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SOIL FERTILITY STUDIES
• 2010 •

Nathan A. Slaton, Editor

UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE

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WAYNE E. SABBE
ARKANSAS
SOIL FERTILITY STUDIES
– 2010 –

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SUMMARY

Rapid technological changes in crop management and production require that the research efforts 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 2010 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 2009. This set of data includes information for counties, soil associations, physiographic areas, and selected cropping systems.

Funding for the associated soil fertility research programs came from commodity check-off funds, state and federal sources, various fertilizer industry institutes, and lime vendors. The fertilizer tonnage fee provided funds not only for soil testing but also for research and publication of this research series.

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.

Extended thanks are given to the staff at state and county extension offices, as well as at research centers and stations; farmers and cooperators; and fertilizer industry personnel who assisted with the planning and execution of the programs.

This publication is available as a web-only research series book online at http://arkansasagnews.uark.edu/1356.htm.

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Soil Test and Fertilizer Sales Data: Summary for the 2009 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 2009 and 31 December 2009 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, and Zn) availability index values indicate the relative level of soil fertility.

RESULTS AND DISCUSSION

Crop Acreage and Soil Sampling Intensity

Between 1 January 2009 and 31 December 2009, 130,259 soil samples were analyzed by the Soil Testing and Research Laboratory in Marianna. After removing standard and check soils measured for quality assurance (10,877), the total number of client samples was 119,382. A total of 58,022 soil samples were collected using the field average sampling technique, representing a total of 1,585,286 acres for an average of 27 acres/sample, and had complete data for total acres and soil pH, P, K, and Zn (Table 1). The difference of 60,196 samples between the total samples and those with reported acreage were grid samples collected primarily from row crop fields (59,155) or special or research samples (1,041). The total acreage value does not include the acreage of grid soil samples, but each grid sample likely represents 2.5 acres. Soil samples from the Bottom Lands and Terraces and Loessial Plains, primarily row-crop areas, represented 49% of the total field average samples and 76% of the total acreage (Table 1). The average number of acres represented by each soil sample (grid and field average samples) ranged from 1 to 67 acres/sample (Table 2). Clients from Craighead (25,389, 89% from three clients); Clay (Corning and Piggott offices, 10,902, 39% from one client); Crittenden (8,387, 80% from one client); Lawrence (7,359, 78% from two clients); Mississippi (5,441, 49% from two clients); Monroe (4,291), and Arkansas (Stuttgart and DeWitt offices, 4,130) counties submitted the most soil samples for analyses. The large percentage of the total samples processed through the Craighead, Clay, Crittenden, Lawrence, and Mississippi county offices were submitted by one to three clients and likely represent commercial grid soil sample collection services.

Soil association numbers show that most samples were taken from soils common to 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), 45 (Crowley-Stuttgart), 25 (Dundee-Bosket-Dubbs), 22 (Foley-Jackport-Crowley), 32 (Rilla-Hebert), and 10 (Enders-Nella-Mountainburg-Steprock). However, the soil associations representing the largest acreage were 44, 45, 24 (Sharkey-Alligator-Tunica), 22, 25, 23 (Kobel), and 32 which represented 27%, 13%, 8%, 6%, 6%, 5%, and 5% of the total sampled acreage, respectively. Crop codes listed on the 58,022 field average samples indicate that land used for i) row crop production accounted for 67% of the sampled acreage and 43% of submitted samples, ii) hay and pasture production accounted for 11% of the sampled acreage and 15% of submitted samples, and iii) home lawns and gardens accounted for 1% of sampled acreage and 14% of submitted samples (Table 4). In row-crop producing areas, soil samples are most commonly collected following soybean in the crop rotation.

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 field average soil samples (i.e., grid samples not included, except by county), respectively. The soil-test levels and median (Md) nutrient availability index 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 may be 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. The pH of most soils in Arkansas ranges from 5.8 to 6.9; 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 nutrient availability index values 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. Median soil K availability is lowest in soils used for warm- and cool-season hay production. The median soil-test K has decreased for several years and suggests that K inputs as fertilizer or manure have declined and K is now likely to be limiting forage yields. 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. The greatest fertilizer tonnage was sold in Arkansas, Poinsett, and Craighead counties. 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 and are normally reported in the category of 'Organic'. The summary indicates that no Organic fertilizers were sold, but this is not likely accurate as these products may have been reported under the Miscellaneous category.

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 2009, 86% of the samples and 99% of the represented acreage had commercial agricultural/farm crop codes. Likewise, 99% 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 (56%), multi-nutrient blends (33%), K (7%), P (2%), and miscellaneous (1%). Five counties in eastern Arkansas (Arkansas, Poinsett, Craighead, Lonoke, and Mississippi) accounted for 33% of the total fertilizer sold.

ACKNOWLEDGMENTS

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

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 2009 through 31 December 2009.

Geographic area	Acres sampled	No. of samples	Acres/ sample
Ozark Highlands - Cherty Limestone and Dolomite	105,058	8,039	13
Ozark Highlands - Sandstone and Limestone	7,066	402	18
Boston Mountains	30,164	2,846	11
Arkansas Valley and Ridges	49,376	4,077	12
Ouachita Mountains	31,629	3,248	10
Bottom Lands and Terraces	572,444	15,723	36
Coastal Plain	42,670	3,744	11
Loessial Plains	637,427	12,747	50
Loessial Hills	11,169	1,157	10
Blackland Prairie	1,851	214	9

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 2009 through 31 December 2009.

County	Acres sampled	No. of samples	Acres/ sample	County	Acres sampled	No. of samples	Acres/ sample
Arkansas, DeWitt	155,852	2,736	57	Lee	111,955	3,634	31
Arkansas, Stuttgart	48,996	1,394	35	Lincoln	6,153	227	27
Ashley	7,512	532	14	Little River	5,933	187	32
Baxter	3,702	393	9	Logan, Booneville	401	139	3
Benton	13,536	1,440	9	Logan, Paris	6,089	307	20
Boone	14,332	820	18	Lonoke	74,613	3,166	24
Bradley	205	91	2	Madison	11,926	737	16
Calhoun	717	67	11	Marion	3,409	196	17
Carroll	21,254	1,042	20	Miller	2,689	308	9
Chicot	13,453	318	42	Mississippi	22,784	5,441	4
Clark	3,329	300	11	Monroe	287,444	4,291	67
Clay, Corning	15,848	4,408	4	Montgomery	5,077	408	12
Clay, Piggott	19,616	6,494	3	Nevada	682	111	6
Cleburne	7,725	550	14	Newton	2,138	160	13
Cleveland	9,195	308	30	Ouachita	957	133	7
Columbia	4,576	362	13	Perry	3,675	245	15
Conway	10,290	424	24	Phillips	13,795	811	17
Craighead	49,645	25,389	2	Pike	5,390	306	18
Crawford	7,800	414	19	Poinsett	89,485	3,557	25
Crittenden	63,425	8,387	8	Polk	8,941	499	18
Cross	53,835	1,162	46	Pope	11,290	685	17
Dallas	211	93	2	Prairie, Des Arc	18,841	451	42
Desha	5,800	705	8	Prairie, De Valls Bluff	9,733	246	40
Drew	1,995	429	5	Pulaski	3,765	1,111	3
Faulkner	4,628	797	6	Randolph	21,221	1,734	12
Franklin, Charleston	216	31	7	Saline	1,697	458	4
Franklin, Ozark	2,494	220	11	Scott	4,042	188	22
Fulton	3,134	303	10	Searcy	2,659	185	14
Garland	1,724	1,169	2	Sebastian	5,737	600	10
Grant	426	110	4	Sevier	6,853	313	22
Greene	31,960	2,525	13	Sharp	3,742	380	10
Hempstead	9,504	570	17	St. Francis	3,782	3,363	1
Hot Spring	1,431	195	7	Stone	855	171	5
Howard	6,537	420	16	Union	934	270	4
Independence	11,880	793	15	Van Buren	2,194	244	9
Izard	6,747	444	15	Washington	31,179	3,117	10
Jackson	27,434	1,929	14	White	6,044	1,130	5
Jefferson	51,625	1,521	34	Woodruff	16,552	676	25
Johnson	6,122	409	15	Yell, Danville	4,814	330	15
Lafayette	5,350	201	27	Yell, Dardanelle	2,975	153	19
Lawrence	59,199	7,359	8				

Table 3. Sample number, total acreage by soil association number (SAN), average acreage per sample, and median soil pH and Mehlich-3 extractable P, K, and Zn values by soil association for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2009 through 31 December 2009.

		Acres sampled	No. of samples	Acres/ sample	Median			
SAN	Soil association				pH	P	K	Zn
1.	Clarksville-Nixa-Noark	18,045	1,046	17	6.2	75	135	7.8
2.	Gepp-Doniphan-Gassville-Agnos	8,796	975	9	6.5	56	135	8.5
3.	Arkana-Moko	28,485	1,504	19	6.1	163	169	14.8
4.	Captina-Nixa-Tonti	45,096	4,238	11	6.2	105	148	10.3
5.	Captina-Doniphan-Gepp	2,670	179	15	6.4	63	120	6.4
6.	Eden-Newnata-Moko	1,966	97	20	6.5	48	118	5.6
7.	Estate-Portia-Moko	1,947	89	22	6.2	111	130	8.2
8.	Brockwell-Boden-Portia	5,119	313	16	6.3	54	96	5.0
9.	Linker-Mountainburg-Sidon	8,734	718	12	6.0	61	100	5.6
10.	Enders-Nella-Mountainburg-Steprock	21,430	2,128	10	6.0	90	112	7.1
11.	Falkner-Wrightsville	461	33	14	5.6	24	88	4.9
12.	Leadvale-Taft	20,340	1,958	10	6.0	62	116	7.0
13.	Enders-Mountainburg-Nella-Steprock	4,562	271	17	5.8	45	86	5.2
14.	Spadra-Guthrie-Pickwick	3,062	151	20	5.9	77	106	8.0
15.	Linker-Mountainburg	20,951	1,664	13	5.8	64	107	6.6
16.	Carnasaw-Pirum-Clebit	11,338	1,045	11	5.8	90	100	8.5
17.	Kenn-Ceda-Avilla	3,507	241	15	5.7	104	107	7.9
18.	Carnasaw-Sherwood-Bismarck	10,789	1,605	7	5.8	114	111	9.2
19.	Carnasaw-Bismarck	2,071	115	18	5.5	123	97	8.5
20.	Leadvale-Taft	886	51	17	5.7	173	133	11.9
21.	Spadra-Pickwick	3,038	191	16	5.7	81	122	9.7
22.	Foley-Jackport-Crowley	101,119	2,961	34	6.3	27	107	4.6
23.	Kobel	85,936	1,450	59	6.5	35	121	4.6
24.	Sharkey-Alligator-Tunica	133,211	1,625	82	6.3	48	243	4.6
25.	Dundee-Bosket-Dubbs	90,048	3,350	27	6.5	56	158	4.5
26.	Amagon-Dundee	18,568	1,658	11	6.3	68	178	5.1
27.	Sharkey-Steele	8,086	246	33	6.6	54	201	5.4
28.	Commerce-Sharkey-Crevasse-Robinsonville	11,411	421	27	6.7	53	239	6.1
29.	Perry-Portland	19,360	730	27	6.3	40	161	4.3
30.	Crevasse-Bruno-Oklared	404	20	20	6.2	254	163	17.9
31.	Roxana-Dardanelle-Bruno-Roellen	6,577	211	31	6.2	45	120	4.7
32.	Rilla-Hebert	83,717	2,566	33	6.5	44	134	3.7
33.	Billyhaw-Perry	3,482	105	33	7.1	50	226	4.6
34.	Severn-Oklared	7,568	159	48	7.4	70	145	4.8
35.	Adaton	355	20	18	5.6	164	144	21.4
36.	Wrightsville-Louin-Acadia	1,812	128	14	5.9	49	106	4.5
37.	Muskogee-Wrightsville-McKamie	790	73	11	6.3	84	192	7.9
38.	Amy-Smithton-Pheba	1,048	173	6	5.5	57	80	3.7
39.	Darco-Briley-Smithdale	87	25	4	5.4	104	84	5.1
40.	Pheba-Amy-Savannah	3,035	274	11	5.6	49	96	5.8
41.	Smithdale-Sacul-Savannah-Saffell	13,545	1,397	10	5.7	86	90	8.2
42.	Sacul-Smithdale-Sawyer	16,750	1,440	12	5.8	58	100	6.0
43.	Guyton-Ouachita-Sardis	8,205	435	19	5.6	75	102	7.3
44.	Calloway-Henry-Grenada-Calhoun	424,694	8,575	50	6.7	31	111	5.0
45.	Crowley-Stuttgart	212,733	4,172	51	6.6	29	109	4.7
46.	Loring	1,156	82	14	6.0	43	119	6.7
47.	Loring-Memphis	9,586	1,044	9	6.3	41	119	5.7
48.	Brandon	427	31	14	6.9	65	238	12.5
49.	Oktibbeha-Sumter	1,851	214	9	6.0	59	106	6.2
	Average				6.1	74	131	7.2

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 2009 through 31 December 2009.

Crop	Acres sampled	No. of samples	Acres/ sample
Corn	94,006	2,053	46
Cotton	148,674	4,416	34
Grain sorghum, non-irrigated	2,029	73	28
Grain sorghum, irrigated	9,486	212	45
Rice	168,719	3,677	46
Soybean	640,817	14,330	45
Wheat	53	17	3
Cool-season grass hay	10,946	580	19
Native Warm-season grass hay	5,191	331	16
Warm-season grass hay	40,764	1,942	21
Pasture, all categories	118,742	5,997	20
Home garden	5,315	4,604	1
Home lawn	4,044	3,435	1
Small fruit	954	563	2
Ornamental	2,049	1,434	1

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.

	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)
Ozark Highlands - Cherty Limestone and Dolomite	9	15	27	28	21	6.3	4	7	9	11	69	97	9	14	20	18	39	147	1	8	7	26	58	10.2
Ozark Highlands - Sandstone and Limestone	8	15	27	36	14	6.3	13	12	11	10	54	62	16	24	23	15	22	103	7	18	13	28	34	5.5
Boston Mountains	17	13	24	28	18	6.0	5	8	8	10	69	82	18	20	22	14	26	108	2	13	10	33	42	6.8
Arkansas Valley & Ridges	23	21	24	21	11	5.9	10	12	9	12	57	62	17	21	23	16	23	111	2	14	12	30	42	6.8
Ouachita Mountains	25	25	24	20	6	5.8	5	7	7	9	72	103	18	20	24	16	22	108	1	9	8	28	54	8.8
Bottom Lands & Terraces	7	11	23	39	20	6.4	7	13	16	21	43	45	4	14	23	21	38	149	4	21	18	40	17	4.6
Coastal Plain	30	22	21	19	8	5.7	13	10	8	10	59	70	25	22	20	11	22	95	5	15	10	26	44	6.8
Loessial Plains	6	9	18	29	38	6.7	13	25	22	20	20	30	5	25	35	18	17	110	4	20	15	39	22	4.9
Loessial Hills	18	14	16	31	21	6.3	15	17	11	14	43	41	11	18	28	20	23	120	3	17	13	29	38	5.9
Blackland Prairie	21	14	22	20	23	6.0	15	14	9	8	54	59	22	17	18	15	28	106	4	16	13	25	42	6.2
Average	16	16	23	27	18	6.1	10	13	11	13	53	65	15	20	24	16	25	116	3	15	12	3	40	6.7

[z] Analysis by electrode in 1:2 soil volume:deionized water volume.

[y] Analysis by ICAP in 1:10 soil volume: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 2009 through 31 December 2009.

	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	2	6	14	26	52	7.0	9	28	26	22	15	30	3	23	42	20	12	112	3	14	15	45	23	5.2
Arkansas, Stuttgart	9	13	26	30	22	6.3	19	29	21	18	13	26	6	33	36	11	14	100	11	26	19	33	11	3.7
Ashley	8	7	16	44	25	6.6	10	17	13	17	43	43	9	23	27	18	23	119	8	30	12	28	22	4.1
Baxter	7	7	11	24	51	7.0	5	7	8	13	67	85	4	13	23	21	39	156	1	5	4	24	66	12.3
Benton	16	14	24	29	17	6.1	2	5	7	9	77	111	8	12	15	21	44	164	0	7	6	31	56	9.0
Boone	5	14	32	34	15	6.2	5	8	11	10	66	83	14	12	17	15	42	148	4	12	9	25	50	8.3
Bradley	31	14	18	17	20	5.8	18	7	6	4	65	119	35	11	11	13	30	101	11	15	10	15	49	7.5
Calhoun	49	15	6	16	14	5.4	8	11	6	12	63	64	22	34	30	11	3	88	8	39	9	18	26	3.6
Carroll	5	15	37	30	13	6.2	2	2	4	6	86	199	4	7	15	15	59	199	0	4	3	11	82	18.5
Chicot	5	8	21	49	17	6.5	11	24	19	16	30	33	4	9	14	13	60	238	4	12	17	47	20	4.9
Clark	35	19	18	18	10	5.7	21	11	5	9	54	67	32	19	22	13	14	88	4	23	13	31	29	5.0
Clay, Corning	7	16	29	35	13	6.2	12	19	23	23	23	34	8	26	37	19	10	105	5	18	12	37	28	5.3
Clay, Piggott	8	11	22	44	15	6.4	6	12	13	20	49	50	3	15	34	27	21	128	5	25	19	37	14	4.1
Cleburne	23	19	23	26	9	6.0	8	13	10	12	57	65	24	20	20	16	20	98	6	16	11	32	35	5.3
Cleveland	17	23	35	20	5	5.9	10	18	13	21	38	44	5	11	19	15	50	178	4	24	15	34	23	4.4
Columbia	38	23	19	15	5	5.5	12	12	11	9	56	65	29	30	23	7	11	77	4	17	11	27	41	6.5
Conway	35	17	23	18	7	5.7	16	17	10	10	47	45	18	20	25	20	17	112	5	16	15	33	31	5.1
Craighead	5	7	18	36	34	6.6	11	16	14	17	42	44	10	19	20	17	34	134	2	16	15	43	24	5.1
Crawford	0	22	21	23	34	6.0	8	12	9	12	59	63	13	18	28	12	29	116	2	11	12	35	40	6.5
Crittenden	7	11	23	36	23	6.4	3	9	14	23	51	52	2	5	12	15	66	222	3	18	17	47	15	4.7
Cross	6	4	11	31	48	6.9	6	23	25	27	19	34	8	28	32	13	19	105	3	22	19	39	17	4.4
Dallas	50	24	13	8	5	5.4	29	15	8	10	38	35	46	25	16	7	6	65	9	33	12	18	28	3.7
Desha	4	7	23	45	21	6.5	3	12	12	26	47	50	3	8	29	26	34	140	5	21	17	41	16	4.5
Drew	18	15	23	37	7	6.1	13	16	12	23	36	42	6	22	25	19	28	124	5	19	10	26	40	6.2
Faulkner	34	22	17	21	6	5.6	15	14	11	12	48	47	23	26	22	12	17	92	4	22	15	30	9	4.8
Franklin, Charleston	16	16	23	13	32	5.9	7	3	16	10	64	87	16	16	10	10	48	152	0	7	3	26	64	12.3
Franklin, Ozark	21	34	23	16	6	5.7	8	21	7	10	54	58	16	23	20	14	27	109	0	10	10	35	45	7.7
Fulton	12	21	27	21	19	6.1	12	16	16	15	41	42	14	23	24	14	25	109	2	19	11	30	38	5.9
Garland	22	20	27	24	7	5.9	2	5	7	10	76	98	8	20	30	18	24	116	1	5	8	34	52	8.5
Grant	33	22	16	17	12	5.7	16	10	7	7	60	60	22	26	29	8	15	94	6	13	10	26	45	7.1
Greene	7	11	27	39	16	6.3	10	21	20	22	27	35	8	21	31	24	16	116	3	25	17	39	16	4.4
Hempstead	17	26	25	17	15	5.9	7	10	7	9	67	97	14	17	19	14	36	133	2	9	8	23	58	9.9
Hot Spring	33	26	25	13	3	5.6	16	8	10	12	54	64	28	27	18	12	15	85	3	21	8	21	47	7.4
Howard	26	31	20	18	5	5.7	8	5	4	4	79	187	20	15	21	15	29	119	1	7	6	16	70	15.1
Independence	8	13	24	38	17	6.3	13	19	14	16	38	39	9	25	27	18	21	112	2	18	16	34	30	5.3
Izard	13	23	31	24	9	5.9	10	8	11	12	59	70	16	26	21	13	24	102	3	16	12	27	42	6.3
Jackson	5	7	21	44	23	6.5	9	16	17	20	38	40	6	18	26	22	28	130	4	18	13	35	30	5.5
Jefferson	9	9	21	35	26	6.5	3	8	20	31	38	44	8	15	29	20	28	127	9	29	17	30	15	3.7
Johnson	25	20	25	20	10	5.8	10	13	9	11	57	60	18	17	23	15	27	115	1	16	9	29	45	7.2
Lafayette	15	9	11	9	56	7.1	6	8	11	12	63	66	11	11	15	35	28	146	2	14	25	32	27	4.6
Lawrence	4	12	27	38	19	6.4	21	25	22	18	14	27	13	27	31	17	12	101	5	27	19	34	15	4.0
Lee	7	8	16	38	31	6.6	5	12	17	22	44	46	3	11	25	23	38	152	8	31	19	34	8	3.6
Lincoln	26	16	19	29	10	6.0	9	9	5	14	63	59	11	6	26	22	25	127	3	23	18	28	28	4.8
Little River	26	19	21	15	19	5.9	18	11	9	15	47	47	26	19	18	10	27	102	13	21	10	29	27	4.6

