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Wayne E. Sabbe Arkansas Soil Fertility Studies 2015

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Wayne E. Sabbe
ARKANSAS
SOIL FERTILITY STUDIES
• 2015 •

Nathan A. Slaton, Editor

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Cover: Rice is planted annually on about 1.5 million acres in Arkansas, which accounts for about 50% of the rice grown in the U.S. and ranks Arkansas 1st in production among rice-producing states. The cover photograph shows seedling rice that is zinc deficient. The lower leaves of zinc-deficient seedlings commonly have a chlorotic midrib with bronzing on the leaf blade. The picture was taken from a production field near England, Arkansas. (photograph by Tyler Richmond, Graduate Research Assistant, University of Arkansas System Division of Agriculture, Department of Crop, Soil, and Environmental Sciences).

Layout and editing by Marci Milus
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Arkansas Agricultural Experiment Station, University of Arkansas System Division of Agriculture, Fayetteville. Mark J. Cochran, Vice President for Agriculture; Clarence E. Watson, AAES Director and Associate Vice-President for Agriculture–Research. WWW/InddCC2015.

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WAYNE E. SABBE
ARKANSAS
SOIL FERTILITY STUDIES
– 2015 –

Nathan A. Slaton, Editor

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University of Arkansas System
Division of Agriculture
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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 2015 Arkansas 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 2014. 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.

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 2015 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 System Division of Agriculture's Soil Testing and Research Laboratory in Marianna between 1 January 2014 and 31 December 2014 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), zinc (Zn) and sulfate (SL_r-S). Soil pH and Mehlich-3 extractable (analyzed using inductively coupled argon 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

The cumulative number of samples and acres from information listed in Tables 1 to 4 may vary somewhat because not all samples included SAN, GA, and/or previous crop. Between 1 January 2014 and 31 December 2014, 167,988 soil samples were analyzed by the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna. After removing standards and check soils measured for quality assurance (14,047), the total number of client samples was 152,908 (Table 1). A total of 46,833 of the submitted soil samples were collected using the ‘field-average’ sampling technique, representing 1,311,854 acres for an average of 28 acres/sample, and had complete data for county, total acres, and soil pH, P, K, and Zn. The difference of 106,075 samples between the total samples and those with reported acreage were grid samples collected primarily from row-crop fields (105,047) or other samples designated for research or troubleshooting field problems (1028).

Values listed in Table 1 include the number of grid samples analyzed but do not include the acreage of grid soil samples. Each grid soil sample likely represents from 2.5 to 5.0 acres. Clients from Crittenden (21,520, 99% from five clients); Craighead (19,186, 93% from four clients); Clay (Corning and Piggott offices, 13,072, 68% from three clients); Little River (8522, 100% from two clients); and Lawrence (7641, 99% from one client) counties submitted the most grid soil samples for analyses. The large percentage of the total samples processed through the Crittenden, Craighead, Clay, Little River, and Lawrence offices were submitted by only a few clients and likely represent commercial grid soil sample collection services.

Soil samples from the Bottom Lands and Terraces and Loessial Plains, primarily row-crop areas, represented 45% of the total field-average samples and 79% of the total acreage (Table 2). The average number of acres represented by each field-average soil sample from the ten geographic areas ranged from 7 to 55 acres/sample. Soil association numbers show that most field-average samples were taken from soils common to row-crop and pasture production areas (Table 3). The five soil associations having the most samples submitted were 4 (Captina-Nixa-Tonti), 44 (Calloway-Henry-Grenada-Calhoun), 45 (Crowley-Stuttgart), 32 (Rilla-Hebert), and 12 (Leadvale-Taft). However, the five soil associations representing the largest acreage were 44, 45, 22 (Foley-Jackport-Crowley), 32, and 4, which represented 39%, 18%, 6%, 6%, and 4% of the total sampled acreage, respectively.

Crop codes listed on the field-average samples indicate that land used for i) row-crop production accounted for 75% of the sampled acreage and 40% of submitted samples, ii) hay and pasture production accounted for 15% of the sampled acreage and 20% of submitted samples, and iii) home lawns and gardens accounted for 10% of sampled acreage and 33% of submitted samples (Table 4). In row-crop producing areas, 62% of the soil samples are collected following soybean in the crop rotation. The cumulative acreage soil sampled following soybean represents 18% of the annual soybean acreage.

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 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 results for cropping systems can be carefully compared by recognizing that 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 median pH of most soils in Arkansas ranges from 5.6 to 7.1; however, the predominant soil pH range varies among GA (Table 5), county (Table 6), and last crop produced (Table 7).

Table 7 summarizes the percentage of acreage from field-average soil samples that falls within selected soil-test levels (as defined by 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 P concentration occurs in samples following rice in the rotation and the lowest median K concentration is for soils following winter wheat and irrigated grain sorghum. Samples collected following cotton production have the highest median P and K concentrations. The median soil K is lowest in soils used for hay production. The median soil-test P and K for the hay crop codes has decreased for several years and suggests that P and K inputs as fertilizer or manure have declined and K availability, but not P, is likely limiting forage yields. The highest median concentrations of P, K, and Zn occur in soils used for fruit production and non-agricultural purposes (e.g., lawn, turf, garden, and landscape/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, Craighead, Poinsett, Clay, and Lonoke counties. Fertilizer tonnage does not account for the use of fresh animal manures or other non-regulated 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 (Table 9).

The availability of soil sulfur (S) for crop growth is important for its role in plant protein formation. Tables 10, 11, and 12 show by county in 2012, 2013, and 2014, respectively, four ranges of S levels. The average soil-test S level slightly decreased from 2012 to 2014 by <1 part per million (ppm), however the median concentration was 14 or 15 ppm for all three years. The counties with the greatest median S concentrations (18 to 20 ppm) were located in western Arkansas, (e.g., Benton, Carroll, Howard, Logan, Madison, Washington, etc.) most notably in the Ozark Highlands and Boston Mountains areas. The counties with the lowest median S concentrations of 8 to 10 ppm were generally located in eastern Arkansas [e.g., Crittenden, Mississippi, Clay (Piggott), Desha, etc.] in the Bottom Lands and Terraces. Less than 10% of the soils usually had <5 ppm of extractable S, but a large percentage of the soils used for row-crop production had S concentrations of 5 to 10 ppm which is often considered low for the production of crops, especially on permeable soils where S may leach below the root zone.

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. For the soil samples submitted in 2014, 67% of the samples and 90% of the represented acreage had commercial agricultural/farm crop codes. Likewise, 98% of the fertilizer and soil amendment tonnage sold was categorized for farm use. Five counties in eastern Arkansas (Arkansas, Craighead, Poinsett, Clay, and Lonoke) accounted for 30% of the total fertilizer sold. The soil status of Mehlich-3 S was summarized for three years and showed that soil S concentrations are geographically variable and probably linked to cropping system, soil properties (e.g., organic matter), and the use of fertilizers versus manure as nutrient sources for crop production.

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 System Division of Agriculture.

Table 1. Sample number (includes grid samples) and total acreage by county for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2014 through 31 December 2014.

