate of potash and triple superphosphate to supply 90 lb K_2O and 90 lb P_2O_5/acre, respectively. All soil amendments were hand-applied and incorporated on 23 May. Each plot was 40-ft long and 12.6-ft wide allowing for four rows of cotton with 38-inch-wide row spacings. Stoneville 4554B2RF cotton was planted on 27 May. Cotton leaf-blades (15) were collected from the 5^{th} node from the top in each plot on 17 July (mid-bloom) and analyzed for total N as described previously. The two center rows of cotton were harvested with a spindle-type picker on 6 October.

Conventional tillage and pest management practices were followed and each treatment was replicated five times for both studies. For each experiment, analysis of variance was performed using the GLM procedure of SAS to evaluate the effect of FPL, PPL, TCO and urea-N on yield, grain N content (corn) and cotton leaf blade N concentration. When appropriate ($P \leq 0.10$), means were separated by the minimum significant difference (MSD) method.

RESULTS AND DISCUSSION

Properties of Soils and Organic Amendments

Soil samples collected from the 0- to 6-inch depth of both experiments showed the soil texture was silt loam, organic matter was relatively low, soil P availability was 'Medium' or higher, and soil K availability was 'Low' (Table 1). The chemical properties differed among the three organic amendments and may have influenced the outcome of the research since the amendments were applied at uniform rates of material resulting in different nutrient (e.g., N) addition rates. The FPL and PPL contained similar amounts of K, but the PPL had a lower moisture content and a higher N content than FPL resulting in slightly more N being applied in each rate increment. Likewise, the TCO had a lower moisture and higher N content than PPL and had the greatest N addition in each application rate increment. The amounts of N added in each rate for the corn and cotton experiments are listed in Tables 3 and 4. The amounts of P, K, and C also varied among amendment rates.

Corn Trial

Organic amendments and urea significantly ($P < 0.0001$) increased corn grain yields and grain N uptake compared to the control (Table 3). The average grain yield of corn receiving no fertilizer (control) was 42 bu/acre as compared to 121 bu/acre for corn receiving 100 lb N/acre as urea. Yield of corn that received any of the organic amendments plus urea-N varied from 129 to 178 bu/acre. The average yields of corn fertilized with 500 lb/acre of either FPL or PPL plus urea-N were not different from corn receiving only 100 lb N/acre as urea. However, yield of corn fertilized with 500 lb TCO/acre plus urea, was significantly greater than the yield of corn fertilized with only 100 lb urea-N/acre. Application of 500-lb/acre of FPL or PPL supplied 15 and 18 lb total N/acre, respectively, compared to 31 lb total N/acre for the same rate of TCO. Grain yield of corn fertilized with 1,000 or 2,000 lb/acre of any organic amendment plus urea-N was significantly higher than corn receiving 100 lb N/acre as urea alone. Within each amendment rate, corn yield was always similar between FPL and PPL, which were both lower than the yield of TCO presumably because of the differences in the amount of N and/or C added. Corn grain N content differences among treatments were similar to those described for corn grain yield. The yield and grain N content differences among treatments observed in this study were attributed in large part to differences in the amount of N applied, but other less obvious benefits attributed to organic amendment properties can not be ruled out.

Cotton Trial

Organic amendment and urea application significantly ($P < 0.0001$) increased seedcotton yield and leaf blade N as compared to cotton receiving no N or soil amendment (Table 4). The average seedcotton yield in the control was 829 lb/acre compared to 2,668 to 3,829 lb/acre for cotton receiving urea-N only or urea-N plus an organic amendment. Among the amended treatments, urea plus 2,000 lb TCO/acre produced the highest yield. Seedcotton yield of cotton fertilized with 2,000 lb TCO/acre plus urea-N was significantly higher than cotton fertilized with the same rates of FPL or PPL plus urea-N. Similar to the corn study, the yield difference among treatments amended with 2000 lb FPL, PPL, TCO can be attributed to the higher N content and/or other yield-enhancing properties of the TCO. Application of 2,000 lb TCO/acre plus urea supplied 174 lb total N/acre, whereas 2,000 lb FPL or PPL/acre plus urea supplied 110 and 122 lb total N/acre, respectively. Average cotton leaf-blade N concentration in cotton receiving no N was 2.79% and that of cotton receiving N and/or organic amendments ranged from 4.17 to 4.67%.The sufficiency range for cotton leaf blade N concentration is 3.0% to 4.5% (Mitchell and Baker, 2000).

PRACTICAL APPLICATIONS

Fresh or pelleted poultry litter and TCO in combination with urea increased corn grain and seedcotton yields, corn grain N uptake and cotton leaf blade N concentration on two precision-leveled soils. Cotton and corn yield response to application of 2,000 lb/acre of TCO plus 100 (corn study) or 50 lb (cotton study) urea-N/acre was more pronounced than with the same amount of either FPL or PPL plus urea. Nitrogen content and perhaps some other constituents (e.g., organic matter) of these organic amendments improved corn and cotton yields. Additional work is needed to ascertain the consistency of these results across a diverse group of soils and cropping systems.

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Table 1. Selected soil chemical property means (0- to 6-inch depth) of samples taken before applying soil amendments on two recently leveled soils at Lon Mann Cotton Research Station in Marianna in 2008.

Test	Soil	Soil	Mehlich-3-extractable nutrients							Soil physical properties			
crop	pH[z]	NO_3-N[y]	P	K	Ca	Mg	Cu	Zn	SOM[x]	Sand	Silt	Clay	Texture
			(ppm)							(%)			
Corn	6.0	7	35	76	1414	224	0.9	2.5	1.12	2	73	25	silt loam
Cotton	5.9	10	54	79	1493	315	1.3	1.9	1.10	5	71	24	silt loam

[z] Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.
[y] NO_3-N measured by ion-specific electrode.
[x] SOM, soil organic matter determined by Weight Loss on Ignition.

Table 2. Selected chemical property means of fresh poultry litter (FPL), pelleted poultry litter (PPL), and Top Choice Organic® (TCO) pelleted biosolids on 'as is' basis.

N source	n^z	pH	H_2O	Total C	Total N	Total P[y]	Total K[x]	Total Ca	NO_3-N	NH_4-N
			(%)						(ppm)	
FPL	5	8.1	34	22.3	2.95	1.85	3.09	2.55	92	5346
PPL	6	7.4	14	28.1	3.57	1.33	3.04	2.18	1530	2632
TCO	8	5.9	7	36.7	6.28	2.23	0.38	2.24	259	2075

[z] Number of subsamples of each N source analyzed.
[y] Lb/ton P_2O_5 = %Total P on "as is" basis multiplied by 20 × 2.29.
[x] Lb/ton K_2O = %Total K on "as-is" basis multiplied by 20 × 1.2.

Table 3. Effect of fresh poultry litter (FPL), pelleted poultry litter (PPL), and Top Choice Organic® (TCO) pelleted biosolids in combination with urea fertilizer on corn grain yield and grain N content on a recently leveled Calloway silt loam at Lon Mann Cotton Research Station in Marianna in 2008.

Organic amendment		Type of N applied			Grain	
Type	Rate	Organic N[z]	Urea N	Total N[y]	Yield	N Uptake
	(lb/acre)	Rate (lb N/acre)			(bu/acre)	(lb/acre)
None (control)	0	0	0	0	42	30
None (urea)	0	0	100	100	121	79
PPL	500	18	100	118	129	83
PPL	1000	36	100	136	142	97
PPL	2000	72	100	172	152	100
FPL	500	15	100	115	123	80
FPL	1000	30	100	130	127	84
FPL	2000	60	100	160	146	99
TCO	500	31	100	131	140	92
TCO	1000	62	100	162	149	101
TCO	2000	124	100	224	178	125
P value					<0.0001	<0.0001
MSD at 0.10[x]					14	12

[z] Calculated from total N content of the organic N amendment on an 'as is' basis in Table 2.
[y] Calculated as the sum of organic N and synthetic N.
[x] Minimum Significant Difference (MSD) as determined by Waller-Duncan Test at $P = 0.10$.

Table 4. Effect of fresh poultry litter (FPL), pelleted poultry litter (PPL), and Top Choice Organic pelleted biosolids (TCO) on seedcotton yield and cotton leaf-blade N concentration in a recently leveled Loring silt loam at Lon Mann Cotton Research Station in Marianna in 2008.

Organic amendment		Nitrogen applied			Seedcotton	Leaf-blade N
Type	Rate	Organic N[z]	Urea-N	Total N[y]	yield	concentration
	(N lb/acre)				(lb/acre)	(%)
None (control)	0	0	0	0	829	2.79
None (urea)	0	0	50	50	2668	4.24
PPL	1000	36	50	86	2782	4.47
PPL	2000	72	50	122	3205	4.69
FPL	1000	30	50	80	2532	4.21
FPL	2000	60	50	110	2895	4.17
TCO	1000	62	50	112	2992	4.53
TCO	2000	124	50	174	3829	4.67
P value					<0.0001	<0.0001
MSD at 0.10[x]					377	0.27

[z] Calculated from total N content of the organic amendment on 'as is' basis in Table 2.
[y] Calculated as the sum of organic N and urea-N.
[x] Minimum Significant Difference (MSD) as determined by Waller-Duncan Test at $P = 0.10$.

Cotton Responds Positively to Biosolids, Poultry Manure, and Urea

M. Mozaffari, N.A. Slaton, L.A. Fowler, and F.M. Bourland

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Nitrogen (N) fertilization is often required for producing maximal cotton (*Gossypium hirsutum* L.) yield in eastern Arkansas. Growers in the region have become interested in organic sources of N due to volatile synthetic fertilizer prices and the beneficial effects of increased soil organic matter. Fresh poultry litter (FPL), pelleted poultry litter (PPL), and heat-dried, pelleted biosolids marketed under the trade name of Top Choice Organic® (TCO), are three low-analysis, high organic matter fertilizers currently available in Arkansas. Unfortunately, there is very little information on cotton response to these materials. The objectives of this field study were to evaluate the effect of FPL, PPL, TCO, and urea-N fertilizer on seedcotton yield and leaf-blade N on a representative cotton soil in eastern Arkansas.

PROCEDURES

A replicated field experiment was conducted in a commercial field on a Dundee soil in 2009. A composite (10 to 12 cores) soil sample was collected from the 0- to 6-inch depth of each replication before application of any soil amendments. Soil samples were oven-dried, crushed, and particle size analysis was performed by the hydrometer method (Arshad et al., 1996). Soil nitrate was extracted with 0.025 *M* aluminum sulfate and measured with a specific ion electrode (Donahue, 1992), soil pH was measured in a 1:2 (weight:volume) soil-water mixture. Other soil nutrients were extracted with Mehlich-3 solution and the concentrations of selected elements in the extracts were measured by inductively coupled plasma atomic emission spectroscopy.

The experimental design was a randomized complete block with a factorial arrangement of four N-fertilizer sources (FPL, PPL, TCO, and urea) where each source was applied at five N rates (30, 60, 90, 120, and 150 lb total N/acre) and compared to a no-N control. Each treatment was replicated four times. The FPL was provided by a baling facility in northwest Arkansas, PPL was purchased from a local dealer, and TCO was provided by MANNCO Fertilizer Company (http://manncofertilizer.com/products.html). Each organic N source was applied based on the total N analysis at rates listed in Table 1. Sub-samples of each organic-N source were analyzed for total nutrient content by the University of Arkansas Agricultural Diagnostic Laboratory using standard methods (Peters et al., 2003; Table 2). Nitrogen treatments were broadcast by hand to the soil surface on 13 May and incorporated with a Do-All on the same day. Potassium (48 lb K_2O/acre) and P (36 lb P_2O_5/acre) fertilizers were broadcast to the research area and incorporated before planting by the cooperating grower. Each plot was 40-ft long and 12.6-ft wide allowing for four rows of cotton with 38-inch wide row spacings.

Cotton ('Stoneville 5458B2RF') was planted on 20 May on conventionally prepared beds. Cotton leaf-blade samples were collected from the fifth node from the top of 15 plants in each plot on 12 August (shortly before cutout) and dried to a constant weight in an oven at 70 °C. Leaf samples were ground to pass through a 60-mesh sieve and analyzed for total N by the Kjeldahl method. Irrigation and pest management was performed by the cooperating grower. The center two rows of cotton in each plot were harvested with a spindle-type picker on 12 November. Analysis of variance was performed using the GLM procedure of SAS. Significant ($P \leq 0.10$) means were separated by the minimum significant difference (MSD) method.

RESULTS AND DISCUSSION

Analysis of soil samples taken before application of treatments, indicated that the soil texture was a loam (53% sand, 30% silt, and 17% clay), soil pH was 7.0, and Mehlich-3 extractable P and K were 61 and 151 ppm, respectively. Soil NO_3-N in the top 6 inches of soil was 7 ppm. Total N content of organic N sources, on as-is basis, ranged from 2.96% for FPL to 4.98% for TCO (Table 2). The TCO had the lowest moisture and K contents, but had the highest total P and C content.

The N source × N rate interaction did not influence seedcotton yield (Table 3). Averaged across N sources, N fertilization significantly increased seedcotton yield, which ranged from 2020 to 2570 lb/acre. Application of 120 lb N/acre produced the highest yield, which was 27% greater than the yield of cotton receiving no N. Although the interaction was not significant,120 lb urea-N/acre produced the numerically highest seedcotton yield of 2775 lb/acre. The yield of cotton fertilized with 120 lb total-N/acre from FPL, PPL, and TCO ranged from 2445 to 2588 lb/acre.

Nitrogen source also significantly affected seedcotton yield (Table 3). Averaged across N rates, yield of cotton fertilized with N ranged from 2215 to 2397 lb/acre and was significantly higher than the yield of cotton receiving no N. Seedcotton yield of urea fertilized plants was significantly higher than cotton treated with FPL and numerically higher than cotton fertilized with PPL or TCO. Yield potential at this site was limited by unfavorable weather conditions as evidenced by significant boll shedding during the cloudy days of August and excess soil moisture from above normal rainfall.

Leaf blade N concentration was significantly affected by N source, N rate, and the source × rate interaction (Table 4). The interaction showed that urea applied at 120 and 150 lb N/acre produced greater leaf blade N concentrations than all other N sources and that there were no differences among N sources when only 30 lb N/acre was applied. For cotton fertilized with 60 and 90 lb N/acre, leaf blade N content was numerically greatest for urea, but the leaf blade N concentrations for urea at these two N rates were similar to PPL and greater than TCO and FPL. For cotton fertilized with ≥60 lb N/acre, the numerical order of leaf blade N concentrations among organic N sources was always PPL > TCO > FPL with the no significant differences between PPL and TCO or TCO and FPL. In general, mean leaf blade N concentrations increased as N rate increased to 120 lb N/acre and tended to be greatest for urea, intermediate for PPL and TCO and lowest for FPL. The leaf analysis results suggest that N from urea was more plant-available than N from the organic N sources.

PRACTICAL APPLICATION

The results of this one-year study suggest that FPL, PPL, and TCO are potential N sources for cotton production in Arkansas. Although each organic N source tended to produce maximal or near maximal seedcotton yields that were comparable to preplant applied urea, the yield increase from N fertilization was relatively low (27%) in this trial. The yield and leaf N concentration data suggest that growers should not use the organic N sources as the sole source of N. The FPL, PPL, and TCO should be used to provide some proportion of the cotton crop's total N requirement with the total application rates being determined by the amount of P recommended to ensure the production of maximum cotton yields or to maintain an optimal soil-test P level to avoid building soil-test P to a high level. The organic materials applied at a 1 ton/acre rate would each supply 53 (PPL), 66 (FPL), and 103 (TCO) lb P_2O_5/acre and 57 (PPL), 66 (FPL), and 8 (TCO) lb K_2O/acre. The use of FPL, PPL, and TCO in P-based recommendations will usually require that supplemental synthetic N fertilizer be applied to achieve economically optimum cotton yields in most fields. Thus, additional research is needed to determine the plant-available N content of each organic N source relative to commercial N fertilizer (e.g., urea) for cotton production in eastern Arkansas.

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Table 1. Total N and product application rates for urea, fresh poultry litter (FPL), pelleted poultry litter (PPL), and Top Choice Organic (TCO) biosolids used in a cotton N fertilization experiment at the Judd Hill Plantation in Poinsett County, Ark in 2009.

	Amendment rate			
N rate	Urea	FPL	PPL	TCO
(lb N/acre)	(lb of material applied/acre)			
30	65	1014	822	602
60	130	2028	1644	1204
90	196	3042	2466	1806
120	261	4056	3288	2410
150	326	5068	4110	3012

Table 2. Selected chemical property means (n = 2-3) for the fresh poultry litter (FPL), pelleted poultry litter (PPL), and Top Choice Organic® (TCO) biosolids used in a N-fertilization trial conducted on a Dundee soil at Judd Hill Plantation in 2009.

				Total nutrient content (as is)					Inorganic N content	
N source	n	pH	Moisture	C	N	P[z]	K[y]	Ca	NO_3-N	NH_4-N
			(%)						(ppm)	
FPL	2	7.7	41.0	19.3	2.96	1.43	2.35	2.31	18	5143
PPL	3	7.4	12.0	28.1	3.65	1.16	2.74	2.30	1626	2751
TCO	3	7.1	7.4	32.4	4.98	2.24	0.33	2.63	22	2256

[z] Lb P_2O5/ton = %Total P on "as is" basis multiplied by 20 × 2.29.
[y] Lb K_2O/ton = %Total K on "as-is" basis multiplied by 20 × 1.2.0.

Table 3. Effect of fresh poultry litter (FPL), pelleted poultry litter (PPL), Top Choice Organic® (TCO) biosolids, and urea each applied at five total-N rates on seedcotton yield on a Dundee loam at the Judd Hill Plantation during 2009.

	N source				N source	N	N rate
	FPL	PPL	TCO	Urea	means	source	means
(lb N/acre)	Seedcotton yield (lb/acre)						Seedcotton yield (lb/acre)
0		2020				None	2020
30	2009	2013	2109	2015	2036	FPL	2215
60	2061	2324	2183	2321	2222	PPL	2380
90	2315	2428	2438	2349	2379	TCO	2314
120	2445	2588	2522	2775	2570	Urea	2397
150	2247	2545	2350	2619	2440		
MSD 0.10[z]		interaction was NS[y]		129			142
P value		0.5965		<0.0001			0.0098

[z] Minimum Significant Difference (MSD) as determined by Waller-Duncan Test at *P* = 0.10.
[y] NS = not significant at *P* = 0.10.

Table 4. Effect of fresh poultry litter (FPL), pelleted poultry litter (PPL), Top Choice Organic® (TCO) biosolids, and urea each applied at five total-N rates on cotton leaf blade N on a Dundee loam at the Judd Hill Plantation during 2009.

	N source				N source	N	N rate
	FPL	PPL	TCO	Urea	means	source	means
(lb N/acre)	Leaf-blade N (%)						Leaf-blade N (%)
0		2.44				None	2.44
30	2.58	2.55	2.60	2.53	2.56	FPL	2.61
60	2.45	2.69	2.61	2.94	2.67	PPL	2.85
90	2.61	3.05	2.80	3.10	2.89	TCO	2.77
120	2.70	3.02	2.94	3.53	3.05	Urea	3.12
150	2.73	2.96	2.89	3.53	3.02		
MSD 0.10[z]		0.27 (interaction MSD)			0.15		0.15
P value		interaction = 0.0348			<0.0001		<0.0001

[z] Minimum Significant Difference (MSD) at *P* = 0.10.

Potassium Fertilization Increases Seedcotton Yield in a Low Testing Silt Loam

M. Mozaffari, N.A. Slaton, and C. Kennedy

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Advances in plant breeding and pest management have resulted in commercial cotton (*Gossypium hirsutum* L.) cultivars that mature faster and produce higher yields than the obsolete cultivars. Potassium (K) is one of the most important nutrients for growth and development of the cotton plant. Potassium is required for regulating the stomatal opening and closing, maintaining leaf turgor pressure and leaf photosynthesis (Bednarz and Oosterhuis, 1999). Therefore, K deficiency will seriously limit cotton yield potential and fiber quality. Information on modern cotton cultivars response to K fertilization will aid in developing agronomically sound K-fertilizer recommendations. The objective of this experiment was to evaluate the effect of K application rate on seedcotton yield and Mehlich-3 extractable soil K for a modern cotton cultivar grown using production practices common to Arkansas.

PROCEDURES

In 2006, a long-term replicated cotton K-fertility experiment was initiated on a Loring silt loam at the University of Arkansas Division of Agriculture Lon Mann Cotton Research Station in Marianna, Ark. The experimental design was a randomized complete block where the same K-rates (0, 30, 60, 90, 120, and 150 lb K_2O/acre applied as muriate of potash) have been applied to the same plots. The experiment was repeated in 2007 with the same K-rates applied in 2006. In 2008, cotton was planted and harvested again, but no K fertilizer was applied. In 2009, the K-rate experiment was resumed as implemented in 2006 and 2007. Each individual plot was 40-ft long and 12.5-ft wide allowing for four rows of cotton with 38-inch wide row spacings.

Prior to application of any K fertilizer, six soil cores were collected from the 0- to 6-inch depth of each plot and composited. The same procedure was followed in the fall after cotton harvest. Soil samples from each plot were oven dried at 65 °C, crushed, and extracted with Mehlich-3 solution and the elemental concentrations were measured by inductively coupled plasma atomic emission spectroscopy. Soil pH was measured in a 1:2 (weight:volume) soil-water mixture. Soil particle size analysis was determined by the hydrometer method (Arshad et al., 1996). The 0- to 6-inch depth of soil contained 14% sand and 23% clay and would be classified as a silt loam. Averaged across all plots, the soil pH was 7.0 and mean values of selected Mehlich-3 extractable nutrients were 45 ppm P, 981 ppm Ca, 266 ppm Mg, and 4.5 ppm Zn.

In late May, 120 lb N/acre as urea (46% N) was surface applied to the entire research area and incorporated with tillage when existing cotton beds were being prepared for planting. Cotton ('Stoneville 4554B2RF') was seeded into a conventionally tilled seedbed on 1 June and emerged on 11 June. All K-fertilizer treatments were surface applied on 30 June. Standard pest management practices as recommended by the University of Arkansas Division of Agriculture Cooperative Extension Service were followed. Cotton was irrigated as needed using the Cooperative Extension Service Irrigation Scheduler program. Cotton was harvested with a spindle-type mechanical picker on 7 November. Analysis of variance was performed to evaluate the effect of K application rate on seedcotton yield and soil-test K using the PROC GLM procedure of SAS. Significant treatment means were separated by the Waller-Duncan minimum significant difference (MSD) test when appropriate ($P < 0.10$).