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	14	12	23	38	13	6.3	12	18	19	17	34	36	7	17	38	17	21	119	4	19	16	32	29	4.7
Logan, Paris	15	34	34	12	5	5.8	7	9	5	9	70	112	14	19	22	16	29	118	0	6	6	24	64	11.9
Lonoke	15	20	31	28	6	6.0	18	29	19	17	17	27	15	31	30	14	10	95	18	32	15	22	13	3.0
Madison	10	25	36	23	6	5.9	3	4	6	8	79	112	10	14	20	16	40	142	0	6	7	31	56	9.5
Marion	5	10	25	33	27	6.4	9	8	10	12	61	63	9	17	26	18	30	126	3	17	8	28	44	7.3
Miller	28	15	19	27	11	6.0	9	10	9	7	65	79	26	23	18	7	26	93	6	12	9	25	48	7.6
Mississippi	7	12	25	43	13	6.3	1	5	8	17	69	62	0	2	12	25	61	192	0	8	17	56	19	5.2
Monroe	4	8	16	31	41	6.7	21	22	16	18	23	29	4	19	29	23	25	128	2	14	14	44	26	5.6
Montgomery	29	30	19	18	4	5.6	5	6	9	9	71	108	31	20	21	13	15	87	1	14	12	25	48	7.8
Nevada	42	21	21	9	7	5.6	14	13	9	6	58	67	23	19	25	13	20	101	3	15	12	33	37	6.0
Newton	11	23	21	23	22	6.1	10	11	13	10	56	60	16	16	19	18	31	127	3	27	14	23	33	4.5
Ouachita	35	23	16	17	9	5.6	14	8	5	10	63	69	41	20	17	6	16	70	6	12	11	29	42	6.3
Perry	18	27	25	24	6	5.8	6	9	10	9	66	82	21	14	17	12	36	126	0	6	6	30	58	9.8
Phillips	7	8	14	35	36	6.7	1	5	14	23	57	55	1	11	24	21	43	156	4	19	15	41	21	4.8
Pike	38	24	20	17	1	5.6	10	7	5	7	71	102	33	25	19	10	13	83	2	14	6	23	55	9.1
Poinsett	2	3	11	39	45	6.9	11	22	21	19	27	34	4	25	38	19	14	110	3	18	11	35	33	5.9
Polk	29	28	21	14	8	5.6	3	7	5	7	78	130	23	17	21	15	24	109	3	14	8	25	50	8.2
Pope	20	23	26	23	8	5.9	7	7	6	8	72	100	18	19	21	16	26	114	2	12	9	25	52	8.4
Prairie, Des Arc	5	12	26	40	17	6.4	9	24	28	20	19	32	3	37	35	17	8	99	7	25	15	31	22	4.4
Prairie, De Valls Bluff	5	9	24	35	27	6.1	14	37	24	12	13	74	6	24	38	16	16	114	5	36	14	30	15	8.6
Pulaski	23	13	19	26	19	6.6	11	9	10	10	60	38	15	19	23	17	26	112	4	12	7	24	53	5.2
Randolph	3	10	23	32	32	6.1	10	18	18	23	31	66	6	25	32	22	15	88	4	19	14	38	25	6.8
Saline	22	16	20	26	16	5.9	10	10	9	11	60	64	30	22	18	15	15	98	8	9	8	33	42	7.2
Scott	19	22	33	17	9	5.9	15	14	7	6	58	62	28	18	14	13	27	105	2	10	18	27	43	5.3
Searcy	20	25	23	24	8	6.1	2	5	13	15	65	59	12	24	30	14	20	122	2	17	16	31	34	8.1
Sebastian	17	17	21	21	24	5.6	10	13	9	14	54	84	10	17	27	17	29	93	1	6	8	34	51	8.3
Sevier	36	31	21	10	2	6.5	12	7	7	10	64	62	28	20	17	12	23	122	3	10	7	29	51	6.5
Sharp	3	14	19	32	32	6.5	9	12	13	10	56	60	9	17	26	19	29	279	5	15	10	29	41	4.2
St. Francis	7	9	20	42	22	6.1	2	9	12	18	59	79	1	4	8	12	75	93	6	27	15	36	16	5.2
Stone	25	15	15	16	29	5.9	6	6	9	14	65	75	26	22	23	12	17	86	6	23	13	29	29	8.7
Union	23	20	23	23	11	5.9	14	8	9	6	63	54	26	28	19	14	13	102	5	16	5	20	54	5.3
Van Buren	19	17	26	28	10	6.2	8	12	8	19	53	99	16	25	23	17	19	150	5	18	9	41	27	10.5
Washington	10	16	26	27	21	6.2	3	7	9	11	70	66	8	13	20	20	39	101	0	5	6	28	61	6.5
White	16	15	20	36	13	6.3	8	12	9	12	59	30	20	23	23	14	20	96	3	15	12	30	40	3.8
Woodruff	6	13	29	34	18	5.7	17	22	24	21	16	118	9	33	38	13	7	121	5	32	19	30	14	13.2
Yell, Danville	15	38	33	11	3	5.9	7	6	5	9	73	79	16	19	20	18	27	122	0	3	5	23	69	7.3
Yell, Dardanelle	24	20	28	18	10	6.5	3	8	9	14	66	25	12	16	24	15	33	107	1	9	10	33	47	3.5
Average	17	17	22	26	18	6.1	10	13	12	14	51	66	15	19	24	16	26	121	4	17	12	31	36	6.6

[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 2009 through 31 December 2009.

	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	9	21	39	25	6.5	4	11	17	23	45	47	4	15	26	22	33	140	3	19	15	42	21	4.9
Cotton	5	9	21	47	18	6.5	1	3	8	19	69	63	0	2	13	28	57	186	3	19	20	45	13	4.5
Grain sorghum, non-irrigated	38	21	23	18	0	5.6	4	8	1	41	46	49	0	11	36	16	37	136	11	27	19	34	9	3.7
Grain sorghum, irrigated	3	12	41	26	18	6.2	7	26	19	25	23	34	2	13	28	19	38	143	4	26	14	48	8	4.3
Rice	4	10	22	38	26	6.5	19	27	22	18	14	27	5	20	26	16	33	129	3	21	18	40	18	4.5
Soybean	6	9	21	33	31	6.5	11	23	23	22	21	32	6	26	35	17	16	109	5	23	17	38	17	4.4
Wheat	41	6	35	18	0	5.8	0	18	47	12	23	31	12	29	47	12	0	96	35	53	6	0	6	1.7
Cool-season grass hay	21	19	24	27	9	5.9	9	9	6	12	64	71	24	20	19	11	26	103	2	14	11	30	43	6.6
Native Warm-season grass hay	31	25	25	14	5	5.7	19	18	15	13	35	34	30	30	19	8	13	76	4	22	14	34	26	4.8
Warm-season grass hay	23	21	25	23	8	5.9	8	11	9	12	60	58	27	24	20	15	14	88	3	16	12	29	40	6.2
Pasture, all categories	22	26	28	20	4	5.8	9	10	8	9	64	83	19	17	20	14	30	117	3	12	10	26	49	8.0
Home garden	9	10	17	30	34	6.6	3	5	5	7	80	147	6	11	19	17	47	167	1	5	5	19	70	13.8
Home lawn	28	17	21	21	13	5.9	7	10	11	15	57	61	9	20	28	22	21	120	2	9	9	39	41	6.9
Small fruit	32	19	19	21	9	5.7	5	9	11	14	61	71	13	23	23	18	23	113	2	16	9	33	40	6.5
Ornamental	12	10	15	28	35	6.6	7	7	9	12	65	83	10	17	24	20	29	127	1	5	5	21	68	13.2
Average	19	15	24	27	15	6.1	8	13	14	17	48	59	11	19	26	17	27	123	5	19	12	32	32	6.3

[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 2009 through 30 June 2010[z].

County	Fertilizer sold	County	Fertilizer sold
	(tons)		(tons)
Arkansas	91,687	Lee	23,473
Ashley	13,098	Lincoln	12,852
Baxter	949	Little River	3,618
Benton	9,820	Logan	1,215
Boone	2,075	Lonoke	58,659
Bradley	1,217	Madison	3,509
Calhoun	174	Marion	422
Carroll	2,085	Miller	7,441
Chicot	30,298	Mississippi	58,834
Clark	933	Monroe	34,714
Clay	57,813	Montgomery	335
Cleburne	1,130	Nevada	666
Cleveland	26	Newton	536
Columbia	986	Ouachita	92
Conway	6,016	Perry	632
Craighead	61,076	Phillips	45,373
Crawford	3,271	Pike	2,741
Crittenden	17,168	Poinsett	82,705
Cross	36,427	Polk	1,613
Dallas	38	Pope	2,091
Desha	33,244	Prairie	27,522
Drew	13,393	Pulaski	11,722
Faulkner	3,177	Randolph	22,239
Franklin	1,342	Saline	1,313
Fulton	939	Scott	300
Garland	5,378	Searcy	1,111
Grant	2,786	Sebastian	2,029
Greene	42,743	Sevier	1,269
Hempstead	3,468	Sharp	631
Hot Spring	994	St. Francis	39,840
Howard	901	Stone	1,248
Independence	8,171	Union	765
Izard	1,721	Van Buren	6,890
Jackson	29,011	Washington	2,989
Jefferson	24,708	White	23,103
Johnson	1,085	Woodruff	33,364
Lafayette	5,957	Yell	784
Lawrence	32,013		

[z] Arkansas Distribution of Fertilizer Sales by County July 1, 2009 to June 30, 2010, 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 2009 through 30 June 2010[z].

	Container			Use		
Fertilizer	Bag	Bulk	Liquid	Farm	Non-farm	Totals
			(tons)			
Multi-nutrient	30,577	312,524	10,392	343,135	10,358	353,493
Nitrogen	4,287	527,662	66,777	597,580	1,146	598,726
Phosphate	187	21,527	2,695	24,398	11	24,409
Potash	813	68,423	448	69,441	243	69,684
Organic	0	0	0	0	0	0
Micronutrient	1,119	1,475	304	2,750	148	2,898
Lime	399	5,021	0	5,380	40	5,420
Miscellaneous	7,737	2,749	996	8,704	2,779	11,482
Totals	45,119	939,381	81,613	1,051,388	14,725	1,066,113

[z] Arkansas Distribution of Fertilizer Sales By Counties 1 July 2009 to 30 June 2010, 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.

Yield Response of Cotton to Timing of Potassium Fertilization

L. Espinoza, M. Ismanov, and P. Ballantyne

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Potassium (K) plays an important role in fiber development and fiber quality. Deficient amounts of this nutrient will result in reduced yields and short fibers since K provides pressure inside the fiber cell walls, which is necessary for elongation (Ruan et al., 2001). The decrease in root activity after flowering, and the use of high-yielding, faster-fruiting cotton (*Gossypium hirsutum* L.) cultivars requiring a greater demand during boll filling makes the correction of a nutrient deficiency in cotton difficult. Understanding when soil-applied fertilizers are no longer effective is critical for optimizing cotton yield. The objective of this experiment was to assess the yield response of cotton grown on a soil with low K availability to K fertilizer applied at different growth stages and to determine at what growth stage granular K is no longer an option.

PROCEDURES

An experiment was established at the Lon Mann Cotton Research Station, near Marianna, Ark, during the 2010 season. The soil has been mapped as a Memphis silt loam (fine silty-mixed, thermic, Typic Hapludalfs). Treatments consisted of 0 and 60 lb K_2O/acre, as muriate of potash, applied once at first square, first bloom, and 200, 400, 600, and 800 heat units after bloom. The K-fertilizer was hand broadcast to designated plots and later incorporated with irrigation. Plants began squaring on 15 June, with the K fertilizer applied on 17 June (first square treatment). The remaining treatments were applied on 7, 15, 21, and 28 July and 8 August 2010. Each plot consisted of 4 rows 38-inch wide by 45-ft long. Treatments were arranged as a randomized complete block design, and were replicated four times. Cotton variety 'Phytogen 375 WRF' was planted at the rate of 40,000 seeds/acre on 6 May 2010. Nitrogen was applied at the rate of 100 lb N/acre, with 40 lb N/acre applied at emergence and 60 lb N/acre applied at first square. Irrigation (furrow) and weed and insect control were performed according to Cooperative Extension Service recommendations.

Soil samples (0- to 6-inches deep) were collected prior to planting and analyzed according to Mehlich-3 standard procedure, with soil pH measured in a 1:2 (volume) soil-water mixture. Petiole samples were collected throughout the season, beginning two weeks prior to bloom and were analyzed for K. The COTMAN crop monitoring program (Oosterhuis and Bourland, 2008) was used to assess differences in crop development among treatments from squaring to physiological cutout. Prior to harvest, ten whole plants were collected from three of the replicates, with cotton manually harvested according to position. At harvest, the two middle rows from each plot were harvested with a plot picker equipped with a weight system. Average yields were calculated and analyzed using ANOVA with mean separation using LSD at the 0.10 level.

RESULTS AND DISCUSSION

Average soil pH for the surface soil samples was 6.6. The soil-test P (43 ppm) and soil-test K (101 ppm) were considered "Optimum" and "Medium", respectively, according to University of Arkansas' guidelines. The study site has not received K fertilizer since 2005. Typical K-deficiency symptoms (interveinal chlorosis initially that changes to a bronze-orange color) were obvious in plants receiving no K fertilizer. Potassium deficiency symptoms first appeared on the first week of bloom (7 to 14 July).

Petiole-K concentrations were within the optimum level according to established sufficiency guidelines for plots fertilized with K by first square (Table 1). A similar trend was observed for plots fertilized with K by first bloom. However, the petiole-K levels for the control treatment were in the deficient range during each sampling period, with the petiole-K levels for the remaining treatments showing a high degree of variability among replicates. The high variability is a probable cause for the lack of significant differences among sampling dates.

COTMAN graphs show earlier squaring initiation in plants that received K by first bloom (Fig. 1B), compared to the no K control treatments (Fig. 1A). Plants growing under both, K-deficient and -sufficient conditions developed similar numbers of fruiting structures, with the effect of deficient K-levels becoming obvious after the plants had bloomed. It is commonly accepted that the onset of K-deficiency symptoms in cotton occurs relatively late in the season as most of the demand for K occurs during the boll filling period.

These preliminary results show that applications of granular K-fertilizer after flowering were effective in recovering some of the potential yield loss due to suboptimal soil-K availability (Table 2). Compared to cotton receiving no K, seed cotton yields were increased by 13% to 32% from K application with earlier K applications resulting in the largest yields. When K fertilizer was applied by first square, an additional 721 lb/acre seed cotton above the no K control was obtained. As K application was delayed, yield gains were reduced. The 2010 growing season was characterized by low rainfall and high temperatures, resulting in heat units accumulating significantly faster than in previous years. The yield response of cotton to applications of K-fertilizer during a year that more closely follows historical weather trends could be drastically different than the response observed during 2010. This study will be repeated in the coming years to validate the results obtained so far.

Figure 2 shows the yield distribution among sympodial nodes of cotton plants growing under K-sufficient and -deficient conditions. As stated before, the number of fruiting nodes, and associated plant height, were similar for plants growing under both conditions. The detrimental effects of K deficiency in cotton are not typically obvious before the 1st or 2nd week of bloom. In this study, plants growing under K-deficient conditions had similar numbers of first position bolls, when compared to plants growing with sufficient K. When yields were separated by boll position on a sympodial node (data not shown) it was obvious that a significant percentage of the yield differences among plants growing under deficient and sufficient K, could be attributed to reduced 2nd and 3rd position bolls. Additionally, yield resulting from top fruiting branches (nodes 14 to 17) represented nearly 20% of the total yield for plants growing under optimum soil-K levels, compared to only 8% for the plants growing under K-deficient conditions.

PRACTICAL APPLICATIONS

The objective of this study was to determine when granular K fertilizer is no longer effective for ameliorating K deficiency of cotton. Results of this preliminary study show that granular K fertilizer applied as late as 800 heat units beyond first bloom was effective in reducing the yield loss associated with deficient soil-K levels. Higher seedcotton yields were obtained when the fertilizer was applied at first square, and were significantly reduced when the fertilizer was applied 600 and 800 heat units after bloom. Growing cotton at suboptimal soil test-K levels resulted in the loss of more than 700 lb seedcotton/acre. These results underscore the importance of soil testing and proper fertilization.