County	Acres sampled	% of total acres	No. of samples	% of total samples	Acres/ sample	County	Acres sampled	% of total samples	No. of samples	% of total sample	Acres/ sample
Arkansas, DeWitt	99,284	8	1899	1	52	Lee	312,490	24	4730	3	66
Arkansas, Stuttgart	12,003	1	448	0	27	Lincoln	3234	0	160	0	20
Ashley	9029	1	418	0	22	Little River	7135	1	8649	6	1
Baxter	3393	0	497	0	7	Logan, Booneville	1	0	1	0	1
Benton	10,522	1	1025	1	10	Logan, Paris	5837	1	381	0	15
Boone	8614	1	625	0	14	Lonoke	104,494	8	3626	2	29
Bradley	380	0	51	0	8	Madison	9767	1	584	0	17
Calhoun	179	0	39	0	5	Marion	2178	0	163	0	13
Carroll	14,529	1	760	1	19	Miller	2472	0	328	0	8
Chicot	20,033	2	423	0	47	Mississippi	12310	1	7865	5	2
Clark	985	0	209	0	5	Monroe	206,891	16	3710	2	56
Clay, Corning	10,455	1	8431	6	1	Montgomery	1107	0	148	0	8
Clay, Piggott	2571	0	4980	3	1	Nevada	979	0	101	0	10
Cleburne	5668	0	383	0	15	Newton	1477	0	167	0	9
Cleveland	1052	0	4711	3	1	Ouachita	357	0	118	0	3
Columbia	395	0	139	0	3	Perry	1054	0	102	0	10
Conway	7656	1	285	0	27	Phillips	7438	1	428	0	17
Craighead	13,430	1	19,974	13	1	Pike	3132	0	182	0	17
Crawford	4789	0	856	1	6	Poinsett	68,772	5	3592	2	19
Crittenden	12,300	1	22,004	14	1	Polk	4447	0	309	0	14
Cross	51,856	4	1063	1	49	Pope	7400	1	638	0	12
Dallas	186	0	81	0	2	Prairie, Des Arc	6222	1	198	0	31
Desha	14,682	1	4189	3	4	Prairie, De Valls Bluff	1203	0	73	0	17
Drew	3607	0	493	0	7	Pulaski	3383	0	1299	1	3
Faulkner	6992	1	758	1	9	Randolph	13,842	1	692	1	20
Franklin, Charleston	225	0	57	0	4	Saline	2062	0	1003	1	2
Franklin, Ozark	4521	0	244	0	19	Scott	2673	0	157	0	17
Fulton	2523	0	206	0	12	Searcy	1311	0	120	0	11
Garland	1675	0	1143	1	2	Sebastian	2342	0	634	0	4
Grant	1029	0	109	0	9	Sevier	3966	0	209	0	19
Greene	24,681	2	3073	2	8	Sharp	3655	0	285	0	13
Hempstead	8936	1	705	1	13	St. Francis	2450	0	3653	2	1
Hot Spring	954	0	132	0	7	Stone	1643	0	171	0	10
Howard	7496	1	384	0	20	Union	1199	0	193	0	6
Independence	7429	1	467	0	16	Van Buren	2111	0	251	0	8
Izard	3573	0	273	0	13	Washington	27,974	2	5243	3	5
Jackson	5539	0	5943	4	1	White	10,817	1	1107	1	10
Jefferson	31,750	2	4598	3	7	Woodruff	2038	0	58	0	35
Johnson	3122	0	236	0	13	Yell, Danville	4408	0	333	0	13
Lafayette	3479	0	90	0	39	Yell, Dardanelle	1277	0	64	0	20
Lawrence	32,784	3	8782	6	4	Sum or Average	1,311,854		152,908		9

Table 2. Sample number and total acreage by geographic area for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2014 through 31 December 2014.

Geographic area	Acres sampled	% of total acres	No. of samples	% of total samples	Acres/ sample
Ozark Highlands - Cherty Limestone and Dolomite	78,871	9	9,239	24	9
Ozark Highlands - Sandstone and Limestone	5,515	1	512	1	11
Boston Mountains	20,841	2	1,907	5	11
Arkansas Valley and Ridges	38,440	4	3,640	9	11
Ouachita Mountains	18,534	2	2,501	7	7
Bottom Lands and Terraces	202,361	22	7,565	20	27
Coastal Plain	22,103	2	2,797	7	8
Loessial Plains	531,361	57	9,703	25	55
Loessial Hills	9,506	1	792	2	12
Blackland Prairie	1,832	0	87	0	21
Sum or Average	929,364		38,743		24

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 2014 through 31 December 2014.

							Median			
SAN	**Soil association**	**Acres sampled**	**% of total acres**	**No. of samples**	**% of total samples**	**Acres/ sample**	**pH**	**P**	**K**	**Zn**
1.	Clarksville-Nixa-Noark	10,218	1	842	2	12	6.2	64	130	5.1
2.	Gepp-Doniphan-Gassville-Agnos	6842	1	796	2	9	6.7	64	139	7.9
3.	Arkana-Moko	21,480	2	1280	3	17	6.2	122	164	12.6
4.	Captina-Nixa-Tonti	39,366	4	6267	16	6	6.3	78	164	7.9
5.	Captina-Doniphan-Gepp	468	0	17	0	28	6.3	25	80	2.9
6.	Eden-Newnata-Moko	497	0	37	0	13	6.1	74	93	4.4
7.	Estate-Portia-Moko	446	0	33	0	14	5.7	50	74	3.1
8.	Brockwell-Boden-Portia	5069	1	479	1	11	6.3	36	97	3.5
9.	Linker-Mountainburg-Sidon	4140	1	329	1	13	5.9	67	111	5.0
10.	Enders-Nella-Mountainburg-Steprock	16,701	2	1578	4	11	5.9	86	123	6.2
11.	Falkner-Wrightsville	84	0	5	0	17	5.8	28	96	13.4
12.	Leadvale-Taft	15,961	2	1907	5	8	5.9	56	114	6.0
13.	Enders-Mountainburg-Nella-Steprock	5106	1	329	1	16	6.1	48	104	4.0
14.	Spadra-Guthrie-Pickwick	3462	0	154	0	23	5.9	75	109	8.5
15.	Linker-Mountainburg	13,827	2	1245	3	11	5.8	67	115	5.5
16.	Carnasaw-Pirum-Clebit	4108	0	429	1	10	5.9	61	102	5.7
17.	Kenn-Ceda-Avilla	2263	0	417	1	5	5.8	60	125	4.3
18.	Carnasaw-Sherwood-Bismarck	8051	1	1362	4	6	5.8	78	108	5.8
19.	Carnasaw-Bismarck	1205	0	36	0	34	6.2	198	121	5.7
20.	Leadvale-Taft	1134	0	140	0	8	5.7	70	93	7.1
21.	Spadra-Pickwick	1773	0	117	0	15	5.6	53	113	5.1
22.	Foley-Jackport-Crowley	51,574	6	1465	4	35	6.4	25	105	3.2
23.	Kobel	11,490	1	422	1	27	6.4	34	106	3.7
24.	Sharkey-Alligator-Tunica	22,235	2	1114	3	20	6.7	30	185	3.4
25.	Dundee-Bosket-Dubbs	16,432	2	642	2	26	6.5	30	115	3.2
26.	Amagon-Dundee	6924	1	242	1	29	6.4	50	143	4.3
27.	Sharkey-Steele	204	0	46	0	4	6.5	53	334	5.4
28.	Commerce-Sharkey-Crevasse-Robinsonville	2177	0	67	0	33	6.4	72	176	6.3
29.	Perry-Portland	15,269	2	562	2	27	6.7	25	200	2.6
30.	Crevasse-Bruno-Oklared	147	0	15	0	10	5.7	241	142	15.4
31.	Roxana-Dardanelle-Bruno-Roellen	11,579	1	235	1	49	6.5	41	133	3.7
32.	Rilla-Hebert	51,371	6	2463	6	21	6.7	42	146	3.5
33.	Billyhaw-Perry	1058	0	28	0	38	6.4	34	169	2.9
34.	Severn-Oklared	8028	1	123	0	65	6.2	33	118	3.3
35.	Adaton	962	0	37	0	26	5.9	78	91	5.5
36.	Wrightsville-Louin-Acadia	2886	0	99	0	29	6.2	33	117	3.4
37.	Muskogee-Wrightsville-McKamie	25	0	5	0	5	6.2	80	118	4.2
38.	Amy-Smithton-Pheba	400	0	120	0	3	6.1	70	106	6.4
39.	Darco-Briley-Smithdale	53	0	4	0	13	5.3	50	151	11.6
40.	Pheba-Amy-Savannah	1009	0	140	0	7	6.0	44	105	4.0
41.	Smithdale-Sacul-Savannah-Saffell	8480	1	1083	3	8	5.8	93	105	7.8
42.	Sacul-Smithdale-Sawyer	7634	1	1199	3	6	5.9	45	76	4.8
43.	Guyton-Ouachita-Sardis	4527	1	251	1	18	5.7	94	110	7.7
44.	Calloway-Henry-Grenada-Calhoun	363,366	39	6082	16	60	6.8	30	103	3.0
45.	Crowley-Stuttgart	167,995	18	3621	9	46	6.4	27	108	3.1
46.	Loring	1509	0	100	0	15	6.0	42	113	5.8
47.	Loring-Memphis	6790	1	617	2	11	6.4	37	117	5.2
48.	Brandon	1207	0	75	0	16	6.9	41	103	7.6
49.	Oktibbeha-Sumter	1832	0	87	0	21	6.2	48	134	5.3
	Sum or Average	929,364		38,743		24	6.2	61	125	5.6

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 2014 through 31 December 2014.