RESULTS AND DISCUSSION

Previous annual K-fertilizer application rates had significantly influenced preplant soil-test K producing mean soil-test K values ranging from 60 to 77 ppm (Table 1). In Arkansas, Mehlich-3 extractable K concentrations ≤90 ppm are interpreted as 'Low'. The average soil-test K in soil fertilized with ≥120 lb K_2O/acre was significantly greater than soil receiving no K. Soil samples collected post-harvest also showed that soil-test K was significantly influenced by annual K-fertilizer rate with mean values ranging from 56 to 91 ppm (Table 1). Soil-test K in all K-fertilized plots was numerically higher in the samples collected post-harvest compared to samples collected preplant despite K removal by the cotton crop.

Potassium fertilization significantly increased seedcotton yield in 2009 (Table 1). Potassium application rates >30 lb K_2O/acre significantly increased seedcotton yields compared to the no K control. The greatest yields were produced by cotton receiving 90 to 150 lb K_2O/acre.

PRACTICAL APPLICATION

Application of ≥ 30 lb/K_2O/acre significantly increased seedcotton yield which was maximized by application of 90 to 150 lb K_2O/acre on a soil having 'Low' to 'Very Low' soil-test K levels. Routine soil testing properly identified the need for K fertilization. Based on preplant soil samples and current recommendations, 95 to 140 lb K_2O/acre would have been recommended depending on annual K rate. For this particular soil, the current University of Arkansas Division of Agriculture K-fertilizer recommendations accurately identified the need for K and recommended K rates that maximized seedcotton yield in this trial. Both short- and long-term fertilization research is needed to develop a robust data base to support and verify soil-test based K-fertilizer recommendations for modern cotton production in Arkansas. The results of this study indicate that soil-test based K-fertilization is a critical component of nutrient management for cotton production in Arkansas.

ACKNOWLEDGMENTS

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Table 1. Mean Mehlich-3 soil-test K concentrations in spring (preplant) and fall (post-harvest) 2009 and seedcotton yield as affected by annual K-fertilizer rate during the fourth year of a continuous-cotton, K-fertilization trial conducted on a Loring silt loam at the Lon Mann Cotton Research Station in Marianna, Ark.

	Mehlich-3 soil-test K		
K-fertilizer rate	Preplant	Post-harvest	Seedcotton yield
(lb K_2O/acre)	---------- (ppm)	----------	(lb/acre)
0	60	56	786
30	63	64	1269
60	66	70	1363
90	65	74	1426
120	69	87	1515
150	77	91	1553
MSD[z] 0.10	8	11	176
P value	0.0101	<0.0001	<0.0001

[z] MSD = Minimum significant difference as determined by Waller-Duncan Test.

The Use of Polyacrylamide as a Soil Conservation Practice in Arkansas

C.R. Shumway

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Arkansas is highly diversified in cropping systems with an increasing proportion of these acres under irrigation. In many regions across the U.S., irrigation-induced erosion has resulted in negative environmental and economic impacts and includes the loss of yield potential and the off-site movement of sediment and nutrients. Improved efficiency in water use while reducing erosion has been reported with the application of polyacrylamide (PAM) to irrigation furrows (Lentz et al., 1992; Lentz and Sojka, 1994). PAM is a high molecular weight polymer that when applied to soil has been effective in reducing erosion and increasing soil infiltration by stabilizing soil aggregates. Earlier research indicated a significant reduction in soil erosion of up to 94% (Sojka and Lentz, 1997). Other benefits of PAM include reduction of nutrient losses (Bahr and Steiber, 1995).

The PAM technology has demonstrated the potential to conserve soil with the benefit of easy implementation. This resulted in the establishment of an interim conservation practice standard in 1995 (Anon., WNTC 201-1. NRCS West National Technical Center, Portland, Ore.). However, the impact of the use of PAM for erosion control and the potential effect on the efficient use of water resources has not been evaluated in Arkansas. The objective was to develop an on-farm demonstration program on the use of PAM with an emphasis on the effect on erosion control and water quality.

PROCEDURES

All field tests were conducted in northeast Arkansas in 2007 and all production inputs were according to local extension recommendations. Specific soil series used for the evaluation of PAM included a Dundee fine sandy loam (Fine-silty, mixed, thermic Aeric Ochraqualfs), a Fountain silt loam (Fine-silty, mixed thermic Typic Glossaqualfs), and a Calhoun silt loam (Fine-silty, mixed, thermic Typic Glossaqualfs).

Studies were located at Judd Hill, Arkansas State University Research Farm (ASU), and Bay, Ark. The demonstration site at the ASU Farm was 0.6 acres with 32 rows (2.5-ft. row spacing) and a length of 320 ft. The Judd Hill site was 4.3 acres with 72 rows (3.16-ft. row spacing) and a length of 822 ft. The Bay site was 2.5 acres with 32 rows (3.16-ft. row spacing) and a length of 1080 ft. Soil tests were taken in the spring of 2007 with the results for each site reported in Table 1. No additional fertilizer was applied to the ASU location. Judd Hill fertilizer rates were 86 lb N, 17 lb P_2O_5, and 63 lb K_2O/acre. Bay fertilizer rates were 112 lb N, 32 lb P_2O_5, and 88 lb K_2O/acre. Judd Hill and Bay sites were a conventional tillage system. The ASU Farm site was a reduced tillage cropping system. Prior to irrigation, the furrows were reestablished with a ripper/cultivator. Treatments were established as PAM and a untreated control (no PAM). A commercially available source of PAM was utilized (SoilFix IR, Ciba Specialty Chemical Corporation, Suffolk, Va.). The application rate of PAM was calculated based on irrigation flow and applied at a target rate of 5 to 10 mg PAM/L. Applications were made at the entry point of the irrigation water into the furrow. One-half of the rows were treated with PAM and the other half were untreated. After the initial application, furrow inflow rates were measured and used to determine the additional application rates to maintain the target concentration of PAM within each furrow. PAM applications to the furrow were accomplished using a commercially available applicator (The Applicator™, Buhl, Idaho). A Powlus-T flume was utilized for the in-furrow measurements of water flow and for the collection of water samples. Both the PAM and the untreated control had 6 sampling sites at each location. PAM evaluations were performed on 22 June, 29 June, and 7 July at the Judd Hill, Bay, and ASU Farm locations, respectively.

Sediment load was estimated by collecting a one liter water sample when flow down the furrow was established. Samples were taken at the ASU and Judd Hill location approximately 5 minutes after the initiation of flow through the flume. The Bay location had samples taken 5, 15, 40, 60, and 90 minutes after flow initiation.

Sediment within the water flow was calculated by taking a 250 mL sub-sample and filtering all sediment out of the fluid fraction. The sediment sample was oven-dried and weighed to determine the sediment level in g/L. An unfiltered sample containing the sediment, but with all suspended materials removed, was evaluated for total nitrogen (N), phosphorous (P), and potassium (K). Phosphorus and K were analyzed using a Spectro CIROS ICP (Spectro Analytical Instruments, Mahwah, N.J.). Total N was analyzed by combustion on the Elementar Variomax (Elementar Americas, Inc., Mt.Laurel, N.J.). The

Agricultural Diagnostic Laboratory (University of Arkansas Division of Agriculture) conducted all nutrient analysis. Data means were compared using descriptive statistics (mean and standard deviation).

RESULTS AND DISCUSSION

Evaluation of sediment loss (runoff) from both the ASU, Judd Hill, and Bay sites demonstrated a reduction in soil loss with an application of PAM. From the initial runoff values, soil loss at the ASU site was reduced 79% while the Judd Hill site was reduced 83% (Fig. 1). The evaluation of sampling time at the Bay location demonstrated a response with PAM (Fig. 2). The early sampling, which was within 5 minutes of an established flow, produced a reduction of sediment flow of 86% with PAM. Sediment content in the late sampling, which was taken approximately 15 minutes after the establishment of water flow, was considerably lower than the early sample time regardless of PAM rate. Subsequent samplings at 40, 60, and 90 minutes produced a minimal sediment flow with no differences between treatments (data not shown). This would indicate a potential benefit during initial water flow, but a reduced impact after a continued flow in the furrow.

With nutrient loss, the trend was a reduction associated with PAM. At the ASU and Judd Hill sites, a reduction of P and K concentrations in irrigation water was measured with PAM (Fig. 3). Nitrogen concentrations were more variable. Runoff N content was not affected by PAM at the ASU site, but was reduced by 32% at the Judd Hill site. Nutrient content in runoff was evaluated at several times during a single irrigation event at the Bay location. The results of the early and the late sampling are shown in Fig. 4. In the early sampling, runoff nutrient concentrations were lower in soil amended with PAM compared to the no PAM control. The late sampling resulted in lower P and K concentrations with and without a PAM application compared to the early sample time. This would correspond to the reduction in sediment loss. Nitrogen concentrations, however, showed a minimal decrease in both treatments with the late sampling.

PRACTICAL APPLICATIONS

Application of PAM resulted in the reduction of sediment and nutrient loss from the field in runoff from irrigation. The early sampling indicated a greater effect than later sampling times. The benefit of PAM would need to be evaluated based on the environmental impact of irrigation runoff. The impact of other techniques including precision leveling would likely reduce the potential benefits of PAM application to irrigation water.

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Table 1. Soil chemical properties for the demonstration sites used for the evaluation of polyacrylamide.

Soil series	Location	soil pH	Soil nutrients NO_3-N	P	K	Ca
			(mg/kg)			
Calhoun silt loam	ASU Farm	6.5	8.8	96	416	1889
Dundee silt loam	Judd Hill	6.0	6.7	97	307	2126
Fountain silt loam	Bay	6.9	-- [z]	18	96	1030

[z] Was not determined.

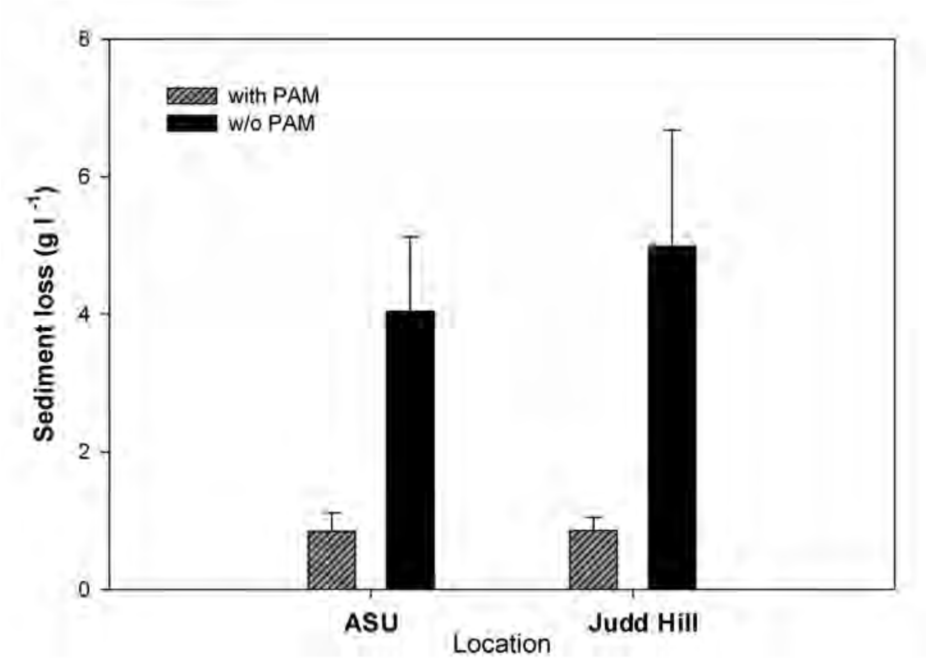

Fig. 1. Effect of a PAM application rate (0 or 5 to 10 mg PAM/L) on sediment content of irrigation runoff measured 5 minutes after flow initiation at the Arkansas State University (ASU) and Judd Hill study locations (Error bars represent ± standard deviation of the mean).

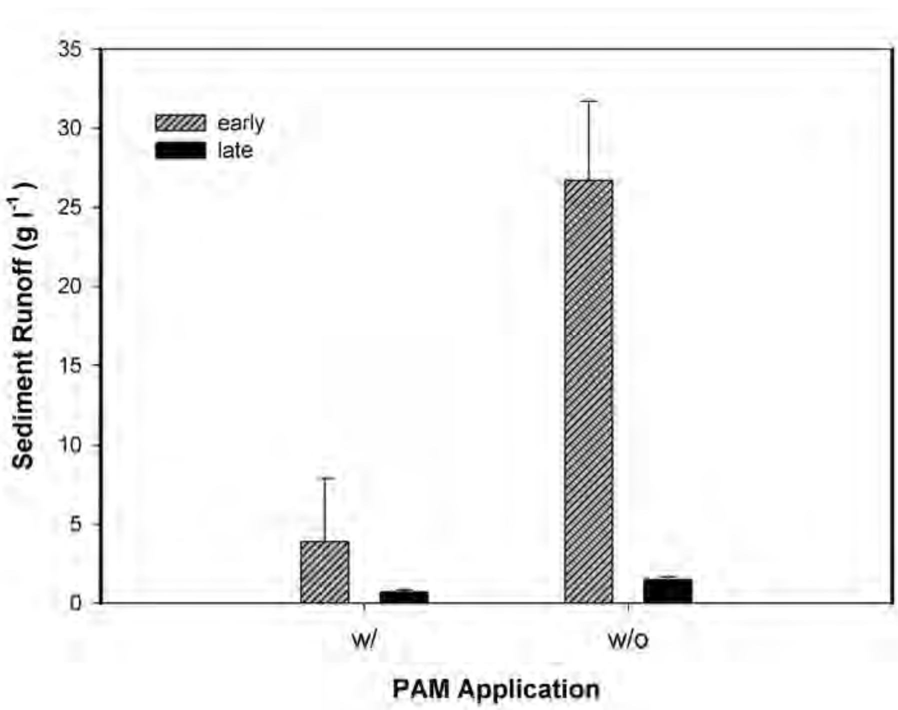

Fig. 2. Effect of a PAM application rate (0 or 5 to 10 mg PAM/L) and sample time (early and late times correspond to 5 and 15 minutes of established flow, respectively) on sediment content of irrigation runoff at the Bay, Ark., location (Error bars represent ± standard deviation of the mean).

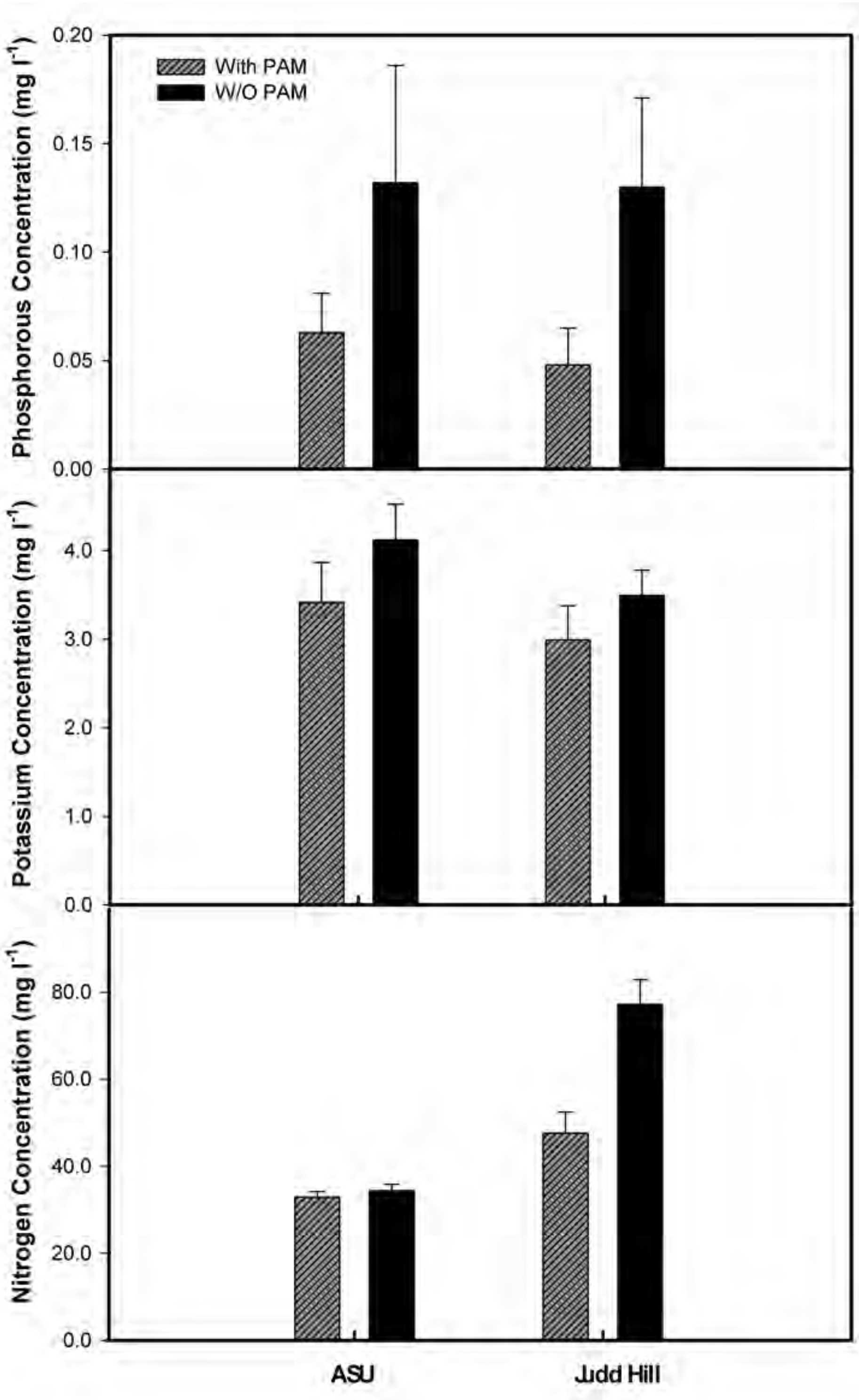

Fig. 3. Nutrient concentrations of irrigation runoff from a furrow-irrigation system within 5 minutes of established flow as influenced by PAM rate at the Arkansas State University (ASU) and Judd Hill study locations (Error bars represent ± standard deviation of the mean).

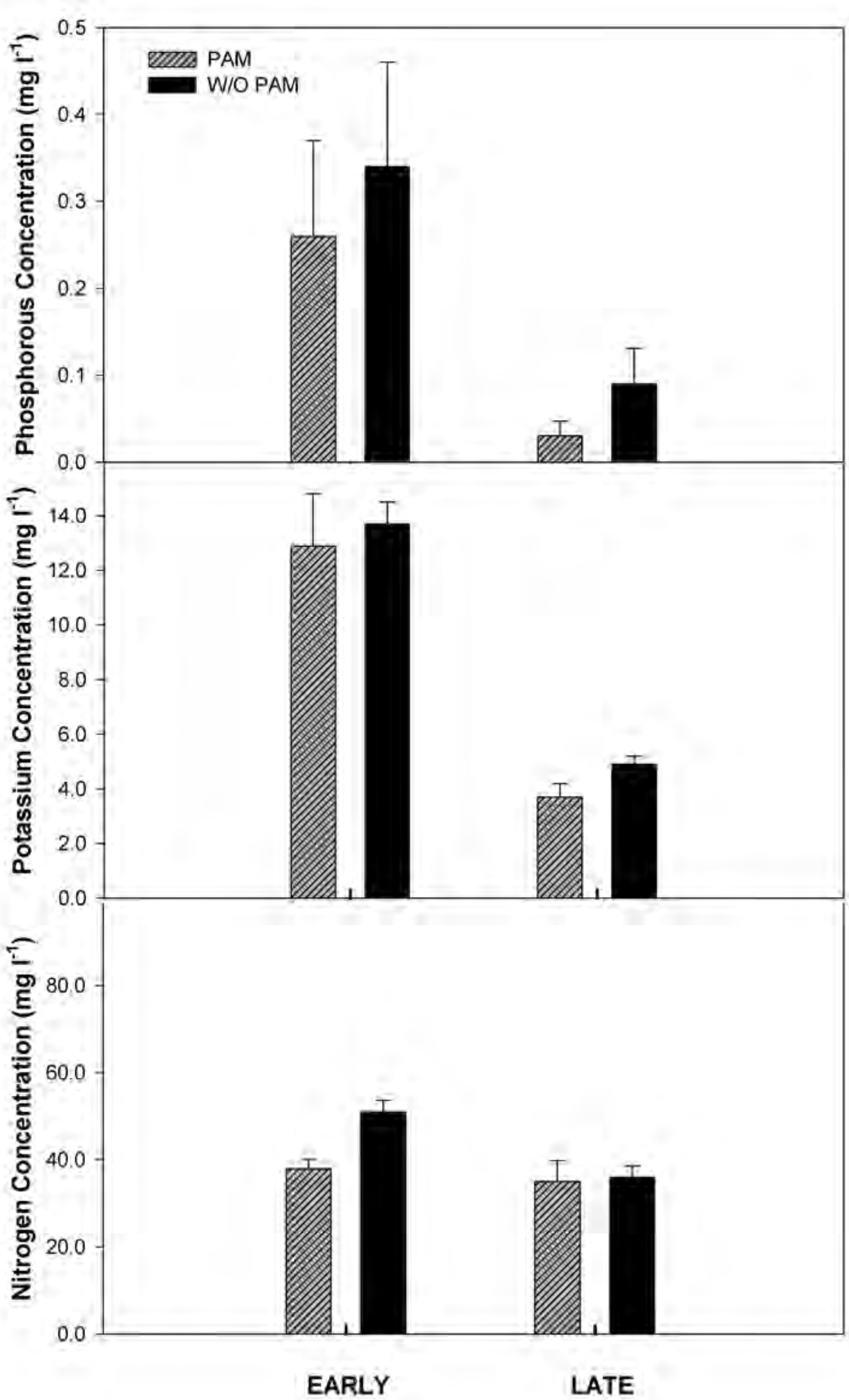

Fig. 4. Nutrient concentrations of irrigation runoff at an early (5 min after the initiation of flow) and late (15 min after the initiation of flow) sample time for the Bay, Ark., study location as affected by PAM rate (Error bars represent ± standard deviation of the mean).

Canola Response to Nitrogen, Sulfur, Phosphorus, and Potassium Fertilization in Arkansas

N.A. Slaton, R.E. DeLong, R.K. Bacon, and J. Kelly

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Canola (*Brassica rapa*) is an oilseed crop that has potential for winter production in the Midsouth. If adopted by Arkansas growers, canola would compete for acreage with soft red winter wheat (*Triticum aestivum*). Before growers consider producing canola commercially, recommendations that reduce risk and help ensure the production of profitable yields are needed. Fertilization with one or more nutrients will likely be required for canola grown on silt and sandy loam soils to achieve its maximum yield potential in the Midsouth USA.