ACKNOWLEDGMENTS

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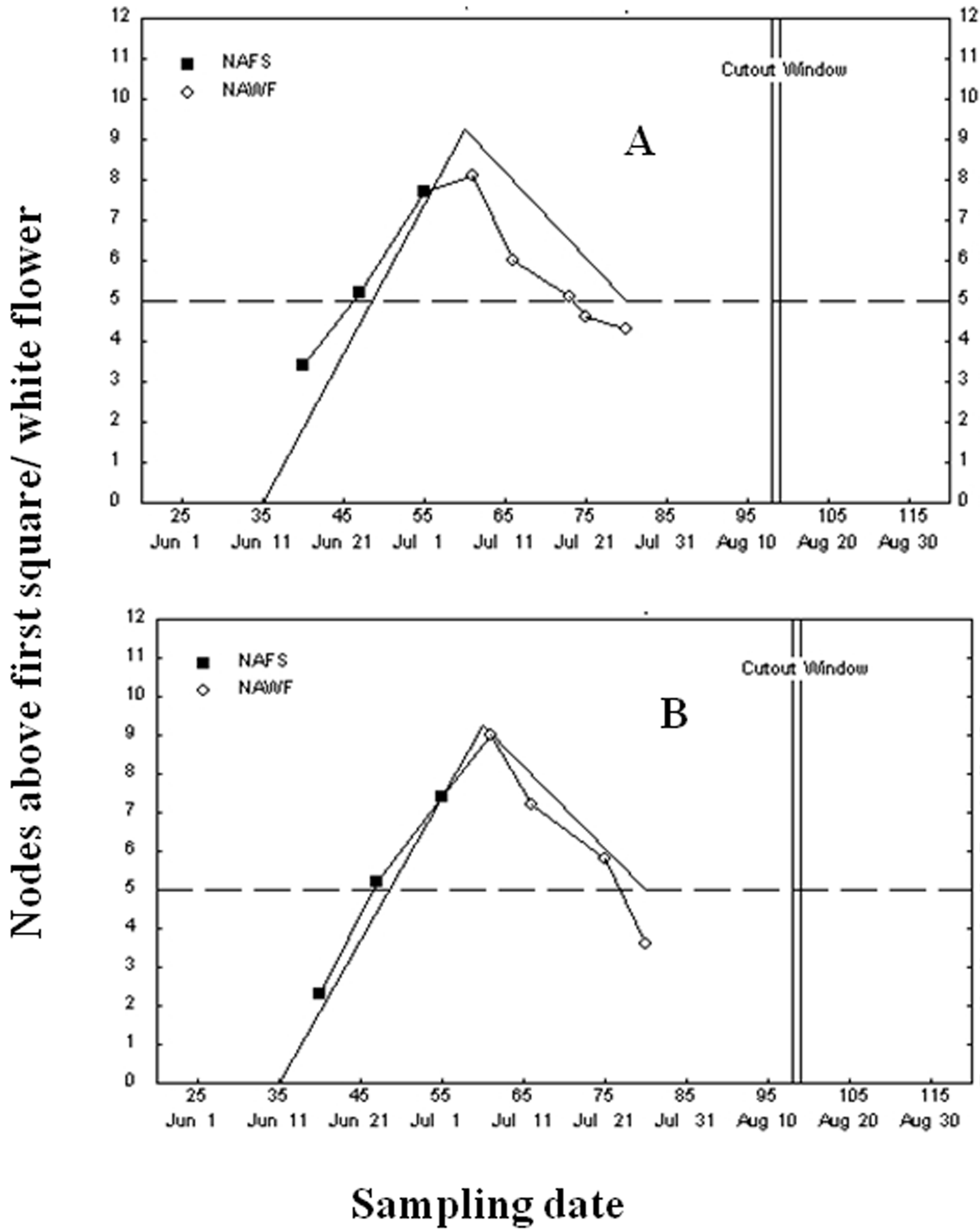

Fig. 1. Average nodes above first square (NAFS) and nodes above white flower (NAWF) development for the no K control treatment (A), and for the treatment receiving 60 lb K_2O/acre at first bloom (B). Each point in the graph represents the average of 30 plants. The dashed horizontal line represents NAWF at physiological maturity. The solid line represents the typical development curve for cotton growing under optimum conditions.

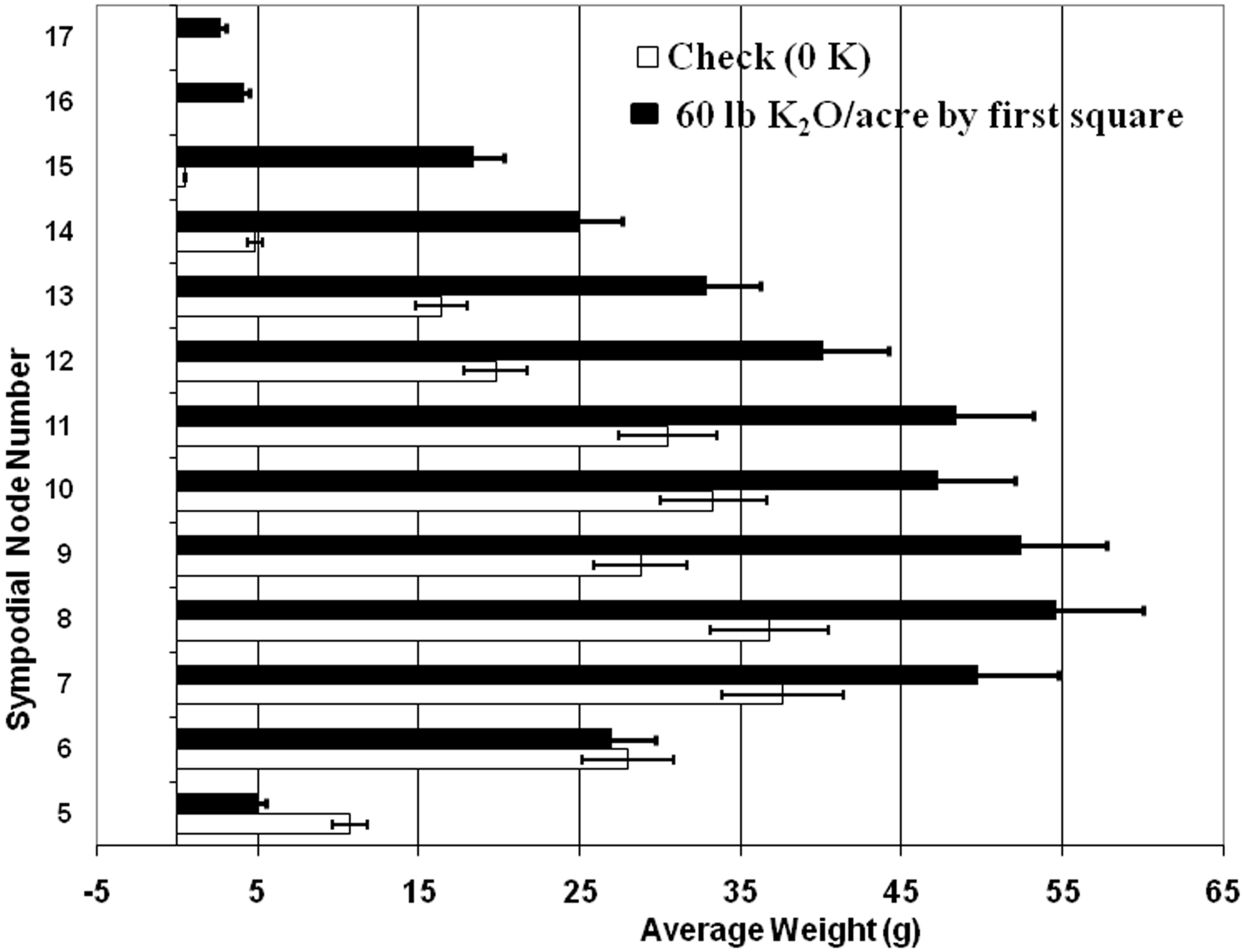

Fig. 2. Average seedcotton yield, and associated standard deviations, according to sympodial node for cotton receiving 60 lb K_2O/acre by first square or no K fertilizer (n = 30).

Table 1. Average petiole-K concentrations (n = 3) for selected treatments, according to growth stage, and associated statistical significance.

	Petiole K				
Treatment	2 weeks pre-bloom	1 week pre-bloom	1 week post-bloom	2 weeks post-bloom	3 weeks post-bloom
	(% K)				
Control (no K)	3.7	2.8	1.4	1.3	0.7
First square	5.1 [z]	3.9 [z]	2.3 [z]	4.1 [z]	2.3 [z]
First bloom	3.7 [z]	3.6 [z]	2.7 [z]	3.0 [z]	2.5 [z]
First bloom + 200 heat units	4.2	3.4	1.4 [z]	2.7 [z]	2.0 [z]
First bloom + 400 heat units	3.9	3.5	1.9	2.8 [z]	1.4 [z]
Minimum Sufficiency Level[y]	4.0	4.0	3.5	3.5	3.0
LSD (0.10)	NS[x]	NS	NS	NS	NS

[z] K fertilizer had been applied when petiole samples were collected.

[y] The minimum sufficiency levels are those reported by Snyder et al. (1995).

[x] NS, not significant ($P > 0.10$).

Table 2. Average seedcotton yield response to K application time. Potassium was applied at a single rate of 60 lb K_2O/acre. Yields followed by the same letter are not statistically different. The number in parentheses following date of fertilization is the actual cumulative heat units after first bloom on the day the K fertilizer was applied.

Treatment description	Date of fertilization	Mean seedcotton yield
		(lb/acre)
First square	17 June	2945 a
First bloom	7 July	2811 a
First bloom + 200 heat units	15 July (222)	2897 a
First bloom + 400 heat units	21 July (378)	2697 ba
First bloom + 600 heat units	28 July (585)	2551 b
First bloom + 800 heat units	5 August (798)	2514 b
Control (no K)	---	2224 c
	LSD (0.10)	249
	CV (%)	8.8
	p-value	0.0004

Corn and Cotton Response to Urea and an Enhanced-Efficiency Fertilizer

M. Mozaffari and N.A. Slaton

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Nitrogen fertilizer is usually required for producing optimum corn (*Zea mays* L.) and cotton (*Gossypium hirsutumn* L.) yields in Arkansas. Improving N-use efficiency will increase the growers' profit margin and reduce potential environmental risks of excessive N application. Enhanced-efficiency N fertilizers are developed to meet that dual need. A polymer-coated urea (44% N, Agrium Advanced Technologies, Loveland, Colo.) is currently being marketed in Arkansas under the trade name of Environmentally Smart Nitrogen or ESN. According to the manufacturer, the polymer coating protects the urea-N against rapid loss to the environment with the N release rate controlled by temperature. The objectives of this study were to evaluate corn and cotton response to ESN and urea fertilizers applied to representative Arkansas soils.

PROCEDURES

Three N fertilization experiments were conducted to evaluate the effect that five preplant N rates applied as urea or ESN had on corn and cotton growth and yield. The corn trial and one cotton trial were located on a Loring silt loam at the Lon Mann Cotton Research Station in Marianna (LMCRS). A second cotton trial was established on a Dundee loam at the Judd Hill Research Farm. Before applying any fertilizer, soil samples were collected from the 0- to 6-inch depth and composited by replication. Soil samples were dried, crushed, and soil NO_3-N was measured with a specific ion electrode (Donahue, 1992). Other soil nutrients were measured with the Mehlich-3 soil test. Selected soil property means are presented in Table 1. Soil particle size analysis was performed by the hydrometer method (Arshad et al., 1996). Agronomically important information for the three experiments is presented in Table 2. Pest and cultural management practices closely followed University of Arkansas Cooperative Extension Service guidelines for irrigated corn and cotton production.

The corn experiment was a randomized complete block design with a factorial arrangement of two N sources (urea and ESN) each applied at five rates ranging from 60 to 300 lb N/acre compared to a no N control. Each treatment was replicated five times. Blanket applications of muriate of potash, triple superphosphate, and $ZnSO_4$ were made to supply 60 lb K_2O, 46 lb P_2O_5, 6.7 lb Zn, and 5 lb S/acre. All fertilizers were hand-applied and incorporated by a Do-all before planting.

Each corn plot was 25-ft long and 12.6-ft wide allowing for four rows of corn planted in 38-inch wide rows. At the early-silk stage, ear-leaf samples were taken from six to eight representative corn plants in the two center rows 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. Corn plants in the center two rows of each plot were harvested with a plot combine and grain yields were adjusted to 15.5% moisture content.

Each cotton trial was a randomized complete block design with five blocks of treatments arranged in a factorial structure as described for the corn trial. Urea and ESN were each applied at 30, 60, 90, 120, and 150 lb N/acre and compared to a no N control. Cotton plots were 40-ft long and 12.6-ft wide allowing for four rows of cotton with 38-inch wide row spacings. Nitrogen treatments were surface applied and incorporated with a Do-all before planting. Muriate of potash was surface applied at LMCRS shortly after planting to supply 60 lb K_2O/acre. No P and K fertilizers were applied at the Judd Hill site. The two center rows of cotton in each plot were harvested with a spindle-type picker.

Analysis of variance was performed using the GLM procedure of SAS. Cotton experiments were analyzed by site. When appropriate, means were separated by the least significant difference (LSD) method and interpreted as significant when $P \leq 0.10$.

RESULTS AND DISCUSSION

Soil analysis indicated that pH ranged from 6.0 to 7.0 and Mehlich-3 extractable P and K were Optimum (K) or Above Optimum (P) for the corn experiment, Medium (K) or Above Optimum (P) for the cotton experiment at LMCRS, and each was Low for the Judd Hill cotton trial (Table 1). Soil NO_3-N ranged from 4 to 28 ppm and suggested that corn and cotton should both respond favorably to N fertilization.

Corn ear-leaf N concentration and grain yield were both affected by the main effects of N rate and source but not by their interaction (Table 3). Corn that received no N had an average ear-leaf N concentration of 1.13% and yielded 13 bu/acre, both of which were substantially lower than the lowest values of corn receiving N. Averaged across N rates, corn receiving ESN (2.20% N) or urea (2.11% N) had equal ear-leaf N that was greater than corn receiving no N (1.13% N, LSD0.10 = 0.14). Ear-leaf N concentration, averaged across N sources, increased with each increase in N rate, except between 180 and 240 lb N/acre, which had similar N concentrations. Corn yield response to N rate was similar to that of ear-leaf N concentration. Corn yield, averaged across N rates, was 12 bu/acre greater for ESN (116 bu/acre, LSD0.10 = 11) than urea (104 bu/acre).

Seedcotton yield at the LMCRS was affected only by N source (*P* = 0.0429), but yield means for each N source and rate combination are listed in Table 4. Averaged across N rates, cotton fertilized with ESN (2053 lb/acre, LSD0.10 = 195) produced numerically greater and statistically similar seedcotton yields as urea (1932 lb/acre), but both yielded greater than cotton receiving no N (1264 lb/acre).

At Judd Hill, seedcotton yields were not affected by N source, N rate, or their interaction (Table 4). Application of 30 lb N/acre, the lowest N rate, maximized cotton yield, producing a 675 lb seedcotton/acre increase compared to the no N control. The mean seedcotton yields produced with ESN and urea, averaged across N rates (*P*-value for N source = 0.6758), differed by only 26 lb/acre. The results suggest that ESN provided equal or slightly better N availability than urea at these sites during 2010.

PRACTICAL APPLICATION

In corn and cotton fields, early season soil moisture conditions, which directly influence N losses that occur following fertilizer application, are known to vary among years due to annual fluctuations in rainfall and temperature. The 2010 summer was drier than normal making fertilizer N losses from denitrification less likely than in wet years. Corn yields, averaged across all N rates, were numerically greater by 10% when ESN was applied preplant compared to urea applied preplant. Cotton yields were not different between urea and ESN. These results indicate that ESN is a suitable alternative N fertilizer (to urea) for both crops. Use of ESN as the preplant N source does not guarantee greater corn and cotton yields than urea, but likely helps reduce the risk of losing greater amounts of N in wet years. Thus, ESN should be considered a tool that can enhance N management and crop uptake. Additional research, encompassing several years and various field and weather conditions common to Arkansas is needed to determine the frequency and magnitude of yield increases and whether other crop management benefits may be realized when ESN is used in place of urea for preplant N applications.

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Table 1. Selected soil property means (0- to 6-inch depth) of samples taken before applying fertilizers to a corn trial at the Lon Mann Cotton Research Station (LMCRS) and cotton trials established at the LMCRS and Judd Hill Research Farm in 2010.

	Soil	Soil	Mehlich-3-extractable nutrients					Soil physical properties			
Site	pH[z]	NO_3-N[y]	P	K	Ca	Mg	Zn	Sand	Silt	Clay	Texture
		(ppm)									
LMCRS-corn	7.0	4	66	144	1330	303	7.0	9	73	18	silt loam
LMCRS-cotton	6.8	28	57	104	1487	196	2.7	4	73	23	silt loam
Judd Hill-cotton	6.0	15	25	85	985	164	2.7	43	39	19	loam

[z] Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.

[y] NO_3-N measured by ion-specific electrode.

Table 2. Agronomically important information for corn and cotton N fertilization trials established at the Lon Mann Cotton Research Station (LMCRS) and Judd Hill Research Farm in Arkansas during 2010.

Site ID	Previous crop	Cultivar	Planting date	N application date	Leaf sampling date	Harvest date
LMCRS-corn	corn	Pioneer 31D59	27 April	27 April	2 July	3 Sep
LMCRS-cotton	cotton	Pure Genetics 92	2 June	19 May	no samples	9 Sep
Judd Hill-cotton	cotton	Stoneville 4288	8 May	21 May	no samples	23 Aug

Table 3. Corn ear leaf N concentration at silking and grain yield as affected by the non-significant (NS, *P* > 0.10) N rate and source interaction and N rate, averaged across N sources, for a trial located at the Lon Mann Cotton Research Station.

	Ear leaf N			Grain yield		
N rate	Urea	ESN[z]	Source mean	Urea	ESN	Source mean
(lb N/acre)	(% N)			(bu/acre)		
0	1.13		1.13	13		13
60	1.34	1.46	1.39	28	36	32
120	1.98	1.85	1.92	86	86	86
180	2.33	2.44	2.39	131	152	143
240	2.38	2.45	2.41	129	141	134
300	2.50	2.68	2.59	154	147	150
LSD0.10	NS		0.15	NS		12
p-value	0.4226		<0.0001	0.4500		<0.0001

[z] ESN, Environmentally Smart N, polymer coated urea.

Table 4. Seedcotton yield as affected by the non-significant (NS, *P* > 0.10) N rate and source interaction and N rate, averaged across N sources, for trials located at the Lon Mann Cotton Research Station (LMCRS) and Judd Hill Research Farm during 2010.

	Judd Hill Research Farm			Lon Mann Cotton Research Station		
N rate	Urea	ESN[z]	Source mean	Urea	ESN	Source mean
(lb N/acre)	(lb/acre)					
0	1795		1795	1264		1264
30	2501	2438	2470	1804	1968	1895
60	2319	2548	2434	1807	2006	1893
90	2542	2510	2528	2036	2046	2041
120	2277	2387	2338	1929	2212	2071
150	2468	2388	2423	2055	2081	2067
LSD0.10	NS		NS	NS		NS
p-value	0.4669		<0.4958	0.6005		<0.4609

[z] ESN, Environmentally Smart N, polymer coated urea.

Effect of Phosphorus Fertilization on Corn in Arkansas

M. Mozaffari and N.A. Slaton

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Phosphorus (P) fertilization may increase corn (*Zea mays* L.) yields in many Arkansas soils. However, excessive buildup of P in agricultural soils will increase the likelihood of P loss via runoff, which contributes to the degradation of water quality. Accurate soil test-based, assessment of soil P fertility and appropriate P fertilizer recommendations is the most effective process for producing optimum corn yields and reducing the risk of excessive soil P buildup. Information on corn response to P fertilization on Arkansas soils is very limited because corn production and acreage in Arkansas have become significant only in the last few years. The objectives of this project were to evaluate the effects of P fertilizer application rates on corn P concentration and uptake at the V6 to V8 stage, P concentration of the corn ear-leaf at silking, and corn grain yield.

PROCEDURES

Replicated field experiments were conducted at the Lon Mann Cotton Research Station in Lee County (LEZ06), Pine Tree Research Station in St. Francis County (SFZ04), two commercial fields located near Lake Village (CHZ01 and CHZ02) in Chico County, and a field near Holly Grove (MOZ03) in Monroe County during 2010. Before planting, composite soil samples were collected from the 0- to 6-inch depth and composited by replication. Soil samples were dried, crushed, extracted with Mehlich-3 solution, and the concentrations of elements in the extracts were measured by inductively-coupled plasma atomic emission spectroscopy (ICP-AES). Soil pH was measured in a 1:2 (weight:volume) soil-water mixture. Soil particle size analysis was performed by the hydrometer method (Arshad et al., 1996). Important agronomic information is provided in Table 1. Experimental plots were 25- to 40-ft long and 10- to 18.9-ft wide allowing for four or six rows of corn spaced 30 to 38 inches apart, depending on the location. Corn was grown on beds and furrow-irrigated at each site.

Phosphorus application rates ranged from 0 to 160 lb P_2O_5/acre in 40 lb/acre increments as triple superphosphate. Phosphorus treatments were applied to the soil surface in a single application either before planting or shortly after crop emergence. Blanket applications of muriate of potash, urea, and $ZnSO_4$ were made to supply 100 lb K_2O, 260 to 280 lb N/acre, 6.7 lb Zn, and 5 lb S/acre, respectively, except at LEZ06 where only 190 lb N/acre was applied. For sites receiving 220 to 280 lb N/acre, 40 to 60 lb N/acre was applied before the 4-lf stage and the balance of N was applied before the 6- to 8-lf stage.