Crop	Acres sampled	% of total acres	No. of samples	% of total samples	Acres/ sample
Corn	73,426	7	2457	6	30
Cotton	4826	1	613	2	8
Grain sorghum, non-irrigated	1174	0	40	0	29
Grain sorghum, irrigated	3793	0	110	0	35
Rice	98,970	10	2471	6	40
Soybean	587,060	56	9609	25	61
Wheat	8609	1	264	1	33
Cool-season grass hay	5293	1	272	1	20
Native warm-season grass hay	3077	0	167	0	18
Warm-season grass hay	33,267	3	1587	4	21
Pasture, all categories	118,353	11	5963	15	20
Home garden	4992	1	4343	11	1
Turf	4736	1	1021	3	5
Home lawn	89,381	9	8508	22	11
Small fruit	841	0	508	1	2
Ornamental	2716	0	1278	3	2
Sum or Average	1,040,514		39,211		27

Table 5. The percentage of sampled acres as distributed within five soil-test levels and median soil chemical property values by geographic area for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2013 through 31 December 2013.

	Soil pH[a]						Mehlich-3 soil P[b] (ppm)						Mehlich-3 soil K[b] (ppm)						Mehlich-3 soil Zn[b] (ppm)					
Geographic area	**<5.4**	**5.4- 5.7**	**5.8- 6.2**	**6.3- 6.9**	**>6.9**	**Md[c]**	**<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	11	14	23	28	24	6.3	5	8	9	12	66	78	6	11	19	21	43	158	3	10	8	29	50	7.9
Ozark Highlands -Sandstone and Limestone	7	17	24	29	23	6.3	21	17	12	12	38	36	22	23	24	14	17	96	16	27	12	21	24	3.5
Boston Mountains	19	22	26	21	12	5.9	6	8	8	11	67	83	15	18	21	17	29	121	6	15	11	32	36	6.0
Arkansas Valley and Ridges	23	18	24	23	12	5.9	10	11	11	12	56	60	14	21	26	18	21	113	8	19	10	26	37	5.7
Ouachita Mountains	24	22	25	21	8	5.8	7	9	9	12	63	70	16	21	24	16	23	109	6	20	11	26	37	5.5
Bottom Lands and Terraces	7	9	19	35	30	6.6	14	19	20	19	38	34	6	17	25	19	33	135	10	33	17	27	13	3.4
Coastal Plain	26	18	23	22	11	5.9	14	12	8	9	57	67	28	21	19	12	20	92	12	19	8	18	43	6.0
Loessial Plains	9	10	16	28	37	6.7	14	26	24	19	17	29	7	26	39	17	11	105	14	36	17	25	8	3.1
Loessial Hills	12	14	20	25	29	6.4	14	15	16	17	38	39	10	22	30	19	19	114	8	20	10	29	33	5.4
Blackland Prairie	20	17	16	21	26	6.2	21	12	10	9	48	48	23	14	13	15	35	134	15	14	13	18	40	5.3
Average													15	19	24	17	25	118	10	21	12	25	32	5.2

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

[b] Analysis by inductively coupled argon plasma spectroscopy (ICAP) in 1:10 soil volume:Mehlich-3 volume.

[c] Md = median.

Table 6. The percentage of sampled acres as distributed within five soil test levels and median soil chemistry property values by county for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2014 through 31 December 2014.

	Soil pH^a						Mehlich-3 soil P^b (ppm)						Mehlich-3 soil K^b (ppm)						Mehlich-3 soil Zn^b (ppm)					
Geographic area	<5.4	5.4-5.7	5.8-6.2	6.3-6.9	>6.9	Md^c	<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	3	7	12	21	57	7.1	10	26	28	21	15	30	2	20	46	22	10	112	5	24	18	42	11	4.3
Arkansas, Stuttgart	1	4	14	39	42	6.8	29	31	18	12	10	22	3	42	33	7	15	96	16	34	18	26	6	3.0
Ashley	9	7	16	34	34	6.7	23	14	14	12	37	34	16	20	19	12	33	113	13	30	16	23	18	3.4
Baxter	3	6	11	25	55	7.1	6	7	9	9	69	83	6	11	20	24	39	153	2	10	6	20	62	11.9
Benton	11	15	22	29	23	6.3	3	6	5	8	78	122	7	13	18	22	40	153	2	8	7	24	59	10.4
Boone	7	17	27	29	20	6.2	5	9	12	9	65	77	13	11	20	19	37	144	4	14	10	29	43	6.6
Bradley	14	16	18	33	19	6.4	8	4	6	12	70	123	22	24	12	20	22	107	2	18	12	18	50	8.7
Calhoun	18	26	21	21	14	5.8	3	8	8	23	58	55	26	10	33	15	16	115	8	31	23	28	10	3.6
Carroll	4	15	32	33	16	6.2	1	4	3	5	87	218	8	7	11	11	63	228	2	2	2	11	83	20.9
Chicot	8	5	9	47	31	6.7	12	20	18	23	27	35	3	7	13	21	56	200	23	30	11	23	13	2.9
Clark	27	21	22	23	7	5.8	11	14	11	12	52	55	37	21	18	8	16	77	18	26	11	20	25	3.5
Clay, Corning	3	8	26	46	17	6.4	12	30	27	20	11	28	4	25	44	21	6	108	18	26	10	28	18	3.6
Clay, Piggott	7	10	23	45	15	6.4	5	13	16	22	44	46	7	21	32	22	18	118	12	33	20	30	5	3.3
Cleburne	22	17	22	25	14	6.0	9	12	13	13	53	58	20	24	23	15	18	99	17	27	10	20	26	3.7
Cleveland	11	12	26	34	17	6.3	10	18	14	18	40	42	2	6	17	24	51	177	14	35	19	27	5	3.1
Columbia	27	21	23	22	7	5.8	17	12	12	9	50	49	37	37	19	4	3	69	20	25	6	21	28	3.8
Conway	21	18	24	19	18	6.0	12	12	11	16	49	49	13	19	24	19	25	118	10	16	12	37	25	5.1
Craighead	4	6	19	38	33	6.6	11	18	18	22	31	37	8	14	24	19	35	139	8	34	24	27	7	3.4
Crawford	8	10	39	30	13	6.2	14	19	20	18	29	34	8	14	19	14	45	161	1	16	21	46	16	4.5
Crittenden	6	8	19	40	27	6.6	9	22	25	24	20	33	3	9	18	18	52	184	11	36	24	26	3	3.2
Cross	5	4	10	29	52	7.0	12	25	26	20	17	31	7	33	34	11	15	99	11	37	19	26	7	3.1
Dallas	27	12	12	30	19	6.2	5	7	14	10	64	91	19	26	21	20	14	98	11	14	5	12	58	10.3
Desha	2	5	17	38	38	6.8	9	16	20	23	32	38	3	9	19	20	49	175	7	36	21	30	6	3.4
Drew	16	10	24	41	9	6.3	15	9	8	19	49	50	12	15	20	18	35	138	10	13	19	40	18	4.5
Faulkner	27	17	23	22	11	5.9	16	14	12	14	44	44	12	23	29	18	18	110	9	28	13	22	28	4.1
Franklin, Charleston	33	16	19	14	18	5.8	30	9	7	7	47	48	25	14	18	12	31	123	11	14	18	18	39	6.2
Franklin, Ozark	25	28	26	16	5	5.7	9	12	8	10	61	81	15	20	18	14	33	127	7	17	11	21	44	6.3
Fulton	14	16	24	22	24	6.2	12	17	12	14	45	48	10	12	33	18	27	121	13	29	9	14	35	5.9
Garland	21	19	27	25	8	5.9	5	10	11	13	61	66	14	24	29	15	18	107	5	19	13	27	36	5.5
Grant	19	19	31	20	11	5.9	9	10	6	9	66	76	24	28	20	10	18	87	14	23	6	23	34	4.5
Greene	6	12	24	34	24	6.4	11	19	19	21	30	37	5	21	31	23	20	112	9	30	20	32	9	3.5
Hempstead	21	20	26	21	12	5.9	24	19	8	7	42	34	46	15	14	9	16	67	20	24	6	16	34	4.1
Hot Spring	27	15	29	24	5	5.9	11	14	8	9	58	66	29	17	22	10	22	95	17	20	10	14	39	4.4
Howard	19	26	31	16	8	5.8	3	2	2	4	89	249	6	8	16	19	51	178	2	5	3	10	80	21.5
Independence	14	15	23	33	15	6.2	9	12	14	13	52	55	20	21	22	15	22	107	9	27	9	29	26	4.4
Izard	11	22	32	22	13	6.1	10	18	11	18	43	47	11	39	22	15	13	92	14	37	7	18	24	3.0
Jackson	7	16	30	32	15	6.2	33	29	19	12	7	21	14	27	35	17	7	100	24	42	11	15	8	2.3
Jefferson	6	8	19	41	26	6.5	11	21	23	23	22	33	7	17	26	17	33	130	21	45	18	13	3	2.5
Johnson	23	18	23	26	10	6.0	4	11	12	13	60	68	12	21	28	15	24	112	4	22	13	23	38	5.0
Lafayette	24	22	9	20	25	5.9	9	14	11	17	49	49	17	18	21	14	30	117	20	17	13	21	29	4.0
Lawrence	5	11	25	37	22	6.4	22	30	21	16	11	25	12	29	32	16	11	101	14	36	14	26	10	3.0
Lee	3	6	17	44	30	6.7	5	14	19	27	35	42	1	10	30	24	35	143	27	35	13	22	3	2.4
Lincoln	19	11	21	31	18	6.2	19	12	13	25	31	41	16	22	16	16	30	111	19	20	13	20	28	3.9
Little River	10	11	22	32	25	6.4	22	24	17	18	19	28	2	15	34	22	27	129	30	40	14	13	3	2.2