Research performed with canola during the 2007-2008 growing season showed i) no yield benefit from sulfur (S) fertilization, ii) maximum yields were generally produced with 105 to 135 lb nitrogen (N)/acre, iii) yields were significantly increased by 40 lb phosphorus (P_2O_5)/acre on a soil low in P (12 ppm Mehlich-3 P), and iv) no yield response to potassium (K) on a soil with a Medium soil-test K (110 ppm K, Slaton et al., 2009). This research also indicated that N application time may influence canola yield and showed differences in leaf and seed nutrient content depending on N application time. Thus, additional research is required to clarify the optimum time of N fertilization and provide additional information regarding yield response to fertilization under different soil and environmental conditions.

Our overall research goal is to develop research-based fertilizer recommendations for canola varieties adapted to Arkansas. Our research objectives were to determine growth and yield responses of canola to i) P and K fertilizer rates; ii) S fertilization; iii) N fertilizer rate, source, and application time; and iv) Zn and B fertilization when grown on soils in eastern Arkansas.

PROCEDURES

Fertilization experiments were established on a Convent silt loam at the Lon Mann Cotton Research Station Station (LMCRS) following soybean, a Dewitt silt loam following summer fallow at the Rice Research Extension Center (RREC), a Loring silt loam at the Pine Tree Research Station (PTRS-F) following fallow, and a Calloway silt loam following rice at the PTRS (PTRS-R) in October 2008. Individual plots measuring 20-ft long by 7.0-ft wide were flagged for each fertilization trial. Before seeding and fertilizer application, composite soil samples (n = 2 or 3) were collected from the 0- to 4-inch depth from each pair of replicates for each experiment. Soil samples were oven-dried at 130 °F, crushed, and passed through a 2-mm sieve. Soils were analyzed for organic matter by weight loss on ignition, soil water pH in a 1:2 soil weight:water volume mixture, and plant-available nutrients were extracted using the Mehlich-3 method and quantified by inductively coupled plasma atomic emission spectroscopy. Soil from the N studies was also analyzed for NH_4-N and NO_3-N by extracting soil with 1 *M* KCl. Soil concentrations of NH_4-N and NO_3-N in the N rate trials were 18 and 11 ppm for LMCRS, 17 and 29 ppm for PTRS-F, and 7 and 1 ppm for PTRS-R, respectively. Selected soil chemical property means are listed in Table 1.

Canola variety AR377 was planted into a conventionally tilled seedbed with a small-plot drill at a seeding rate of 6 lb/acre in all trials. Canola was drill seeded on 10 October at LMCRS, 15 October at both PTRS sites, and 29 October at RREC. Each plot contained seven rows (7-inches wide) of canola. Each research area received 1 pt Treflan/acre prior to seeding for controlling weeds.

The N-fertilization trials received blanket applications of P (46 lb P_2O_5/acre), K (60 lb K_2O/acre), zinc (Zn) (10 lb Zn/acre), and boron (B) (1 lb B/acre) fertilizer. Nitrogen treatments at the LMCRS and PTRS-F sites served two primary objectives: 1) to identify the proper N rate and application time combination that allows for near maximal yield production and 2) to identify whether S fertilizer is needed to maximize canola yield. For the first objective, N was applied in single or split applications at 0, 45, 75, 105 (45 + 60), 135 (60 + 75), and 165 (85 + 80) lb N/acre urea (46% N). Nitrogen fertilizer was applied on 20 January, 16 or 20 February, and/or 19 March. With regards to N application time, N treatments can be categorized as applied in i) January and February or ii) February and March. For the 105 or 135 lb N/acre rates, the first split was 45 and 60 lb N/acre for the January-February application, respectively, but when N was split between February-March the first split was 60 and 75 lb N/acre, respectively. The eleven N treatments in this trial were a randomized complete block (RCB) arranged as a 2 (time of application) × 5 (total N rate) factorial and compared to an unfertilized (0 lb N/acre) control with four replications.

Four additional N treatments were included in the LMCRS and PTRS-F trials to examine whether S is needed to maximize canola yield. Nitrogen was applied as 100 lb ammonium sulfate/acre plus the balance of each N rate as urea for total N rates of 105 and 135 lb N/acre made in two split applications in January-February or February-March to correspond with the previously described treatments applied as urea. For this objective only treatments applied at 105 and 135 lb N/acre were compared, which resulted in a a RCB design with a 2 (N application time) × 2 (N source) × 2 (N rate) factorial arrangement with four replications.

Similar N treatments were planned for PTRS-R and RREC. At the RREC, poor soil drainage resulted in stand loss in all planted trials except the P fertilization experiment. At PTRS-R, canola emergence was not uniform, but 15 plots in one corner of the research area had a stand sufficient for research. Therefore, N rates of 0, 80, 120, 160, and 200 lb N/acre were applied in split applications with the total N rate divided equally between applications made on 20 January and 16 February. The trial was a RCB design with three replications.

The P- and K-rate trials were conducted only at PTRS-F and RREC with each site evaluating five fertilizer rates (0, 40, 80, 120, and 160 lb P_2O_5 or K_2O/acre) as triple superphosphate or muriate of potash, respectively, which were broadcast to the soil surface (27 November 2007) after emergence. Triple superphosphate (60 lb P_2O_5/acre) was applied to the K-rate trial and muriate of potash (60 lb K_2O/acre) was applied to the P-rate trials. Zinc (10 lb Zn/acre) and B (1 lb B/acre) fertilizers were also applied to each trial. Each trial was a RCB design with six replications. For the RREC site, data from only the P-rate trial will be reported for reasons previously discussed. The RREC P-rate trial had 4 or 5 plot observations from each P rate that were of sufficient quality for research.

A Zn and B fertilization trial was also established at PTRS-F and included a no micronutrient control, 10 lb Zn/acre as granular $ZnSO_4$ (35.5% Zn, Zinc-Gro), 1 lb B/acre as granubor (15% B), and 10 lb Zn + 1 lb B/acre using the same fertilizers arranged as a RCB with six replications. The micronutrient fertilization trial received blanket applications of P (46 lb P_2O_5/acre) and K (60 lb K_2O/acre). Zinc and B fertilizers and blanket applications of P and K were applied to the soil surface on 27 November after emergence. A total of 120 lb N/acre was applied to the P, K, and micronutrient trials. The first N application included 21 lb N as ammonium sulfate plus 60 lb urea-N/acre on 20 January followed by 39 lb urea-N/acre on 20 February.

The uppermost, mature leaves (20) were collected from selected plots and trials at the late boot growth stage (stage 3.3) on 1 April, dried to a constant moisture, ground to pass a 1-mm sieve, digested with concentrated HNO_3 and 30% H_2O_2, and analyzed for elemental concentrations. The late-boot stage, also called green bud, is when flower buds are visible from above with few, if any, open flowers (Anonymous, 2005). In the P, K, and micronutrient rate trials, leaf samples were collected from all treatments, but in the N trials, samples were collected only from the no N control and plots receiving 105 lb N/acre at LMCRS and PTRS-F. Tissue analysis data from the N study was a RCB design with a 2 (N sources) × 2 (N application times) factorial treatment structure compared to a no N control.

A 15- to 16-ft long section of each plot was harvested with a small-plot combine at maturity. Canola seed moisture was adjusted to 8.5% for final yield calculations and converted to bushels per acre based on 50 lb/bushel. A sub-sample of the harvested canola seed was saved and whole seeds (~0.25 g) were digested as described previously for leaf analysis.

For each study or objective, analysis of variance was conducted with the PROC GLM procedure in SAS v9.1 (SAS Institute, Inc., Cary, N.C.) using the designs mentioned previously for each trial and measurement. When appropriate, mean separations were performed using Fisher's Protected Least Significant Difference method at a significance level of 0.10.

RESULTS AND DISCUSSION

Nitrogen Trials

Canola yields at LMCRS or PTRS-F were not affected by the N rate × application time interaction (P = 0.9766 and 0.9313, respectively) or the main effect of application time (P = 0.2878 and 0.5762, respectively) in 2008-2009. Only the main effect of N rate affected canola yield. Canola yields, averaged across application times, were maximized by application of 75 to 165 lb N/acre at the LMCRS and PTRS-F (Table 2). The canola yields in the PTRS-R, N-rate trial were relatively low and maximized by application of 80 to 200 lb N/acre (Table 2). Similar to the results of 2007-2008, canola seed yield, averaged across N rates and application times (data not shown), at LMCRS or PTRS-F did not benefit from S fertilization at either site.

Leaf tissue samples were collected from the 105 lb N/acre rate of canola receiving urea-N or a combination of urea and ammonium sulfate at two application times. Leaf P concentrations at the green bud growth stage were affected only by N application time, averaged across N sources, at the PTRS (P = 0.0017) and LMCRS (P = 0.0802). At PTRS-F, leaf P was greater for canola receiving N in February-March (0.56% P, LSD (0.10) = 0.02%) compared to January-February (0.51 %P). At the LMCRS, leaf P concentrations were also greater when N was applied in February-March (0.44% P, LSD (0.10) = 0.03%) than January-February (0.41% P). It is interesting to note that leaf Fe and Cu concentrations were also significantly affected by N application time (data not shown). At both sites, leaf Fe was higher when N was split applied in February-March, but leaf Cu was higher when N was applied in January-February.

Leaf S concentrations were affected by the significant N source by application time interaction (Table 3). Leaf S concentrations tended to be numerically highest when fertilized with S in February-March and lowest when fertilized with urea in February-March. The average leaf concentrations of nutrients for canola receiving 105 lb N/acre was 0.43% P, 2.11% K, 2.34% Ca, 0.31% Mg, 0.78% S, 1064 ppm Na, 82 ppm Fe, 213 ppm Mn, 96 ppm Zn, 6.6 ppm Cu, and 31 ppm B at LMCRS and 0.53% P, 1.61% K, 2.82% Ca, 0.33% Mg, 0.80% S, 2179 ppm Na, 85 ppm Fe, 224 ppm Mn, 51 ppm Zn, 6.1 ppm Cu, and 25.2

ppm B at PTRS-F. At the PTRS-R site, urea-N rate influenced leaf Na, Fe, Mn, Zn, and Cu concentrations (Table 4).

Seed nutrient concentrations of canola receiving 105 lb N/acre as urea or ammonium sulfate plus urea at the two N application times was occasionally affected by one of the main effects of N source or application time or their interaction (data not shown) at the LMCRS and PTRS-F. However, the main objective of seed analysis was to determine the average seed nutrient contents for estimating nutrient removal by harvested seed. Therefore, only the average seed nutrient concentrations will be given. The average seed concentrations for canola receiving 105 lb N/acre was 0.81% P, 0.84% K, 0.42% Ca, 0.41% Mg, 0.41% S, 13 ppm Na, 59 ppm Fe, 58 ppm Mn, 47 ppm Zn, 2.9 ppm Cu, and 10.1 ppm B at LMCRS and 0.84% P, 0.85% K, 0.44% Ca, 0.40% Mg, 0.38% S, 17 ppm Na, 62 ppm Fe, 65 ppm Mn, 43 ppm Zn, 2.6 ppm Cu, and 10.9 ppm B at PTRS-F. Based on the average seed concentrations canola removes, on average, 0.94 lb P_2O_5 and 0.51 lb K_2O/bu.

Phosphorus, Potassium, and Micronutrient Trials

Soil test nutrient levels on the Loring silt loam at PTRS-F were classified as 'Optimum' for K (131-175 ppm), 'Above Optimum' for P (>50 ppm, Table 1), and 'Low' for Zn (<1.6 ppm Zn). Based on these levels, canola grown on this soil would not be expected to respond positively to P or K fertilization. Despite the low soil-test Zn level, no positive response to Zn or B fertilization was expected because the soil pH was <6.5.

Canola yield and leaf nutrient concentrations were not affected by P fertilization on this soil with an 'Above Optimum' soil-test P level (Table 5). Tissue P concentrations did not increase significantly as P-fertilizer rate increased and all were above the proposed critical concentration of 0.37% P (Plank and Tucker, 2000) suggesting soil P availability was more than sufficient. Harvested seed nutrient concentrations from canola fertilized with 0, 80, and 160 lb P_2O_5/acre were also unaffected ($P > 0.10$) by P fertilizer rate with average concentrations of 0.87% P, 0.91% K, 0.43% Ca, 0.42% Mg, 0.42% S, 24 ppm Na, 67 ppm Fe, 72 ppm Mn, 47 ppm Zn, 3.0 ppm Cu, and 10.7 ppm B, which were comparable to the concentrations from the N trial at PTRS-F described previously.

The P rate trial at the RREC suffered some stand loss from excessive rainfall and poor drainage, but the yield results are worthy of reporting with recognition that the yield data had a relatively high coefficient of variation (17.7%). The soil-test P was 'Very Low' (Table 1) and a positive response to P fertilization was expected and perhaps more dramatic provided the poor drainage. Canola yields were significantly [$P < 0.0001$, LSD (0.10) = 9] increased by P fertilization. Canola yields increased numerically and often significantly as P rate increased up to 120 lb P_2O_5/acre. Mean canola yields were 22, 38, 48, 52, and 58 bu/acre for canola fertilized with 0, 40, 80, 120, and 160 lb P_2O_5/acre, respectively.

Canola yields at PTRS-F were not significantly affected by K-fertilizer rate (Table 6). However, leaf K concentrations increased as K rate increased and were all below the suggested critical concentration of 2.15% K (Plank and Tucker, 2000). The lack of a positive yield response to K fertilization suggests the proposed critical tissue concentration may be too high for canola grown in Arkansas. All other plant nutrients were present at a sufficient level and were affected nominally by K rate. Harvested seed nutrient concentrations of canola fertilized with 0, 80, and 160 lb K_2O/acre were also unaffected ($P > 0.10$) by K fertilizer rate with average concentrations of 0.82% P, 0.88% K, 0.45% Ca, 0.39% Mg, 0.42% S, 24 ppm Na, 63 ppm Fe, 66 ppm Mn, 46 ppm Zn, 3.1 ppm Cu, and 10.7 ppm B.

Canola yield was not affected by Zn and B fertilization at PTRS-F (Table 7), but leaf B and Zn concentrations were affected by micronutrient fertilization. Application of Zn increased leaf Zn concentrations and application of B increased leaf B concentrations. In the absence of B fertilization, leaf B concentrations were <10 ppm at the green bud stage. Plank and Tucker (2000) suggested a sufficient leaf B concentration range of 25-54 ppm B at early flowering and a critical value of 20 ppm for canola.

PRACTICAL APPLICATIONS

Canola variety AR 377 required minimum N rates of 75 to 105 lb N/acre to produce near maximal yields on three silt loams that were previously cropped to rice and soybean or summer fallowed in 2008. Canola yields following rice, a high residue crop, were generally low and establishing a uniform stand sufficient for research was difficult indicating that rice straw management is an important factor for canola production following rice. Canola yields were not affected by N application time or S fertilization during 2008-2009. Although numerous site-years of research are required to correlate and calibrate soil-test P and K, canola exhibited the expected responses to fertilization based on our current interpretations of soil-test P and K.

The nutrient concentration of harvested canola seed was often affected by fertilization (i.e., application rate, source, and/or application time). Using average seed nutrient concentrations of selected fertilizer treatments from four studies (0.835% P, and 0.87% K), the P and K removal rates of harvested canola seed were equivalent to about 0.96 lb P_2O_5/bu and 0.53 lb K_2O/bu.

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Table 1. Selected soil chemical property means from the unfertilized controls of canola fertilization experiments established in fall 2008.

Study - Site	Organic matter	Soil pH	Mehlich-3 extractable nutrients P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
	(%)		---- (ppm) ----								
Nitrogen											
LMCRS-S	2.2	6.0	25	110	895	161	7	155	187	1.8	1.3
PTRS-F	3.3	6.0	57	184	1188	182	9	166	349	3.2	1.8
PTRS-R	3.1	6.2	53	148	1327	256	34	294	132	1.7	0.8
Phosphorus											
PTRS-F	3.3	6.0	57	184	1188	182	9	166	349	3.2	1.8
RREC-F	2.2	5.8	9	139	970	176	10	299	182	0.6	1.0
Potassium											
PTRS-F	3.2	6.1	46	135	1163	194	10	161	347	1.8	1.2
Micronutrient											
PTRS-F	3.1	6.3	35	121	1319	215	1	154	351	1.8	1.3

Table 2. Canola seed yield response to urea-N fertilizer rate, averaged across N application times, for field trials conducted on silt loam soils at the Pine Tree Research Station following fallow (PTRS-F) or rice (PTRS-R) and Lon Mann Cotton Research Station (LMCRS) following soybean.

Total N rate	LMCRS	PTRS-F	Total N rate	PTRS-R
(lb N/acre)	---- (bu/acre) ----		(lb N/acre)	(bu/acre)
0	60	52	0	18
45	74	57	40	--
75	79	64	80	39
105	82	66	120	45
135	79	68	160	39
165	81	64	200	41
p-value	0.0368	0.0642		0.0088
LSD (0.10)	4	6		10

Table 3. Leaf S concentrations at the green bud growth stage of canola receiving 105 lb N/acre as affected by the N source by application time interaction at the Lon Mann Cotton Research Station (LMCRS) and Pine Tree Research Station (PTRS-F) following soybean and fallow, respectively, during 2008-2009.

	LMCRS		PTRS-F	
N Source	Jan-Feb	Feb-March	Jan-Feb	Feb-March
	(% leaf S)			
Ammonium Sulfate + Urea	0.838	0.933	0.770	0.835
Urea	0.718	0.625	0.805	0.773
p-value	0.0109		0.0882	
LSD (0.10)	0.076		0.066	

Table 4. Leaf nutrient concentrations at the green bud stage of canola following rice as affected by N rate for a trial conducted at the Pine Tree Research Station (PTRS-R) in 2008-2009.

	Leaf nutrient concentration										
N rate	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
(lb N/acre)	(%)					(ppm)					
0	0.35	1.60	2.69	0.33	0.77	991	44	188	30.4	3.6	23.7
80	0.34	1.44	2.30	0.24	0.75	885	47	134	41.8	3.4	29.0
120	0.37	1.42	2.53	0.27	0.75	1178	53	159	43.6	3.9	24.3
160	0.35	1.37	2.47	0.28	0.81	1961	61	187	56.5	4.1	28.7
200	0.37	1.47	2.35	0.29	0.82	2342	64	139	48.6	4.4	27.8
p-value	0.65	0.56	0.18	0.16	0.59	0.02	0.01	0.06	0.02	0.01	0.30
LSD (0.10)	NS[z]	NS	NS	NS	NS	674	6	36	10.5	0.44	NS

[z] NS = not significant (*P* > 0.10).

Table 5. Canola seed yield and leaf nutrient concentration at green bud stage responses to P-fertilizer rate on a Loring silt loam at the Pine Tree Research Station following fallow during 2008-2009.

P-fertilizer	Grain	Leaf nutrient concentration										
rate	yield	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
(lb P_2O_5/acre)	(bu/acre)	(%)					(ppm)					
0	59	0.55	1.78	2.36	0.30	0.83	2702	90	225	61.5	7.1	24.8
40	64	0.55	1.80	2.46	0.32	0.84	2462	89	253	62.3	7.1	27.4
80	57	0.56	1.73	2.44	0.31	0.83	2859	90	231	61.1	7.0	25.4
120	57	0.58	1.79	2.42	0.30	0.83	2443	95	247	63.5	7.2	30.7
160	55	0.57	1.75	2.55	0.30	0.89	3059	88	234	59.7	7.0	24.0
p-value	0.205	0.40	0.91	0.70	0.73	0.17	0.58	0.59	0.73	0.75	0.97	0.39
LSD (0.10)	NS[z]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z] NS = not significant (*P* > 0.10).

Table 6. Canola seed yield and leaf nutrient concentration at green bud stage responses to K-fertilizer rate on a Loring silt loam at the Pine Tree Research Station following fallow during 2008-2009.

K-fertilizer	Grain	Leaf nutrient concentration										
rate	yield	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
(lb K_2O/acre)	(bu/acre)	--------------(%)--------------					--------------(ppm)--------------					
0	63	1.42	0.48	2.28	0.29	0.80	3626	79	215	50.9	6.6	6.6
40	66	1.48	0.47	2.27	0.29	0.78	3568	76	203	51.2	6.5	6.5
80	69	1.57	0.48	2.37	0.29	0.81	3184	77	197	60.3	6.7	6.7
120	62	1.58	0.47	2.40	0.30	0.76	3032	74	207	57.3	6.4	6.4
160	67	1.71	0.47	2.24	0.27	0.75	3207	75	217	57.8	6.4	6.4
p-value	0.547	0.01	0.59	0.67	0.16	0.09	0.63	0.61	0.71	0.10	0.41	0.99
LSD (0.10)	NS[z]	0.08	NS	NS	NS	0.04	NS	NS	NS	6.8	NS	NS

[z] NS = not significant (*P* > 0.10).

Table 7. Canola seed yield and leaf nutrient concentration at green bud stage responses to Zn and B fertilization on a Loring silt loam at the Pine Tree Research Station following fallow during 2008-2009.

Nutrient	Grain	Leaf nutrient concentration										
and rate	yield	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
	(bu/acre)	--------------(%)--------------					--------------(ppm)--------------					
Control	62	0.50	1.56	2.65	0.31	0.82	1999	91	183	36.9	7.0	8.5
10 lb Zn/acre	64	0.48	1.47	2.59	0.30	0.83	2324	124	181	49.0	6.7	8.1
1 lb B/acre	62	0.51	1.47	2.36	0.30	0.80	2187	82	182	38.2	7.0	23.6
10 lb Zn + 1 lb B/acre	66	0.49	1.46	2.35	0.30	0.82	2632	84	181	49.9	7.0	22.7
p-value	0.834	0.293	0.144	0.004	0.935	0.900	0.068	0.502	0.997	0.001	0.651	0.001
LSD (0.10)	NS[z]	NS	NS	0.15	NS	NS	386	NS	NS	3.2	NS	1.9

[z] NS = not significant (*P* > 0.10).

Wheat Grain Yield Response to Phosphorus, Potassium, and Micronutrient Fertilization

N.A. Slaton, R.E. DeLong, S. Clark, J. Shafer, and B.R. Golden

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Soft red winter wheat (*Triticum aestivum* L.) often responds positively to phosphorus (P) fertilization when soil-test P is 'Medium' or lower, especially following rice. However, less is known about wheat response to potassium (K) fertilization as few studies have been conducted to correlate and calibrate wheat response to K fertilization. Sweeney et al. (2000) reported that K fertilization increased yields and reduced leaf rust severity of wheat cultivars rated as susceptible to leaf rust. Snyder and Mascagni (1998) reported similar benefits of P and K fertilization on wheat yields and disease suppression in Louisiana. Because fertilization of winter wheat represents about 60% of the direct crop production expenses in Arkansas (Stiles and Kelley, 2008), fertilizer recommendations need to be as accurate as possible. Establishing fertilization trials on soils with a wide range of chemical properties is needed to develop and/or verify the accuracy of soil-test based P and K fertilizer recommendations.