At all sites except CHZ01 and CHZ02, five representative plants/plot were cut two inches above the soil surface at the 6- to 8-lf stage, dried in an oven at 70 °C to a constant weight, and ground to pass through a 60-mesh sieve. Plant samples were digested with concentrated HNO_3 and 30% H_2O_2 (Jones and Case, 1990) and P concentrations were determined by ICP-AES. When corn was at the early to mid-silk stage, 8 to 10 ear-leaves per plot were collected and processed as above at all sites except SFZ04 where corn was damaged by wildlife and the plots were abandoned. The middle two rows of each plot were harvested either with a plot combine or by hand with harvested ears placed through a combine later. The calculated grain yields were adjusted to a uniform moisture content of 15.5% for statistical analysis.

Analysis of variance was performed by site using the GLM procedure of SAS v9.1 (SAS Institute, Inc., Cary, N.C.) to evaluate the effect of P fertilizer rates on plant response variables. Significant differences among P rate means were separated using Fishers least significant difference (LSD) test when $P \leq 0.10$.

RESULTS AND DISCUSSION

Soil pH ranged from 5.9 to 7.9 and Mehlich-3 extractable P ranged from 24 to 84 ppm (Table 2). University of Arkansas Cooperative Extension Service fertilizer recommendations for corn classified the soil P availability as Low (15-25 ppm) at LEZ06 and SFZ04 and Above Optimum (>50 ppm) at the other three sites with recommended P rates of 100 and 0 lb P_2O_5/acre, respectively, for a corn yield goal of 175 bu/acre.

Phosphorus fertilization did not influence seedling corn P concentration, dry matter accumulation, or P uptake at MOZ02 and SFZ04 (Table 3). However, P fertilization significantly increased P concentration, dry matter, and P uptake at LEZ06. These results are consistent with the interpretation of Mehlich-3 extractable P in the 0-to 6-inch depth for MOZ02 and LEZ06, but not SFZ04 where a positive response to P was expected.

Phosphorus fertilization significantly increased corn ear-leaf P concentration only at LEZ06 (Table 4). At LEZ06, ear-leaf P concentration of corn receiving no P was less than the proposed critical concentration of 0.25% (Campbell and Plank, 2000) suggesting a yield response to P was possible. Corn grain yields at the four harvested sites were not influenced by P fertilization (Table 4). Yields at LEZ06 were lower than expected and ranged from 122 to 128 bu/acre suggesting that another factor (such as N availability) was more limiting than P availability. The lack of significant grain yield increases to P fertilization is not surprising since soil-test P was either Medium or Above Optimum at the four harvested sites. Although P is recommended for soils having a Medium soil-test P level, only a nominal yield increase would be expected as the P recommendation is mostly for ensuring early season vigor and replacing a portion of the nutrients removed by the harvested grain.

PRACTICAL APPLICATIONS

Phosphorus fertilization did not increase P concentration or uptake by young corn plants, ear-leaf P, or grain yield in three soils having Above Optimum soil-test P levels. Phosphorus fertilization significantly increased young corn plant P concentration, P uptake, and ear-leaf P in a soil having Low soil-test P. These results are consistent with our current P fertilizer recommendations for corn. Additional trials with soils having a wide range of Mehlich-3 extractable P values are needed to evaluate the accuracy of soil-test P in identifying soils that need P to produce near maximum corn yields.

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Table 1. Previous crop, corn cultivar, and planting, P fertilizer application, plant sampling and harvest dates for five P fertilization trials conducted in Chico (CHZ02 and CHZ03), Lee (LEZ06), Monroe (MOZ02), and St. Francis (SFZ04) counties during 2010.

		Previous		Planting	P application	Sampling date		Harvest
Site	Soil series	crop	Cultivar	date	date	Ear leaf	Whole plant	date
CHZ02	Rilla silt loam	soybean	Pioneer 175	9 April	20 April	15 June	none	10 Aug
CHZ03	Hebert silt loam	soybean	Pioneer 175	9 April	20 April	6 July	none	10 Aug
LEZ06	Loring silt loam	cotton	Pioneer 31D49	27 April	18 May	6 July	7 June	2 Sep
MOZ02	Bosket sandy loam	soybean	not available	14 April	5 May	28 June	7 May	23 Aug
SFZ04	Calhoun silt loam	soybean	Pioneer 33D49	9 May	30 April	--[z]	11 June	NH[y]

[z] No samples taken.

[y] NH, not harvested due to wildlife damage.

Table 2. Selected properties of the soil samples collected from 0- to 6-inch depth before P-fertilizer application in four P fertilization trials conducted in Chico (CHZ02 and CHZ03), Lee (LEZ07), Monroe (MOZ03), and St. Francis (SFZ05) counties during 2010.

	Soil	Mehlich-3-extractable nutrients					Soil physical properties			
Site	pH[z]	P	K	Ca	Mg	Zn	Sand	Silt	Clay	Texture
		(ppm)					(%)			
CHZ02	6.7	64	178	705	102	3.9	32	56	12	silt loam
CHZ03	6.7	54	190	1031	172	4.2	22	62	16	silt loam
LEZ06	7.0	29	67	939	253	3.0	6	76	18	silt loam
MOZ02	5.9	84	125	621	76	11.9	55	35	15	sandy clay loam
SFZ04	7.9	24	73	3095	303	5.1	6	68	26	silt loam

[z] Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.

[y] Standard deviation of soil test P means: 2 ppm for CHZ02, 3 ppm for CHZ03, 5 ppm for LEZ06, 13 ppm for MOZ02, and 1 ppm for SFZ05.

Table 3. Effect of P fertilization rate on dry weight, P concentration and P uptake in the above-ground portion of young corn plants sampled at the 6- to 8-lf stage for three P fertilization trials conducted in Lee (LEZ06), Monroe (MOZ02), and St. Francis (SFZ04) counties during 2010.

	LEZ06			MOZ02			SFZ04		
P rate	P concentration	Dry weight	P uptake	P concentration	Dry weight	P uptake	P concentration	Dry weight	P uptake
(lb P_2O_5/acre)	(%)	(g/5 plants)		(%)	(g/5 plants)		(%)	(g/5 plants)	
0	0.38	62.3	0.24	0.46	64.8	0.30	0.33	58.3	0.20
40	0.42	69.0	0.29	0.47	71.6	0.34	0.33	52.2	0.18
80	0.43	60.8	0.26	0.47	68.4	0.32	0.33	59.7	0.20
120	0.43	58.0	0.25	0.44	73.2	0.32	0.34	59.5	0.20
160	0.49	63.5	0.31	0.44	69.0	0.31	0.34	57.5	0.20
P value	0.0004	0.0995	0.0073	0.162	0.26	0.36	0.8423	0.3153	0.5640
LSD0.10	0.03	6.5	0.03	NS[z]	NS	NS	NS	NS	NS

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

Table 4. Effect of P fertilization rate on corn grain yield and ear-leaf P concentration at the silking stage in four P fertilization trials conducted in Chico (CHZ02 and CHZ03), Lee (LEZ06), Monroe (MOZ02), and St. Francis (SFZ04) counties during 2010.

	CHZ02		CHZ03	LEZ06		MOZ02	
P rate	Grain yield	Leaf P	Grain yield	Grain yield	Leaf P	Grain yield	Leaf P
(lb P_2O_5/acre)	(bu/acre)	(%)	(bu/acre)	(bu/acre)	(%)	(bu/acre)	(%)
0	194	0.31	191	126	0.21	156	0.34
40	199	0.35	180	129	0.23	171	0.33
80	191	0.37	176	123	0.24	161	0.34
120	194	0.37	191	129	0.23	177	0.34
160	–[z]	0.40	193	122	0.24	168	0.34
P value	0.3523	0.2610	0.1559	0.2649	0.010	0.2520	0.4510
LSD0.10	NS[y]	NS	NS	NS	0.02	NS	NS

[z] Data was not collected because samples were lost in transport from CHZ02. Ear leaf samples were not collected at CHZ03.

[y] NS, not significant (*P* > 0.10).

Potassium Fertilization Increases Corn Grain Yield

M. Mozaffari and N.A. Slaton

BACKGROUND INFORMATION AND RESEARCH PROBLEM

The renewed interest in biofuels has increased corn (*Zea mays* L.) production in Arkansas. In 2009, more than 400,000 acres of corn were harvested in Arkansas and the state average yield was 148 bu/acre. A 150 bu/acre corn crop contains about 245 lb K_2O/acre in the aboveground biomass making K fertilization a requirement to produce optimum grain yields and/or to maintain sufficient soil-K availability. Improved soil-test based K fertilization guidelines are vital for increasing growers' profit margins. The objectives of this research were to evaluate the effect of soil-applied K fertilizer rate on K concentration and uptake of young (6- to 8-lf stage) corn, corn ear-leaf K concentration at silking, and grain yield. These results will contribute to a database that will verify and, if needed, update the existing K fertilization recommendations for corn.

PROCEDURES

Four replicated field experiments were conducted at different sites including the Rohwer Research Station in Desha County (DEZ03), Lon Mann Cotton Research Station in Lee County (LEZ07), Pine Tree Research Station in St. Francis County (SFZ05), and a commercial farm in Holly Grove (MOZ03) on representative corn producing soils in 2010. Prior to K application, soil samples were taken from the 0- to 6- and 6- to 12-inch depths and composited by replication. Soil samples were dried, crushed, extracted with Mehlich-3 solution, and the concentrations of elements in the extracts were measured by inductively coupled plasma atomic emission spectroscopy (ICP-AES). Soil pH was measured in a 1:2 (weight:volume) soil-water mixture and particle size analysis was performed by the hydrometer method (Arshad et al., 1996).

Selected agronomically important information is listed in Table 1. Potassium application rates ranged from 0 to 200 lb K_2O/acre in 40 lb K_2O/acre increments applied as muriate of potash and all of the K was applied to the soil surface in a single application. Triple superphosphate and $ZnSO_4$ were blanket applied to supply 46 lb P_2O_5, 6.7 lb Zn, and 5 lb S/acre, respectively. All experiments, except LEZ07, were fertilized with a total of 220 to 280 lb N/acre, where 40 to 60 lb N/acre was applied before the 4-lf stage and the balance of N was applied before the 6- to 8-lf stage. At LEZ07, corn was fertilized with 190 lb N/acre. Corn management closely followed University of Arkansas Cooperative Extension Service recommendations for irrigated corn. At each site, corn was planted on beds and furrow irrigated as needed. At LEZ07 and DEZ03, the plots were 40-ft long and 12.6-ft wide allowing for four rows of corn planted in 38-inch wide rows, and each treatment was replicated eight times. At MOZ03 and SFZ05, treatments were replicated five or six times and plots were 25-ft long and either 10- (MOZ03) or 12-ft (SFZ05) wide allowing for four or six rows of corn planted in 30-inch wide rows. All experiments were randomized complete blocks.

When corn plants were at the 6- to 8-lf stage, five representative whole (aboveground) plants per plot were cut 2 inches above the soil surface, dried in an oven at 70 °C to constant weight, and dry weight was measured at all sites except DEZ03 (no samples were collected). When corn was at the early to mid-silk stage, corn ear-leaf samples were collected from 8 to 10 plants/plot and processed as described previously. At DEZ03, ear-leaf samples were collected from six of the eight replications. All plant samples were ground to pass through a 60-mesh sieve and K concentration was measured by wet ashing (Jones and Case, 1990). At DEZ03 and LEZ07, the middle two rows of each plot were harvested for grain yield. At SFZ05, wildlife damaged some segments of the two center rows in several plots making them unsuitable for mechanical harvest requiring that plots be hand harvested in undamaged areas of the middle rows. The hand harvested corn was shelled in a plot combine. At MOZ03, corn was harvested by hand from 12.5-ft long segments in each of the two center rows and eventually shelled with a plot combine. Grain yields from all sites were adjusted to a uniform moisture content of 15.5% for statistical analysis.

Analysis of variance was performed using the GLM procedure of SAS. Each experiment was analyzed separately. When appropriate, significant differences among means were separated by the least significant test (LSD) test with significance interpreted at the 0.10 level.

RESULTS AND DISCUSSION

Mehlich-3 extractable K in the 0- to 6-inch depth ranged from 57 to 142 ppm (Table 2). According to the University of

Arkansas soil test interpretation, soil-test K was Optimum (131 to 175 ppm) at MOZ03, Low (61 to 90 ppm) at LEZ07 and DEZ03, and Very Low (<61 ppm) at SFZ05. Current fertilization guidelines recommended 50, 110, and 155 lb K_2O/acre for Optimum, Low, and Very Low soil test K levels, respectively, for corn with a yield goal of 175 bu/acre. Soil-test K in the 6- to 12-inch depth ranged from 43 to 97 ppm, which was numerically lower than or comparable to the 0- to 6-inch depth. Soil-test K at LEZ07 was numerically higher in the 6- to 12-inch depth than the 0- to 6-inch depth.

At the 6- to 8-lf stage, corn dry weight was not affected by K fertilizer rate at any of the three sites where plant samples were collected (Table 3). Potassium concentration and uptake were unaffected by K rate at MOZ03, the site with the highest soil-test K, but both parameters were increased by K fertilization at LEZ07 and SFZ05. Results suggest that early season K uptake is enhanced by K fertilization for corn grown in silt loams having low soil-K availability.

Corn ear-leaf K concentration was significantly increased by K application at all sites except MOZ03, the site that had the highest surface and subsoil-K availability (Table 4). Corn ear-leaf concentrations <1.80% K indicate possible K deficiency (Campbell and Plank, 2000). Corn grain yields were significantly increased by K fertilization at all sites except LEZ07 (Table 4). Grain yields at LEZ07 were relatively low and may have been limited by insufficient N fertilization or perhaps other factors. Compared to corn recieving no K, corn yields were increased by 12% to 60% by K fertilization at the three K responsive sites. Yields were maximized by application of 40 (DEZ03 and MOZ03) or 80 (SFZ05) lb K_2O/acre. Corn ear-leaf K concentrations at tasseling appear to be a good indicator of the K nutritional status of corn and soil-test K appears to be a good indicator of soil-K availability.

PRACTICAL APPLICATIONS

In soils having Low soil-test K levels, K fertilization increased K concentration and uptake by corn. Potassium fertilization also increased corn grain yields at three of four sites having Very Low to Optimum soil-test K levels. The only site that was unresponsive to K fertilization had Low soil-test K and relatively low yields (<140 bu/acre) suggesting that other factors besides K availability (such as N availability) were more yield-limiting. In these studies, 40 and 80 lb K_2O/acre was required to produce optimum corn yields. These results suggest that current University of Arkansas soil test-based K fertilizer recommendations are able to predict the need for K fertilization on these soils with reasonable accuracy. Additional site-years of research are needed to evaluate the reproducibility of these results and develop a robust database for verifying and improving the accuracy of K fertilizer recommendations for corn.

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Table 1. Previous crop, corn cultivar, and planting, K application, plant sampling and harvest dates for K fertilization trials conducted in Desha (DEZ03), Lee (LEZ07), Monroe (MOZ03), and St. Francis (SFZ05) counties during 2010.

Site	Soil series	Previous crop	Cultivar	Planting date	K application date	Sampling date		Harvest date
						Whole plant	Ear leaf	
DEZ03	Hebert silt loam	corn	Pioneer 11845	14 April	7 May	none	21 June	24 Aug
LEZ07	Loring silt loam	cotton	Pioneer 31D49	27 April	18 May	7 June	6 July	2 Sep
MOZ03	Bosket sandy loam	soybean	not available	14 April	5 May	7 May	28 June	23 Aug
SFZ05	Calloway silt loam	soybean	Pioneer 33D49	9 May	15 April	11 June	8 July	11 Sep

Table 2. Selected properties of soil taken from 0 -to 6- and 6- to12-inch depths before K-fertilizer application for K fertilization trials conducted in Desha (DEZ03), Lee (LEZ07), Monroe (MOZ03), and St. Francis (SFZ05) counties during 2010.

	Sample	Soil	Mehlich-3-extractable nutrients						Soil physical properties			
Site ID	depth	pH	P	K^z	Ca	Mg	Cu	Zn	Sand	Silt	Clay	Texture
	(inches)		-------------------------------(ppm)-------------------------------						-------------- (%) -------------			
DEZ03	0-6	6.2	31	84	778	128	0.9	5.0	29	57	14	silt loam
	6-12	6.7	16	55	1050	162	0.9	8.3	22	57	21	silt loam
LEZ07	0-6	7.2	44	72	964	256	0.9	1.7	9	75	16	silt loam
	6-12	7.1	27	81	1104	379	0.9	1.0	3	70	27	silt loam
MOZ03	0-6	5.8	81	142	544	63	1.1	10.7	56	28	17	sandy clay loam
	6-12	6.3	85	97	815	92	1.4	11.4	56	28	17	sandy clay loam
SFZ05	0-6	6.8	20	57	1450	188	0.8	3.6	1	75	24	silt loam
	6-12	6.6	13	43	1308	146	0.6	3.6	1	77	22	silt loam

[z] Standard deviation of soil-test K in the 0- to 6- and 6- to 12-inch depths: 9 and 5 ppm for DEZ03; 14 and 22 ppm for LEZ07; 8 and 6 ppm for MOZ03; and 19 and 8 ppm for SFZ05, respectively.

Table 3. Effect of K fertilization rate on dry weight, K concentration, and K uptake of the aboveground portion of corn plants at 6- to 8-lf stage in three K fertilization trials conducted in Lee (LEZ07), Monroe (MOZ03), and St. Francis (SFZ05) counties during 2010.

	LEZ07			MOZ03			SFZ05		
K rate	K concentration	Dry weight	K uptake	K concentration	Dry weight	K uptake	K concentration	Dry weight	K uptake
(lb K$_2$O/acre)	(%)	--- (g/5 plants) ---		(%)	--- (g/5 plants)----		(%)	--- (g/5 plants) ---	
0	2.31	63.1	1.4	2.95	87.0	2.6	1.62	45.3	0.75
40	2.85	60.4	1.7	3.21	84.6	2.7	2.20	47.4	1.05
80	3.74	57.4	2.1	3.22	79.2	2.6	2.27	48.8	1.13
120	3.75	55.3	2.1	3.21	84.4	2.7	2.57	47.2	1.23
160	4.52	56.3	2.5	3.24	78.8	2.6	2.76	49.5	1.38
200	4.43	62.6	2.8	3.14	80.6	2.5	2.57	51.3	1.34
P value	<0.0001	0.4469	<0.0001	0.4576	0.6779	0.8216	<0.0001	0.6537	0.0087
LSD0.10	0.41	NS^z	0.35	NS	NS	NS	0.32	NS	0.28

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

Table 4. Effect of K fertilization rate on corn ear-leaf K concentration at silk-stage and grain yield in K fertilization trials conducted in Desha (DEZ03), Lee (LEZ07), Monroe (MOZ03), and St. Francis (SFZ05) counties during 2010.

	DEZ03		MOZ03		LEZ07		SFZ05	
K rate	Grain yield	Leaf K	Grain yield	Leaf K	Grain yield	Leaf K	Grain yield	Leaf K
(lb K$_2$O/acre)	(bu/acre)	(%)	(bu/acre)	(%)	(bu/acre)	(%)	(bu/acre)	(%)
0	148	1.35	145	1.83	132	1.35	138	1.20
40	170	1.62	178	2.35	132	1.61	188	1.68
80	165	1.72	159	2.13	136	1.79	221	1.75
120	169	1.88	180	2.22	126	1.80	221	1.88
160	174	1.92	177	2.22	123	1.96	210	2.01
200	177	2.02	176	2.30	126	1.93	217	2.13
P value	0.0038	<0.0001	0.0545	0.4096	0.1219	<0.0001	0.0314	<0.0001
LSD0.10	12	0.15	22	NS^z	NS	0.08	28	0.20

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

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 phosphorus (P) and/or potassium (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 and Extension Center (Dewitt silt loam) and Northeast Research and 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 inorganic fertilizers.