continued

Table 6. Continued.

	Soil pH^a						Mehlich-3 soil P^b (ppm)						Mehlich-3 soil K^b (ppm)						Mehlich-3 soil Zn^b (ppm)					
Geographic area	**<5.4**	**5.4-5.7**	**5.8-6.2**	**6.3-6.9**	**>6.9**	**Md^c**	**<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	0	0	0	100	0	6.8	0	0	0	100	0	36	0	100	0	0	0	84	0	0	100	0	0	3.9
Logan, Paris	17	28	36	16	3	5.8	11	9	12	9	59	70	23	21	20	13	23	104	7	18	10	26	39	6.0
Lonoke	12	20	29	30	9	6.1	22	29	23	14	12	25	12	27	34	15	12	102	30	40	14	12	4	2.2
Madison	12	30	31	19	8	5.9	3	4	6	9	78	115	9	14	18	21	38	149	2	11	9	29	49	7.9
Marion	14	15	20	25	26	6.3	6	10	11	15	58	60	10	14	17	23	36	144	6	13	13	31	37	5.7
Miller	30	18	24	18	10	5.8	18	12	8	11	51	54	23	27	20	15	15	95	10	22	10	19	39	5.6
Mississippi	5	9	23	48	15	6.4	2	6	12	24	56	54	1	10	27	27	35	148	4	28	24	33	11	3.7
Monroe	16	8	11	23	42	6.8	23	26	19	17	15	36	8	32	37	17	6	100	18	35	17	26	4	2.9
Montgomery	22	23	28	20	7	5.9	6	7	13	19	55	58	20	20	21	16	23	109	3	21	1	29	37	5.5
Nevada	27	20	16	29	8	5.9	25	15	12	4	44	34	24	25	11	23	17	95	18	20	6	24	32	5.1
Newton	20	17	23	26	14	6.0	13	11	10	14	52	53	8	18	21	22	31	132	18	17	11	29	25	4.4
Ouachita	36	18	20	14	12	5.6	9	13	11	3	64	70	26	24	18	10	22	89	6	20	6	19	49	7.1
Perry	28	25	25	16	6	5.7	14	22	11	6	47	40	14	26	13	18	29	120	6	25	13	19	37	4.8
Phillips	10	9	14	40	27	6.5	2	13	21	30	34	43	1	18	37	25	19	120	15	39	14	25	7	2.8
Pike	30	16	23	23	8	5.8	9	7	2	8	74	135	17	17	25	18	23	112	8	9	7	20	56	11.0
Poinsett	2	5	11	36	46	6.9	20	30	24	18	8	25	6	26	30	17	21	110	8	28	21	32	11	3.7
Polk	36	20	17	17	10	5.6	6	7	9	6	72	120	19	25	23	14	19	102	7	22	8	29	34	5.6
Pope	23	18	26	21	12	5.9	8	10	9	9	64	76	15	20	23	17	25	116	8	21	10	21	40	5.7
Prairie, Des Arc	5	15	21	33	26	6.5	19	30	23	16	12	27	11	20	44	15	10	104	17	38	16	20	9	2.7
Prairie, De Valls Bluff	16	11	29	26	18	6.0	15	34	19	10	22	26	12	18	34	18	18	102	16	25	12	18	29	3.9
Pulaski	26	13	18	24	19	6.0	9	9	9	13	60	69	15	24	26	16	19	104	6	13	9	27	45	7.0
Randolph	7	15	32	34	12	6.2	16	25	20	18	21	29	9	29	35	15	12	103	6	31	20	29	14	3.6
Saline	30	17	20	22	11	5.9	10	11	9	15	55	56	15	16	25	17	27	118	7	24	15	28	26	4.3
Scott	13	26	30	24	7	5.9	7	8	8	10	67	77	20	14	19	19	28	120	2	12	5	33	48	7.9
Searcy	20	33	19	18	10	5.7	7	11	12	13	57	62	18	28	18	13	23	97	12	29	8	23	28	4.1
Sebastian	27	16	18	22	17	5.9	9	10	10	13	58	65	10	15	30	23	22	125	2	6	10	34	48	7.6
Sevier	35	18	24	16	7	5.7	4	7	10	10	69	104	22	19	15	12	32	117	4	14	6	23	53	8.7
Sharp	5	15	23	30	27	6.4	15	13	11	15	46	47	23	18	22	17	20	104	19	22	11	21	27	3.9
St. Francis	7	10	22	41	20	6.4	4	12	21	28	35	42	2	15	28	20	35	140	31	44	10	13	2	2.1
Stone	20	17	19	22	22	6.1	5	11	7	15	62	80	15	20	20	16	29	117	9	21	9	22	39	5.9
Union	19	15	20	32	14	6.1	13	7	10	11	59	67	26	25	26	11	12	87	10	14	10	19	47	7.4
Van Buren	24	22	20	21	13	5.8	7	11	11	10	61	69	21	21	18	15	25	108	14	24	16	18	28	3.8
Washington	13	14	21	28	24	6.3	5	7	10	14	64	72	3	9	20	23	45	165	1	8	8	36	47	7.5
White	16	16	27	29	12	6.1	7	14	14	15	50	51	17	23	30	14	16	101	10	27	12	29	22	4.1
Woodruff	10	10	24	28	28	6.3	7	19	21	17	36	37	7	31	29	16	17	106	9	33	14	21	23	3.4
Yell, Danville	24	27	27	17	5	5.7	7	7	8	8	70	88	14	21	25	15	25	114	5	10	8	20	57	9.1
Yell, Dardanelle	20	22	22	23	13	5.9	14	3	5	8	70	109	16	25	19	19	21	104	9	14	6	22	49	7.2
Average	16	15	22	29	18	6.2	11	14	13	15	47	60	14	21	24	17	24	119	11	24	13	24	28	5.3

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

[b] Analysis by inductively coupled argon plasma spectroscopy (ICAP) in 1:10 soil volume:Mehlich-3 volume.

[c] Md = median.

Table 7. The percentage of sampled acres as distributed within five fertilizer levels and median soil chemistry property values by previous crop for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January 2014 through 31 December 2014.