Micronutrient fertilizers are not currently recommended for winter wheat production in Arkansas as micronutrient deficiencies are uncommon or are yet to be diagnosed. Despite the lack of documented micronutrient deficiencies of wheat, wheat plants often have Zn and B concentrations that are considered low-to-deficient based on diagnostic information published by Plank and Donohue (2000) .

The ultimate goals of this fertilization project are to i) identify the critical soil P and K availability index (Mehlich-3) values for which winter wheat requires fertilization and ii) calibrate the appropriate P and K fertilizer rates that should be recommended for each soil-test level. Our short-term objective was to determine wheat grain yield response to P and K fertilization rates on silt loam soils. Furthermore, we sought to evaluate the utility of Zn and B fertilization on wheat grain yield.

PROCEDURES

Field studies were established during the fall of 2008 to evaluate the effect of P and K fertilization rate and Zn and B fertilization on wheat yield. Tests were located at the Pine Tree Research Station (PTRS) on soils mapped as a Calhoun-Calloway silt loam following rice (*Oryza sativa* L.) and Calloway-Loring silt loam [*Glycine max* (L.) Merr.] following soybean. A composite soil sample (0- to 4-inch depth) was taken from each replicate at each site to determine soil chemical properties. Soil was oven dried, crushed, and passed through a 2-mm sieve for measurement of Mehlich-3 extractable nutrients, organic matter by weight loss on ignition, and soil water pH. Mean values of selected soil chemical properties are listed in Table 1.

'Pat' wheat was drill seeded (100 to 120 lb seed/acre) into conventionally tilled seedbeds on 22 October into plots that were 20-ft long and 6.5-ft wide allowing for 9 rows of wheat with 7.5-inch wide row spacings. Potassium fertilizer (100 lb muriate of potash/acre) was applied to P trials and P fertilizer (130 lb triple superphosphate/acre) was applied to K trials on 27 November to ensure these nutrients were not yield-limiting factors. The micronutrient trials also received the same rates of P and K.

Nitrogen fertilizer was applied in two split applications at each site with total N rates equaling 130 lb N/acre for wheat following soybean and 176 lb N/acre for wheat following rice. For wheat following rice, 46 lb N/acre as urea was broadcast on 6 December 2008 to stimulate growth. On 20 February, each location received a mixture of 60 lb N/acre as urea plus 20 lb N/acre as ammonium sulfate, which was followed by another 50 lb N/acre as urea on 19 March. Results from N-rate trials established in an adjacent area at each site suggested that 120 to 160 lb N/acre produced 80 to 90% of maximum wheat yield.

After wheat was seeded, P-fertilizer treatments were applied to the soil surface (27 November) at rates of 0, 30, 60, 90, 120, and 150 lb P_2O_5/acre as triple superphosphate and K-fertilizer treatments were applied to the soil surface at rates of 0, 30, 60, 90, 120, and 150 lb K_2O/acre as muriate of potash. The micronutrient trials contained a total of six treatments including a control (no Zn or B), 10 lb Zn/acre applied at planting as granular $ZnSO_4$ (Zinc Gro, 35.5% Zn and 17.5% S), 1 lb Zn/acre applied to wheat foliage on 20 February (Super-Tel Zn, 35.5% Zn and 17.5% S), 1 lb B/acre applied at planting as granular B (Granubor, 15% B), 0.33 lb B/acre applied to wheat foliage on 20 February (Borosol, 10% B), and 10 Zn + 1 lb B/acre applied as granular fertilizers at planting. Foliar treatments were applied with a CO_2-backpack sprayer calibrated to deliver 10 gpa at a speed of 3 mph.

Whole, aboveground plant samples were taken at Feekes stage 10.1 to 10.5 (heading) at both sites to determine whole-plant nutrient concentrations. A 3-ft section of the first inside row was cut at the soil surface, placed in a paper bag, oven dried at 60 °C to a constant weight, weighed for dry matter accumulation, and ground to pass a 1-mm sieve. A 0.25 g subsample was digested in concentrated HNO_3 and 30% H_2O_2 and analyzed for nutrient concentration. At maturity, grain yields were measured by harvesting eight rows of each plot with a small-plot combine. Grain yields were adjusted to a uniform moisture content of 13%.

For each experiment, fertilizer rates were arranged in a randomized complete block design with five replicates per treatment. Each experiment was analyzed separately. Analysis of variance procedures were conducted with the PROC GLM procedure in SAS v9.1 (SAS Institute, Inc., Cary, N.C.). Mean separations were performed using Fisher's Protected Least Significant Difference method at a significance level of 0.10.

RESULTS AND DISCUSSION

Site Descriptions

The soil-test level associated with the average Mehlich-3 extractable P was classified as 'Very Low' (<16 ppm) for wheat grown following soybean and 'Optimum' (36 to 50 ppm) for wheat following rice at the PTRS (Table 1). Based on the University of Arkansas fertilizer guidelines for winter wheat, 100 lb P_2O_5/acre was recommended only for wheat grown following soybean. For K trials, the average Mehlich-3 extractable K was 'Optimum' (131 to 175 ppm) for wheat following rice and 'Low' (61 to 90 ppm) for wheat following soybean with recommended rates of 0 and 90 lb K_2O/acre, respectively. For the micronutrient trials, soil pH was 6.2 and Mehlich-3 extractable Zn was 1.2 ppm at both sites. The soil at both research sites would be classified as 'Very Low' (<1.6 ppm) in Zn, but no Zn fertilizer would be recommended for wheat as Zn deficiency of wheat has not been knowingly observed in Arkansas. The University of Arkansas also has no formal soil-test based guidelines for making B recommendations. Boron fertilizer recommendations are made only for cotton and soybean production with soybean fertilization guidelines based on soil pH and geographic region where B is known to be a problem. The primary reason for examining wheat response to Zn and B fertilization was due to consistently low concentrations of these essential elements in winter wheat and not because of routine diagnosis of Zn and B deficiencies.

Wheat Response to P-fertilizer Rate

Whole-aboveground dry matter accumulation of wheat that ranged in development from Feekes stage 10.1 to 10.5 was significantly affected by P rate at both sites (Table 2). For wheat grown following rice, wheat receiving >90 lb P_2O_5/acre had significantly greater dry matter than wheat receiving no P, which had the lowest numerical dry matter. The soil where wheat was grown following soybean required >90 lb P_2O_5/acre to significantly increase wheat dry matter compared to the no P control, but application of 30 to 90 lb P_2O_5/acre numerically increased dry matter. Dry matter was increased by more than 54% from application of 120 to 150 lb P_2O_5/acre. Between mid February and early April, wheat receiving no P could be visually identified at both sites, but overall wheat growth was much greater in the field following rice.

Whole-plant P concentrations of wheat following rice were not significantly affected by P application rate and ranged from 0.26% to 0.28% P at Feekes stage 10.5 (Table 2). For wheat following soybean, application of P fertilizer significantly increased whole-plant P concentrations from 0.17% P for plants receiving no P to 0.19% to 0.21% for plants receiving P (Table 2). Plank and Donohue (2000) estimated, based on extensive experience, that the critical concentration for wheat encompassing all growth stages and tissues was 0.15% P.

For wheat following soybean, 90 lb P_2O_5/acre was required to increase grain yields above those of the no P control (Table 2), but 120 to 150 lb P_2O_5/acre was needed to maximize grain yield. Wheat yields were increased 26% to 32% by application of 120 to150 lb P_2O_5/acre. Although wheat following rice showed a visual growth response to P fertilization, there was no significant yield increase from P fertilization. The mean yields suggest there was a trend for numerically higher yields when P fertilizer was applied.

Wheat Response to K-fertilizer Rate

Wheat dry matter yield was not affected by K-fertilizer rate at either site at Feekes stage 10.1 to 10.5 (Table 3). Whole-plant K concentration at Feekes stage 10.5 for wheat following rice was not affected by K fertilizer rate, which is not surprising as tissue concentrations of wheat receiving no K were near the established critical level of 2.00% (Plank and Donohue, 2000) and soil-test K was Optimum (Table 1). Whole-plant K concentration for wheat following soybean, in soil with a 'Low' K level, increased as K rate increased (Table 3). Wheat grain yields were not significantly affected by K-fertilization rate at either site. Wheat yields averaged 54 bu/acre following rice and 46 bu/acre following soybean. The below average to average yields produced in these trials were typical for the year and attributed largely to excessive rainfall in April and May and high disease levels in the wheat.

Wheat Response to Zn and B Fertilization

Wheat dry matter yield was not affected by Zn- or B-fertilizer rate at either site at Feekes stage 10.1 to 10.5 (Table 4). There was no benefit from Zn and/or B fertilization to wheat grain yield at either site. Zinc and B nutrient concentrations were significantly affected by fertilization with these nutrients. At both sites, whole-plant Zn and B concentrations were generally increased only by the fertilizer treatments that contained these nutrients. Wheat receiving no B or no Zn had plant B and Zn concentrations that were just above the estimated critical concentrations of 1 ppm for B and 15 ppm for Zn (Plank and Donohue, 2000).

PRACTICAL APPLICATION

Wheat yields were not affected by K fertilization on two soils that had Low to Optimum soil-test K levels at the time of planting suggesting that the current interpretation for the Optimum level is accurate. The relatively low yields common to wheat harvested in 2009 partially explain why there was no significant yield increase from K fertilization on the soil with a low soil-test K level. For P, soil-test based recommendations accurately predicted that wheat yield would respond positively to P fertilization on the soil testing very low in P and there would be no yield benefit on a soil having adequate P availability. For wheat grown on the soil with very low soil-test P, the recommended P rate of 90 lb P_2O_5/acre increased yield, but failed to maximize wheat yields. Winter wheat did not benefit from Zn or B fertilization despite relatively low concentrations of these nutrients in wheat tissue. Further research is required to develop more appropriate diagnostic thresholds for Zn and B nutrition of wheat grown in Arkansas.

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Table 1. Selected soil chemical property means (*n* = 5) of P, K, and micronutrient fertilization trials with winter wheat conducted at the Pine Tree Research Station during 2008-2009.

Nutrient -		Soil	Mehlich-3 extractable nutrients									
Site	SOM	pH	P[z]	K[y]	Ca	Mg	S	Na	Fe	Mn	Cu	Zn[x]
	(%)		(ppm)									
Phosphorus												
Rice	2.6	6.2	41	105	1150	229	34	65	294	152	0.7	1.3
Soybean	2.4	6.5	6	75	977	312	8	42	118	325	0.8	1.6
Potassium												
Rice	3.1	6.2	48	168	1373	272	40	60	298	184	0.7	1.2
Soybean	1.9	6.4	6	86	989	317	12	48	114	300	0.8	1.7
Micronutrient												
Rice	2.8	6.2	43	144	1332	241	37	66	294	185	0.8	1.2
Soybean	1.8	6.2	5	87	880	303	17	62	108	187	0.8	1.2

[z] Standard deviation (*n* = 5) of soil-test P in P trials was 5 ppm following rice and 0.9 ppm following soybean.
[y] Standard deviation (*n* = 5) of soil-test K in K trials was 23 ppm following rice and 11 ppm following soybean.
[x] Standard deviation (*n* = 5) of soil-test Zn in micronutrient trials was 0.07 ppm following rice and 0.13 ppm following soybean.

Table 2. Winter wheat aboveground plant dry matter and P concentration at Feekes stage 10.1 to 10.5 and grain yield as affected by P fertilizer rate at the Pine Tree Research Station following rice or soybean during the 2008-2009 growing season.

	Following rice			Following soybean		
P rate	Dry matter	Tissue P	Grain yield	Dry matter	Tissue P	Grain yield
(lb P_2O_5/acre)	(lb/acre)	(% P)	(bu/acre)	(lb/acre)	(% P)	(bu/acre)
0	5863	0.26	46.4	3108	0.17	40.4
30	6805	0.26	49.6	3566	0.19	41.9
60	5894	0.26	52.9	3708	0.19	43.3
90	6973	0.26	52.4	4083	0.20	46.6
120	7283	0.28	49.7	4800	0.21	50.7
150	7934	0.28	54.4	5139	0.21	53.5
P-value	0.0942	0.4679	0.5893	0.0193	0.0027	<0.0001
LSD (0.10)	1601	NS[z]	NS	1216	0.01	3.6

[z] NS = not significant ($P > 0.10$).

Table 3. Winter wheat aboveground plant dry matter and K concentration at Feekes stage 10.1 to 10.5 and grain yield as affected by K fertilizer rate at the Pine Tree Research Station following rice or soybean during the 2008-2009 growing season.

	Following rice			Following soybean		
K rate	Dry matter	Tissue K	Grain yield	Dry matter	Tissue K	Grain yield
(lb K_2O/acre)	(lb/acre)	(% K)	(bu/acre)	(lb/acre)	(% K)	(bu/acre)
0	6782	1.90	55.7	3792	1.24	43.8
30	7524	2.03	54.6	3745	1.57	46.3
60	6159	2.10	55.9	3862	1.83	45.3
90	6643	2.09	53.2	3861	1.92	49.6
120	3270	2.21	51.2	4191	2.08	48.6
150	5943	2.16	54.2	3730	2.24	47.4
P-value	0.4395	0.3181	0.7467	0.9840	<0.0001	0.3771
LSD (0.10)	NS[z]	NS	NS	NS	0.17	NS

[z] NS = not significant ($P > 0.10$).

Table 4. Winter wheat whole, aboveground plant dry matter, B, and Zn concentration at Feekes stage 10.1 to 10.5 and grain yield as affected by Zn and B fertilization at the Pine Tree Research Station following rice or soybean during the 2008-2009 growing season.

	Following rice				Following soybean			
Treatment	Dry matter	Tissue Zn	Tissue B	Grain yield	Dry matter	Tissue Zn	Tissue B	Grain yield
	(lb/acre)	----------(ppm)	---------	(bu/acre)	(lb/acre)	----------(ppm)	---------	(bu/acre)
Control	7059	15.8	2.1	56.3	2907	17.1	2.5	40.6
Soil Zn	6321	17.7	2.2	55.0	3099	25.4	3.0	41.5
Foliar Zn	7110	19.4	2.2	55.7	2596	17.3	2.1	37.1
Soil B	6275	15.6	3.1	57.5	3238	17.3	4.8	39.9
Foliar B	6625	14.8	2.7	55.5	2930	18.3	3.6	38.0
Soil Zn+B	6492	14.7	3.5	55.4	2900	25.8	4.2	39.0
P-value	0.6664	0.0045	0.0079	0.9182	0.7288	0.0004	0.0001	0.3085
LSD (0.10)	NS[z]	2.1	0.7	NS	NS	3.8	0.7	NS

[z] NS = not significant ($P > 0.10$).

Soil and Bermudagrass Forage Responses to Four Years of Phosphorus and Potassium Fertilization

N.A. Slaton, R.E. DeLong, C.G. Massey, and B.R. Golden

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Phosphorus (P) and potassium (K) are important macronutrients for forage production. Forage uptake and removal of N and K are nearly equal (~45 lb N or K/ton forage) and eight to ten times greater than P uptake and removal (~5 lb P/ton). The difference in uptake and removal of P and K coupled with long-term application of poultry litter on fields used for forage production have resulted in accumulation of soil P and negative or neutral soil K balances. The use of poultry litter as a nutrient source is now limited or prohibited, requiring that farmers apply commercial fertilizer to maintain moderate to high forage yields. Growers may choose to apply little or no fertilizer and produce forage yields that are likely to be low and decline across time.

The relationships between nutrient availability index values for P and K (soil-test) and forage fertilization recommendations, as well as the rates at which soil P and K accumulates or depletes are important for long-term soil and forage management objectives. We initiated this research in 2006 to begin collecting data describing the relationships between soil-test P and K, nutrient uptake, and forage yield of bermudagrass and have maintained it for four years. This report provides soil-test P and K results as affected by three years of fertilization and forage yield during the fourth year as affected by annual P and K fertilization.

PROCEDURES

Fertilization trials were initiated (year 1) in April 2006 on a Captina silt loam with an established stand of common bermudagrass at the Arkansas Agricultural Research Extension Center located in Fayetteville, Ark. Site characteristics and the first three years of forage yield and soil test results have been reported by Slaton et al. (2007, 2008a,b, 2009a,b).

Composite soil samples were collected from each plot in January 2009 to a depth of 4 inches from each plot to monitor changes in soil-test P and K following three years of fertilization. Each composite soil sample consisted of eight soil cores. Soils were dried at 130 °F, crushed to pass a 2-mm diameter sieve, analyzed for water pH (1:2 soil weight:water volume ratio), and extracted for plant-available nutrients using the Mehlich-3 method (Table 1).

In the K rate trial, muriate of potash was applied in one to three applications for cumulative season-total rates equaling 0, 100 (100 × 1), 200 (100 × 2), 300 (100 × 3), 400 (133 × 3), and 500 (167 × 3) lb K_2O/acre. Potassium fertilizer treatments were applied on 8 May (green-up), 17 June following the first harvest, and 20 July following the second harvest. Phosphorus fertilizer (100 lb triple superphosphate/acre) was broadcast applied to the K rate trial at greenup and following the second harvest in July.

In the P rate trial, triple superphosphate was applied in one to three split applications for cumulative rates equivalent to 0, 45 (45 × 1), 90 (45 × 2), 135 (45 × 3), 180 (60 × 3), and 225 (75 × 3) lb P_2O_5/acre. Fertilizer application dates were the same as given for K. Potassium fertilizer (150 lb muriate of potash/acre) was broadcast applied to the P rate trial at greenup and following each harvest.

At green-up, 100 lb $(NH_4)_2SO_4$/acre plus 300 lb NH_4NO_3/acre were applied (~120 lb N/acre). Following the first and second harvests, 120 lb N/acre was applied as urea to stimulate forage production resulting in a season total of 360 lb N/acre.

In each trial, forage was harvested by cutting an 18-ft long by 3.8-ft wide swath with a self-propelled cycle-bar mower at a height of 2.0 to 2.5 inches. Forage was harvested on 17 June, 20 July, and 1 September. Hay harvests were scheduled for every 28 to 35 days, but were adjusted according to growth and weather conditions. The freshly cut biomass from each plot was weighed and eventually adjusted to a total dry weight expressed as lb dry forage/acre. Subsamples of forage from the P and K fertilization trials were ground to pass a 1-mm sieve and digested in concentrated HNO_3 and 30% H_2O_2 to determine forage P and K concentrations and total nutrient uptake and removal. Nutrient analysis for the third forage harvest is not yet available.

Each experiment was a randomized complete block design with each fertilizer rate replicated five times. Analysis of variance procedures were performed with the PROC GLM procedure in SAS (SAS Institute, Inc., Cary, N.C.). Forage yield, nutrient concentration, and nutrient uptake data were analyzed by harvest time and for the season total production (sum of each harvest). Soil-test data were analyzed as a split-plot design where annual fertilizer rate was the whole plot factor and year was the subplot factor. When appropriate, mean separations were performed using Fisher's Protected Least Significant Difference method at a significance level of 0.05.

RESULTS AND DISCUSSION

Soil moisture, as affected by precipitation, varied for each forage growth and harvest period during the summer. The total rainfall accumulation measured within 0.5 mile of the research area for each harvest was 9.6, 1.1, and 9.0 inches for the first, second, and third harvest periods, respectively. Bermudagrass growth may also have been limited by cooler than normal air temperatures during the first and third harvest periods. The average daily minimum and maximum air temperatures were 57 °F and 76 °F for harvest 1 (i.e., greenup to harvest 1), 68 °F and 90 °F for harvest 2, and 64 °F and 85 °F for harvest 3.

Soil-test K has changed due to annual K rate and time as indicated by the significant interaction (Table 2). Soil-test K was uniform within the test area when the study was initiated. Between 2006 and 2009, soil-test K has declined in soil receiving <300 lb K_2O/acre and remained relatively constant or increased across time for soil fertilized with ≥300 lb K_2O/acre. Linear regression of the annual soil-test K values from soil receiving no K suggests that soil-test K in the top 4 inches of soil has declined by about 19 ppm/year (not shown).

Soil-test P has also changed due to cropping and annual P fertilization rate across time (Table 2). The significant interaction showed that soil-test P was uniform within the research area before annual P fertilization treatments were initiated in 2006 and has changed after three years of cropping and fertilization. Compared to the mean soil-test P values in 2007 (after one year of cropping and fertilization), soil-test P in 2009 had decreased for soil receiving no P, remained constant for soil receiving 45 lb P_2O_5/acre/yr, and increased for soil receiving >45 lb P_2O_5/acre/yr. Soil receiving 45 and 90 lb P_2O_5/acre/yr has shown the least change in annual soil-test P values across time, which is attributed to the fact that annual P inputs and removals are close to being balanced between these P fertilization rates. Linear regression of the annual soil-test P values from soil receiving no P suggests that soil-test P in the top 4 inches of soil has declined by 11 ppm/year (analysis not shown). Linear regression of mean soil-test P values in 2009 of each annual P_2O_5 rate suggest that soil-test P changes by 1 ppm for each 1.6 lb P_2O_5 applied/acre.

As in previous years, bermudagrass forage yields were affected significantly by K fertilization for each harvest and the sum total of all three harvests in 2009 (Table 3). Depending on the harvest, application of 200 or 400 lb K_2O/acre/year was required to maximize bermudagrass yield. Application of 200 lb K_2O/acre/year maximized forage yield only for harvest 1, whereas all other harvests required higher K fertilization to optimize yield. For forage fertilized with <300 lb K_2O/acre/year, season-total dry matter yield declined incrementally as annual K rate declined. Bermudagrass receiving no K produced only 38% to 41% of the total yield as forage fertilized with ≥300 lb K_2O/acre/year. Compared to soil receiving K rates that maximize season-total forage yield, the productivity of soil receiving no K has declined each year from 85% in 2006 to a low of 38% in 2009.

As expected, annual K fertilization rate has also significantly affected tissue K concentrations and K removal by harvested forage (Table 4). Tissue K concentrations and content in bermudagrass during the fist two harvests increased incrementally as annual K rate increased. After the first two harvests, the cumulative uptake of soil K by bermudagrass in the no-K control plots was only 26 lb K/acre. Application of 200 or 300 lb K_2O/acre/year was required for forage to have a K concentration >1.5% K during the first two harvests.