PROCEDURES

Trials were established at three sites in 2010 including a Calhoun silt loam at the Pine Tree Research Station (PTRS-W), a Calloway silt loam at the PTRS (PTRS-N), and a Henry silt loam in a commercial field located in Poinsett County (Poinsett). The PTRS-N field was selected for this trial because soybean typically does not grow and yield well in this field, but it has not been leveled. 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 122 °F, crushed to pass a 2-mm sieve, and analyzed for soil pH (1:2 soil weight: water volume ratio), and total carbon (C) and nitrogen (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 boron (B) fertilizer (1.0 lb B/acre) was broadcast only to the Poinsett field to ensure B was not yield limiting. Soybean were flood-irrigated (six irrigations) at the PTRS sites and furrow-irrigated at the Poinsett site.

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. Three subsamples of litter were analyzed for total nutrient content and showed litter averaged 4.47% total N, 1.5% P, 2.70% K, 17.6% moisture and had a mean pH of 8.3. 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 2038 and 4076 lb moist litter/acre and supplied 66 and 132 lb K_2O/acre, respectively.

Inorganic-fertilizer treatments were prepared to provide an equivalent amount of total P_2O_5 and K_2O/acre as poultry litter and/or a similar amount of plant-available N (PAN) as the low and high poultry litter rates. A calculation error resulted in the inorganic K fertilizer rates being 55 and 110 lb K_2O/acre, which is 83% of the actual litter K_2O rates. The PAN of poultry litter was estimated as 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 61 and 122 lb N/acre for the low and high rates, respectively. Super Urea was used because it contains both a urease and nitrification inhibitor, which would help reduce fertilizer-N losses.

At the Poinsett site, fertilizer and litter treatments were hand broadcast to the soil surface of a tilled seedbed on 2 June after soybean was drill seeded on 31 May. At the two PTRS sites, treatments were hand broadcast to the surface of a freshly tilled seedbed on 28 April, but planting was delayed until 21 May. Individual plots were 10- to 13-ft wide and 20- to 26-ft long (260 ft^2/plot).

Trifoliate leaves (15) were collected from each plot at the R2 growth stage from the Poinsett and PTRS-W, dried to a constant moisture, ground to pass a 1-mm sieve, digested, and analyzed for elemental concentrations by ICPS.

An 18- to 22-ft long section from the middle rows of each plot was harvested with a plot combine. Soybean moisture was adjusted to 13% for final yield calculations. A 500-g subsample of harvested seed from soybean receiving 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 2010 trials. However, seed nutrient concentrations from four similar poultry litter trials conducted in 2009 is included in this report. Details for the 2009 trials were reported by Slaton et al. (2010).

Each experiment was a randomized complete block design with treatments structured as 2 (rate) × 4 (nutrient source) factorial plus a no fertilizer control. Each treatment was replicated six times per site. Analysis of variance for yield data was conducted with the PROC GLM procedure in SAS v9.1 (SAS Institute, Inc., Cary, N.C.) with yield and leaf nutrient concentration data from each site analyzed separately. Seed nutrient content data from the four 2009 trials were analyzed as a split plot where site was the whole plot and nutrient source applied at 70 lb P_2O_5/acre 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 Very Low (<61 ppm) at PTRS-N and Low (61 to 90 ppm) at the other two sites. Soil-test P was classified as 'Very Low' (<16 ppm) at Poinsett and 'Low' (16 to 25 ppm) at both PTRS sites. Recommended fertilizer rates would have ranged from 80 to 100 lb P_2O_5 and 120 to 160 lb K_2O/acre.

Soybean yields were not significantly affected by the main effects of nutrient source and rate or their interaction at any site (Table 3). Yields at the PTRS-N site were highly variable and relatively low compared to the other two sites. Soybean growth during the early season was poor with soybean exhibiting symptoms that resembled Mn deficiency shortly after emergence. A Mn fertilizer solution containing 1 lb Mn/acre was applied in mid June and early July in unsuccessful attempts to stimulate early-season growth. Soybean growth did appear to be slightly better in plots amended with poultry litter. Soybean yield also showed a numerical trend to be slightly better in litter amended soil.

Trifoliate leaf samples were collected from all plots at the PTRS-W and Poinsett sites. Leaf nutrient concentrations at Poinsett were not significantly affected by rate, source, or their interaction. Nutrient sources means are listed in Table 4. At the PTRS-W, leaf P and K concentrations were each affected by nutrient source, averaged across nutrient rates (Table 4). For P, soybean receiving PK fertilizer had greater P concentrations than that of soybean receiving fresh litter or N. For K, soybean receiving P and K from any source had numerically greater K concentrations than when no P or K was applied, but the difference was significant only for soybean receiving only N. Examination of the twelve plots that received no fertilizer or litter show that there was considerable variation within the plot area as leaf K concentrations ranged from 1.17% to 1.96% K. Leaf P concentrations were near the minimum range of the sufficient level (>0.30%) for soybean at both sites, and at or near the minimum sufficient range (>1.5%) for K at the PTRS-W (Sabbe et al., 2000).

In late June, soybean in the PTRS-W trial area showed symptoms of B deficiency in random plots and was confirmed with tissue analysis. At the R2 stage, trifoliate-leaf B concentrations, averaged across nutrient rates, were greatest in soybean receiving poultry litter (23.6 ppm) and numerically or significantly lower in all other treatments, which ranged from 19.2 to 20.9, LSD0.05 = 2.7 ppm). Thus, use of poultry litter may provide low levels of plant-available B. The poultry litter usually contains about 40 to 60 ppm B and supplies about 0.1 lb B/ton. Boron fertilizer was broadcast at the Poinsett site.

Phosphorus and sulfur (S) concentrations of harvested soybean seed from the four 2009 trials were affected by the site by source interaction ($P < 0.0001$, data not shown). The main effects of site and/or nutrient source were significant for all nutrients (Table 5). In fact, environment, which includes the soil, climate, and variety at each site (a different variety was planted at each site), had a much greater effect on seed nutrient concentrations than the fertilizer treatments. These data suggest site has a consistent, significant effect on seed nutrient concentrations. For example, seed P and K concentrations were much greater on the Sharkey clay at the Rohwer Research Station than on the three silt loam soils. Based on the range of mean seed P (0.40% to 0.55%) and K (1.56% to 2.14%) concentrations (by site), harvested soybean removes the equivalent of 0.55 to 0.76 lb P_2O_5 and 1.12 to 1.55 lb K_2O/bu.

PRACTICAL APPLICATIONS

Results from the trials conducted in 2010 suggest that P and K availability in poultry litter is equivalent to that of muriate of potash and triple superphosphate. The application of N to soybean had no apparent benefit to soybean yield in these trials. Trifoliate leaf P and K concentrations also tended to be similar among nutrient sources. 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 three trials comparing soybean growth and yield to fresh poultry litter and inorganic fertilizers during 2010.

Site[z]	Soil series	Previous crop	Cultivar	Plant date	Tillage	Row width
Poinsett	Henry	Rice	NK51T8	31 May	Conventional	7.5
PTRS-W	Calhoun	Soybean	Armor 47-F8	21 May	Conventional	15.0
PTRS-N	Calloway	Soybean	Armor 53-Z5	21 May	Conventional	15.0

[z] Site abbreviations: PTRS, Pine Tree Research Station West (-W) or North (-N).

Table 2. Selected soil chemical property means (*n* = 6) of poultry litter fertilization trials conducted at three sites during 2010.

	Soil	Total soil		Mehlich-3 extractable nutrients										
Site[z]	pH	C	N	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
		----(%)----		---(ppm)---										
Poinsett	8.3	1.04	0.087	10	68	3398	246	27	46	291	222	6.4	1.3	1.2
PTRS-W	7.7	1.09	0.095	16	90	1883	313	8	29	455	134	2.5	1.1	0.4
PTRS-N	7.0	1.17	0.099	25	56	1338	205	8	55	323	41	2.8	1.4	0.3

[z] Site abbreviations: Poinsett, commercial field in Poinsett County; and PTRS, Pine Tree Branch Station North (-N) and West (-W).

Table 3. Soybean seed yield as affected by the non-significant source by rate interaction (main effects were also not significant, *P* > 0.10) for three trials conducted on silt loam soils in a grower field in Poinsett County and two fields (W and N) at the Pine Tree Research Station (PTRS) during 2010.

	Poinsett		PTRS-W		PTRS-N	
Fertilizer	Low rate[z]	High rate	Low rate	High rate	Low rate	High rate
	------Grain yield (bu/acre)------					
No fertilizer	54		57		30	
N only	57	56	60	57	27	29
PK	53	58	59	54	31	36
NPK	55	56	59	57	38	32
Fresh litter	52	58	56	59	34	38
LSD0.05	NS[y]		NS		NS	
p-value	0.2767 (C.V., 14.3%)		0.2205 (C.V., 7.5%)		0.3949 (C.V., 25.9%)	

[z] For treatments including P and K, the ‘Low’ rate received 70 lb P_2O_5 and 55 to 66 lb K_2O/acre and the ‘High” rate received 140 lb P_2O_5 and 110 to 132 lb K_2O/acre. For treatments that received N, the Low and High rates were equivalent to 61 and 122 lb N/acre as urea or estimated N availability from poultry litter.

[y] NS, not significant (P > 0.05).

Table 4. Soybean trifoliate leaf P and K concentrations at the R2 stage as affected by nutrient source, averaged across rates, in two trials evaluating the P and K availability of poultry litter compared to inorganic fertilizers conducted on silt loam soils in a grower field in Poinsett County and one field (W) at the Pine Tree Research Station (PTRS) during 2010.

	Poinsett		PTRS-W	
Fertilizer	Phosphorus	Potassium	Phosphorus	Potassium
	(% P)	(% K)	(% P)	(% K)
No fertilizer	0.29	1.79	0.31	1.51
N only	0.32	1.80	0.30	1.40
PK	0.31	1.98	0.33	1.62
NPK	0.31	1.94	0.31	1.60
Fresh litter	0.30	1.86	0.31	1.65
LSD0.05	NS[y]	NS	0.018	0.16
p-value	0.5765	0.1052	0.0255	0.0113

[z] For treatments including P and K, the ‘Low’ rate received 70 lb P_2O_5 and 55 to 66 lb K_2O/acre and ‘High” rate received 140 lb P_2O_5 and 110 to 132 lb K_2O/acre. For treatments that received N, the Low and High rates were equivalent to 61 and 122 lb N/acre as urea or estimated N availability from poultry litter.

[y] 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 2009.

Site[z] or source	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
	------(%)------					------ (ppm) ------				
Site-Soil Series										
PCC-Dewitt	0.40	1.62	0.30	0.23	0.27	68	38	34.7	11.5	37.3
Poinsett-Henry	0.41	1.56	0.27	0.22	0.16	68	29	39.8	9.2	34.0
PTRS-Calhoun	0.47	1.61	0.33	0.23	0.26	73	52	31.7	8.6	11.3
RRS-Sharkey	0.55	2.14	0.29	0.24	0.32	89	32	39.8	9.8	37.0
LSD0.05	0.02	0.06	0.02	<0.01	0.01	5	3	1.6	0.7	2.0
P-value	0.0001[y]	<0.0001	<0.0001	<0.0001	0.0001[y]	<0.0001	<0.0001	<0.0001	<0.00012	<0.0001
Nutrient Source										
None	0.45	1.67	0.30	0.23	0.26	76	38	37.1	9.8	29.9
PK	0.46	1.73	0.30	0.23	0.25	74	39	36.6	9.4	29.4
NPK	0.47	1.76	0.28	0.23	0.25	75	36	36.2	9.7	29.0
Poultry litter	0.47	1.77	0.29	0.23	0.25	75	39	36.5	9.7	29.0
LSD0.05	0.01	0.05	0.02	NS[x]	<0.01	NS	NS	NS	NS	NS
P-value	0.0001[y]	<0.0001	0.0478	0.0764	0.0169[y]	0.9619	0.3095	0.4014	0.1656	0.1485

[z] Site abbreviation: PCC, Phillips Community College Campus, Dewitt, Ark.; Poinsett, Poinsett County; PTRS, Pine Tree Research Station; and RRS, Rohwer Research Station.

[y] The site by source interaction was significant (*P* < 0.05, data not shown).

[x] NS, not significant (*P* > 0.05).

Soybean Yield Response to Phosphorus and Potassium Fertilization Rate and Time

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

BACKGROUND INFORMATION AND RESEARCH PROBLEM

The primary focus of our 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 allow 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 fall applying P and K fertilizers 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* L.) 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 or commercial fertilizers are applied weeks or months in advance of crop planting. 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.

MATERIALS AND METHODS

Research was established on a soil mapped as a Convent silt loam at the Lon Mann Cotton Research Station. The site had been cropped to soybean and wheat for the previous two years without P and K fertilization. Wheat was drilled-seeded as a cover crop on 38-inch wide beds following soybean harvest in fall 2009. Wheat received no N fertilizer and was sprayed with glyphosate herbicide to terminate growth on 21 April 2010.

Composite soil samples were collected (0- to 4-inches) on 20 November 2009, 2 March 2010, and 22 April 2010 from each plot designated to receive no P or K fertilizer. Soil samples were analyzed for soil pH (1:2 soil: water volume mixture), Mehlich-3 extractable nutrients, and organic matter by weight loss on ignition. Selected soil chemical property means from April 2010 sample time are listed in Table 1. Soil pH, P, K, and Zn means for the three sample times are compared in Table 2. In April 2010, composite soil samples were collected from each plot to examine how P and K fertilizer applied in November 2009 and March 2010 affected soil-test P and K (Tables 3 and 4).

Phosphorus- (as triple superphosphate) and K-fertilizer (as muriate of potash) treatments were hand-broadcast to the soil surface at rates of 0, 45 and 90 lb K_2O or P_2O_5/acre on 20 November 2009, 2 March 2010, and 22 April 2010. The K research area received 50 lb P_2O_5/acre as triple superphosphate and the P area received 60 lb K_2O/acre as muriate of potash in April. Soybean (Pioneer 94Y70) was drill-seeded on the 38-inch beds in late May. Soybean were furrow-irrigated with irrigation water flowing through the P trial before entering the K trial.

Fully-expanded trifoliate leaves (15/plot) from one of the top three nodes of soybean plants were collected in each plot at the R2 growth stage. Plant samples were oven dried to a constant weight, ground to pass a 1-mm sieve, and a subsample of tissue was digested in 30% H_2O_2 and concentrated HNO_3 to determine tissue nutrient concentrations. Leaf samples were collected only from the P trial.

The 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. Soil-test P and K values from the April 2010 sample time were subjected to analysis of variance to evaluate the effect of fertilizer applied in November 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. 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 November, February, and April to determine the effect of sample month. Data were pooled across the two test areas resulting in 12 replicates per treatment. 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 v9.1 (SAS Institute Inc., 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

Month of soil sample collection resulted in significant differences in soil pH and Mehlich-3 extractable P, K, and Zn (Table 2). Soil pH was 0.3 units greater for samples collected in February 2010 compared to samples collected in November 2009 or April 2010. Soil-test nutrient values also fluctuated across time. For P, samples collected in November and April had 'Optimum' (36 to 50 ppm) soil-test P levels, whereas samples collected in February were classified as having a Medium (26 to 35 ppm) soil-test P level. Soil-test K declined slightly with each successive sample time with the soil-test K level declining from Optimum (131 to 175 ppm) for samples collected in November to Medium (91 to 130 ppm) for the February and April sample times. For both P and K, the mean concentrations were near the boundary concentration that defines the Medium and Optimum soil-test levels. We observed a similar decrease in soil-test K across time at the LMCRS in the 2008-2009 growing season (Slaton et al., 2010), which may have been caused by nutrient uptake by the wheat cover crop or soil moisture at the time of sampling.

Soil-Test K

Soil-test K in April 2010 was affected by the main effects of month of fertilizer application ($P < 0.0001$) and fertilizer rate ($P = 0.0723$). Means of the non-significant interaction are shown in Table 3. Soil-test K, averaged across application times, increased from 114 to 122 ppm as K_2O rate increased from 45 to 90 lb K_2O/acre. Soil receiving K had greater K availability than soil receiving no K, but soil-test K decreased as the time of soil sample collection after fertilization increased (Table 3). Using a typical soil bulk density value of 1.20 g/cm^3 as outlined by Slaton et al. (2010), the theoretical maximum soil-test K would increase from the applied K fertilizer rates would be 35 and 70 ppm. However, soil-test K increased by 8 to 16 ppm (23% to 46% recovery) or 14 to 28 ppm (20% to 40% recovery) for the 45 and 90 lb K_2O/acre rates, respectively, with recovery ranging from 20% to 46% of the applied K. Recovery of K applied in November averaged 20% to 23% compared to 40% to 46% for K applied in February suggesting greater K loss or fixation across time.

Soil-Test P

Soil-test P as determined in soil samples collected in April 2010 was affected significantly by the month of fertilizer application and application rate interaction ($P < 0.0636$, Table 4). Soil-test P was similar for soil receiving no P fertilizer, but increased as P rate increased from 45 to 90 lb P_2O_5/acre. There was no significant difference between P applied in November and February within the same P rate. Using the same bulk density assumption outlined for K, the maximum possible 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. The Mehlich-3 soil extractant recovered 18% to 21% of applied P fertilizer, with application time and rate having minimum influence on recovery.

Trifoliate Leaf-P Concentration

Soybean leaf-P concentration at the R2 stage was affected by the P rate by application time interaction (Table 5), however the numerical differences among most of the treatments were small. Leaf-P concentration in soil receiving 90 lb P_2O_5/acre applied in April was greater than most other P rates and application times. These data suggest that soil-P availability was not growth limiting, and P fertilization had little effect on leaf-P concentration.

Seed Yield

Seed yield was not significantly affected by P or K fertilization in either trial (data not shown). Soybean yields in the K trial were, on average, 16 bu/acre (range 39 to 47 bu/acre and mean, 43 bu/acre) lower than yields in the P trial (range 58 to 59 bu/acre). The yield difference between trials was attributed primarily to irrigation. Irrigation water flowed through the P trial before reaching the K trial. Visual inspection of the K trial following several irrigation events suggested insufficient water was delivered to the K trial, which affected plant growth and yield during the very hot and dry weather of 2010. Because soybean plants in the K trial were stressed early in the season, leaf tissue was not sampled. In contrast, visual plant growth and yield means both indicate that soybean in the P trial was adequately irrigated. Little or no yield increase from P or K fertilization was expected as the soil-test values were near Optimum at all sample times (Table 2).

PRACTICAL APPLICATION

Soybean yields were not affected by the different P fertilization rates or times and leaf-P concentrations were generally comparable. In the absence of growth, yield, or nutrient uptake differences to fertilization, we can make few conclusions regarding whether fertilizer application time is of significant or practical concern. We did learn that only about 20% of fertilizer P and 20% to 46% of applied fertilizer K is recovered by the Mehlich-3 extractant. Recovery of P was relatively consistent across treatments, but fluctuated considerably for K. Growers are advised to collect soil samples before manure or fertilizer is applied to fields.

ACKNOWLEDGMENTS

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Table 1. Selected soil chemical property means (0- to 4-inch depth) at the Lon Mann Cotton Research Station used to evaluate soybean response to P and K fertilization rate and time as determined from soil samples collected in April 2010.

	Soil	Soil	Mehlich-3 extractable soil nutrient concentrations[y]							
Trial	OM	pH[z,y]	P[x]	K[w]	Ca	Mg	S	Fe	Mn	Zn	Cu
	(%)		(ppm)								
Phosphorus	2.3	6.5	35	118	885	181	7	200	256	2.2	1.8
Potassium	2.4	6.3	46	112	989	186	7	220	237	2.2	2.3

[z] Soil pH measured in a 1:2 soil:water volume mixture.