	Soil pH[a]						Mehlich-3 soil P[b] (ppm)						Mehlich-3 soil K[b] (ppm)						Mehlich-3 soil Zn[b] (ppm)					
Geographic area	<5.4	5.4-5.7	5.8-6.2	6.3-6.9	>6.9	Md[c]	<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	4	9	20	34	33	6.6	7	18	25	24	26	36	2	17	36	24	21	124	8	32	15	33	12	3.7
Cotton	12	3	12	39	34	6.8	2	4	8	36	50	51	1	23	26	25	25	129	15	26	13	36	10	3.8
Grain sorghum, non-irrigated	30	13	23	20	14	5.9	5	15	20	28	32	39	3	23	40	25	9	118	15	48	15	18	4	2.8
Grain sorghum, irrigated	2	12	21	35	30	6.5	4	22	26	27	21	33	6	32	40	8	14	100	12	39	19	24	6	3.0
Rice	9	12	17	31	31	6.6	29	33	20	11	7	21	8	23	27	13	29	116	10	44	23	20	3	2.9
Soybean	3	7	18	35	37	6.7	11	24	23	22	20	31	4	21	33	17	25	119	10	34	19	31	6	3.3
Wheat	24	27	26	22	1	5.7	16	16	17	19	32	36	13	30	29	14	14	97	25	44	10	15	6	2.2
Cool-season grass hay	18	20	27	25	10	6.0	13	11	16	14	46	45	27	24	25	13	11	87	9	26	14	27	24	4.1
Native warm-season grass hay	33	22	21	15	9	5.7	17	16	19	15	33	35	27	26	19	11	17	88	19	29	13	19	20	3.2
Warm-season grass hay	24	21	27	22	6	5.8	10	11	9	12	58	67	27	27	20	12	14	84	11	23	10	23	33	4.8
Pasture, all categories	18	22	30	23	7	5.9	11	10	9	9	61	77	16	16	19	15	34	129	8	17	9	21	45	6.9
Home garden	8	9	16	28	39	6.7	4	4	5	6	81	133	6	11	18	18	47	166	3	8	6	19	64	12.8
Turf	16	13	26	32	13	6.2	4	7	8	11	70	80	24	17	23	15	21	105	3	11	12	34	40	6.3
Home lawn	20	14	20	27	19	6.2	8	15	16	18	43	45	6	18	28	23	25	129	7	20	14	36	23	4.8
Small fruit	20	20	26	21	13	6.0	8	7	9	13	63	75	9	21	31	16	23	115	6	19	9	24	42	6.4
Ornamental	11	9	15	30	35	6.7	7	7	7	11	68	79	10	20	27	19	24	122	5	7	6	20	62	11.3
Average	16	15	22	27	20	6.3	10	14	15	17	44	55	12	22	28	17	21	114	10	27	13	25	25	5.1

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

[b] Analysis by inductively coupled argon plasma spectroscopy (ICAP) in 1:10 soil weight:Mehlich-3 volume.

[c] Md = median.

Table 8. Fertilizer tonnage sold in Arkansas counties from 1 July 2014 through 30 June 2015[a].

County	Fertilizer sold	County	Fertilizer sold	County	Fertilizer sold
	(tons)		(tons)		(tons)
Arkansas	87,893	Garland	1,331	Newton	719
Ashley	14,687	Grant	120	Ouachita	57
Baxter	1,645	Greene	36,031	Perry	352
Benton	4,638	Hempstead	6,814	Phillips	52,933
Boone	2,869	Hot Spring	441	Pike	316
Bradley	766	Howard	1,046	Poinsett	60,252
Calhoun	74	Independence	10,102	Polk	448
Carroll	1,873	Izard	1,602	Pope	1,781
Chicot	35,776	Jackson	32,098	Prairie	35,596
Clark	706	Jefferson	33,364	Pulaski	7,778
Clay	56,821	Johnson	661	Randolph	16,828
Cleburne	4,383	Lafayette	6,493	Saline	1,429
Cleveland	118	Lawrence	28,946	Scott	45
Columbia	862	Lee	39,526	Searcy	1,442
Conway	4,598	Lincoln	13,613	Sebastian	2,258
Craighead	61,735	Little River	4,510	Sevier	737
Crawford	4,744	Logan	1,048	Sharp	988
Crittenden	25,036	Lonoke	53,678	St. Francis	30,601
Cross	40,555	Madison	3,896	Stone	771
Dallas	4	Marion	1,500	Union	2,281
Desha	30,915	Miller	7,904	Van Buren	6,079
Drew	9,424	Mississippi	50,199	Washington	5,282
Faulkner	3,112	Monroe	44,912	White	17,233
Franklin	986	Montgomery	263	Woodruff	26,946
Fulton	1,103	Nevada	552	Yell	359

[a] Arkansas Distribution of Fertilizer Sales by County, 1 July 2014 to 30 June 2015, Arkansas State Plant Board, Division of Feed and Fertilizer, Little Rock, Ark., and University of Arkansas System Division of Agriculture, Arkansas Agricultural Experiment Station, Fayetteville, Ark.

Table 9. Fertilizer nutrient, formulation, and use category sold in Arkansas from 1 July 2014 through 30 June 2015[a].

	Container			Use		
Fertilizer	**Bag**	**Bulk**	**Liquid**	**Farm**	**Non-farm**	**Totals**
	-----	-----	-----	(tons)	-----	-----
Multinutrient	27,016	263,322	18,086	287,106	21,318	308,424
Nitrogen	64,821	429,957	61,913	555,811	880	556,691
Phosphate	55	53,273	79	53,380	27	53,407
Potash	440	116,920	190	117,373	177	117,550
Organic	5	1,213	0	1,213	5	1,218
Micronutrient	576	1,760	326	2,381	281	2,662
Lime	309	6,404	0	6,680	33	6,713
Miscellaneous	521	3,609	1,666	5,471	324	5,795
Total	93,743	876,458	82,260	1,029,415	23,045	1,052,460

[a] Arkansas Distribution of Fertilizer Sales by County, 1 July 2014 to 30 June 2015, Arkansas State Plant Board, Division of Feed and Fertilizer, Little Rock, Ark., and University of Arkansas System Division of Agriculture, Arkansas Agricultural Experiment Station, Fayetteville, Ark.

Table 10. The percentage of sampled acreage distribution among four soil sulfate-S (SO_4-S) ranges and median values by county for soil samples submitted to the Soil Testing and Research Laboratory in Marianna in 2012. Values based on 192,317 soil samples from field average and grid samples.