Forage yield responses to P fertilization have been less consistent and dramatic than those observed from K fertilization during the first three years of this study and 2009, the fourth year, was no exception. Significant yield increases from P fertilization occurred for harvest 1 and season-total yields (Table 3). For harvest 1, bermudagrass receiving no P fertilizer produced significantly lower yields than that fertilized with 90, 180, and 225 lb P_2O_5/acre/year. Season total yields from bermudagrass fertilized with 180 and 225 lb P_2O_5/acre/year were greater than those from the no-P control. Season total dry matter produced by bermudagrass fertilized with no P was 87% of the maximum yield. In previous years, the relative season total yield of forage receiving no P has ranged from 86% to 89% of maximum, similar to that produced in 2009. Soil-test P was 'Above Optimum' (>50 ppm) at the beginning of the study and although it has declined gradually it apparently still contains sufficient plant-available P to sustain near maximum forage yields with no supplemental P.

The P concentration of harvested forage was numerically (not statistically compared) greater for the first forage harvest compared to harvest 2 and may reflect differences in soil moisture availability (Table 5). Application of 90 and 45 lb P_2O_5/acre/year was required to maximize forage P concentrations in harvest 1 and 2, respectively. Harvested forage contained between 12.7 and 16.9 lb P_2O_5/ton in harvest 1 and 10.5 to 12.3 lb P_2O_5/ton in harvest 2, with the P removal rate increasing numerically as annual P rate increased.

PRACTICAL APPLICATION

Insufficient K fertilization accompanied by moderate to high rates of N fertilization has resulted in rapid depletion of soil exchangeable K and declining bermudagrass forage yields during a four-year period. Although this study was not designed to evaluate the interaction of N and K fertilization, the K fertilization rate should likely be at least 80% of the season-total N rate since harvested forage removes near equal quantities of N and K. Soil-test K appears to be an excellent predictor of K availability for bermudagrass forage; and soil samples should probably be collected annually or biennially, especially in high yielding systems due to the magnitude of K removal by harvested forage. This Captina soil had an 'Above Optimum' soil-test P level when this trial was initiated in 2006 and it is still Above Optimum even in soil receiving no P after

3-years of cropping. Although some significant yield benefits from P fertilization have been observed in this 4-year study, the magnitude of the yield increases attributed to P fertilization have been relatively small. Application of sufficient N and K fertilizer is required to maximize forage growth and P removal, which may hasten the desired reduction of soil P.

ACKNOWLEDGMENTS

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Table 1. Selected annual soil chemical property means (*n* = 30; 0-to 4-inch depth) for bermudagrass P and K fertilization trials conducted on a Captina silt loam in Fayetteville, Ark., since 2006.

Trial type	Year	Soil pH	Mehlich-3 extractable nutrients P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu
			(ppm)									
Potassium	2006	5.0	121	116	710	71	29	11	179	193	6.9	1.6
Potassium	2007	5.3	109	–[z]	629	76	21	6	163	123	6.2	1.9
Potassium	2008	4.7	127	–[z]	527	72	24	8	177	91	5.7	1.7
Potassium	2009	5.4	118	–[z]	637	136	21	8	170	86	4.3	1.7
Phosphorus	2006	5.1	116	113	613	60	26	9	179	193	7.8	1.5
Phosphorus	2007	5.2	–[y]	213	587	63	21	5	167	147	6.5	1.7
Phosphorus	2008	4.8	–[y]	130	476	57	20	7	169	100	4.7	1.4
Phosphorus	2009	5.5	–[y]	90	616	134	21	7	184	96	4.3	1.6

[z] Soil-test K values as affected by annual K rate are listed in Table 2.
[y] Soil-test P values as affected by annual P rate are listed in Table 2.

Table 2. Mehlich-3 extractable soil P and K from 2006 (before year 1 fertilization) through 2009 (following 3-years of fertilization) as affected by annual P or K fertilizer rate.

Annual K rate	Potassium trial (Mehlich-3 K) 2006	2007	2008	2009	Annual P rate	Phosphorus trial (Mehlich-3 P) 2006	2007	2008	2009
(lb K_2O/acre)	(ppm)				(lb P_2O_5/acre)	(ppm)			
0	113	85	69	54	0	112	97	86	79
100	118	124	73	64	45	123	98	97	101
200	125	128	96	77	90	114	113	103	128
300	108	175	171	105	135	115	116	152	170
400	106	211	214	152	180	118	144	152	181
500	121	240	275	245	225	112	151	184	222
LSD (0.05)	27 (rate among years) and 35 (rate within year)				LSD (0.05)	13 (rate among years) and 19 (rate within year)			
p-value	<0.0001				*p*-value	<0.0001			

Table 3. Forage dry matter yields during 2009 as affected by 4-years of annual P or K fertilization rates for trials conducted on a Captina silt loam in Fayetteville, Ark.

Season total	Potassium trial				Season total	Phosphorus trial			
K_2O rate^{z}	Total	Harv 1	Harv 2	Harv 3	P_2O_5 rate^{z}	Total	Harv 1	Harv 2	Harv 3
(lb K_2O/acre)	(lb forage/acre)				(lb P_2O_5/acre)	(lb forage/acre)			
0	5495	2218	1212	2065	0	12760	4406	2909	5445
100 $^{\times1}$	9847	3920	2038	3889	45 $^{\times1}$	13454	4858	3048	5548
200 $^{\times2}$	12077	4431	2483	5163	90 $^{\times2}$	13470	5012	3091	5367
300 $^{\times2}$	13470	4799	2915	5756	135 $^{\times2}$	13604	4822	3203	5579
400 $^{\times3}$	13803	4553	3065	6185	180 $^{\times3}$	14687	5158	3475	6054
500 $^{\times3}$	14654	4998	3201	6455	225 $^{\times3}$	14340	5226	3423	5691
LSD (0.05)	1005	602	392	571	LSD (0.05)	887	544	NS^{y}	NS
p-value	<0.0001	<0.0001	<0.0001	<0.0001	*p*-value	0.0030	0.0595	0.1703	0.2497
C.V., %	6.6	11.0	11.9	8.8	C.V., %	4.9	8.4	11.7	8.0

^{z} The superscripted value indicates the number of split applications needed to apply the season-total P or K rate.
^{y} NS = not significant.

Table 4. Bermudagrass forage K concentration and aboveground K uptake as affected by annual K-fertilization rate for the fourth year of a trial conducted on a Captina silt in Fayetteville, Ark., during 2009.

	Forage K concentration (by harvest)				Forage K uptake (by harvest)		
Total K_2O rate^{z}	Harv 1	Harv 2	Harv 3	Total	Harv 1	Harv 2	Harv 3
(lb K_2O/acre)	(% K)			(lb K_2O/acre)			
0	0.71	0.45	NA^{y}	26	19	7	NA
100 $^{\times1}$	1.44	0.78	NA	87	68	19	NA
200 $^{\times2}$	1.41	1.54	NA	121	75	46	NA
300 $^{\times2}$	1.74	1.65	NA	158	100	58	NA
400 $^{\times3}$	1.98	2.06	NA	185	109	76	NA
500 $^{\times3}$	1.85	2.27	NA	198	111	87	NA
LSD (0.05)	0.26	0.23	--	--	18	9	--
p-value	<0.0001	<0.0001	--	--	<0.0001	<0.0001	--
C.V., %	13.1	11.9	--	--	17.3	14.0	--

^{z} The superscripted value indicates the number of split applications needed to apply the season-total K rate.
^{y} NA = data not yet available.

Table 5. Bermudagrass forage P concentration and aboveground P uptake as affected by annual P-fertilization rate for the fourth year of a trial conducted on a Captina silt in Fayetteville, Ark., during 2009.

	Forage P concentration (by harvest)				Forage P uptake (by harvest)		
Total P_2O_5 rate^{z}	Harv 1	Harv 2	Harv 3	Total	Harv 1	Harv 2	Harv 3
(lb P_2O_5 /acre)	(% P)			(lb P_2O_5/acre)			
0	0.28	0.23	NA^{y}	43.1	27.9	15.2	NA
45 $^{\times1}$	0.31	0.24	NA	51.5	34.7	16.8	NA
90 $^{\times2}$	0.32	0.26	NA	54.7	36.6	18.1	NA
135 $^{\times2}$	0.33	0.26	NA	55.8	36.9	18.9	NA
180 $^{\times3}$	0.34	0.26	NA	60.3	40.0	20.3	NA
225 $^{\times3}$	0.37	0.26	NA	65.1	44.1	21.0	NA
LSD (0.05)	0.046	0.022	--	--	5.4	2.8	--
p-value	0.0104	0.0284	--	--	0.0002	0.0031	--
C.V., %	10.7	6.8	--	--	11.2	11.6	--

^{z} The superscripted value indicates the number of split applications needed to apply the season-total P rate.
^{y} NA = data not yet available.

Winter Wheat Yield Response to Poultry Litter Application Time

N.A. Slaton, R.E. DeLong, J. Shafer, and S. Clark

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Soft red winter wheat (*Triticum aestivum* L.) requires nitrogen (N) fertilizer to produce optimum yields on most soils in Arkansas. Nitrogen fertilizer is typically applied as urea at total rates ranging from 90 to 160 lb N/acre depending on yield potential, previous crop and soil texture. Research has shown that efficient uptake of fertilizer N occurs when urea is applied in split applications in late winter with the first split usually applied in early to mid February (~Feekes stage 3) and the second application made about 3 weeks later at jointing (Feekes stage 5). Bashir et al. (1997) determined that wheat recovery of urea-N by Feekes stages 8 to 9 was about 74% with this N-management strategy. While the recommended rates and times of urea application remain an efficient system of fertilization, recent increases in inorganic-N fertilizer prices and the surplus of poultry litter (PL) in western Arkansas have stimulated interest in alternative N sources for winter wheat as well as other crops grown in eastern Arkansas.

Poultry litter contains a relatively low concentration of N (3% to 4% N) compared with inorganic N fertilizers, but also contains other essential nutrients that are often applied as inorganic fertilizer to optimize wheat growth and yield. Research has established some recommendations for estimating plant-available N (PAN) in PL for summer-grown crops such as corn (*Zea mays* L., Bitzer and Sims, 1988; Sims, 1987). However, few studies have described the inorganic-N equivalence of PL for winter grown crops.

Our previous research has shown that N in poultry litter applied in the fall and early winter provided very little plant-available N for winter wheat (Slaton et al., 2009). Specific reasons why N uptake and yield of wheat fertilized with poultry litter were poor are unknown, but are probably related to either N losses, immobilization, or slow mineralization of organic N caused by cool temperatures. The primary objective of this research was to determine how poultry litter application time influences winter wheat yield. We anticipated that wheat yields would be greatest when poultry litter was applied near planting and would decline as application time was delayed.

PROCEDURES

Field studies were established at the Pine Tree Research Station on soils mapped as a Calhoun-Calloway silt loam (*Oryza sativa* L.) following rice and Calloway-Loring silt loam [*Glycine max* (L.) Merr.] following soybean. Composite soil samples (0- to 4-inches) were collected from each replicate to characterize soil chemical properties. Soil samples were dried at 60 °C, crushed to pass a 2-mm sieve, and analyzed for soil pH, Mehlich-3 extractable nutrients, and total N and C (Table 1).

Fresh broiler litter remaining from the 2007-2008 field trial was used for the 2008-2009 field trials (Slaton et al., 2009). The litter was collected from the University of Arkansas Savoy Poultry Production unit, had been in the house for about 18 months with rice hulls and wood shavings as the bedding material, and was stored in sealed 18 gal containers following removal from the poultry house. Two composite litter samples were collected and analyzed for chemical properties including total and inorganic N content (Analysis A, Table 2). The N content was somewhat different than that from the 2007 analysis (Slaton et al., 2009). Two additional composite samples were collected and analyzed (Analysis B, Table 2), which showed results comparable to the first analysis. Therefore, the amount of litter needed for each plot was calculated based on the average (n = 4), moist (i.e., 'as is') total N concentration (4.58%), weighed, and placed into plastic bags which were sealed until the litter was applied. In preparation for chemical analyses, litter samples were mixed thoroughly using a coffee bean grinder. Total N and C were determined by combustion and litter NH_4-N and NO_3-N concentrations were determined by extracting a 0.5 g sub-sample of ground litter with 2 *M* KCl and the NH_4-N and NO_3-N concentrations of filtrates were determined by colorimetery. The concentrations of P, K, and other elements were determined by digestion of a 0.5-to 1.0-g sub-sample of ground litter using the concentrated HNO_3 and 30% H_2O_2 method.

Wheat ('Pat') was drill seeded on 22 October 2008 at a rate of 120 lb/acre into conventionally tilled seedbeds. Each plot was 6.5-ft wide × 20-ft long and contained nine rows (7.5-inch row spacing) of wheat. Litter was applied at a single total-N rate of 150 lb total-N/acre which corresponded to 3275 lb moist litter/acre. Litter was broadcast to the soil surface on 22 October before drill seeding wheat and to the surface of predetermined plots on 14 December, 6 February, and 5 March. Each trial also contained treatments that received urea, but no poultry litter, at N rates of 0, 30, 60, 90, 120, and 150 lb N/acre. Urea-N rates ≤60 lb N/acre were applied in a single application on 20 February and rates >60 lb N/acre received 60 lb N/acre on 20 February followed by the balance of the total N rate on

19 March. Each research area received 46 lb P_2O_5/acre as triple superphosphate and 60 lb K_2O/acre as muriate of potash at planting. A second application of triple superphosphate (23 lb P_2O_5/acre) was applied in February to wheat following soybean. At maturity, grain yields were measured by harvesting each plot with a small-plot combine. Grain yields were adjusted to a uniform moisture content of 13%.

Each experiment was a randomized complete block of the six urea-N rates and four poultry litter application times with each treatment replicated five times. Data from the four poultry litter application time treatments were subjected to analysis of variance using the PROC GLM procedure of SAS v9.1 (SAS Institute, Inc., Cary, N.C.). When appropriate, treatment means were separated using Fishers Protected Least Significant Difference method (LSD) with significance interpreted at the 0.05 level. For each site, the urea-N rates were included to develop a wheat grain yield response to N rate curve, which was defined by regressing replicate grain yield data against urea-N rate. Linear and curvilinear models were tested using the Proc Reg procedure in SAS. The mean grain yields of each poultry litter application time were superimposed on the N rate curve to estimate the urea-N equivalence of poultry litter applied at 150 lb total-N/acre.

RESULTS AND DISCUSSION

Wheat grain yields increased significantly to fertilization with urea-N at both sites (Table 3). Maximum numerical grain yields were always produced with the greatest urea-N rate applied (150 lb N/acre), but yields were not significantly different than wheat receiving 120 lb N/acre at either site. Wheat yields increased linearly following soybean in rotation and curvilinearly for wheat following rice (Fig. 1). The intercept, linear, and quadratic (only for wheat following rice) coefficients were significant and statistically different than zero.

The time of poultry litter application had no significant effect on wheat grain yield (Table 3). Wheat grain yield, averaged across all poultry litter application times, was 36 bu/acre for wheat following rice and 31 bu/acre for wheat following soybean. We expected wheat grain yields to be greatest from litter applied in October (at planting) and that yields would decline as the time of application was delayed until February or later. However, wheat yields failed to show any trend supporting this expectation. Visual observations showed that each poultry litter application caused the plants to ‘green up’ and grow vigorously for only a short time. By harvest, wheat receiving litter at all application times appeared to have similar yield potential.

Poultry litter applied at 150 lb total-N/acre produced wheat yields 11 to 16 bu/acre greater than wheat receiving no N that were comparable numerically to yields of wheat receiving 60 lb urea-N/acre. Based on the urea-N rate yield curve, about one-third (33%) of the total N applied as poultry litter would be considered plant available. This estimate is slightly greater than the suggested estimate of 20% from our previous research (Slaton et al., 2009).

PRACTICAL APPLICATION

Poultry litter is not likely to be applied to wheat in late-winter due to the wet soil conditions that preclude the use of ground-based application equipment and the fact that aerial application of poultry litter is not economically feasible. This research sought only to examine how wheat responded to poultry litter application time to provide insight as to why the plant-available N content of litter is apparently low. Growers are more apt to apply poultry litter following the harvest of the summer crop grown before wheat or shortly after wheat is planted. Results from these two trials indicate that applying poultry litter between late October and mid-March had no significant influence on wheat grain yield. These trials do not indicate the fate of the N in poultry litter following application, but suggest that the amount of N available to wheat was uniform across the application times that were evaluated. The cool temperatures are likely preventing rapid mineralization of the majority of organic N present in litter, but other pathways (NH_3 volatilization, nitrification, denitrification, etc.) in the N cycle may also interact with the time of litter application to influence the net amount of plant-available N. Further research investigating wheat yield response to poultry litter applied in advance of planting is warranted to determine if the plant-available N increases when litter is applied under warmer conditions which would allow more time for mineralization of the organic N present in poultry litter.

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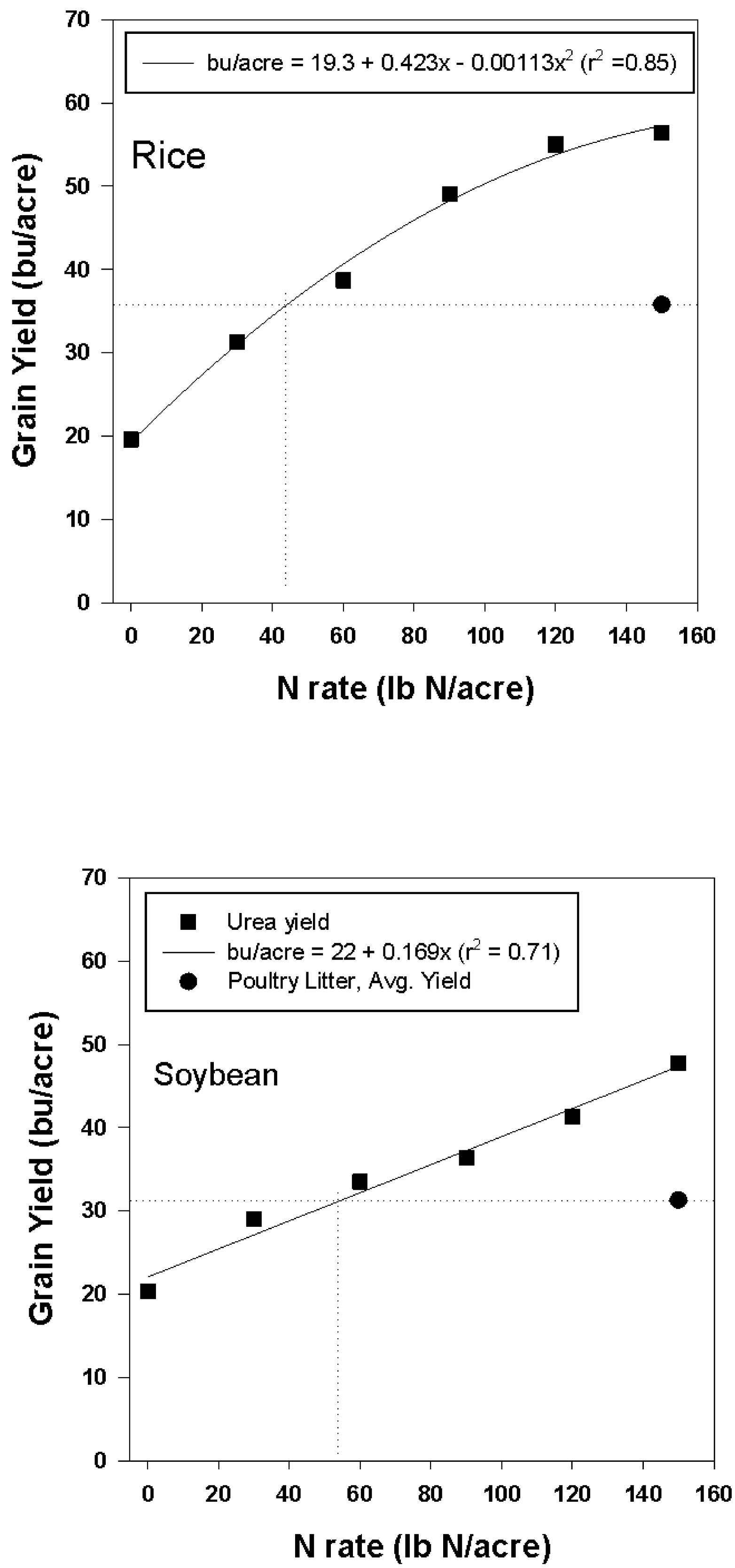

Fig. 1. Mean grain yield of soft red winter wheat grown following rice or soybean as affected by late-winter urea-N rate and fresh poultry litter applied at 150 lb N/acre, averaged across four application times.

Table 1. Selected soil chemical property means (0- to 4-inch depth) for samples taken before seeding winter wheat following either rice or soybean in rotation at the Pine Tree Research Station during 2008-2009.

Previous	Soil		Mehlich-3 extractable soil nutrients							
crop	pH	SOM[z]	P	K	Ca	Mg	S	Mn	Zn	Cu
		(%)	(ppm)							
Rice	6.4	3.2	48	110	1238	241	31	116	1.7	0.9
Soybean	6.4	2.2	7	86	911	283	14	314	1.9	0.8

[z] SOM = soil organic matter by weight loss on ignition.

Table 2. Selected chemical property means of fresh poultry litter analyzed 'as is' and used in fertilization trials for winter wheat conducted during 2008-2009.

		Litter source	
Property	Unit	Analysis A	Analysis B
n (subsamples)		2	2
Moisture	%	21.7	19.0
pH	--	8.7	8.5
Total C	%	34.6	31.3
Total N	%	4.68	4.48
NH_4-N	mg/kg	135	91
NO_3-N	mg/kg	5476	4751
Total P	%	1.49	1.58
Total K	%	2.67	2.78
Total Ca	%	1.96	2.21
Total Mg	%	0.57	0.59
Total S	%	0.61	0.63
Total Fe	mg/kg	437	584
Total Mn	mg/kg	348	360
Total Zn	mg/kg	341	347
Total Cu	mg/kg	383	381
Total Na	mg/kg	4545	5180
Total B	mg/kg	40.8	40.9
Total Al	mg/kg	194	189

Table 3. Wheat grain yield as affected by urea-N rate or poultry litter application time at two sites following either rice or soybean in rotation during 2008-2009.