[y] Mean of 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 mean soil-test P was 3.5 ppm.

[w] For K trials, the standard deviation of mean soil-test K was 14 ppm.

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 the Lon Mann Cotton Research Station in 2009 and 2010.

		Mehlich-3 extractable		
Sample time	Soil pH	P	K	Zn
		(ppm)		
November 2009	6.4	39	138	1.9
February 2010	6.7	35	126	2.0
April 2010	6.4	41	115	2.2
LSD0.05	0.1	<2	6	0.14
p-value	<0.0001	<0.0001	<0.0001	0.0004

Table 3. The effect of fertilizer application month and K-fertilizer rate on Mehlich-3 extractable soil K as determined in April 2010 at the Lon Mann Cotton Research Station.

Application month	K rate mean	45 lb K_2O/acre	90 lb K_2O/acre
	(ppm K)		
None	107	105	109
November 2009	118	115	121
February 2010	129	123	135
LSD0.10	7	NS[z]	
p-value	<0.0001	0.6090 (interaction)	

[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 2010 at the Lon Mann Cotton Research Station.

Application month	P rate mean	45 lb P_2O_5/acre	90 lb P_2O_5/acre
	---------- (ppm P) ----------		
None	34	34.5	33.6
November 2009	40	37.8	41.2
February 2010	40	37.1	42.4
LSD0.10	2	3.08	
p-value	0.0002	0.0636	

Table 5. Soybean trifoliate leaf P concentrations at the R2 growth stage as affected by the P application rate by fertilizer application month interaction during 2010.

Nutrient rate	November 2009	February 2010	April 2010
(lb P_2O_5/acre)	---------- (% P) ----------		
0		0.353	
45	0.360	0.350	0.355
90	0.347	0.357	0.377
LSD0.10		0.019	
p-value		0.0909	

Canola Response to Nitrogen and Phosphorus Fertilization Rate in Arkansas

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

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Canola (*Brassica rapa* L.) is an oilseed crop that has potential for winter production in the mid-South. If adopted by Arkansas growers, canola would compete for acreage with soft red winter wheat (*Triticum aestivum* L.). 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 mid-South United States.

Our prior research with canola has shown i) no yield benefit from sulphur (S) fertilization, ii) maximum yields were generally produced with 75 to 135 lb nitrogen (N)/acre, iii) yields were significantly increased by phosphorus (P) fertilization on soils very low in P (<16 ppm Mehlich 3), and iv) no yield response to potassium (K) on soils with Medium to Optimum soil-test K values (110 ppm K, Slaton et al., 2009, 2010). 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 fertilizer rates and ii) N fertilizer rate, source, and application time when grown on soils in eastern Arkansas.

RESEARCH PROCEDURES

Fertilization experiments were successfully established on a Memphis silt loam at the Lon Mann Cotton Research Station (LMCRS) following summer fallow. Experiments were attempted at the Rice Research Extension Center and Pine Tree Research Station, but the stand from the first planting was poor due to excessive rainfall in October and second plantings in November suffered from poor emergence and/or freeze damage and were subsequently abandoned. This report includes results from trials at the LMCRS, which evaluated canola response to N and P rate. In each trial, individual plots were 20-ft long and 7.0-ft wide. 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 122 °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: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. Selected soil chemical property means are listed in Table 1.

Canola variety AR377 was planted on 30 September 2009 into a conventionally-tilled seedbed with a small-plot drill having 6-inch drill spacings at a seeding rate of 6 lb/acre in both trials. Each plot contained seven rows of canola. Preventative weed control was performed by preplant application of 1 pt Treflan/acre.

The P-rate trial evaluated canola response to 0, 40, 80, 120, and 160 lb P_2O_5/acre as triple super phosphate that was broadcast to the soil surface on 19 November 2009. The N rate trial evaluated total N rates of 0, 45, 75, 105, 135, and 165 lb N/acre applied as a blend of urea and ammonium sulfate made in applications on 14 January and 25 February or 25 February and 15 March 2010. Each N rate included 21 lb N/acre as ammonium sulfate with the balance of N supplied as urea. The 45 and 75 lb N/acre rates were applied as a single application on 14 January or 25 February 2010. Nitrogen rates >75 lb N/acre were applied in two split applications of 45 + 60 lb N (105 lb N/acre), 60 + 75 lb N (135 lb N/acre), and 85 + 80 lb N (165 lb N/acre) with ammonium sulfate always included in the earliest application. Both trials received 60 lb K_2O/acre as muriate of potash, 10 lb Zn/acre as $ZnSO_4$, and 1 lb B/acre. The N-rate trial also received 60 lb P_2O_5/acre as triple superphosphate. The P-rate trial received 130 lb N/acre as a combination of ammonium sulfate and urea split applied on 14 January and 25 February 2010 as described for the same N rate used in the N-rate trial.

The uppermost, mature leaves (20) were collected from plants in the P-rate trial 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).

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. Sub-samples of seed were saved from canola fertilized with 0, 80, and 160 lb P_2O_5/acre and 0 and 105 lb N/acre from both N application times. Whole seeds (~0.25 g) were digested and analyzed as described previously for leaf analysis.

The P-rate experiment was a randomized complete block design with 6 blocks. The N-rate experiment was a randomized complete block design with a 2 (application time) by 6 (N rate) factorial treatment structure and 4 blocks. For each study, 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 a significance level of 0.10.

RESULTS AND DISCUSSION

Nitrogen Trial

Canola yield was not significantly affected by the N rate by N application time interaction at the LMCRS. The main effect of N application time, averaged across N rates, also had no significant influence on canola yield with average yields of 61 and 58 bu/acre when N was applied in Jan-Feb and Feb-March, respectively. Only N rate, averaged across N application times, affected canola yield (Table 2). Canola receiving no N fertilizer yielded 30 bu/acre compared to the maximum yields of 70 to 73 bu/acre for canola receiving 135 to 165 lb N/acre. These results are similar to research conducted during the two previous years (Slaton et al., 2009, 2010).

Four N rate trials have been conducted during the past three years at three different research sites (Slaton et al., 2009, 2010). Results indicate that there is little to no difference in canola yield response to split N applications in January-February or February-March. The relationship between relative canola yield and N rate was quadratic for each site except the LMCRS in 2010, which showed a linear yield response to N rate and was more responsive to N than previous sites (Fig. 1). When all sites were considered, a linear-plateau model predicted that canola yields would be maximized (98.1 % relative yield) by application of 118 lb N/acre (not shown). When the 2010 LMCRS site was omitted, the optimum N rate declined to 94 lb N/acre (Fig. 1).

The timing of N fertilizer application had a significant effect ($P < 0.10$) on the concentration of P, calcium (Ca), magnesium (Mg), and iron (Fe) in harvested canola seed. Seed P concentration was greatest in canola receiving no N (0.87% P, LSD0.10 = 0.25), intermediate when N was applied in Jan-Feb (0.85% P), and lowest when N was delayed until Feb-March (0.83% P). Seed Mg concentrations averaged 0.29% Mg for canola receiving no N and were greater than seed from canola receiving N in Jan-Feb (0.25 % Mg, LSD0.10 = 0.02) and Feb-March (0.24 % Mg). Although the seed Fe and Ca concentrations were different among N application times, the range of values was relatively narrow with seed having 65 to 70 ppm Fe and 0.45% to 0.47% Ca. For nutrients that were not significantly affected by N application time, the average seed concentrations were 0.95% K, 0.44% S, 61 ppm Mn, 43.6 ppm Zn, 3.5 ppm Cu, and 11.7 ppm B.

Phosphorus Trial

Soil-test P was classified as 'Medium' (Table 1) suggesting little or no positive yield increase would result from P fertilization. Based on the LSD mean separations, P fertilization had no significant influence on canola yield (Table 3). However, comparing the yield of canola receiving no P (62 bu/acre) against the average yield of canola fertilized with 40 to 120 lb P_2O_5/acre (66 bu/acre) suggested that a small, but significant yield increase occurred from P fertilization.

Leaf concentrations of P, K, and S were significantly affected by P fertilizer rate (Table 3). Leaf-P concentrations tended to increase as P rate increased, but leaf-K and -S concentrations showed no particular logical order among P rates. Results from three canola P fertilization trials conducted during the last three years suggest that leaf-P concentrations >0.35% at the green bud stage are sufficient for the production of near optimal yields (Slaton et al., 2009, 2010). Plank and Tucker (2000) suggested 0.37% P as the critical value and 0.42% to 0.69% as the sufficiency range for canola.

The P and K concentrations of harvested canola seed were significantly affected by P rate (data not shown). Seed-P concentrations in canola receiving no P fertilizer averaged 0.75% P and were significantly lower than canola that received 80 (0.84% P, LSD0.10 = 0.03) and 160 (0.83% P) lb P_2O_5/acre. Seed-K concentrations followed a similar pattern with canola receiving no P fertilizer having an average seed-K concentration of 0.94% K (LSD0.10 = 0.03) compared to 1.00% K for canola receiving 80 and 160 lb P_2O_5/acre. For nutrients that were not significantly affected by P rate, the average seed concentrations were 0.41% Ca, 0.25% Mg, 0.44% S, 69 ppm Fe, 69 ppm Mn, 48.2 ppm Zn, 3.7 ppm Cu, and 12.0 ppm B.

PRACTICAL APPLICATION

Near maximum canola yields were produced with 135 lb N and 40 lb P_2O_5/acre at the LMCRS in the 2009-2010 season. Results from four canola N trials conducted during the last three years indicate that application of 118 lb N/acre will produce near maximum canola yields on most silt loam soils. Research performed during the last three years is insufficient to develop strong nutrient management recommendations, but is sufficient for making preliminary recommendations should canola be produced commercially in Arkansas. Overall, the N and P fertilizer requirements of canola appear to closely match the recommendations for winter wheat.

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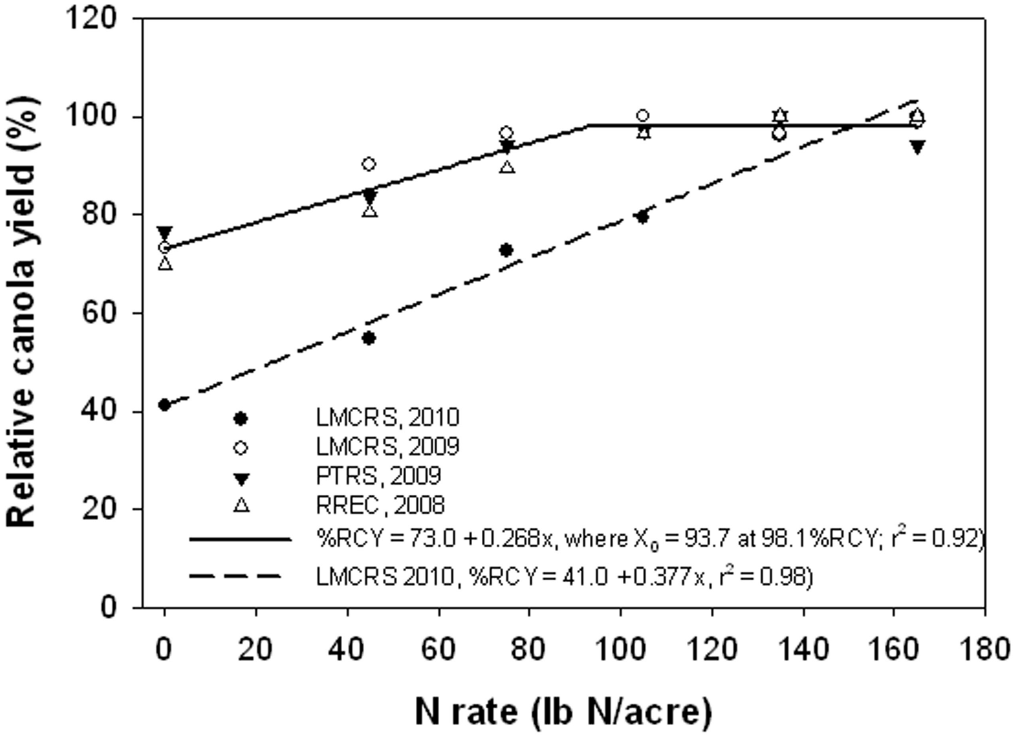

Fig. 1. Nitrogen calibration curves for the 2010 site at Lon Mann Cotton Research Station (LMCRS) and three other sites at the LMCRS, Rice Research Extension Center (RREC), and Pine Tree Research Station (PTRS) as defined using linear and liner-plateau models, respectively.

Table 1. Selected soil chemical property means from the unfertilized controls of canola fertilization experiments established at the Lon Mann Cotton Research Station in fall 2009.

	Organic	Soil	Mehlich-3 extractable nutrients								
Study	matter	pH	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
	(%)		------------------------------ (ppm) ------------------------------								
Nitrogen[z]	1.6	7.0	47	130	1038	118	5	130	142	2.5	1.6
Phosphorus	1.5	6.3	35[y]	119	968	122	6	132	109	1.3	1.2

[z] The mean soil inorganic N content in the top 4 inches of soil was 10 ppm NH_4-N and 7 ppm NO_3-N.

[y] The standard deviation of the mean soil test P (n = 3) was 2.1.

Table 2. Canola seed yield response to N fertilizer rate, averaged across N application times, for a field trial conducted on a Memphis silt loam at the Lon Mann Cotton Research Station following summer fallow in 2010.

Total N rate	Grain yield
(lb N/acre)	(bu/acre)
0	30
45	40
75	53
105	58
135	70
165	73
p-value	<0.0001
LSD(0.10)	6

Table 3. Canola seed yield and leaf nutrient concentration at green bud stage responses to P-fertilizer rate on a Memphis silt loam at the Lon Mann Cotton Research Station following summer fallow during 2009-2010.

	Grain	Leaf nutrient concentration										
P-fertilizer rate	yield	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
(lb P_2O_5/acre)	(bu/acre)	-------------------- (%) --------------------					-------------------- (ppm) --------------------					
0	62	0.322	2.89	2.62	0.328	1.11	433	84	208	89.2	6.2	41.0
40	66	0.350	2.95	2.44	0.323	1.01	610	70	201	84.1	6.6	36.4
80	66	0.378	2.66	2.34	0.308	1.04	798	63	201	85.3	6.1	36.2
120	64	0.368	2.64	2.42	0.305	1.05	676	67	195	77.5	6.0	38.9
160	62	0.390	2.80	2.31	0.297	1.01	650	59	186	78.8	5.5	36.3
p-value	0.234	0.002	0.033	0.128	0.290	0.009	0.197	0.246	0.787	0.454	0.372	0.410
LSD(0.10)	NS[z]	0.026	0.182	NS	NS	0.05	NS	NS	NS	NS	NS	NS

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

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

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

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. Establishment of 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 unrecognized and have not yet been diagnosed. Despite the lack of documented micronutrient deficiencies of wheat, wheat plants often have zinc (Zn) and boron (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 2009 to evaluate the effect of P and K fertilization rate and Zn fertilization on wheat growth and yield. Trials were located at the Lon Mann Cotton Research Station (LMCRS) on a Memphis silt loam following summer fallow, the Pine Tree Research Station (PTRS) on soils mapped as Loring (PTRS-L) and Calhoun (PTRS-C) silt loams both following soybean [*Glycine max* (L.) Merr.], and the Rice Research Extension Center (RREC) on a Dewitt silt loam following summer fallow. 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.

'Roane' wheat was drill-seeded (100 to 120 lb seed/acre) into conventionally tilled seedbeds on 7 November at LMCRS and PTRS-L and 10 November at PTRS-C. 'Pat' wheat was drill-seeded into a conventionally tilled seedbed at the RREC on 11 November. Individual plots were 20-ft long and 6.5-ft wide allowing for 7 or 8 rows of wheat with 6.0- to 7.5-inch wide row spacings.

Fertilizer treatments were broadcast by hand to each plot in mid November after wheat was seeded and emerged. Each P and K rate trial included 0, 30, 60, 90, 120, and 150 lb K_2O or P_2O_5/acre as muriate of potash or triple superphosphate, respectively. Potassium fertilizer (100 lb muriate of potash/acre) was broadcast applied to P trials and P fertilizer (130 lb triple superphosphate/acre) was broadcast applied to K trials on 19 or 20 November to ensure these nutrients were not yield-limiting factors. The Zn trial included treatments of no Zn plus 60 lb P_2O_5/acre as monoammonium phosphate (MAP, 11-52-0), 60 lb P_2O_5/acre as MAP plus 5 lb Zn/acre as $ZnSO_4$ (35.5% Zn granular), 60 lb P_2O_5/acre as MAP plus 1.5 lb Zn/acre as Zn lignosulfonate (Origin 10% granular Zn, Winfield Solutions), and 60 lb P_2O_5/acre as MESZ [Microessentials fertilizer (12% N, 40% P_2O_5, 10% S, and 1% Zn), The Mosaic Company] which supplied 1.5 lb Zn/acre. All fertilizer treatments in the Zn trial were applied by hand on 25 February 2010. The Zn trial also received a blanket application of K fertilizer on 25 February 2010.

Nitrogen fertilizer was applied in two or three split applications, depending on soil moisture status at each site. For nutrient trials at the LMCRS, RREC, and PTRS-L, a total of 130 lb N/acre was applied as 21 lb N/acre as $(NH_4)_2SO_4$ on 25 February, 59 lb N/acre as urea on 2 March, and 50 lb N/acre as urea on 24 March. Trials at the PTRS-C received 130 lb N/acre, which was applied with 80 lb N/acre applied as a combination of urea and $(NH_4)_2SO_4$ on 2 March followed by 50 lb N/acre as urea on 23 March. At maturity, grain yields were measured by harvesting all seven or 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 (P and K trials) or six (Zn trial) replicates per treatment. Data from 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). When appropriate mean separations were performed using Fisher's Protected Least Significant Difference method at a significance level of 0.10. Each site was also classified as responsive ($P < 0.10$) or non-responsive to P fertilization using a single-degree-of -freedom contrast that compared the no P control yield against the yield of wheat fertilized with 60 to 150 lb P_2O_5/acre.

RESULTS AND DISCUSSION

Site Descriptions

The soil-test level associated with the average Mehlich-3 extractable P at each site was classified as 'Very Low' (<16 ppm) at the RREC, 'Low' (16 to 25 ppm) at both PTRS sites, and 'Medium' (26 to 35 ppm) at the LMCRS (Table 1). Based on the University of Arkansas Cooperative Extension Service fertilizer guidelines for winter wheat, 100, 70 and 50 lb P_2O_5/acre would have been recommended for the Very Low, Low, and Medium soil-test P levels. For K trials, the average Mehlich-3 extractable K level was 'Medium' (131 to 175 ppm) at all three sites with a recommended rate of 60 lb K_2O/acre for wheat. For the micronutrient trial, the soil pH was 7.3 and Mehlich-3 extractable Zn was 1.8 ppm. The soil would be classified as 'Low' (1.6 to 2.5 ppm) in Zn, but no Zn fertilizer would have been recommended for wheat.

Wheat Response to P-Fertilizer Rate

Three of the four P trial sites were responsive to P fertilization (Table 2) with the lone unresponsive site being PTRS-L. Wheat fertilized with 60 to 150 lb P_2O_5/acre produced average yields that were 5 to 10 bu/acre greater than wheat receiving no P. The maximum yield increase from P fertilization was 9 to 12 bu/acre at the RREC, which had the lowest soil-test P, and required 90 to 150 lb P_2O_5/acre to maximize wheat yield. Statistical analysis using the LSD method failed to show significant yield differences among P fertilizer rates at LMCRS and PTBS-C, but results show a clear trend for yields to increase numerically at both sites when adequate P was applied.