	SO_4-S[a] range (ppm)						SO_4-S[a] range (ppm)				
County	**<5**	**5-10**	**11-20**	**>20**	**Md[b]**	**County**	**<5**	**5-10**	**11-20**	**>20**	**Md[b]**
	(% of samples)						(% of samples)				
Arkansas, DeWitt	1	37	49	13	12	Lee	3	53	36	8	10
Arkansas, Stuttgart	0	26	45	29	15	Lincoln	0	35	45	20	12
Ashley	3	40	35	22	12	Little River	0	21	50	29	15
Baxter	1	16	58	25	15	Logan, Booneville	0	11	49	40	18
Benton	0	3	59	38	18	Logan, Paris	0	6	55	39	19
Boone	0	11	62	27	16	Lonoke	1	35	45	19	12
Bradley	0	20	49	31	14	Madison	0	5	65	30	18
Calhoun	3	22	56	19	13	Marion	0	12	64	24	16
Carroll	1	6	56	37	18	Miller	0	27	53	20	14
Chicot	2	20	41	37	17	Mississippi	5	62	28	5	9
Clark	0	26	46	28	14	Monroe	0	23	42	35	15
Clay, Corning	3	46	43	8	11	Montgomery	1	5	57	37	18
Clay, Piggott	8	57	31	4	9	Nevada	0	26	49	25	15
Cleburne	1	18	64	17	15	Newton	1	23	58	18	14
Cleveland	0	21	52	27	15	Ouachita	2	36	47	15	12
Columbia	8	41	37	14	11	Perry	0	12	55	33	16
Conway	1	30	50	19	13	Phillips	3	50	39	8	10
Craighead	5	40	33	22	11	Pike	0	11	62	27	15
Crawford	1	24	55	20	14	Poinsett	3	41	43	13	11
Crittenden	6	55	32	7	9	Polk	1	10	58	31	17
Cross	2	29	47	22	13	Pope	0	16	55	29	16
Dallas	2	38	43	17	12	Prairie, Des Arc	0	41	48	11	11
Desha	1	54	40	5	10	Prairie, De Valls Bluff	0	30	57	13	13
Drew	1	30	51	18	13	Pulaski	1	16	49	34	16
Faulkner	1	19	53	27	16	Randolph	2	41	43	14	12
Franklin, Charleston	1	17	53	29	16	Saline	0	20	53	27	16
Franklin, Ozark	0	16	52	32	16	Scott	0	5	55	40	19
Fulton	0	21	60	19	14	Searcy	0	14	64	22	15
Garland	0	11	55	34	14	Sebastian	2	18	53	27	15
Grant	0	16	66	18	14	Sevier	0	7	61	32	17
Greene	5	48	36	11	10	Sharp	0	24	66	10	13
Hempstead	0	24	50	26	15	St. Francis	0	52	39	6	10
Hot Spring	0	24	54	16	13	Stone	3	18	64	18	14
Howard	6	14	55	31	16	Union	0	38	42	16	12
Independence	0	22	50	28	15	Van Buren	4	20	64	16	14
Izard	2	38	52	8	11	Washington	0	6	49	45	19
Jackson	4	50	28	18	10	White	0	23	55	21	14
Jefferson	3	51	37	9	10	Woodruff	1	34	46	17	12
Johnson	2	29	53	16	13	Yell, Danville	3	8	56	35	18
Lafayette	0	24	54	22	15	Yell, Dardanelle	1	24	49	22	15
Lawrence	1	26	35	38	16	Average	1	26	50	23	14

[a] Analysis by inductively coupled argon plasma spectroscopy (ICAP) in 1:10 soil volume:Mehlich-3 volume.

[b] Md = median.

Table 11. The percentage of sampled acreage distribution among four soil sulfate-S (SO_4-S) ranges and median values by county for soil samples submitted to the Soil Testing and Research Laboratory in Marianna in 2013. Values based on 163,433 soil samples from field average and grid samples.

	SO_4-S[a] range (ppm)						SO_4-S[a] range (ppm)				
County	**<5**	**5-10**	**11-20**	**>20**	**Md[b]**	**County**	**<5**	**5-10**	**11-20**	**>20**	**Md[b]**
	------------- (% of samples) ----------------						------------- (% of samples) ---------------				
Arkansas, DeWitt	0	27	57	16	13	Lee	1	47	41	11	11
Arkansas, Stuttgart	2	34	39	25	13	Lincoln	2	38	46	14	12
Ashley	0	39	47	14	12	Little River	0	22	53	25	14
Baxter	0	15	55	30	15	Logan, Booneville	0	10	64	26	18
Benton	0	3	56	41	19	Logan, Paris	0	5	60	35	18
Boone	0	9	65	26	16	Lonoke	0	29	53	18	13
Bradley	0	21	46	33	13	Madison	0	4	60	36	18
Calhoun	0	31	63	6	13	Marion	0	11	51	38	18
Carroll	0	5	54	41	19	Miller	0	21	60	19	14
Chicot	2	23	49	26	16	Mississippi	2	65	31	2	9
Clark	0	15	59	26	16	Monroe	0	20	42	38	16
Clay, Corning	3	44	39	14	11	Montgomery	1	8	63	28	17
Clay, Piggott	3	55	39	3	10	Nevada	2	31	43	24	13
Cleburne	1	10	68	21	16	Newton	0	8	66	26	17
Cleveland	0	25	50	25	14	Ouachita	2	26	56	16	13
Columbia	2	30	50	18	12	Perry	0	5	79	16	15
Conway	5	35	46	14	12	Phillips	1	58	35	6	10
Craighead	3	52	32	13	10	Pike	0	11	61	28	15
Crawford	2	48	40	10	11	Poinsett	1	30	40	29	14
Crittenden	3	58	32	7	9	Polk	0	7	59	34	18
Cross	0	25	50	25	14	Pope	0	12	56	32	17
Dallas	0	23	67	10	13	Prairie, Des Arc	0	28	54	18	13
Desha	2	37	43	18	12	Prairie, De Valls Bluff	0	21	52	27	14
Drew	0	15	43	42	18	Pulaski	1	15	53	31	16
Faulkner	2	15	58	25	16	Randolph	3	23	58	16	13
Franklin, Charleston	0	2	63	35	18	Saline	0	12	61	27	17
Franklin, Ozark	0	14	61	25	16	Scott	0	5	62	33	17
Fulton	0	7	72	21	16	Searcy	0	6	61	33	16
Garland	0	10	62	28	17	Sebastian	1	13	52	34	17
Grant	0	29	57	14	13	Sevier	0	5	61	34	18
Greene	1	26	37	26	13	Sharp	0	23	64	13	14
Hempstead	1	26	53	20	14	St. Francis	2	54	40	4	10
Hot Spring	0	23	60	17	14	Stone	1	13	56	30	16
Howard	0	13	47	40	18	Union	4	35	49	12	12
Independence	0	18	62	20	14	Van Buren	2	23	62	13	14
Izard	0	44	51	5	11	Washington	0	5	52	43	19
Jackson	2	27	47	24	13	White	1	16	59	24	15
Jefferson	1	31	49	29	12	Woodruff	0	19	55	26	16
Johnson	0	24	50	26	15	Yell, Danville	1	6	66	27	17
Lafayette	0	17	62	21	15	Yell, Dardanelle	0	34	45	21	13
Lawrence	0	15	36	49	20	Average	1	23	53	23	15

[a] Analysis by inductively coupled argon plasma spectroscopy (ICAP) in 1:10 soil volume:Mehlich-3 volume.

[b] Md = median.

Table 12. Sulfur (S) percentage of sampled acreage distribution among four ranges and median values by county for soil samples submitted to the Soil Testing and Research Laboratory in Marianna in 2014. Values based on 152,908 soil samples from field average and grid samples.

	SO_4-S[a] range (ppm)				
County	<5	5-10	11-20	>20	Md[b]
	(% of samples)				
Arkansas, DeWitt	0	24	60	16	13
Arkansas, Stuttgart	1	32	43	24	13
Ashley	3	40	35	22	11
Baxter	0	17	57	26	15
Benton	0	5	61	34	18
Boone	0	17	70	13	15
Bradley	0	28	53	19	14
Calhoun	0	13	85	2	14
Carroll	0	4	56	40	19
Chicot	0	33	44	23	13
Clark	5	37	46	12	12
Clay, Corning	1	41	43	15	12
Clay, Piggott	4	63	30	3	9
Cleburne	0	16	71	13	14
Cleveland	1	51	38	10	10
Columbia	4	50	40	6	10
Conway	0	26	51	23	14
Craighead	4	48	29	19	10
Crawford	2	55	33	10	10
Crittenden	7	63	24	6	8
Cross	0	23	52	25	14
Dallas	0	40	48	12	12
Desha	1	54	37	8	10
Drew	1	34	53	12	11
Faulkner	1	17	61	21	14
Franklin, Charleston	0	2	75	23	15
Franklin, Ozark	0	14	57	29	16
Fulton	1	19	62	18	14
Garland	0	13	64	23	15
Grant	0	1	64	35	13
Greene	5	52	30	13	10
Hempstead	8	30	42	20	13
Hot Spring	0	25	50	25	13
Howard	0	6	48	46	20
Independence	0	10	75	15	15
Izard	0	39	55	6	12
Jackson	1	28	43	28	14
Jefferson	4	60	20	16	9
Johnson	0	31	56	13	13
Lafayette	0	29	61	10	12
Lawrence	1	23	32	44	17
Lee	5	73	20	2	8
Lincoln	0	26	48	26	13
Little River	0	32	54	14	13
Logan, Booneville	0	0	100	0	14
Logan, Paris	0	12	62	26	16
Lonoke	0	18	53	29	15
Madison	0	7	72	21	16
Marion	0	15	60	25	16
Miller	0	24	56	20	14
Mississippi	7	73	17	3	8
Monroe	0	18	51	31	16
Montgomery	1	4	67	28	17
Nevada	0	18	57	25	15
Newton	0	11	53	36	18
Ouachita	0	35	35	30	14
Perry	0	8	72	20	15
Phillips	0	59	35	6	10
Pike	0	13	58	29	15
Poinsett	1	24	50	25	14
Polk	0	14	75	11	14
Pope	1	18	62	19	15
Prairie, Des Arc	0	26	57	23	13
Prairie, De Valls Bluff	0	23	49	28	15
Pulaski	1	21	55	23	15
Randolph	1	37	47	15	12
Saline	0	18	59	23	15
Scott	0	9	62	29	17
Searcy	0	16	67	17	16
Sebastian	0	12	56	32	16
Sevier	0	19	55	26	16
Sharp	0	35	55	9	12
St. Francis	1	65	28	3	9
Stone	4	19	67	14	14
Union	0	56	33	7	10
Van Buren	4	26	57	15	13
Washington	2	7	61	32	17
White	0	15	63	21	14
Woodruff	1	41	40	19	13
Yell, Danville	0	12	65	23	15
Yell, Dardanelle	0	30	61	9	13
Average	1	27	52	20	14