		Grain yield (by previous crop)	
N Source	N rate	Rice	Soybean
	(lb N/acre)	(bu/acre)	
None	0	19.6	20.3
Urea	30	31.3	29.0
Urea	60	38.7	33.5
Urea	90	49.1	36.4
Urea	120	55.0	41.3
Urea	150	56.4	47.7
	p-value	<0.0001	<0.0001
	C.V., %	11.5	15.7
	LSD (0.05)	7.0	7.5
Litter-October	150	35.4	32.5
Litter-December	150	35.1	30.9
Litter-February	150	37.3	30.9
Litter-March	150	35.5	30.9
	P-value	0.8055	0.8568
	C.V., %	15.4	11.3
	LSD (0.05)	NS	NS

Soybean Yield Response to Phosphorus and Potassium Fertilization Rate and Time

N.Slaton, R.E. DeLong, J. Shafer, S. Clark, and B.R. Golden

BACKGROUND INFORMATION AND RESEARCH PROBLEM

The primary focus of recent research has been to correlate and calibrate soil-test based fertilizer recommendations for phosphorus (P) and potassium (K) and determine how to ameliorate deficiencies of these nutrients during the season. These research efforts have increased our confidence in P and K fertilization recommendations and allowed research to focus on other questions that require research-based answers.

Phosphorus and K fertilizers are usually applied within a few days or weeks before soybean is planted. One of the most common questions in recent years has been whether P and/or K fertilizers can be applied four to six months before planting without loss of availability. As a general rule, we have discouraged growers from applying P and K fertilizers in the fall due to soil reactions (i.e., fixation) that could reduce plant availability of fertilizer nutrients across time and the increased risk of nutrient loss via erosion, runoff, and/or leaching. Furthermore, we have occasionally observed P deficiency in rice (*Oryza sativa* L.) fields that reportedly received fall-applied P fertilizer. Recent research conducted with soybean double-cropped following soft red winter wheat (*Triticum aestivum*) harvest suggests that nutrient application rate is more critical than the time of fertilizer application. Knowledge of how nutrient application time influences crop response to fertilization will become increasingly important as poultry litter is applied weeks or months in advance of rice planting and fertilizer prices fluctuate. Our research objective was to evaluate soybean yield and nutrient uptake response to P and K fertilizer applied in December, February, and April (planting) on soils having below optimum soil-test P and K levels.

PROCEDURES

Research was established on a soil mapped as a Calloway silt loam at the Pine Tree Research Station (PTRS) and a Convent silt loam at the Lon Mann Cotton Research Station (LMCRS). Soybean was grown in both fields during the summer of 2008. At the LMCRS, beds (38-inch wide) were pulled in October 2008 and wheat was drill seeded as a cover crop. Wheat received no N fertilizer and was eventually sprayed with glyphosate herbicide to terminate growth in early spring 2009. At the PTRS, the Calloway soil was conventionally tilled and floated in November 2008 to prepare a level seedbed. Four adjacent research areas, two each for P and K, were flagged to define individual plot boundaries (7-ft wide × 25-ft long) for rice and soybean fertilization trials. This report uses soil data from both the rice and soybean research areas, but includes yield and plant nutrition data only for soybean.

At both locations, composite soil samples were collected (0- to 4-inch depth) in December 2008, February 2009, and April 2009 from each plot designated to receive no P or K fertilizer. Composite soil samples were analyzed for soil pH (1:2 soil: water mixture), Mehlich-3 extractable soil nutrients, and soil organic matter by weight loss on ignition. Selected soil chemical property means from samples collected in April are listed in Table 1. Soil test means for soil pH, P, K, and Zn are listed in Table 2 to examine the consistency of soil-test nutrient levels across time. In April 2009, composite soil samples were collected from each plot to examine how P and K fertilizer applied in December 2008 and February 2009 affected soil-test P and K levels (Table 3).

Phosphorus- (as triple superphosphate) and K-fertilizer (as muriate of potash) treatments were broadcast applied to the soil surface at rates of 0, 45, and 90 lb K_2O or P_2O_5/acre on 14 December 2008, 6 February 2009, and 22 April 2009. The K research area received 60 to 90 lb P_2O_5/acre in April 2009. Likewise, the P research area received 60 to 120 lb K_2O/acre as muriate of potash in April. At the PTRS, Armor 47-F8 soybean (60 lb/acre, 15-inch wide rows) was drilled into an undisturbed (i.e., stale) seedbed on 22 April 2009. At the LMCRS, Armor 53-Z5 soybean was planted on the 38-inch beds on 28 April 2009.

Fully expanded trifoliate leaves (15/plot) were collected from one of the top three nodes of soybean plants in each plot at the R2 growth stage. Plant samples were oven dried to a constant weight, ground to pass a 2-mm sieve, and a subsample of tissue was digested in 30% H_2O_2 and concentrated HNO_3 to determine tissue nutrient concentrations.

Each experiment was a randomized complete block design with a 2 (fertilizer rate) × 3 (application month) factorial treatment arrangement compared to a no fertilizer (P or K) control. Each treatment was replicated six times and each replicate contained two no fertilizer control plots. Mehlich-3 soil P and K concentrations from the April 2009 sample time were subjected to an analysis of variance to evaluate the effect of fertilizer applied in December and February on soil-test P and K using a 2 (fertilizer rate) × 3 (application month) factorial treatment arrangement. The April fertilizer application time served as an unfertilized control since fertilizer had not been applied when soil samples were collected. At the PTRS, data were pooled from rice and soybean research areas resulting in 12 replicates of each application time and fertilizer rate combination. A second analysis of variance was performed on selected soil chemical property data from plots designated to receive no P or K fertilizer and sampled in December, February, and April to determine the effect of sample time. Data were pooled across the four test areas at PTRS and two test areas at LMCRS resulting in 24 and 12 replicates per treatment, respectively. Soybean leaf nutrient concentration and grain yield data were analyzed using a 2 (fertilizer rate) × 3 (application month) factorial treatment arrangement compared to a no fertilizer (P or K) control with each treatment replicated six times. All statistical analyses were performed with the GLM model in SAS v9.2 (SAS Institute, Cary, N.C.) with significant differences interpreted when $P < 0.05$ for soil data and $P < 0.10$ for yield and plant nutrient concentration data.

RESULTS AND DISCUSSION

Soil-Test Results as Affected by Month of Sample Collection

The month of soil collection significantly affected soil pH and Mehlich-3 extractable P, K, and Zn of soil that had received no fertilizer at the PTRS (Table 2). Although the differences among sample times were significant, differences were relatively small and had no practical significance for crop nutrient management. These data suggest that soil samples collected between early December and mid April would result in similar soil chemical properties and recommendations. It should be noted that fertilizer rates can change dramatically with small changes (i.e., 1 ppm) in soil nutrient concentrations when the nutrient concentration is near the upper and lower thresholds of two soil-test levels (e.g., Low and Medium).

Month of soil sample collection also resulted in statistically significant differences in soil pH and Mehlich-3 extractable P, K, and Zn at the LMCRS (Table 2). Unlike the PTRS, the month of sample collection caused larger differences in soil test parameters that could influence fertilizer recommendations. Soil pH was 0.6 units greater for samples collected in February 2009 compared to samples collected in December 2008 or April 2009. Despite the differences in soil pH and Mehlich-3 extractable Zn and P across time, the magnitude of the differences would have no influence on crop fertilizer or soil amendment recommendations. However, soil-test K tended to decrease with time and changed from an ‘Optimum’ level of 138 ppm in December 2008 to ‘Medium’ levels in February and April 2009 (Table 2). The significant decline in soil-test K and numerical decline in soil-test P could be attributed in part to nutrient uptake by wheat that was grown on the LMCRS test site as a cover crop.

Soil-Test K

The interaction between month of fertilizer application and K rate significantly affected Mehlich-3 extractable (soil-test) K in April 2009 at the PTRS (Table 3). Soil-test K was lowest in soil that had received no K fertilizer with an average soil-test K of 105 ppm, which would be interpreted as a Medium (91 to 130 ppm) soil-test K level. Soil-test K increased incrementally as K rate increased with month of application having no significant effect within each K rate. Application of K at 45 lb K_2O/acre increased Mehlich-3 extractable K by, on average, 16% above soil receiving no K and did not change the soil test level (Medium). Application of 90 lb K_2O/acre increased Mehlich-3 extractable K by, on average, 38% and changed the soil-test K level to Optimum (131 to 175 ppm). Assuming a soil bulk density of 1.20 g cm^{-3}, a 4-inch deep soil sample represents approximately 1,071,600 lb soil/acre. The theoretical increase (100% recovery of applied K) in soil-test K would be approximately 35 and 70 ppm K from application of 45 and 90 lb K_2O/acre, respectively. Thus 3 to 5 months after K fertilizer application, about 50% of the applied K fertilizer was extracted in the April soil samples. These data indicate that about one-half of K fertilizer applied between crop harvest and soil sampling should be reflected as greater soil-test K values on a soil-test report. However, this relationship may vary among soils and environmental conditions.

At the LMCRS, soil-test K in April 2009 was affected by the main effects of month of fertilizer application ($P = 0.0007$) and fertilizer rate ($P = 0.0189$). The data for the non-significant interaction are shown in Table 3. Soil-test K, averaged across K_2O rates, was similar when K fertilizer was applied in December 2008 (151 ppm, LSD0.05 = 15 ppm) and February 2009 (145 ppm) with both application times being greater than soil-test K in plots receiving no K (120 ppm). Based on the same assumptions described for the PTRS and the soil-test K values, averaged across December and February applications, for each K_2O rate, 49% to 56% of the applied K fertilizer was recovered in soil samples collected in April 2009, which is very similar to the proportion recovered in the soil at the PTRS.

Soil-Test P

Soil-test P at the PTRS was also affected by the interaction between fertilizer application month and fertilizer rate (Table 4). Soil receiving no P had similar soil-test P values that averaged 10.4 ppm. Compared to soil receiving no P, P fertilization in December and February increased Mehlich-3 extractable P by 3.1 to 4.7 ppm and 8.0 to 10.2 ppm for the 45 and 90 lb P_2O_5/acre application rates, respectively. Using the same soil weight assumptions outlined for K, the theoretical increase in soil-test P would be 18.5 and 37 ppm P from application of 45 and 90 lb P_2O_5/acre, respectively. Despite significant increases in soil-test P, the Mehlich-3 extractant recovered only 17% to 28% of the P fertilizer applied in December and February. Recovery of fertilizer P tended to increase as P rate increased from 45 to 90 lb P_2O_5/acre and decrease when P fertilizer was applied in December 2008 compared with February 2009.

At the LMCRS, soil-test P as determined in soil samples collected in April 2009 was affected significantly only by month of fertilizer application ($P < 0.0001$). The data for the non-significant interaction are shown in Table 4. Soil-test P, averaged across P_2O_5 rates, was greatest for P applied in February 2009 (48 ppm, LSD = 4 ppm), intermediate for P applied in December (43 ppm), and lowest for soil receiving no P (37 ppm). On average, the Mehlich-3 soil extractant recovered 22% to 40% of applied P fertilizer, which is comparable, albeit slightly greater, than the highest recovery found for the soil at the PTRS.

Trifoliate Leaf P and K Concentrations

At the PTRS and LMCRS, trifoliate leaf K concentrations were significantly affected only by K application rate (Table 5). Soybean leaf K increased incrementally as K fertilizer increased (Table 5). Averaged across fertilizer rates, leaf K concentrations were quite consistent across K application times averaging from 1.72% to 1.75% K at the PTRS and 1.63% to 1.65% K at the LMCRS. The leaf K concentration data clearly suggest that soybean uptake of K was similar regardless of the month K fertilizer was applied.

Trifoliate leaf P concentrations were not significantly affected by application month, application rate, or their interaction at either location. At the R2 growth stage, trifoliate leaves of soybean receiving no P fertilizer had mean P concentrations of 0.31% and 0.34 % P at the PTRS and LMCRS, respectively (Table 5). The results showed no consistent trend for leaf P concentrations to change with application rate or time of application at either location.

Grain Yield

At the PTRS, soybean yield was not affected by the main effects of K rate (P = 0.6874), application time (P = 0.6671) or their interaction ($P = 0.8640$, Table 6). Although not significant, soybean receiving no K produced the lowest numerical yield (57 bu/acre) compared to soybean that received K in December, February, or April before planting (59 to 60 bu/acre), averaged across application rates. The lack of a positive response to K fertilization was not entirely unexpected since the soil had a ‘Medium’ soil test K level (Table 1) and soil moisture was sufficient for most of the growing season.

At the PTRS, soybean yield was also not affected by P rate ($P = 0.2071$), application time ($P = 0.3393$) or their interaction ($P = 0.8250$, Table 6). Soybean receiving no P produced the lowest numerical yield (63 bu/acre) compared to soybean that received P in December, February, or April before planting (66 to 69 bu/acre), averaged across application rates. The lack of a positive response to P fertilization was surprising since the soil had a ‘Very Low’ soil-test P level (Table 1). However, when the model was simplified to a randomized complete block to evaluate the effect of only P rate, analysis of variance showed a significant P rate effect on soybean yield ($P = 0.0668$). Although, soybean yields were numerically greater when P was applied, only soybean fertilized with 45 lb P_2O_5/acre produced significantly greater yields than soybean receiving no P fertilizer.

At the LMCRS, soybean yield was not significantly ($P > 0.10$) affected by K fertilization. Soybean yields ranged from 37 to 42 bu/acre and were average considering the early planting date and excellent soil moisture conditions (Table 7). The interaction between P fertilizer rate and application month significantly affected soybean yield. Soybean yields in the P study were below average (24 to 32 bu/acre). The response to P was not consistent as the yield of soybean receiving no P fertilizer was different than only soybean fertilized with 90 lb P_2O_5/acre in February. Yield data from both the P and K trials at LMCRS had relatively high coefficients of variation (14% to 16%) and had non-uniform growth across the research areas. Specific reasons for the non-uniform growth are unknown, but were not attributed to drainage problems.

PRACTICAL APPLICATION

Soil-test results showed significant changes in soil pH and Mehlich-3 extractable P, K, and Zn for 4-inch deep samples collected from soil receiving no fertilizer in December 2008, February 2009, and April 2009 at two sites. Despite the significant differences among sample times, the magnitude of the differences was seldom great enough to influence fertilizer or soil amendment recommendations. These results suggest that soil samples collected to estimate soil fertility status between December and April generally provide similar crop nutrient management recommendations. Furthermore, the results also indicate that soil-test results of samples collected from large areas (i.e., fields), rather than small defined plots of soil as used in this research, may show significant differences across time. This is mentioned only because samples are sometimes collected from the same field at different times (i.e., several weeks apart) to check the consistency of recommendations from a previous soil sample. Theoretically the recommendations and soil-test information should be consistent across short intervals of time provided that each composite soil sample consisted of enough subsamples for sufficient accuracy and precision to account for in-field spatial variations (i.e., represent the true field mean).

The second question addressed by this research concerns the ability of soil testing to recognize fertilizer nutrients applied in the fall or winter prior to soil sample collection. Soil samples collected to a 4-inch depth recovered, on average, 50% of K fertilizer and 26% (range = 17% to 40%) of P fertilizer applied 3 to 5 months before samples were collected in April 2009 at two sites. The practical significance of these findings is that the P or K fertility level of a soil may not change substantially following moderate rates of P and K fertilization. Increasing the soil fertility level of a soil is a long-term process. Soybean yield and trifoliate leaf P and K concentrations provide evidence suggesting that fertilizer P and K applied 3 to 5 months in advance of planting have similar availability as fertilizer applied immediately before planting. Although these two trials with soybean indicate no loss in P and K availability from fertilizer applied 3 to 5 months before planting, application of fertilizer as close to planting as possible may still be the best time for application. Growers should consider fertilizer prices, time management, and field characteristics when considering early applications of P and K fertilizers. Soils that require fertilizer rates to maintain a 'Medium' soil fertility level may be the best candidates for early fertilization.

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Table 1. Selected soil chemical property means (0- to 4-inch depth) of two sites used to evaluate rice and soybean response to P and K fertilization rate and time on silt loam soils as determined from soil samples collected in April 2009.

Site	Soil pH[z]	Mehlich-3 extractable soil nutrient concentrations[y] P[x]	K[w]	Ca	Mg	S	Fe	Mn	Zn	Cu
		(ppm)								
LMCRS - Soybean										
P trial	6.0	37	102	941	213	7	188	115	1.2	1.7
K trial	6.2	39	116	762	181	7	183	130	1.3	1.2
PTRS - Soybean										
P trial	6.7	10	105	1023	266	9	141	355	2.6	1.0
K trial	6.6	11	107	968	254	9	148	361	2.8	1.0
PTRS - Rice										
P trial	6.5	11	105	995	261	9	164	385	2.5	1.4
K trial	6.6	8	96	1023	271	9	150	368	2.2	1.1

[z] Soil pH measured in a 1:2 soil:water mixture.
[y] Mean of 12 or 6 composite samples (0- to 4-inch depth) from plots designated to receive no P or K fertilizer.
[x] For P trials, the standard deviation of soil-test P was 4 for LMCRS, <2 ppm for PTRS-Soybean, and <2 ppm for PTRS-Rice.
[w] For K trials, the standard deviation of soil-test K was 11 ppm for LMCRS, 14 ppm for PTRS-Soybean, and 19 ppm for PTRS-Rice.

Table 2. The effect of sample month on the pH and Mehlich-3-extractable P, K, and Zn concentrations of soil receiving no P or K fertilizer at two research sites.

Site and sample month	Soil pH	Mehlich-3-extractable P	K	Zn
		(ppm)		
PTRS				
December 2008	6.8	11.6	118	2.8
February 2009	6.6	11.4	108	2.5
April 2009	6.6	10.0	103	2.4
LSD (0.05)	<0.1	0.6	3	0.1
P-value	<0.0001	<0.0001	<0.0001	<0.0001
LMCRS				
December 2008	6.1	42.8	138	1.3
February 2009	6.7	38.9	123	1.3
April 2009	6.1	37.5	109	1.1
LSD (0.05)	0.2	2.7	11	<0.2
p-value	<0.0001	0.0008	<0.0001	0.0351

Table 3. The effect of fertilizer application month and K-fertilizer rate on Mehlich-3-extractable soil K as determined in April 2009 at the Pine Tree Research Station (PTRS) and Lon Mann Cotton Research Station (LMCRS).

Fertilizer application month	45 lb K_2O/acre		90 lb K_2O/acre
	------------------------------(ppm K)------------------------------		
PTRS			
None	108		101
December 2008	122		143
February 2009	121		139
LSD (0.05)		12	
P-value		0.0018	
LMCRS			
None	117		122
December 2008	137		165
February 2009	139		152
LSD (0.05)		NS[z]	
p-value		0.2902	

[z] NS = not significant ($P > 0.10$).

Table 4. The effect of fertilizer application month and P-fertilizer rate on Mehlich-3-extractable soil P as determined in April 2009 at the Pine Tree Research Station (PTRS) and Lon Mann Cotton Research Station (LMCRS).

Fertilizer application month	45 lb P_2O_5/acre		90 lb P_2O_5/acre
	------------------------------(ppm K)------------------------------		
PTRS			
None	10.6		10.2
December 08	13.5		18.4
February 09	15.1		20.6
LSD (0.05)		2.8	
P-value		0.0059	
LMCRS			
None	38.3		35.7
December 08	42.7		44.2
February 09	46.8		49
LSD (0.05)		NS[z]	
p-value		0.4325	

[z] NS = not significant ($P > 0.10$).

Table 5. Soybean trifoliate leaf P and K concentrations at the R2 growth stage as affected by K application rate, averaged across fertilizer application month, for soybean grown at the Pine Tree Research Station (PTRS) and Lon Mann Cotton Research Station (LMCRS) during 2009.

	Potassium trials		Phosphorus trials	
Nutrient rate	PTRS	LMCRS	PTRS	LMCRS
(lb K_2O or P_2O_5/acre)	-------------------- (% K) --------------------		-------------------- (% P) --------------------	
0	1.58	1.53	0.310	0.344
45	1.68	1.59	0.314	0.338
90	1.79	1.69	0.321	0.343
LSD (0.10)	0.07	<0.06	NS[z]	NS
p-value	0.008	0.0038	0.1487	0.4677

[z] NS = not significant ($P > 0.10$).

Table 6. Soybean seed yield means as affected by the non-significant interaction between P or K fertilizer rate and application month for soybean grown at the Pine Tree Research Station during 2009.

Fertilizer application month	45 lb K_2O/acre		90 lb K_2O/acre
	------------------------------	(bu/acre)	------------------------------
Potassium			
None		57	
December 2008	59		60
February 2009	59		61
April 2009	60		59
LSD (0.10)		NS[z]	
P-value		0.864	
Phosphorus	45 lb P_2O_5/acre		90 lb P_2O_5/acre
None		64	
December 2008	69		67
February 2009	68		64
April 2009	69		69
LSD (0.10)		NS	
P-value		0.825	

[z] NS = not significant ($P > 0.10$).

Table 7. Soybean seed yield means as affected by the interaction between fertilizer rate and application month for soybean grown at the Lon Mann Cotton Research Station during 2009. Note the interaction was significant only for P fertilization.

Fertilizer application month	45 lb K_2O/acre		90 lb K_2O/acre
	(bu/acre)		
Potassium			
None		39	
December 2008	39		39
February 2009	37		42
April 2009	39		39
LSD (0.10)		NS[z]	
P-value		0.4915	
Phosphorus	45 lb P_2O_5/acre		90 lb P_2O_5/acre
None		27	
December 2008	29		28
February 2009	24		32
April 2009	27		30
LSD (0.10)		4	
P-value		0.0386	

[z] NS = not significant ($P > 0.10$).

Soybean Response to Phosphorus and Potassium Fertilization Strategies

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Soybean [*Glycine max* (L.) Merr.] grown on silt- and sandy-loam soils in Arkansas often require phosphorus (P) and potassium (K) fertilizer to avoid deficiencies or maintain adequate soil fertility of these nutrients. Our research has shown that soil-test K (Mehlich-3) is a good indicator of soybean yield response to K fertilization on silt loam soils and that adequate K fertilization is needed to maintain high yield potential on these soils. Additional research regarding soybean response to K fertilization is still needed, but can now be focused on examining other aspects of K fertilization such as the time and method of K fertilization.

Refining soil-test based recommendations for P fertilization of soybean have proven to be more challenging. The Mehlich-3 soil-test method is not as good at identifying P-deficient soils or assessing soil P availability for soybean production as we have shown for K. Although the relationship between soybean relative yield and Mehlich-3 extractable soil P is significant, the relationship is relatively weak ($r^2 < 0.40$, unpublished data). Additional research is needed to evaluate other soil-test P methods and/or find other soil chemical properties that can be used with soil-test P that improve the accuracy of identifying P-deficient soils.

The overall research goals were to i) correlate Mehlich-3 soil-test P and K with soybean yield and ii) calibrate the appropriate P and K fertilizer rates needed to produce optimum soybean yields for irrigated soybean production. Our specific research objectives for trials conducted in 2009 were to evaluate soybean response to i) P fertilizer rate, ii) K fertilizer rate and application time, and iii) long-term K fertilization rate.