Phosphorus rate trials with winter wheat have been established and harvested at 28 sites since 2002. Trial results were summarized into six soil-test P categories to outline the frequency and magnitude of significant wheat yield increases to P fertilization on silt loam soils (Table 3). Significant wheat grain yield increases to P fertilization are most common and largest in soils having Mehlich-3 extractable P values ≤10 ppm. Significant and positive yield increases to P fertilization have occurred in 56% of soils having soil-test P between 11 and 30 ppm. Soil test ranges that contain <5 observations require additional research. The relative yield of wheat receiving no P fertilizer regressed against Mehlich-3 soil P using a linear-plateau model predicted the critical soil-test P for winter wheat was 50 ppm (plateau at 96.6 % relative yield, $r^2 = 0.36$).

Wheat Response to K- and Zn-Fertilization

Potassium and Zn fertilization had no significant effect on winter wheat yield at any of the sites (Tables 4 and 5). The single-degree-of-freedom contrast analysis also showed that none of the three sites were responsive to K fertilization. The limited amount of information we have collected on wheat response to Zn fertilization during the last two years suggests that Zn is not a common yield-limiting nutrient on alkaline soils with low soil-test Zn.

PRACTICAL APPLICATION

Soil test results accurately predicted the need for P fertilization on three of four sites conducted during the 2009-2010 growing season. The coefficient of determination for the correlation between Mehlich-3 P and wheat relative yield is relatively low and typical for soil-test P correlations with crop yield. Conceptually, yield increases from P fertilization should be common and larger on soils with very low or low soil-test P and both would be expected to diminish as soil-test P increases. In this regard, soil-test P reflects the relative availability of P for wheat with reasonable accuracy. Wheat appears to be less responsive to K fertilization and additional research is needed to clarify the accuracy of correlation and calibration relationships between soil-test K, relative wheat yield, and K rate.

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Table 1. Selected soil chemical property means (n = 5) of P, K, and micornutrient fertilization trials wtih winter wheat conducted at the Lon Mann Cotton Research Station (LMCRS), two trials at the Pine Tree Research Station (PTRS), and the Rice Research and Extension Center (RREC) during the 2009-2010 growing season.

		Soil	Mehlich-3 extractable nutrients									
Site	SOM	pH	P[z]	K[y]	Ca	Mg	S	Na	Fe	Mn	Cu	Zn[x]
	(%)		--					(ppm)				--
Phosphorus Trials												
LMCRS	1.6	6.2	31	115	877	115	6	8	124	123	1.2	1.2
PTRS-C	2.6	7.3	18	107	1464	302	7	17	235	243	1.6	1.7
PTRS-L	3.0	7.5	19	102	1590	312	7	20	249	224	2.0	1.3
RREC	2.0	5.5	11	121	973	158	13	48	351	156	1.4	0.5
Potassium Trials												
LMCRS	1.6	6.2	32	117	983	139	7	9	135	110	1.2	0.9
PTRS-C	2.7	7.6	22	107	1674	303	7	17	259	175	1.3	1.3
PTRS-L	3.0	6.9	22	108	1472	297	7	14	282	174	1.5	1.9
Micronutrient Trials												
PTRS-L	3.1	7.3	14	94	1560	296	13	17	213	309	1.5	1.8

[z] Standard deviation (n = 5) of soil-test P in P trials was 2.2 ppm for LMCRS, and 3.3 ppm for PTRS-C, 2.3 ppm for PTRS-L, and 1.6 ppm for RREC.

[y] Standard deviation (n = 5) of soil-test K in K trials was 12 ppm for LMCRS, 25 ppm for PTRS-C, and 4 ppm for PTRS-L.

[x] Standard deviation (n = 6) of soil-test Zn in micronutrient trials was <0.3 ppm.

Table 2. Winter wheat grain yield as affected by P fertilizer rate at the Lon Mann Cotton Research Station (LMCRS), two trials at the Pine Tree Research Station (PTRS, Calhoun or Loring soil), and the Rice Research and Extension Center (RREC) during the 2009-2010 growing season.

	Grain yield			
P rate	LMCRS	PTRS-L	PTRS-C	RREC
(lb P_wO_5/acre)	--	(bu/acre)		--
0	82	95	81	54
30	90	96	82	61
60	89	94	84	59
90	86	93	85	63
120	88	94	89	66
150	85	95	86	66
LSD0.05	NS[z]	NS	NS	4
P-value	0.1671	0.8778	0.3058	0.0010
SDF contrast[y]	0.0558	0.6208	0.0863	0.0001

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

[y] SDF = single-degree-of-freedom contrast compares yields of wheat receiving no P against the yield of wheat receiving 60 to 150 lb P_2O_5/acre.

Table 3. Summary of wheat grain yield responses to P fertilization based on soil-test (Mehlich-3) P increments in the 0- to 4-inch depth.

Mehlich-3 soil P	Total sites	Responsive sites	Response frequency	No P Avg. yield	No P yield averages[z] % yield	Increase
(ppm)	-------------(No.)	-----------------	(% of sites)	(bu/acre)	(% relative)	(bu/acre)
≤10	3	3	100	43.5	76.3	10.5
11-20	7	4	57	63.9	89.5	6.6
21-30	9	5	56	53.4	85.3	9.0
31-40	3	1	33	71.0	93.3	5.2
41-50	3	0	0	52.5	92.9	3.8
>50	3	0	0	66.3	96.6	2.3

[z] % relative yield indicates the mean yield of wheat receiving no P compared to the maximum yield of wheat receiving P. 'Increase' indicates the yield difference between wheat receiving no P and the maximum yield of wheat receiving P.

Table 4. Winter wheat grain yield as affected by K fertilizer rate at the Lon Mann Cotton Research Station (LMCRS) and two trials at the Pine Tree Research Station (PTRS) during the 2009-2010 growing season.

K rate	Grain yield LMCRS	PTRS-L	PTRS-C
(lb K_wO/acre)	---(bu/acre)	---	
0	87	96	92
30	82	97	91
60	87	91	90
90	87	93	86
120	89	93	88
150	89	91	90
P-value	0.3240	0.8437	0.5367
LSD(0.10)	NS	NS	NS

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

Table 5. Winter wheat grain yield as affected by Zn fertilizer treatment at the Pine Tree Research Station (PTRS-L) during the 2009-2010 growing season.

Fertilizer[z]	Zn rate	Grain yield
	(lb Zn/acre)	(bu/acre)
MAP (no Zn)	0	88
MAP + $ZnSO_4$	10	85
MAP + Zn-LS	10	86
MESZ	1.5	85
P-value		0.7530
LSD(0.10)		NS[y]

[z] All treatments received 60 lb P_2O_5/acre as MAP (11-52-0) or MESZ (12-40-0-10S-1Zn). Three different Zn fertilizer were used including: MESZ (1% Zn), Zn Gro (35.5% Zn, $ZnSO_4$), and Zn lignosulfonate (10% Zn, Winfield Solutions, LLC).

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

Soil Test and Bermudagrass Forage Yield Responses to Five Years of Phosphorus and Potassium Fertilization

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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 four years of fertilization and forage yield during the fifth 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 four years of forage yield and soil test results have been reported by Slaton et al. (2007, 2008a,b, 2009a,b, 2010).

Composite soil samples were collected from each plot in March 2010 to a depth of 4 inches from each plot to monitor changes in soil-test P and K following four 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 20 April (green-up), 3 June following the first harvest, and 19 July following the second harvest. Phosphorus fertilizer (100 lb triple superphosphate/acre) was broadcast applied to the K-rate trial at greenup.

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 the second harvest.

Nitrogen fertilizer was applied as 100 lb $(NH_4)_2SO_4$/acre plus 300 lb NH_4NO_3/acre on 29 April (greenup) and following the second harvest on 19 July (~120 lb N/acre). Following the first harvests, 120 lb N/acre as urea was applied 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 2 June, 14 July, and 1 August. 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 v. 9.1 (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 where the whole plot was annual fertilizer rate and the subplot was year. 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-test P and K values were changed significantly by annual P and K fertilization rate (Table 2). As expected, soil-test P and K declined when suboptimal P or K rates were applied with the greatest changes occurring in the first two or three years of each trial. Although there were differences in soil-test P and K among annual rates for soil samples collected during 2010, the mean values were generally similar to those during 2009 and 2008. Regressing mean soil-test P or K values across time for soil that has received no P or K fertilizers in each trial suggests that soil-test availability index has decreased by 7.4 ppm P and 15.5 ppm K per year due to a negative P or K balance (P or K removed in harvested forage without P or K addition). Regressing the 2009 and 2010 soil-test means against the sum total amount of P_2O_5 applied indicated a linear relationship showing that soil-test P changed by ± 0.21 (2009) or 0.15 (2010) ppm per 1 lb P_2O_5/acre after three or four years of cropping and fertilization, respectively. The same approach for K showed a quadratic relationship for both 2009 and 2010 [ppm K (2009) = $59.9 + 0.045x - 0.00011x^2$ ($r^2 = 0.99$) or ppm K (2010) = $53.0 + 0.0087x - 0.000049x^2$ ($r^2 = 0.997$)]. The nonlinear relationship shows that soil K was depleted by removal of bermudagrass forage when insufficient K fertilizer rates were applied, which appears to be annual K rates ≤200 lb K_2O/acre.

Forage yields for each harvest accurately reflect moisture availability during the summer months. Monthly rainfall as measured at the AAREC totaled 6.0 inches in May, 0.83 inches in June, 9.9 inches in July, and 0 inches in August. No measurable rainfall was received following the second hay harvest.

In the K-rate trial, season-total forage yields in soil receiving no K fertilizer were only 39% of the maximum yield, which was produced by the highest annual K rate (Table 3). Yields in each of the three individual harvests showed similar trends as season total yield. After four years of cropping, plots receiving no K have little or no bermudagrass. Crabgrass and foxtail species now comprise the majority of the forage harvested in plots receiving no K suggesting these annual weedy grasses are more tolerant of low-K fertility. Total K removal ranged from 41 to 428 lb K_2O equivalent/acre and increased incrementally and linearly (not shown, 0.79 lb K_2O removed/1 lb K_2O applied) as annual K rate increased (Table 4). Potassium removal by harvested forage (calculated using season total mean yield and K uptake values) ranged from 17 to 70 lb K_2O equivalent per ton of dry matter with K removal increasing as annual K rate increased.

Season-total and first harvest forage yields were significantly affected by annual P fertilizer rate, but July and August harvest yields were not different among P rates (Table 3). Forage receiving no P had the lowest overall yield producing 89% of the highest yielding P rate (90 lb P_2O_5/acre/year), which was not different than all other annual P rates. Although overall and June harvest yields were greater when P was applied, the magnitude of the yield increase was relatively small compared to the response from K fertilization. Forage P removal was greatest for the first (June) harvest (Table 5) despite slightly higher yields being produced during the July harvest (Table 3). Phosphorus removed by harvested forage never exceeded the second highest annual P rate (90 lb P_2O_5/acre, Table 5). Forage removed from 9 to 15 lb P_2O_5 equivalent/ton of dry matter with the rate of removal increasing as annual P rate increased. Unlike K, P removal was nonlinear across annual P rates (lb P_2O_5 removal/acre = $45.5 + 0.308x - 0.00074x^2$, $r^2 = 0.97$).

PRACTICAL APPLICATION

Application of sufficient K to bermudagrass grown for hay production is critical to maintain high yields and prevent stand decline on soils with medium soil-test K levels. In the absence of sufficient K fertilization, bermudagrass stand has diminished and yield losses have been large and immediate. In contrast, soil P has been depleted much slower than K on a soil that had an initial P level considered above optimum (>50 ppm) and has remained above optimum after 4 years of cropping and no P fertilization. Yield increases from P fertilization have been small and intermittent during the past five years. Soil with a lower initial soil-test P is needed to gain a better understanding of the relationship between forage yield response to P fertilization and soil-test P. Hay growers should pay close attention to forage yields and nutrient removal to ensure that P and K fertilization programs are adequate and do not result in depletion or accumulation of soil P and K.

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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.

		Soil	Mehlich-3 extractable nutrients									
Nutrient	Year	pH	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	--	527	72	24	8	177	91	5.7	1.7
Potassium	2009	5.4	118	--	637	136	21	8	170	86	4.3	1.7
Potassium	2010	5.3	126	--	587	108	26	7	201	118	4.5	2.1
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	--	130	476	57	20	7	169	100	4.7	1.4
Phosphorus	2009	5.5	--	90	616	134	21	7	184	96	4.3	1.6
Phosphorus	2010	5.5	--	119	598	110	23	6	208	130	4.4	1.4

[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 2010 (following four years of fertilization) as affected by annual P or K fertilizer rate.

Annual	Potassium trial (Mehlich-3 K)					Annual	Phosphorus trial (Mehlich-3 P)				
K rate	2006	2007	2008	2009	2010	P rate	2006	2007	2008	2009	2010
(lb K_2O/acre)	(ppm)					(lb P_2O_5/acre)	(ppm)				
0	113	85	69	54	51	0	112	97	86	79	84
100	118	124	73	64	63	45	123	98	97	101	111
200	125	128	96	77	74	90	114	113	103	128	132
300	108	175	171	105	110	135	115	116	152	170	156
400	106	211	214	152	170	180	118	144	152	181	191
500	121	240	275	245	231	225	112	151	184	222	225
LSD0.05	22 (rate among years) and 28 (rate within year)					LSD0.05	11 (rate among years) and 15 (rate within years)				
p-value	<0.0001					*p*-value	<0.0001				

Table 3. Forage dry matter yields by harvest during 2010 as affected by five 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	4777	950	3009	818	0	9496	3229	4677	1590
100^{x1}	7778	3223	3944	611	45^{x1}	10340	3887	4685	1768
200^{x2}	9760	4005	4818	937	90^{x2}	10716	4125	4691	1900
300^{x3}	10904	4253	5045	1606	135^{x3}	10612	4136	4743	1733
400^{x3}	11515	4180	5674	1661	180^{x3}	10655	4245	4601	1809
500^{x3}	12239	4451	5885	1903	225^{x3}	10579	3863	4948	1768
LSD(0.05)	683	469	502	220	LSD(0.05)	782	516	274	259
p-value	<0.0001	<0.0001	<0.0001	<0.0001	*p*-value	0.0340	0.0071	0.1966	0.2875
C.V., %	6.6	12.2	9.8	16.1	C.V., %	5.7	10.0	4.4	11.2

^{z} The superscripted value indicates the number of split applications needed to apply the season-total P or K rate.

Table 4. Bermudagrass forage K concentration and aboveground K uptake as affected by annual K-fertilization rate for the fifth year of a trial conducted on a Captina silt loam in Fayetteville, Ark., during 2010.

	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	0.65	0.80	0.54	41	8	28	5
100^{x1}	1.42	0.93	0.86	106	55	44	7
200^{x2}	1.59	1.72	1.20	190	77	100	14
300^{x3}	2.23	2.10	2.37	284	114	125	46
400^{x3}	2.59	2.38	3.11	356	130	163	63
500^{x3}	3.11	2.68	3.14	428	167	189	72
LSD(0.05)	0.22	0.37	0.29	26	17	17	10
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	25.6
C.V., %	10.4	18.9	14.0	10.2	16.6	14.1	<0.0001

^{z} The superscripted value indicates the number of split applications needed to apply the season-total K rate.

Table 5. Bermudagrass forage P concentration and aboveground P uptake as affected by annual P-fertilization rate for the fifth year of a trial conducted on a Captina silt in Fayetteville, Ark., during 2010.

	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	0.22	0.18	0.21	43.6	16.2	19.5	7.8
45^{x1}	0.32	0.22	0.23	61.6	28.2	24.1	9.8
90^{x2}	0.33	0.24	0.24	66.6	31.0	25.5	10.2
135^{x3}	0.35	0.26	0.25	71.6	33.3	28.3	10.0
180^{x3}	0.37	0.27	0.28	77.2	35.9	30.2	11.8
225^{x3}	0.39	0.29	0.28	78.0	34.4	30.9	11.5
LSD(0.05)	0.04	0.039	0.02	7.2	5.0	4.8	1.8
p-value	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0006	0.0028
C.V., %	9.2	12.0	6.3	9.9	12.7	13.7	13.5

^{z} The superscripted value indicates the number of split applications needed to apply the season-total K rate.

Corn Yield Response to Nitrogen Source, Rate, and Application Strategy

N.A. Slaton, R.E. DeLong, C.G. Massey, J. Schafer, and S. Clark

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Urea is the primary nitrogen (N) fertilizer used for corn production in Arkansas making proper urea-N management critical to producing high yields. For corn grown in loamy soils, the University of Arkansas recommends 250 lb N/acre, which is usually applied in two or three split applications to help increase N fertilizer use efficiency. Growers typically preplant incorporate a portion of the N fertilizer and apply additional N at the V6 to V8 and tasseling growth stages. Efficient uptake of fertilizer N is critical for producing high corn yields and reducing N losses via leaching, runoff, ammonia volatilization, and/or denitrification.

A controlled-release N fertilizer called Environmentally Smart N (ESN, http://www.smartnitrogen.com/) is being manufactured by Agrium Advanced Technologies (Loveland, Colo.) and marketed as a N source for corn production. The ESN fertilizer is urea encased in a thin, permeable polymer-coating, which should help minimize N losses under some field conditions. The rate of N release from ESN is most influenced by temperature with the N release rate increasing as temperature increases. The ESN is now being produced at a fertilizer plant in New Madrid, Mo., and will likely be commercially available to Arkansas growers during the 2011 growing season. Although ESN has been used quite successfully in Midwest corn-producing states for several years, limited research has been conducted in the mid-South. Thus, our research objective was to compare corn yield response to urea and ESN fertilizers.

PROCEDURES

A trial was established in a commercial production field mapped as a McGehee silt loam in Jefferson County (Altheimer, Ark.). A composite soil sample (0- to 6-inches) was collected from one plot designated to receive no N fertilizer in each of five blocks. Each composite soil sample consisted of five soil cores collected from the shoulder of beds that had been formed in mid-March. The field had been fertilized with 80 lb K_2O/acre before soil samples were collected. Soil was dried, crushed to pass through a 2-mm-diameter sieve, and analyzed for soil water pH, Mehlich-3 extractable nutrients, inorganic N, and total N content (Table 1).

The experiment included 15 treatments arranged in a randomized complete block (*n* = 5) design. Each plot was 4 rows (38-inch wide rows) wide and 30 ft long. The blocks were situated perpendicular to the row direction. The primary treatments (10) included three N rates 70, 140, and 210 lb N/acre applied as preplant urea, preplant ESN, and urea applied in split applications (preplant and V6) compared to a no-N control. Four additional N treatments of interest were added to the study including 140, 210, and 255 lb N/acre as combinations of ESN applied preplant plus urea applied at V6, and 140 and 210 lb N/acre as ESN applied preplant plus urea applied at tasseling. The rates and times of each fertilizer application are summarized in Table 2. Preplant N was broadcast by hand onto the dry beds on 31 March and incorporated the next day when the beds were reformed immediately before corn (Pioneer 33B49) was planted. At the V7 stage (12 May), urea was hand broadcast to a dry soil surface to the designated plots and followed by irrigation (e.g., furrow irrigation) to incorporate the urea. The tasseling application was made on 7 June immediately before irrigation.

Corn was furrow-irrigated as needed by the cooperating grower. Each replicate was 32-corn rows wide (8 plots) and 60-ft deep (2 plots), which allowed for irrigation water to pass through each replicate before entering into the next replicate. Replicates were positioned in this manner (i.e., across rows) to account for NO_3-N that could potentially move with irrigation water and influence corn response to N.

At maturity, the middle 20 ft of the two center rows in each plot was marked, the total number of plants were counted, corn was hand-harvested and placed into labeled burlap bags, and transported to the Pine Tree Research Station where it was shelled in a small-plot combine. Grain weight and moisture content were determined and yields were adjusted to a uniform moisture content of 15.5% and expressed as bu/acre. The average stand density in harvested areas was 33,698 plants/acre.