[a] Analysis by inductively coupled argon plasma spectroscopy (ICAP) in 1:10 soil volume:Mehlich-3 volume.

[b] Md = median.

Effect of Delaying the Sidedress Nitrogen Fertilization on Corn Yields

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

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Nitrogen (N) is the mineral nutrient required in the largest amount by a corn (*Zea mays* L.) plant. In Arkansas, the total amount of N is normally applied in a 2- or 3-way split, with the majority of fertilizer-N applied at the V6 growth stage. The larger portion is applied around V6 to correspond with the period of rapid growth, and it is believed to be the practice that results in the greatest fertilizer-N uptake and yield potential (Wells and Blitzer, 1984). Timely N applications are critical to optimize yield potential; however timely application is sometimes compromised by weather and can conflict with other cultural practices. Delaying the sidedress-N application until the time when the corn is experiencing substantial biomass accumulation is reported to be detrimental to corn yields (Varvel et al., 1997; Binder et al., 2000). However, Scharf et al. (2002) reported that N fertilization could be delayed as late as the V11 growth stage without significant yield loss. There is a lack of data to quantify how delayed N fertilization influences corn yield under Arkansas growing conditions. The objective of this study was to assess the yield implications associated with sidedressing N at different growth stages.

PROCEDURES

Research plots were established at the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center (NEREC) near Keiser, and at the Rohwer Research Station (RRS) near Rohwer, during 2013, 2014, and 2015. The soils are mapped as Sharkey silty clay at NEREC and RRS (2013 only), and as Desha silt loam at RRS during 2014 and 2015. In 2014, the NEREC trial was lost due to considerable lodging caused by strong winds and will not be reported. The preceding crop at both locations was soybean [*Glycine max* (L.) Merr.] in 2013 and corn in 2014 and 2015.

Soil samples were collected during the spring of each year, from the shoulder of existing beds or before beds were formed. One composite soil sample from the 0- to 6-inch soil depth was collected from each location, each year. The soil was extracted for plant-available nutrients using the Mehlich-3 procedure (Table 1). Nitrate-N was determined with an ion-selective electrode, and pH was measured in a 1:2 soil: water (vol:vol) mixture. Soil fertility levels were optimum. During 2014, 0.5 lb Zn/acre was applied after corn emergence at each site.

Treatments consisted of an application of 80 to 100 lb N/acre at emergence, followed by a sidedress application of 100, 120, or 140 lb N/acre, depending on soil texture, at one of four different growth stages including V4 to V6, V6 to V8, V8 to V10, and V10 to tassel (VT) (Table 2). Plots received an additional application of 46 lb N/acre at VT. The total-N applied was 286 lb N/acre for clayey soils (NEREC and RRS 2013) and 246 lb N/acre for silt loam soils (RRS 2014 and 2015). The fertilizer-N source used for all N applications was urea amended with a recommended rate of an N-(n-butyl) thiophosphoric triamide (NBPT)-based urease inhibitor to reduce ammonia volatilization loss. The only exception was during the 2015 season, when ammonium sulfate was applied as part of the preplant N (100 lb/acre). The fertilizer was applied by hand to each plot for each application time.

The planting date at each site is listed in Table 2. Each trial included two of the most popular hybrids and varied from year-to-year including: Pioneer 1615HR and DeKalb 64-69 hybrids were planted in 2013, Pioneer 1319HR and DeKalb 64-69 were planted in 2014, and DeKalb 6208 and Pioneer 2089AM were planted in 2015. Corn was planted to achieve an intended population of 32,000 plants per acre. At maturity, the two middle rows of each plot were harvested with a plot combine equipped with a weigh-system and grain moisture meter. Yields were adjusted to 15.5% moisture content for statistical analysis.

Statistical analysis was performed by site using the GLM procedure in SAS v. 9.2 (SAS Institute, Inc., Cary, N.C.). At RRS, treatments were arranged as a 2 × 4 factorial (2 hybrids and 4 application times). At NEREC, treatments were also arranged as a 2 × 4 factorial with the exception of the 2013 trial when the two hybrids were planted as separate tests. Treatments were replicated five times. Mean separations were performed using Fisher's protected least significant difference method at a significance level of 0.10.

RESULTS AND DISCUSSION

The grain yields of both hybrids at NEREC during 2013 may have been affected by the relatively late planting date (16 May). Results show significant yield loss when the sidedress-N application was delayed until after the V8 to V10 growth stage (Table 3). There is no good explanation for the abnormally low yield of 144 bu/acre observed for the DeKalb 64-69 hybrid receiving the sidedress-N at the V8 to V10 stage.

For the RRS in 2013, the statistical analysis showed that hybrid and the hybrid × sidedress-N application time had no significant effect ($P > 0.10$) on grain yield (Table 3). A significant yield loss occurred when the N-sidedress application was delayed until after the V6 to V8 growth stage. Overall, grain yields from both trials in 2013 were probably affected by adverse weather conditions that did not allow planting until mid-May, a month later than normal (Table 2). Corn planted at RRS in mid-May normally yields 15% to 20% lower than corn planted in mid-April (Jason Kelley, pers. comm.).

During the 2014 season, weather conditions were very favorable to grow corn at the RRS, and the test was planted in April on a soil with good yield potential (Table 2). The statistical analysis of 2014 RRS grain yield data showed no differences between hybrids, and both hybrids responded to sidedress-N application timing the same (non-significant interaction, Table 3). Corn yields were reduced by 8% when the sidedress-N application was delayed until after the V6 to V8 stage compared to the conventional application timing (V4 to V6).

During the 2015 season, logistics and weather conditions did not allow for separate fertilizer-N applications at the V6 to V8 and V8 to V10 growth stages at either location (Table 2). As observed in previous years, in 2015, both hybrids followed the same yield trend as evidenced by the lack of significant interaction (Table 3). For the NEREC location, significant yield loss was recorded when the sidedress-N application was delayed beyond the V10 stage. At the RRS, no significant yield difference was observed among treatments. A possible explanation for the contrasting results is the amount of residual inorganic-N present in the soil before planting (Table 1). The soil residual nitrate concentration was 46 ppm for the RRS suggesting that corn may not have required fertilizer-N to produce near maximal yield. The hybrid effect was significant at RRS during 2015, with Pioneer 2089AM yielding significantly more (233 bu/acre) compared to DeKalb 6208 (211 bu/acre). For all site-years except RRS in 2015, there was an obvious numerical trend for corn yields to decline as the sidedress-N application was delayed past the V10 growth stage.

PRACTICAL APPLICATIONS

The purpose of these studies was to quantify the yield loss potential when the sidedress-N application was delayed beyond the V4 to V6 growth stage. Growing conditions during a particular season, native or residual soil-N availability, and the amount of N applied before or by planting could affect the outcome of a study of this nature. Under the conditions of these studies, delaying the sidedress-N application beyond the V8 growth stage increases the risk of significant yield loss. The two corn hybrids used each year appeared to respond similarly to the sidedress-N application timing.