PROCEDURES

Phosphorus and K fertilization trials with soybean were established at two Agricultural Experiment Stations (Pine Tree Research Station, PTRS; and Rice Research Extension Center, RREC) and two off-station sites (Phillips Community College in Dewitt, Ark., PCC; and Poinsett County) during 2009. Specific soil and agronomic information for each site is listed in Table 1. Each location will be referred to by the site name listed in Table 1. In the commercial fields, P and K fertilizers were applied to the surrounding field, but not to the area where research plots were established. A maturity group IV or V soybean cultivar was grown at each site. For the study conducted in the commercial fields, cultivar selection, planting, and management were performed by the cooperating grower. Management with respect to seeding rate, irrigation, and pest control at all sites closely followed recommendations from the University of Arkansas Cooperative Extension Service.

At each site, individual plots were 16- to 25-ft long by 6.5- to 24-ft wide. Before fertilizer was applied to the research tests, a composite soil sample was collected from the 0- to 4-inch depth from each replicate (n = 4-8) for each nutrient study area. Soil samples were oven-dried at 130 °F, crushed, and passed through a 2-mm sieve. Soil water pH was determined in a 1:2 soil weight:water volume mixture, plant-available nutrients were extracted using the Mehlich-3 method, and elemental concentrations in the extracts were determined using inductively coupled plasma spectroscopy (ICPS). Selected soil chemical property means are listed in Table 2. More specific details of each trial are provided in the following sections.

Long-term Potassium Trial (PTRS)

In 2000, a long-term K fertilization trial was established and cropped to rice at the PTRS (PTRS-LT). In 2009, the tenth year of the study, soybean was grown following the 2008 rice crop. Soybean (Armor 47F8) was planted into an untilled seedbed in April following the annual application of muriate of potash treatments ranging from 0 to 160 lb K_2O/acre. Soil samples (0- to 4-inch depth) were collected from each plot in February 2009 and processed as described previously. Boron (1 lb B/acre as granubor) and triple superphosphate (50 lb P_2O_5/acre) were broadcast applied to the research area before planting. The trial was a randomized complete block design with eight replicates of each annual K rate. Soil samples were also extracted with 1 mol L^{-1} HNO_3 which is a measure of exchangeable plus non-exchangeable soil K.

RREC Phosphorus Trial

Four adjacent research areas were established at the RREC in 2007 and cropped with a rice-soybean or soybean-rice rotation in 2007 and 2008. In April 2009, rice and soybean were planted into an untilled seedbed, but excessive rainfall, poor drainage, and variable seeding depth resulted in stand failures for both crops. Replanting was delayed until early June at which time soybean was drill-seeded into all four research areas (Table 1). An adequate stand was established from this seeding, but excessive rainfall and poor drainage caused uneven soybean growth in three of the four areas. Yield results for the P research area that followed soybean in 2008 and was initially seeded to rice in 2009 will be reported. Soil-test P and K information from samples collected in February from this P research area is also described. Phosphorus has been applied annually since 2007 at rates of 0, 40, 80, 120, and 160 lb P_2O_5/acre as triple superphosphate and muriate or potash has been applied to maintain sufficient soil K availability. The trial is a randomized complete block deign with six replications of each P rate. The reported soil test and yield data were analyzed by year.

Phosphorus Rate Trials

Phosphorus fertilizer trials were conducted at three sites (Table 1) and included five rates (0, 40, 80, 120, and 160 lb P_2O_5/acre) of triple superphosphate which were broadcast to the soil surface shortly before or after planting. Muriate of potash (~80 lb K_2O/acre) was broadcast to the soil surface to ensure that K was not yield limiting. Granular B fertilizer (1.0 lb B/acre) was applied at the PTRS and Poinsett sites. Soil samples (0- to 4-inch depth) were collected before planting or emergence at each site. Each trial was a randomized complete block design with six or seven replications.

Potassium Time and Rate Trials

Potassium fertilizer trials were conducted at the same three sites (Table 1) as the P rate trials and included three rates (0, 60, and 120 lb K_2O/acre) of muriate of potash which were broadcast to the soil surface shortly before or after planting and post-emergence at two other times during the growing season. Potassium fertilizer treatments were applied 20 May, 9 July (R1), and 29 July (R3 to R4) at the PCC site; 19 May, 8 July (R1), and 11 August (R4) at the PTRS; and 10 June, 3 August (R2), and 20 August (R3) at the Poinsett site. Triple superphosphate (50-60 lb P_2O_5/acre) was broadcast to the soil surface to ensure that P was not yield limiting. Granular B fertilizer (1.0 lb B/acre) was applied at the PTRS and Poinsett sites. Soil samples (0- to 4-inch depth) were collected before planting or emergence at each site. Trifoliate leaf samples were collected at the R1 to R2 stage from plots that received K preplant or no K. Each trial was a randomized complete block design with a 2 (K rate) by 3 (K time) factorial treatment structure compared to a no K control. Each treatment was replicated five times per site.

Double-Crop Soybean Trials

Wheat ('Pat') fertilization trials with P and K were established following soybean at the PTRS in fall 2008 with muriate or potash or triple superphosphate applied at rates of 0, 30, 60, 90, 120, and 150 lb P_2O_5 or K_2O/acre. Each research area received a broadcast application of either P or K to ensure that P in the K trial or K in the P trial was not yield limiting (note additional details on the wheat trials are available in another report published in this issue). Following wheat harvest, wheat stubble was burned and Armor 47F8 was drill seeded (15-inch wide rows) into an untilled seedbed in mid June following wheat harvest, but the initial planting had to be destroyed due to a thin stand and was replanted with Schillinger R557 in late June (Table 1). In each nutrient trial, plots that had received 30 and 90 lb P_2O_5 or K_2O/acre in fall 2008 were amended with an additional 30 or 60 lb P_2O_5 or K_2O/acre with the same fertilizer sources applied to wheat before soybean was planted. The soybean study contained six total treatments including a check (no P or K), 60 lb K_2O or P_2O_5/acre applied in the fall or split equally between wheat and soybean, 120 lb K_2O or P_2O_5/acre applied only to wheat, and 150 lb K_2O or P_2O_5/acre applied in the fall to wheat or split between wheat (90) and soybean (60). Each trial was a randomized complete block design with five replications.

In all trials, trifoliate leaves (15) were collected at the R1 to R2 growth stage, dried to a constant moisture, ground to pass a 1-mm sieve, digested, and analyzed for elemental concentrations by ICPS. A 12- to 20-ft long section of the middle of each plot was harvested with a plot combine. Soybean moisture was adjusted to 13% for final yield calculations. For all studies, analysis of variance was conducted by site with the PROC GLM procedure in SAS v9.1 (SAS Institute, Inc., Cary, N.C.). When appropriate, mean separations were performed using Fisher's Protected Least Significant Difference method at a significance level of 0.10. Single-degree-of-freedom contrasts were used to compare selected treatments with significant differences identified when $P < 0.10$.

RESULTS AND DISCUSSION

PTRS-LT Trial Results

Soil-test K (Mehlich-3) of soil receiving no K fertilizer for the last 10 years averaged 83 ppm and would be considered a 'Low' (61 to 90 ppm) soil-test K value (Table 3). Soil from all other annual K rates ranged from 96 to 114 ppm and would be considered a 'Medium' level (91 to 130 ppm). Based on the soil-test K values, soybean yield differences from annual K fertilization were expected. Both Mehlich-3 and HNO_3 extractable soil K showed similar trends among annual K rates. As expected, the amount of K extracted by HNO_3 and the range of mean soil-test K values was greater for the HNO_3 extractant compared to Mehlich-3 K. Extractable soil K was greatest for soil receiving 120 and 160 lb K_2O/acre, intermediate for 40 and 80 lb K_2O/acre, and lowest for soil receiving no K. These data suggest that increasing soil-test K (Mehlich-3) on this Calhoun soil is difficult and that a significant amount of the K fertilizer not removed by harvested grain or lost via runoff exists in a non-exchangeable form.

Soybean trifoliate leaf K concentration and grain yield both increased as annual K rate increased (Table 3) with maximum numerical values produced by soybean that received 160 lb K_2O/acre/yr. Statistically, yields of soybean receiving 120 and 160 lb K_2O/acre/yr were greatest, but annual application of 40 lb K_2O/acre also increased yields compared to soybean receiving no K. Trifoliate leaf K concentrations of soybean receiving 0 and 40 lb K_2O/acre/yr were considered deficient (<1.5%).

Other K-Rate Trials

The University of Arkansas soil-test guidelines for soybean showed that soil-test K (Table 2) was 'Low' (61 to 90 ppm) at Poinsett and 'Medium' (91 to 130 ppm) at PCC and PTRS. Small to moderate yield increases were expected at all three sites which would have received recommendations for 60 (Medium level) or 120 (Low level) lb K_2O/acre.

Analysis of variance showed that soybean yield was not significantly affected by the main effects of K rate and application time or their interaction for any of the three sites. Single-degree-of-freedom contrasts ($P < 0.10$) comparing the yield of soybean that received K against the yield of soybean receiving no K showed a positive response to K fertilization only at the Poinsett site (Table 4). On average, K fertilization increased soybean yield by 6 bu/acre at the Poinsett site. Tissue analysis from these sites has not been completed.

RREC Phosphorus Trial

The mean soil-test P was uniform among plots when the trial was initiated and the soil-test P (in 2009) of soil fertilized with ≥40 lb P_2O_5/acre/year has been increased after two years of P fertilization (Table 5). Soil-test P was numerically greater in February 2009 compared to the previous years due, in part, to P fertilization and the application of lime after soil samples were collected in February 2008.

Comparison of mean yields using the protected LSD showed no difference among yields (Table 5). However, the single-degree-of-freedom contrast showed that the yield of soybean receiving P fertilizer was significantly greater than the yield of soybean receiving no P fertilizer. Soybean yields in these same plots during 2008 did not respond to P fertilization (Slaton et al., 2009). Tissue analysis from the 2009 soybean crop is not yet complete.

Other P-Rate Trials

The University of Arkansas soil-test guidelines for soybean at the three P trial sites showed that soil-test P was 'Very Low' (<16 ppm) at PCC, 'Low' (16 to 25 ppm) at PTRS, and 'Optimum' (36 to 50 ppm) at Poinsett (Table 2). However, soil-test P at Poinsett was quite variable within the study area and ranged from 17 to 52 ppm in the no P control plots.

Soybean yield was significantly affected by P fertilization only at the Poinsett site (Table 6). Application of 40 lb P_2O_5/acre significantly increased yield compared to the no P control and was similar to the yield of soybean receiving higher P rates. Analysis of trifoliate leaf tissue collected at the R2 stage has been completed only for the Dewitt site and showed that leaf P concentration increased significantly as P rate increased.

Double-Crop Soybean Trials

Soil samples collected following wheat harvest showed that soil-test P level was 'Very Low' in the P trial and soil-test K was 'Low' in the K trial (Table 2). Thus, positive yield response to both P and K fertilization were expected. Based on current fertilizer recommendations and soil-samples collected before wheat was planted in the fall 2008, a total of 150 lb K_2O/acre and 140 lb P_2O_5/acre would have been recommended for both crops. Wheat yields were significantly increased by 26% to 32% from P fertilization, but K fertilization had no influence on wheat yields, which were rather low to due to excessive rainfall.

The yield of double-cropped soybean were increased by application of 120 to 150 lb P_2O_5/acre, regardless of when the P was applied, but yields were not affected by application of 60 P_2O_5/acre (Table 7). Soybean receiving K fertilizer, regardless of application strategy, produced greater yields than when no K was applied. Soybean yields tended to be numerically greater for the highest K application rates. Tissue analysis is not yet complete.

PRACTICAL APPLICATION

The 2009 growing season was characterized by cooler than normal temperatures and above average rainfall, which provided more than sufficient, and sometimes excessive soil moisture, and eliminated the need for irrigation. Sufficient soil moisture may have aided the vertical movement of surface applied fertilizers, allowed for more efficient nutrient uptake by soybean, and diminished the benefit of P and K fertilization in some fields having 'Medium' or 'Low' soil nutrient availability levels. Positive yield responses were generally measured only on soils that were nutrient depleted (PTRS-LT) or had 'Very Low' soil P and K levels. All soils used for P and K fertilization trials but one (Poinsett P trial) in 2009 would have received a recommendation for P or K. Soil-test based fertilization guidelines correctly identified three (PTRS-LT, Poinsett, and PTRS-DC) of five soils that required K fertilizer and two of five soils that needed P fertilizer to maximize soybean yield. The two sites that did not respond to K had 'Medium' soil-test K levels and only nominal yield increases were expected from relatively low rates of K fertilizer that would have been recommended. For P, soybean did not benefit from P fertilization on two soils that had 'Low' or 'Very Low' soil P levels that would have received a recommendation for 80 to 100 lb P_2O_5/acre and did benefit from P fertilization on one soil that had an 'Optimal' soil-test P level. These results suggest that K fertilizer recommendations for soybean are reasonably accurate, but soil-test P levels and P fertilizer rate recommendations for soybean must be improved. Additional research is needed to improve the accuracy of soil-test P for identifying P-deficient and sufficient soils and calibrate the rate of P needed to maximize soybean yield on P deficient soils.

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Table 1. Selected soil and agronomic management information for P and K fertilization trials conducted in 2009.

Site	Nutrients	Soil series	Cultivar	Previous crop/Tillage[z]	Row width	Plant date
					(inches)	(month/day)
PCC	P & K	Dewitt	Armor 47F8	Fallow/CT	30	21 May
PTRS	P & K	Calhoun	Armor 47F8	Soybean/CT	15	20 May
PTRS-LT	K	Calhoun	Armor 47F8	Rice/NT	15	24 April
PTRS-DC	P & K	Calloway	Schillinger R557	Wheat/NT	15	29 June
Poinsett	P and K	Henry	HBK 4772	Rice/CT	15	8 June
RREC	P	Dewitt	Schillinger R557	Soybean/NT	7.5	2 June

[z] Tillage abbreviations: CT, conventional till; NT, no-till.

Table 2. Selected soil chemical property means (n = 4-8) of the unfertilized control in P and K fertilization trials conducted at multiple sites during 2009.

Site	Soil pH	Organic matter	P	K	sd[z]	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
			Mehlich-3 extractable nutrients											
		(%)	(ppm)											
K trials														
PCC	6.2	3.6	15	104	6	1196	222	17	39	373	220	1.3	1.9	0.2
PTRS	7.9	2.4	22	98	9	1932	402	13	58	361	309	2.9	2.0	0.2
PTRS-DC	6.2	1.9	11	90	10	929	268	17	41	159	341	1.8	1.0	0.1
PTRS-LT	7.8	--	22	–[y]	--	2199	415	20	74	450	202	6.2	1.2	0.3
Poinsett	7.2	2.3	24	84	15	1113	147	14	38	517	51	5.2	0.5	0.1
P Trials														
Dewitt	6.2	3.5	14	104	2	1161	230	17	47	337	271	1.4	2.0	0.2
PTRS	7.8	2.8	19	106	2	2029	366	10	37	211	374	1.3	1.3	0.5
PTRS-DC	6.3	2.4	7	95	<1	912	255	15	36	169	373	1.8	1.1	0.1
Poinsett	7.0	2.6	39	100	12	1152	160	15	40	557	47	7.3	0.5	0.1
RREC	6.4	--	22	139	–[x]	1135	188	11	44	382	160	14.4	1.8	0.1

[z] sd is the standard deviation of the mean soil-test K in K trials or soil-test P in P trials for each site.
[y] The listed soil-test data for PTRS-LT are the average values for all samples (n = 40). Soil-test K is given in Table 3.
[x] The listed soil-test data for RREC are the average values for all samples (n = 30) from the P trial with reported yield data. Soil-test K is given in Table 5.

Table 3. Soil-test K, trifoliate-leaf K (at R2 stage), and seed yield data means and seed yield data means from the long-term K fertilziation trial conducted at the PTRS-LT trial in 2009 as affected by annual K fertilizer rate.

Annual K rate	Soil-test K[z]	HNO_3 K[y]	R2 trifoliate	Seed yield
(lb K_2O/acre/yr)	(ppm)	---------------------- (% K) ---------------------		(bu/acre)
0	83	267	1.06	43
40	96	296	1.45	50
80	100	313	1.71	54
120	110	334	1.80	58
160	114	348	2.00	60
LSD (0.10)	10	16	0.16	4
p-value	0.0002	<0.0001	<0.0001	<0.0001
C.V., %	12.0	6.3	11.7	9.3

[z] Soil K extracted with Mehlich-3.
[y] Soil K extracted with 1 *M* HNO_3.

Table 4. The effect of K fertilizer rate, averaged across K application times, on soybean yield at three sites in 2009.

K rate	PCC	Poinsett	PTRS
(lb K_2O/acre)	--(bu/acre)	--	
0	64	55	60
60	64	60	62
120	63	62	60
LSD (0.10)	NS[z]	NS	NS
p-value	0.6563	0.4866	0.2272
C.V., %	5.8	10.2	9.8
SDF contrast[y]	0.6919	0.0695	0.8716

[z] NS = not significant ($P > 0.10$)
[y] SDF = single-degree-of-freedom contrast comparing the yield of no K vs all treatments receiving K.

Table 5. Soil-test P (Mehlich-3), trifoliate leaf P (R2 stage) concentration, and seed yield means from the third year of long-term P fertilization trial at the Rice Research and Extension Center in 2009 as affected by annual P rate.

	Mehlich-3 Soil P				
Annual P rate	2007	2008	2009	R2 trifoliate	Seed yield
(lb P_2O_5/acre/yr)	------------------------(ppm)------------------------			(% P)	(bu/acre)
0	20	16	22	NA[z]	55
40	19	17	27	NA	58
80	19	19	33	NA	60
120	19	21	33	NA	58
160	19	22	49	NA	60
LSD (0.10)	NS[y]	2.8	3.9	--	NS
p-value	0.7243	0.0047	<0.0001	--	0.3664
C.V., %	8.3	14.7	11.9	--	6.4
SDF contrast[x]	--	--	--	--	0.0772

[z] NA = not available at time of publication.
[y] NS = not significant ($P > 0.10$).
[x] SDF = single-degree-of-freedom contrast comparing the yield of no K vs all treatments receiving K.

Table 6. Soybean yield and trifoliate leaf P concentration response to P-fertilizer rate at three sites during 2009.

P rate	Trifoliate leaf P concentration			Grain yield		
	PCC	Pine Tree	Poinsett	PCC	Pine Tree	Poinsett
(lb P_2O_5/acre)	(% P)			(bu/acre)		
0	0.32	NA[z]	NA	62	56	54
40	0.34	NA	NA	59	55	58
80	0.36	NA	NA	62	59	58
120	0.37	NA	NA	60	57	60
160	0.38	NA	NA	61	63	62
LSD (0.10)	0.018	--	--	NS[y]	NS	4
p-value	<0.0001	--	--	0.6542	0.2930	0.0365
C.V., %	5.6	--	--	9.6	10.8	6.9

[z] NA = not available at time of publication.
[y] NS = not significant ($P > 0.10$).

Table 7. Yield response of double-cropped soybean (following winter wheat) to P and K fertilization strategy at the Pine Tree Research Station in 2009.

Total rate	Split		Grain yield	
	Fall (to wheat)	Summer (to soybean)	P trial	K trial
(lb K_2O or P_2O_5/acre)			(bu/acre)	
0	0	0	24	19
60	30	30	25	25
60	60	0	24	27
120	120	0	32	26
150	90	60	29	27
150	150	0	29	31
		LSD (0.10)	4	5
		p-value	0.0093	0.0227
		C.V., %	14.2	16.5

Soybean Response to Poultry Litter and Inorganic Fertilizer

N.A. Slaton, R.E. DeLong, J. Shafer, S. Clark, B.R. Golden, and C.G. Massey

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 to satisfy only 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 four sites in 2009 including a Calhoun silt loam at the Pine Tree Research Station (PTRS), a Dewitt silt loam at the Phillips Community College of the University of Arkansas campus (PCC, DeWitt, Ark.), a Henry silt loam in Poinsett County (Poinsett), and a Sharkey clay at the Rohwer Research Station (RRS). Information regarding the planting method, cultivar, row width, previous crop, and planting dates are listed in Table 1. At each site a composite soil sample (n = 6 per site) was collected to a depth of 4 inches from each unfertilized control before fertilizer application. Soil samples were oven-dried at 130 °F, 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, and Mehlich-3 extractable nutrients were determined by inductively coupled plasma spectroscopy (ICPS). Selected mean soil chemical properties are listed in Table 2. Granular B fertilizer (1.0 lb B/acre) was broadcast just before or after planting to ensure B was not yield limiting at the PTRS and Poinsett sites.

Poultry litter was obtained in April 2008 directly from a poultry house in northwest Arkansas. Broilers had been grown for 18 months before litter removal. Seven subsamples of litter were analyzed for total nutrient content and showed litter averaged 4.20% total N, 1.35% P, 2.54% K, 18.2% moisture and had a mean pH of 8.5. Poultry litter was stored in sealed plastic tubs until treatments were weighed and stored in sealed plastic bags to provide the equivalent of 70 (low rate) and 140 (high rate) lb P_2O_5/acre. The 'Low' and 'High' P_2O_5 rates corresponded to 2265 and 4530 lb moist litter/acre and supplied 69 and 138 lb K_2O/acre, respectively.

Inorganic-fertilizer treatments were prepared to provide the same equivalent amount of total P_2O_5 and K_2O/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 64 and 128 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.

Litter was applied to the soil surface of a tilled or stale seedbed the same day that soybean was planted at PTRS and PCC, 11 days before planting at RRS, and 2 days after planting at the Poinsett site. Individual plots were 8- to 13-ft wide and 20- to 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. Analysis of leaf tissue from all sites is not yet complete. Data from the PCC and RRS sites has been completed and will be reported by site.

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. A 500-gram subsample of harvested seed from soybean receiving the equivalent of no P and K and 70 lb P_2O_5/acre as PK, NPK, and poultry litter was saved, ground, digested, and analyzed for nutrient content as described for leaf tissue. Seed nutrient content data is not available from the 2009 trials, but information from three trials conducted in 2008 using these same treatments is reported (Slaton et al., 2009).

Each experiment was a randomized complete block design with treatments structured as a 2 (rate) × 4 (nutrient source) factorial plus a no fertilizer control. Each treatment was replicated six times per site. Analysis of variance for yield data 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. Leaf nutrient content data were analyzed by site with a factorial treatment structure. Seed nutrient content data from the three 2008 trials was analyzed as split plot where site was the whole plot and nutrient source was the subplot. When appropriate, mean separations were performed using Fisher's Protected Least Significant Difference method at a significance level of 0.05.