The experiment was a randomized complete block design (RCB) with five blocks. Analysis of variance was performed with the Proc Mixed procedure of SAS v9.1. (SAS Institute, Cary, N.C.). Two statistical analyses were performed including one that included all 15 treatments (RCB) and a second that included only the three N rates (70, 140 and 210 lb N/acre) receiving preplant ESN, preplant urea, or a portion of the urea applied preplant with the balance of N sidedressed at the V7 stage (factorial treatment structure). When appropriate, Fisher's Protected Least Significant Difference method was used to separate means at a significance level of 0.05.

RESULTS AND DISCUSSION

The total amount of precipitation recorded at Pine Bluff, the closest weather station to the field, totaled 2.7 inches during April, 3.8 inches during May, 0.7 inches in June, and 3.8 inches in July. Rainfall and temperatures following planting and emergence were ideal for early season corn growth. Based on weather and field traits (e.g., drainage), early-season N losses in this field were believed to have been low.

Significant corn yield differences existed among the 15 N fertilizer treatments (Table 2). Corn receiving no N produced the lowest yield of 135 bu/acre. In general, corn yields increased as N rate increased (Tables 2 and 3). Treatments receiving the same total N rate produced the same yield in all cases except one (Table 2). Corn fertilized with 140 lb N/acre as ESN produced lower yields than corn receiving 140 lb N/acre as Urea-SPL. Although this trial was not designed to answer all questions pertaining to N fertilization of corn, several items of specific interest should be noted. Application of N to corn at tasseling provided no additional yield increase above the yields produced by most other treatments receiving the same total amount of N. However, corn yields receiving the tassel N were greater than the yield of corn fertilized with the same preplant ESN rate. Both observations suggest that the tassel N is beneficial and needed when insufficient N is applied and/or when N losses following early season N applications are great. The optimum N rate for this soil appears to be between 160 and 230 lb N/acre (includes 21 lb N/acre as ammonium sulfate applied by producer) because grain yields were quite uniform among the six N treatments fertilized with 210 lb N/acre rates (Table 2).

Finally, corn fertilized with equal preplant N rates as ESN and urea produced statistically similar yields (Tables 2 and 3), which would be expected when N losses via leaching, volatilization, and/or denitrification are low. The ESN would be expected to minimize fertilizer N loss via these pathways when field conditions are favorable for significant N loss. Environmental and field (i.e., surface drainage) conditions were not highly favorable for leaching or denitrification during the first 8 weeks after planting and NH_3 loss should have been low since preplant urea was incorporated within 24 hours.

PRACTICAL APPLICATION

Based on this limited data, ESN appears to be a suitable alternative N fertilizer source for irrigated corn production in Arkansas. These results suggest that ESN and urea are equal N sources when conditions for N loss are minimized via proper management and ideal weather conditions. The polymer-coated urea should help reduce early season N losses via denitrification and leaching in years when rainfall is frequent and abundant. However, additional research is needed to evaluate the consistency of the responses.

Table 1. Selected soil properties (0- to 6-inch depth) for a corn N fertilization trial conducted in Jefferson County, Ark., during 2010.

	Total		Inorganic N		Mehlich-3					
pH	C	N	NH_4-N	NO_3-N	P	K	Ca	Mg	S	Zn
	------ (%) -------		---------- (ppm) ----------							
7.0	0.90	0.080	15	14	27	99	1218	176	8	3.6

Table 2. The effect of N fertilizer source and N rate on corn grain yield (15.5% moisture) and harvested plant population for a trial located in Jefferson County, Ark., near Altheimer.

	N rate					Plant
N source	Total N[z]	Preplant N	V7 N	Tassel N	Yield	population[y]
	-- (lb N/acre)			-----------------------------------	(bu/acre)	(no.)
No N	0	0	0	0	135	98.8
ESN	70	70	0	0	163	98.2
Urea-PP	70	70	0	0	167	97.4
Urea-SPL	70	0	70	0	183	100.0
ESN	140	140	0	0	190	95.0
Urea-PP	140	140	0	0	204	96.2
Urea-SPL	140	45	95	0	215	98.0
ESN-Urea	140	80 (ESN)	60 (urea)	0	197	97.2
ESN+Tas	140	70 (ESN)	0	70 (urea)	200	97.2
ESN	210	210	0	0	218	97.4
Urea-PP	210	210	0	0	217	95.4
Urea-SPL	210	70	140	0	220	97.2
ESN-Urea	210	150 (ESN)	60 (urea)	0	220	99.0
ESN+Tas	210	140 (ESN)	0	70 (urea)	227	100.4
ESN-Urea	255	195 (ESN)	60 (urea)	0	212	95.2
				LSD0.05	20	NS
				P-value	<0.0001	0.3431
				C.V., %	8.1	3.6

[z] Test area (all treatments) received a uniform application of 21 lb N/acre as ammonium sulfate that is not accounted for in the total N applied column.

[y] Plant population is the total number of harvested plants in the harvested area, which consisted of a 20 ft length in each of the two middle corn rows (40 row ft total).

Table 3. Comparison of selected N fertilizer treatments that received a total of 70, 140 and 210 lb N/acre. The interaction between N source and rate was not significant, but each main effect was significant. Refer to Table 2 for the exact times and rates that each N source and rate were applied.

Fertilizer, application time	Grain yield	N rate	Grain yield
	(bu/acre)	(lb N/acre)	(bu/acre)
Urea, preplant	196 ab[z]	70	171 a
ESN, preplant	190 b	140	203 b
Urea, preplant fb V7	206 a	210	218 c

[z] Mean yield values within a column followed by the same letter are not statistically different.

Soybean Yield Response to Phosphorus and Potassium Fertilization

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

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Soybean [*Glycine max* (L.) Merr.] grown on silt- and sandy-loam soils in Arkansas may require phosphorus (P) and/or potassium (K) fertilizer to avoid deficiencies or maintain adequate soil availability. 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. Potassium research with soybean is now addressing other aspects of K fertilization, such as time of fertilization.

Refining soil-test based recommendations for P fertilization of soybean has 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 statistically 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 2010 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 and Extension Center, RREC) and in a commercial field in Poinsett County during 2010. Soil and agronomic information for each location is listed in Table 1. In the Poinsett County field, P and K fertilizers were applied to the surrounding field, but not to the research area. A maturity group IV or V variety was grown at each site. For the study conducted in Poinsett County, 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 10- 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). 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-LTK)

In 2002, a long-term K fertilization trial (PTRS-LTK) was established and cropped to rice at the PTRS (PTRS-39 and -40). In 2010, the ninth year of the study, soybean was grown following the 2009 rice crop (Table 1). Soil samples (0- to 4-inch depth) were collected from each plot in April 2010 and processed as described previously. The research area was carefully tilled to remove ruts formed during the 2009 rice harvest. Soybean (Armor 47F8) was planted into a stale seedbed on 28 April following the annual application of muriate of potash treatments ranging from 0 to 160 lb K_2O/acre. Boron (1 lb B/acre as granubor) and triple superphosphate (50 lb P_2O_5/acre) were broadcast applied before planting. Trifoliate leaf samples were collected from each plot on 20 July. The trial was a randomized complete block design with nine blocks containing each of the annual K rates. Soybean were flood irrigated as needed. Soil-test K, leaf nutrient concentration and grain yield results from only the 2010 production year are summarized in this report.

RREC Annual Fertilization Trials

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; but, in 2009, the entire research area was cropped to soybean after stand failures of the rice and soybean planted in April. Soil samples were collected in April 2010, about two months later than soil samples are usually collected (due to wet field conditions). Phosphorus or K treatments have been applied annually to the same plots at rates of 0, 40, 80, 120, and 160 lb P_2O_5 or K_2O/acre as triple superphosphate or muriate or potash, respectively (Table 1). Each nutrient trial (RREC-K or RREC-P) is a randomized complete block design with six replications of each fertilizer rate. Muriate of potash was applied to the P trial and triple superphosphate was applied to the K trial to maintain uniform availability of these nutrients. Trifoliate leaf samples were collected from each plot of both trials on 21 July. Soil-test P and K, leaf nutrient concentration, and grain yield results from only the 2010 production year are summarized in this report.

Phosphorus Rate Trials

Phosphorus fertilization trials were conducted at three sites (Poinsett, PTRS-N, and PTRS-W, Table 1) and each 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) and granular B (1 lb B/acre) were uniformly applied to ensure that K was not yield limiting. Soil samples (0- to 4-inch depth) were collected before planting or emergence at each site. Trifoliate leaf samples were collected from the PTRS-W (20 July) and Poinsett (26 July) sites. Each trial was a randomized complete block design with five (Poinsett) or six (PTRS sites) replications.

Potassium Time and Rate Trials

A K fertilizer trial was conducted at the PTRS (PTRS-KT) to examine the effects of rate and time of K fertilization on soybean yield (Table 1). Soybean were fertilized with muriate of potash at three rates including 45, 90, and 135 lb K_2O/acre broadcast to the soil surface shortly after emergence (V2 stage, 2 June) and post-emergence at an early reproductive growth stage (R2 to R3 stage, 4 August). Triple superphosphate (50 to 60 lb P_2O_5/acre) and 1 lb B/acre were broadcast to the area to ensure these nutrients were not yield limiting. Trifoliate leaf samples were collected on the same day that the last K treatments were applied. The experiment was a randomized complete block design with a 3 (K rate) by 2 (K time) factorial treatment structure compared to a no K control. Each treatment was replicated five times.

Grain yield was measured in all trials by harvesting a 12- to 20-ft long section of the middle of each plot 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

Soil and Crop Responses to Annual Fertilization

Soil test (Mehlich-3) P and K in the multi-year trials (PTRS-LTK, RREC-K, and RREC-P) increased numerically with each incremental increase in annual P or K fertilizer rate (Table 3). The increases between nutrient rates were often significant. For each site there was a strong linear relationship ($r^2 > 0.95$, not shown) between the mean soil-test P or K availability index values from 2010 samples and the cumulative amounts of K_2O or P_2O_5 applied during the previous three (RREC) or eight (PTRS) years of fertilization. The relationships showed that soil test P (slope = 0.056 ppm P/1 lb P_2O_5 applied) and K (slope = 0.13 ppm K/1 lb K_2O applied) of the Dewitt silt loam increases by 1 ppm for each 17.9 lb P_2O_5/acre and 7.7 lb K_2O/acre. In contrast to the Dewitt soil, the Calhoun soil at the PTRS requires 38.0 lb K_2O/acre (slope = 0.0263 ppm K/1 lb K_2O applied) to increase soil-test K by 1 ppm. Differences in the amount of K fertilizer needed to increase soil-test K between the two soils is likely from clay mineralogy and relative K availability.

Trifoliate leaf P and K concentrations of soybean were always significantly affected by fertilization rate with leaf concentrations increasing as annual nutrient rate increased (Table 4). Leaf K concentrations from only the PTRS-LTK trial were deficient (<1.5% K). At the RREC, leaf P and K concentrations of soybean receiving either no P or no K fertilizer were low (<0.30% P or <1.8% K) or marginally sufficient. Yield differences among annual fertilizer rates were significant only in the PTRS-LTK trial. As observed in previous years, soybean yields were greatest in soil that received the greatest annual K rate.

Phosphorus Rate Trials

Soybean at the PTRS-N site suffered from poor overall growth due to an unknown cause, but, based on symptoms and soil test results (Table 2), Mn deficiency was suspected as one possible cause. Despite three foliar Mn applications of 0.5 to 1.25 lb Mn/acre (as Mn sulfate), soybean growth was poor for the duration of the season and varied within the research area. Leaf samples were collected only from selected plots for troubleshooting the potential problem (data not shown). At the other two sites, trifoliate leaf samples were collected at the R2 stage and showed that leaf P increased as P fertilization rate increased at the Poinsett site, but was unaffected by P fertilization at the PTRS-W site (Table 5). No growth responses from P fertilizer rate were visually evident at either site. Despite two sites having Mehlich-3 extractable P values <12 ppm, soybean yield was not affected by P fertilization at any site. The lack of positive responses to P fertilization on soils low in P has been the norm in most P fertilization trials, which suggests that soybean is relatively unresponsive to P fertilization in the production systems and soils common to Arkansas or Mehlich-3 P is not a good indicator of soil-P availability.

Potassium Fertilization Time

Trifoliate leaf K concentration of soybean at PTRS-KT was significantly affected by K fertilizer rate applied at the V2 stage (Table 6). Leaf K concentrations of soybean in plots designated to receive K during reproductive growth were similar to the leaf K concentrations of soybean in the no K controls indicating the research area was relatively uniform. The ANOVA indicated that the main effects of application rate (p = 0.9158), time (p = 0.1190), and their interaction (p = 0.5518) had no significant effect on soybean yield. A second ANOVA that evaluated only K application time (p = 0.0019) data pooled across K rates showed that soybean yields were equal when K was applied and greater than the yield of soybean receiving no K. The mean yields do hint that some yield potential was lost when K fertilization was delayed until early reproductive growth or when the K rate was insufficient (45 lb K_2O/acre).

PRACTICAL APPLICATION

Projects that are evaluating the longer-term effects of P and K fertilization show that soil-test P and K and plant P and K nutrition are affected by annual fertilization rate. Yields of soybean grown on a Dewitt silt loam have not yet been affected by application of no or insufficient P and K rates, but soil test results suggest that the soil is being mined of these nutrients and will eventually become yield limiting. In contrast, soybean yields on a soil that appears to readily fix K were increased by 36% to 72%, depending on annual K rate, compared to soil that has been cropped and received no K in over 10 years.

During the past seven years, we have established over 40 P-rate trials in Arkansas fields cropped to irrigated soybean. Significant soybean yield responses to P fertilization have been measured in 10 of 40 fields used in our soil test correlation analysis. Although this is encouraging, soybean has failed to respond positively to P fertilization on 12 of 20 soils with P availability index values currently considered Low (16-25 ppm) or Very Low (<16 ppm). Overall, soil-test P has accurately predicted soybean response to P fertilization in 60% of the sites. Based on results from these 40 P trials, soybean recommendations for the 2011 year will be reduced by 20 lb P_2O_5/acre in the Very Low, Low, and Medium (26 to 35 ppm) levels such that the updated recommendations will be 80, 60, and 40 lb P_2O_5/acre in each of these soil-test levels, respectively. Phosphorus recommended for the Medium soil test level is intended to help maintain soil P levels by replacing a portion of the P that will be removed in harvested grain.

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Table 1. Selected soil and agronomic management information for P and K fertilization trials conducted in 2010.

Site	Soil series	Cultivar	Previous crop	Tillage	Row width	Plant date
Poinsett	Hilleman	NK51T8	Rice	Conventional	7.0	31 May
PTRS-W & PTRS-KT	Calhoun	Armor 53-Z5	Soybean	Conventional	15.0	22 May
PTRS-N	Calloway	Armor 53-Z5	Soybean	Conventional	15.0	21 May
PTRS-LTK	Calhoun	Armor 47-F8	Rice	Conventional	15.0	28 April
RREC	Dewitt	Schilinger 557RR	Soybean	No-till	7.0	12 May

Table 2. Selected soil chemical property means (n = 4-8) and standard deviation (sd) of P or K of soil from the unfertilized control in P and K fertilization trials conducted at multiple sites during 2010.

Site	Soil	Soil	Mehlich-3 soil nutrients									
(Nutrient)	OM	pH	P	K	sd	Ca	Mg	S	Fe	Mn	Zn	Cu
	(%)		---------------------- (ppm) ----------------------									
Poinsett (P)	2.3	8.3	10	68	1.4[z]	3515	255	25	280	248	7.0	1.3
PTRS-KT (K)	2.6	8.2	10	73	5.7[y]	2537	311	7	339	347	1.8	1.6
PTRS-N (P)	2.7	7.0	30	60	3.2[z]	1413	198	9	293	41	3.9	1.6
PTRS-W (P)	2.7	7.8	10	76	2.4[z]	1909	313	9	490	155	2.0	1.3
PTRS-LTK (K)	--	7.7	24	--[x]	--	2472	388	26	456	318	12.3	1.1
RREC-K (K)	--	5.3	36	--[x]	--	731	111	10	540	158	7.3	1.4
RREC-P (P)	--	5.6	--[x]	95	--	842	129	9	441	221	7.3	1.7

[z] Standard deviation of soil-test P mean.

[y] Standard deviation of soil-test K mean.

[x] Soil test P and or K means for each annual P or K rate are listed in Table 3.

Table 3. Mehlich-3 extractable soil-P or -K means as affected by annual P or K fertilization rate for three multi-year trials from samples collected in April 2010 at the Pine Tree Research Station (PTRS-LTK) or the Rice Research and Extension Center (RREC) in 2010.

Annual	RREC[z]		PTRS-LTK[y]
nutrient rate	P rate trial	K rate trial	K rate trial
(lb K_2O or P_2O_5/acre)	(ppm P)	--------------------- (ppm K)	---------------------
0	13.8	106	35
40	20.2	112	44
80	26.8	143	54
120	31.5	148	57
160	41.7	168	64
LSD0.10	4.4	13	6
p-value	<0.0001	<0.0001	<0.0001

[z] Fertilization of trials at the RREC was initiated in 2007. Cumulative fertilizer rates can be calculated as the rate shown × 3.

[y] Fertilization of the PTRS trial was initiated in 2002, but annual rates were changed after 2006. Cumulative rates after the 2009 season were 0, 270, 540, 810, and 1080 lb K_2O/acre.

Table 4. Trifoliate leaf P or K concentration and seed yield of soybean as affected by annual P or K fertilization rate for three multi-year trials from samples collected in April 2010 at the Pine Tree Research Station (PTRS-LTK) or the Rice Research and Extension Center (RREC) in 2010.

Annual	RREC-P trial		RREC-K trial		PTRS-LTK trial	
nutrient rate	Leaf P	Yield	Leaf K	Yield	Leaf K	Yield
(lb K_2O or P_2O_5/acre)	(% P)	(bu/acre)	(% K)	(bu/acre)	(% K)	(bu/acre)
0	0.292	48	1.66	49	0.84	25
40	0.307	52	1.76	52	0.93	34
80	0.327	48	1.83	52	1.14	38
120	0.332	50	1.93	49	1.48	39
160	0.340	50	1.96	51	1.59	43
LSD0.10	0.013	NS[z]	0.11	NS	0.09	3
p-value	<0.0001	0.4798	0.0014	0.7425	<0.0001	<0.0001

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

Table 5. Trifoliate leaf P concentration and seed yield of soybean as affected by P fertilization rate at three sites including two at the Pine Tree Research Station (PTRS) and one in Poinsett County in 2010.

Annual	Poinsett County		PTRS-W		PTRS-N	
nutrient rate	Leaf P	Yield	Leaf P	Yield	Leaf P	Yield
(lb P_2O_5/acre)	(% P)	(bu/acre)	(% P)	(bu/acre)	(% P)	(bu/acre)
0	0.294	28	0.308	58	--	42
40	0.304	28	0.302	60	--	43
80	0.304	31	0.313	58	--	41
120	0.326	30	0.312	60	--	43
160	0.330	29	0.312	60	--	38
LSD0.10	0..021	NS[z]	NS	NS	--	NS
p-value	0.0309	0.8540	0.7465	0.9520	--	0.1802

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

Table 6. Trifoliate leaf K concentration and seed yield of soybean as affected by K fertilization rate and time at the Pine Tree Research Station (PTRS-KT) in 2010.

K Fertilizer	K Application	PTRS-KT trial[z]	
rate	time	Leaf K[y]	Yield
(lb K_2O/acre)	(% K)	---------------(bu/acre) -------------	
0	None	1.14 b	45
45	V2	1.17 b	55
45	R2-3	1.09	54
90	V2	1.34 a	57
90	R2-3	1.18	54
135	V2	1.44 a	59
135	R2-3	1.14	52
LSD0.10		0.16	NS
p-value		0.0197	0.5518

[z] Leaf K means for soybean receiving no K or K at the V2 stage (means followed by small case letters) were compared statistically. Means for the R2 to R3 stage application are listed as general information as leaf samples were taken the same day that the R2 to R3 K fertilizer application was made.

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