RESULTS AND DISCUSSION

The University of Arkansas soil-test guidelines for soybean showed that soil-test K (Table 2) was Low (61 to 90 ppm) at Poinsett, 'Medium' (<91 to 130 ppm) at PTRS and PCC, and 'Above Optimum' (>175 ppm) at RRS. Soil-test P was classified as 'Very Low' (<16 ppm) at PCC, 'Low' (16 to 25 ppm) at PTRS and Poinsett, and 'Above Optimum' (>50 ppm) at RRS. Recommended fertilizer rates would have ranged from 0 to 100 lb P_2O_5 and 0 to 120 lb K_2O/acre. Only the RRS site, a clayey soil with high fertility, would have received a recommendation for no P and K fertilization.

Soybean yields were affected significantly only by the main effects of site ($P < 0.0001$) and source ($P = 0.0010$). The 2- and 3-way interactions had *p*-values that ranged from 0.1006 (source × rate) to 0.2324 (site × source). Soybean yields, averaged across nutrient sources and rates, were in order of decreasing yield Poinsett (63 bu/acre, LSD = 4 bu/acre) = PTRS (61 bu/acre) = PCC (61 bu/acre) > RRS (54 bu/acre). Averaged across nutrient rates and sites, the greatest seed yields were produced by soybean receiving P and K, regardless of nutrient source, which were higher than soybean receiving only N or no N, P, or K fertilizer (Table 3).

Trifoliate leaf P and K concentrations at PCC were both affected by nutrient source (Table 4), but only leaf P concentration was affected by nutrient source at RRS (Table 4). At both sites, trifoliate leaf P and K concentrations were numerically or statistically greater for soybean receiving P and K, regardless of source. Leaf K concentrations of soybean receiving no P and K, were always considered sufficient (>1.5%), albeit marginally, for normal soybean growth and yield. Leaf P concentrations were regarded as sufficient for all soybean at RRS, but marginally sufficient for soybean receiving no P at PCC (Sabbe et al., 2000).

Nutrient concentrations of soybean seed from the three 2008 trials were never affected by the site by source interaction, but the main effects of site and source sometimes significantly affected seed nutrient concentrations (Table 5). The concentrations of all nutrients, except for molybdenum (Mo) were significantly affected by site. Specific reasons for the significant differences among sites are unknown, but are likely due to different cultivars, soil properties, and growing environments. Only P, K, Zn and B seed concentrations were affected by nutrient source (Table 5). Based on the average seed P (0.542%) and K (1.54%) concentrations for these three sites, harvested soybean removes the equivalent of lb 0.75 lb P_2O_5 and 1.11 lb K_2O/bu.

PRACTICAL APPLICATION

Results from these four trials conducted in 2009 suggest that P and K availability in poultry litter is equivalent to that of muriate of potash and triple superphosphate as similar yields were produced regardless of P and K source. The application of N to soybean had no apparent benefit to soybean yield in these four trials. Trifoliate leaf P and K concentrations also tended to be similar among nutrient sources and support this conclusion. The P and K concentrations of harvested soybean seed are comparable to published values. Growers should compare the costs of inorganic fertilizers and poultry litter and apply the rates of P and K recommended based on soil-test results.

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Table 1. Selected agronomic information for four sites used to compare soybean growth and yield to fresh poultry litter and inorganic fertilizers during 2009.

Site[z]	Soil series	Previous crop	Cultivar	Plant date	Tillage	Row width
				(month - day)		(inches)
PCC	Dewitt	Fallow	Armor 47F8	May 21	Conventional	30 (beds)
Poinsett	Henry	Rice	Hornbeck 4727	June 8	Conventional	15
PTRS	Calhoun	Soybean	Armor 47F8	May 20	Conventional	15
RRS	Sharkey	Soybean	Hornbeck 5525	June 2	Conventional	19

[z] Site abbreviations: PCC, Phillips County Community College-University of Arkansas Dewitt Campus; PTRS, Pine Tree Research Station; RRS, Rohwer Research Station

Table 2. Selected soil chemical property means (*n* = 6) of poultry litter fertilization trials conducted at four sites during 2009.

	Soil	Total soil		Mehlich-3 extractable nutrients										
Site[z]	pH	C	N	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
		-----(%)-----		---(ppm)---										
PCC	6.2	1.64	0.181	12	115	1135	208	18	37	347	238	1.1	1.9	0.3
PTRS	7.9	1.06	0.097	18	95	1850	404	13	62	382	271	3.0	1.7	0.2
Poinsett	7.2	1.07	0.100	24	87	1068	143	13	33	493	51	5.6	0.5	0.2
RRS	7.7	1.12	0.113	75	408	4338	1067	8	129	322	118	3.4	3.5	0.8

[z] Site abbreviations: PCC, Phillips County Community College-University of Arkansas Dewitt Campus; PTRS, Pine Tree Research Station; and RRS, Rohwer Research Station.

Table 3. Soybean seed yield as affected by the non-significant source × rate interaction, averaged across sites, and the main effect of nutrient source, averaged across sites and rates, for four trials conducted during 2009.

	Yield		Mean yield
Fertilizer source	Low rate[z]	High rate	(Averaged across rates)
	---(bu/acre)---		
No fertilizer (control)	58	58	
N only	59	56	58
PK	60	63	61
NPK	60	62	61
Poultry litter	62	62	62
LSD (0.05)	Not significant		2
P-value	0.1006		0.0010

[z] For treatments including P and K, the 'Low' rate received 70 lb P_2O_5 and 69 lb K_2O/acre and 'High" rate received 140 lb P_2O_5 and 138 lb K_2O/acre. For treatments that received N, the Low and High rates were equivalent to 64 and 128 lb N/acre as urea or estimated N availability from poultry litter.

Table 4. Soybean trifoliate leaf K and P concentrations as affected by nutrient source, averaged across rates, for soybean at the R2 growth stage from the Phillips Community College (PCC) and Rohwer Research Station (RRS) sites during 2009. Data from the other two sites was not yet available.

	Potassium		Phosphorus	
Nutrient source	PCC	RRS	PCC	RRS
	---------------------(% K)-------------------		--------------------(% P)--------------------	
None	1.74	1.79	0.29	0.38
N only	1.73	1.78	0.29	0.38
PK	1.83	1.89	0.34	0.41
NPK	1.79	1.88	0.36	0.43
Poultry litter	1.93	1.90	0.34	0.43
LSD (0.05)	0.11	NS[z]	0.02	0.04
P-value	0.0048	0.0600	<0.0001	0.0487

[z] NS = not significant (*P* > 0.05).

Table 5. Soybean seed nutrient concentrations as affected by site, averaged across nutrient sources, or nutrient source, averaged across sites, of soybean receiving no P and K or the equivalent of 70 lb P_2O_5/acre from three nutrient sources during 2008.

Site or Source	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B	Mo
	------------------------- (%) -------------------------					--------------------------------------(ppm) --------------------------------------						
Site												
PTRS	0.538	1.51	0.34	0.24	0.31	4	65	44	32.4	9.6	22.6	5.3
Poinsett-1	0.513	1.51	0.24	0.22	0.32	7	70	26	43.2	11.5	23.7	5.3
Poinsett-2	0.576	1.60	0.32	0.22	0.32	5	96	36	39.3	10.8	33.3	5.2
LSD (0.05)	0.021	0.06	0.01	<0.01	<0.01	<1	5	4	1.4	0.7	2.7	NS[z]
P-value	0.0002	0.0090	<0.001	<0.001	0.0163	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.4972
Nutrient source												
None	0.526	1.44	0.31	0.22	0.30	6	74	36	38.6	10.4	24.2	5.4
PK	0.541	1.57	0.30	0.23	0.31	6	76	36	36.4	10.5	26.0	5.3
NPK	0.549	1.59	0.30	0.23	0.31	5	77	36	37.9	10.7	26.5	5.2
Poultry litter	0.550	1.54	0.30	0.23	0.32	6	76	36	37.9	10.6	27.8	5.1
LSD (0.05)	0.021	0.07	NS	NS	NS	NS	NS	NS	1.4	NS	2.2	NS
P-value	0.0036	0.0017	0.7124	0.0622	0.1238	0.1645	0.5828	0.6220	0.0327	0.7894	0.0255	0.7232

[z] NS = not significant (*P* > 0.05).

Wheat Grain Yield Response to Nitrogen Source or Amendment and Application Time

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Nitrogen (N) is generally the most-limiting nutrient for soft red winter wheat (*Triticum aestivum* L.) production in Arkansas. Environmental conditions during the late winter when most N fertilizer is applied to wheat vary from year to year and may influence N uptake by wheat. The April freeze that caused widespread wheat grain yield losses during 2007 made many Arkansas wheat growers question whether to apply N early or delay the initial N application in an effort to delay wheat development and reduce the risk of freeze damage. Delaying N application to wheat may also increase the likelihood of ammonia (NH_3) volatilization of surface applied urea-N.

Ammonia volatilization from urea applied to winter wheat is assumed to be negligible due to cool temperatures and more frequent rainfall during February and March when N is commonly applied. Griggs (2004) evaluated NH_3 volatilization from urea and ammonium sulfate applied to winter wheat during February and March using a semi-open, static-chamber method. Results showed that NH_3 volatilization from urea accounted for 13% of the applied urea-N compared to <1% of the applied N for ammonium sulfate. These results suggest that when air temperatures and moisture are favorable, NH_3 volatilization can result in significant N losses during the winter months. However, Griggs (2004) also reported that total-N uptake and wheat grain yield were not different between N sources, averaged across several N rates.

The urease inhibitor, [N-(n-Butyl)-thiophosphoric triamide, NBPT] marketed under the name of Agrotain® is being used extensively to reduce NH_3 volatilization from surface-applied urea for the production of summer-grown crops (e.g., rice, *Oryza sativa* L.). Questions have been asked whether Agrotain® should also be applied to urea fertilizer that will be applied in the late winter to winter wheat. A preliminary study conducted in 2007-2008, showed that wheat yields tended to decline as N application time was delayed and Agrotain®-treated urea tended to produce higher yields than urea alone (Slaton et al., 2009). Our primary research objectives were to evaluate whether i) wheat yields benefit from urea treated with Agrotain® and ii) N application time influences wheat grain yield.

PROCEDURES

Wheat response to different N sources and application times was evaluated in two experiments established on soils mapped as a Calloway silt loam following soybean [*Glycine max* (L.) Merr.] at the Pine Tree Research Station (PTRS) and a Convent silt loam following soybean at the Lon Mann Cotton Research Station (LMCRS) in fall 2008. Composite soil samples were collected from the 0- to 4-inch depth at planting. Samples were oven-dried at 60 °C, crushed to pass a 2-mm sieve and analyzed for pH (1:2 soil weight:water volume mixture), Mehlich-3 extractable nutrients, and total C and N by combustion (Table 1).

Triple superphosphate (130 lb/acre) and muriate of potash (100 lb/acre) fertilizers were blanket applied to ensure these nutrients were not yield limiting. 'Pat' wheat was drill-seeded on 22 October at the PTRS (7.5-inch row spacing) and 10 October at LMCRS (7.5-inch row spacing). The seedbeds were conventionally tilled and the seeding rate was approximately 120 lb/acre. Wheat grown at PTRS received a second application of triple superphosphate (50 lb/acre) in February due to very low soil-test P (Table 1).

Nitrogen fertilizer treatments included N rates of 0 (no N control), 75, and 125 lb N/acre. Agrotain®-treated urea (urea+NBPT) was applied in a single application of 125 lb N/acre as a high N control on 15 February, 1 March, 15 March, and 1 April. Wheat received 75 lb N/acre as a single application of urea-N, Agrotain®-treated urea, or Super Urea (urea, Agrotain®, and DCD, a nitrification inhibitor) on 15 February, 1 March, 15 March, and 1 April. The Agrotain® was applied to urea in the laboratory at a rate equivalent to 4 qt/ton urea. Each trial included a total of 17 treatments. A composite soil sample was collected from each replicate to determine the gravimetric soil moisture content on each date that fertilizer was applied. Soil samples were placed in a weighed plastic bag, sealed, weighed (wet wt), dried for 5 to 7 days at 60 °C, weighed (dry wt), and gravimetric soil moisture was calculated. Rainfall dates and amounts were recorded at each site and daily maximum and minimum temperatures were recorded at the Marianna site (Fig. 1). Eight rows of wheat in each plot were harvested with a small plot combine. Harvested grain was weighed and moisture content was determined immediately. Grain yields were calculated and adjusted to a uniform moisture content of 13% for statistical analysis.

The primary research objectives were to determine 1) whether urease and nitrification inhibitors provide any grain yield benefit of wheat fertilized with urea and 2) how date of N application influenced wheat yield. Each experiment was arranged in a randomized complete block design with a 4 (N sources) × 4 (N application time) factorial structure compared to a no N control. Each treatment was replicated five times. Data from LMCRS and PTRS were analyzed as a split-plot design where site was the whole plot and the factorial arrangement of N sources and application times was the subplot. Analysis of variance was conducted with the PROC GLM procedure in SAS v9.1 (SAS Institute, Inc., Cary, N.C.). When appropriate, mean separations were performed using Fisher's Protected Least Significant Difference method at significance levels of 0.05.

RESULTS AND DISCUSSION

Gravimetric soil moisture content ranged from 24.0% to 27.3% at the time of N application with both sites having comparable soil moisture content at each N application time. Rainfall during February and March totaled 9.4 inches at LMCRS and 7.4 inches at PTRS (Fig. 1). At the PTRS, measurable rainfall occurred within 1 to 3 d after N fertilizer was applied 15 February (0.09 inches) and 1 April (0.83 inches). At the LMCRS, measurable precipitation occurred within 1 to 3 d after N was applied on each date that N fertilizer was applied, but the amount was <0.1 inch on 15 March. Daily maximum and minimum air temperatures are shown only for LMCRS, which should be representative of the PTRS since the sites are about 34 miles apart and both sites received comparable amounts of rainfall. The average daily maximum air temperature for the 7 d following each N application was 55 °F for 15 to 22 February, 52 °F for 1 to 7 March, 62 °F for 15 to 22 March, and 67 °F for 1 to 7 April. Based on the rainfall, temperature, and soil moisture information, rainfall was not sufficient to adequately incorporate N fertilizer at LMCRS or PTRS when N was applied on 15 March, which also had an average maximum air temperature >60 °F and the greatest soil moisture content. Thus, NH_3 volatilization might be expected to be greatest for urea-N fertilizer applied on 15 March at both research sites.

For wheat grown following soybean at LMCRS and PTRS, grain yields were lowest for wheat receiving no N, intermediate for wheat receiving 75 lb N/acre, and greatest numerically for wheat receiving 125 lb N/acre as urea+NBPT (Table 3). Results of N rate trials (with urea as the N source) adjacent to these N source and application time trials suggested that maximum agronomic yields were produced with 120 to 200 lb urea-N/acre at LMCRS and 200 lb urea-N/acre at PTRS. Thus, evaluation of the selected N sources at 75 lb N/acre should reflect potential yield differences due to N loss differences among N sources.

Wheat grain yield was affected by the N source by application date interaction (Table 3). Wheat receiving 125 lb N/acre as urea+NBPT produced greater yields than all N sources applied at 75 lb N/acre when N was applied 15 February or 1 March. Wheat yields were uniform among all N sources, regardless of N rate, when N was applied 1 April. Comparing N application dates within each N source applied at 75 lb N/acre showed that wheat yields were generally equal when urea-N + NBPT was applied from 15 February through 15 March with a decline in yield, compared to the maximum yield, when N fertilization was delayed until 1 April. When urea was the N source, yields were equal when N was applied 15 February, 15 March, and 1 April and greater than the yield produced for N applied on 1 March. When 125 lb N/acre was applied, wheat grain yields were greatest for the 15 February application date, intermediate for the 1 and 15 March application dates, and lowest for N applied on 1 April. The yield decline observed for the 1 April application date for all N fertilizer sources including a urease inhibitor suggests the lower yields may be due to early-season N deficiency rather than excessive N loss when air temperatures were warmer (Fig. 1) since rainfall occurred following the 1 April N application.

PRACTICAL APPLICATION

Grain yield results from two trials conducted in 2008-2009 suggest that N application time influenced wheat grain yield when near optimal amounts (125 lb N/acre as urea+NBPT) of N were applied, but yield fluctuated less across four N application times when a sub-optimal (75 lb N/acre) N rate was applied. Grain yields were greatest when 125 lb N/acre was applied in mid February suggesting a portion of the total N requirement should be applied in mid February to achieve maximum grain yield potential. Wheat grain yields were different among N sources applied at 75 lb N/acre at only one N application time, 1 March. Wheat yields were numerically or significantly lower for wheat fertilized with urea-N fertilizer compared to all N sources including urea plus the urease inhibitor NBPT. Although N uptake and NH_3 volatilization were not measured, the results suggest, but do not conclusively prove, that a urease inhibitor may help reduce NH_3 volatilization when urea is surface applied and no rainfall occurs within several days after application. More research is needed to verify the consistency of these results before a recommendation can be made. In the meantime, growers should be aware that significant N losses from surface applied urea may occur and, when possible, apply urea-N fertilizer applications when the soil is dry and rainfall is imminent.

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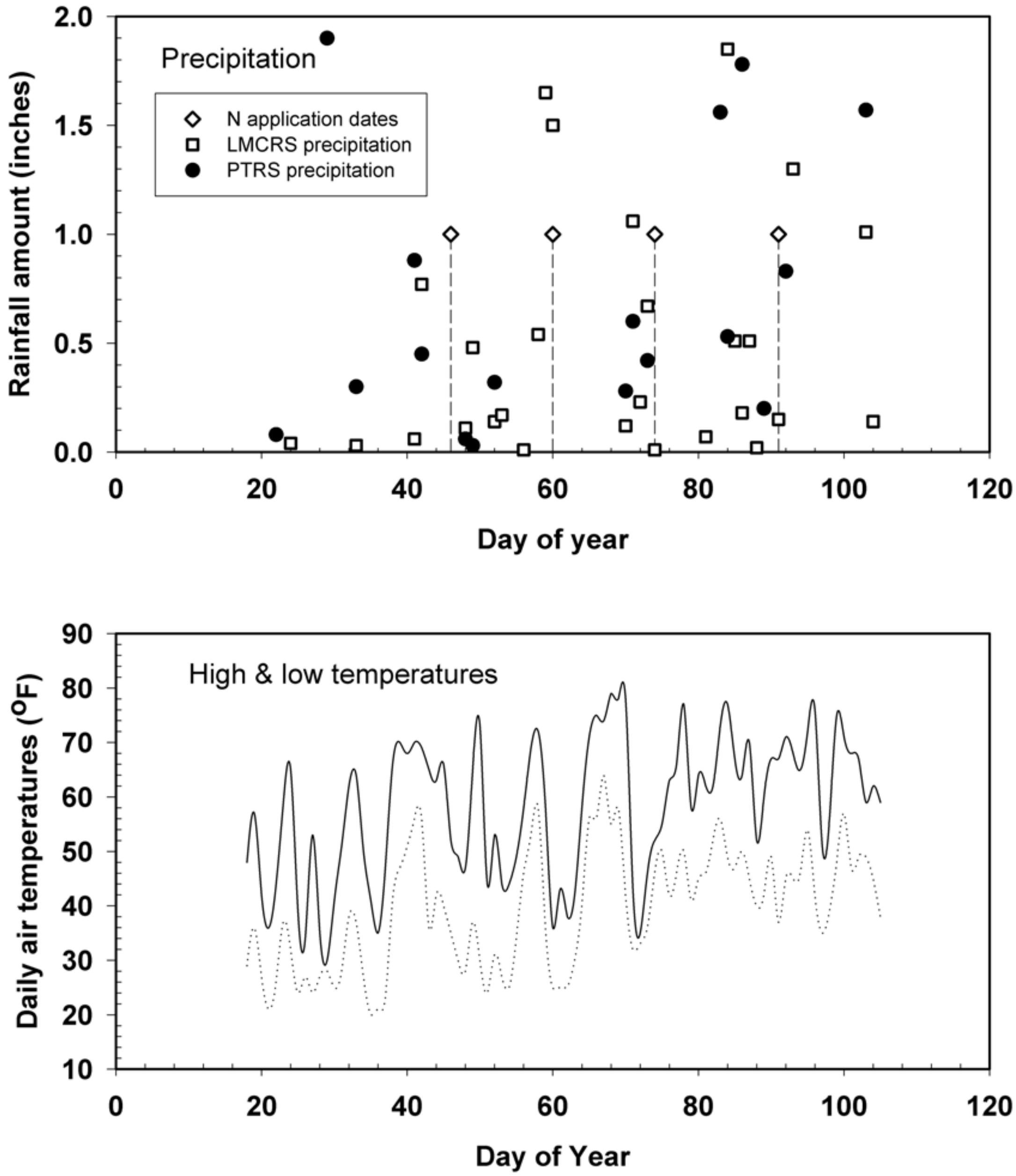

Fig. 1. Daily high and low temperatures and rainfall amounts during February, March, and April 2009. Temperature data was recorded at Marianna, Ark., and rainfall data was recorded at each site (day of year 32-60 is 1-28 February and 61-91 is 1-31 March).

Table 1. Selected soil chemical property means (*n* = 5) for trials established on two silt loams soils during the 2008-2009 growing season.

	Total		Soil	Mehlich-3 extractable nutrients									
Site	C	N	pH	P	K	Ca	Mg	S	Na	Fe	Mn	Cu	Zn
	------(%)-----			---(ppm)---									
PTRS	0.90	0.10	7.0	10	69	1078	279	7	36	145	367	2.5	1.1
LMCRS	0.88	0.10	6.0	21	111	892	163	7	12	144	144	1.2	1.4

Table 2. Soil moisture content at the time of N application for two trial sites conducted at the Lon Mann Cotton Research Station (LMCRS) and Pine Tree Research Station (PTRS) in 2008-2009.

	N application date			
Site	15 February	1 March	15 March	1 April
	---gravimetric soil water content (%)---			
LMCRS	24.0	27.3	26.6	27.3
PTRS	24.4	26.4	26.4	26.2
Average	24.2	26.9	26.5	26.8

Table 3. Winter wheat grain yield means as affected by the N source and time of N application interaction, averaged across two sites, during the 2008-2009 growing season.

N Source	N rate	15 February	1 March	15 March	1 April
	(lb N/acre)	---(bu/acre)---			
Control	0	45			
Urea + NBPT	125	76	70	67	60
Urea	75	63	57	63	62
Urea + NBPT	75	66	62	62	60
Super Urea	75	64	65	63	58
P-value			0.0055		
C.V., %			8.3		
LSD (0.05)			5		

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