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Table 1. Selected soil chemical properties from the 0- to 6-inch soil depth at the Northeast Research and Extension Center (NEREC) and at the Rohwer Research Station (RRS). Composite soil samples were collected in the spring, before planting.

Location	Year	pH	NO_3-N	P†	K†	Zn†	Ca†
			(ppm)				
NEREC	2013	6.5	9	69	298	7.1	4088
RRS	2013	6.3	11	81	211	5.6	3842
RRS	2014	6.7	16	75	285	6.1	2048
RRS	2015	6.8	46	62	149	5.4	1191
NEREC	2015	6.6	10	62	278	5.5	3851

† Mehlich-3 extractable nutrients.

Table 2. Dates of planting and preplant-, sidedress-, and pretassel-N application for trials conducted at the Northeast Research and Extension Center (NEREC) and Rohwer Research Station (RRS) in 2013, 2104, and 2015.

		Fertilizer-N application times[†]						
Location	Year	Planted	Emergence	V4-V6	V6-V8	V8-V10	V10-VT	VT
		(day month)						
NEREC[‡]	2013	16 May	29 May	7 June	17 June	24 June	2 July	16 July
RRS[‡]	2013	11 May	24 May	5 June	14 June	25 June	5 July	10 July
RRS[§]	2014	19 April	29 April	9 May	20 May	3 June	12 June	17 June
RRS[§]	2015	22 April	30 April	21 May	3 June	3 June	19 June	19 June
NEREC[‡]	2015	1 May	8 May	4 June	10 June	10 June	2 July	2 July

[†] Fertilizer-N was applied preplant at 80 to 100 lb N/acre, 100, 120, or 140 lb N/acre at one of the four sidedress application treatment times (V4 to V6, V6 to V8, V8 to V10, and V10 to VT) and 46 lb N/acre at VT.

[‡] Fertilized with a total of 286 lb N/acre.

[§] Fertilized with a total of 246 lb N/acre.

Table 3. Corn grain yield means as affected by fertilizer-N sidedress application time in five trials conducted at the Northeast Research and Extension Center (NEREC) and Rohwer Research Station (RRS) in 2013, 2104 and 2015.

Sidedress	NEREC 2013		RRS 2013	RRS 2014	NEREC 2015	RRS 2015
N time	P1615HR	DeKalb 64-69	Hybrid mean	Hybrid mean	Hybrid mean	Hybrid mean
	(bu/acre)					
V4 to V6	162 a[†]	169 a	177 a	296 a	176 a	229
V6 to V8	165 a	160 b	173 a	283 ab	--	--
V8 to V10	163 a	144 d	162 b	272 b	157 b	219
V10 to VT	153 b	153 c	155 c	271 b	144 c	218
LSD0.10	7.2	8.3	5.7	15.2	8.8	NS[‡]
C.V., %	5.9	9.9	6.3	7.2	6.4	6.2
N Time	0.010	0.004	0.002	0.034	0.001	0.444
Hybrid	--	--	0.111	0.530	0.283	0.002
Interaction	--	--	0.644	0.772	0.153	0.888

[†] Means within a column followed by different lowercase letters indicate statistically different yields.

[‡] NS, not significant.

Evaluation of the Applicability of the Corn Stalk Nitrate Test for Furrow-Irrigated Corn Production in Arkansas

C.E. Greub, T.L. Roberts, N.A. Slaton, J. Kelley, K. Lawson, and J.T. Davidson

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Corn (*Zea mays* L.) is an economically important row crop in Arkansas. The Corn Stalk Nitrate Test (CSNT) is a post-season nitrogen (N) management tool developed in the upper Midwest and is used to evaluate how much N was available to a producer's corn crop so that N management adjustments can be made for sequential corn crops grown in the same field (Binford et al., 1990). The NO_3-N concentration of the lower portion of the cornstalk can be used to indicate the N status of the corn plant at the end of the growing season by identifying if the plant had inadequate, adequate, or excessive available N (Binford et al., 1990; Brouder et al., 2000). Corn can be a luxury consumer of N, meaning that a corn plant can take up more N than needed to achieve maximal yield if it is available.

At maturity, corn plants that receive more N than needed for maximizing yield will accumulate NO_3-N in the lower portion of the cornstalk. However, corn plants that receive inadequate amounts of N will remobilize NO_3-N from the lower portion of the stalk and leaves to the developing grain, resulting in low concentrations of NO_3-N accumulating in the stalk at physiological maturity. The results of the CSNT can be divided into three categories: Low (≤250 ppm), Optimal (251 to 2000 ppm), and Excessive (>2000 ppm) NO_3-N concentrations (Camberato and Nielson, 2014). The Low CSNT category indicates that there was potentially inadequate N available to the corn crop for that specific growing season. The Optimal CSNT category indicates N availability was adequate for the crop to produce maximal yield without surplus N being available. In the Excessive CSNT category, high stalk NO_3-N concentrations show that the N supply likely exceeded the amount needed to produce maximum yield. The CSNT concentration thresholds that define these categories can vary from state to state depending on the environment and management practices used for that production region.

The CSNT cannot directly identify how much the N rates should be adjusted. Cornstalk NO_3-N may need to be measured multiple years in a single field to determine the magnitude by which N management needs to be adjusted. Arkansas production practices are considerably different than the practices used in the upper Midwest where the CSNT was developed. Differences in corn management, N application strategy and fertilizer-N recovery efficiency (FNRE) could potentially result in different CSNT concentrations and interpretations. Furthermore, significant variability in CSNT values have been identified within a field (Balkcom et al., 2003; Isla and Blackmer, 2007). A large number of stalk samples are recommended by most states (7.5 stalks/acre) to offset the variability.

Due to the relatively small amount of land dedicated to corn production in Arkansas, little research has been conducted to evaluate the suitability of the CSNT for irrigated corn production in Arkansas. The objective of our research was to evaluate how applicable the CSNT is for furrow-irrigated corn production in Arkansas and identify potential future research needs.

PROCEDURES

To evaluate the applicability of the CSNT for furrow-irrigated corn production in the mid-South, cornstalk samples and yield data were collected from corn fields enrolled in the Arkansas Corn Verification Program, which requires producers to use University of Arkansas System Division of Agriculture's Cooperative Extension Service recommendations when managing their fields. Stalk samples were acquired from eleven corn fields with silt loam soil scattered throughout the primary corn-producing area of Arkansas during 2014 and 2015. Within each field, 10 randomly selected sampling sites were determined and 5 stalk samples were collected within each sampling site. Stalk samples were collected within 1 to 2 weeks after the R6 growth stage or kernel black layer formation (Binford et al., 1990). Stalk samples were collected by cutting the lower portion of the cornstalk at 6 and 14 in. above the soil surface, followed by removing the dried leaf sheaths from the resulting 8 in. stalk segment (Binford et al., 1992). Following collection, all five stalk samples were composited, dried at 55 °C and ground to pass a 1-mm screen. Stalk NO_3-N concentration was determined by shaking a 0.5-g subsample of ground tissue with 30 mL of 2 mol KCl/L for 30 minutes. The extracts were filtered (Whatman 4, qualitative filter papers) and analyzed for NO_3-N colorimetrically (Mulvaney, 1996) using a SKALAR Segmented Flow Auto Analyzer (San System, Brenda, The Netherlands). Extracts were refrigerated after extraction. Stalk NO_3-N interpretations were made based on Purdue University concentration limits (Camberato and Nielson, 2014). Statistical analyses were carried out using JMP PRO 12.0 (SAS Institute, Inc., Cary, N.C.). The 10 sampling sites within each location were treated as replicates (random effect) and location was treated as a fixed effect. Location means were calculated by averaging the 10 sampling positions within each location. Means were separated using Fisher's protected least significant difference (LSD) method, assessing significance at $P \leq 0.05$.

RESULTS AND DISCUSSION

Yield (field average) results indicate that there was high yield potential (>186 bu/acre) at all eleven locations (Table 1). Based on the Purdue University interpretation of stalk NO_3-N concentration, all locations were identified in either the Low or Optimal category. None of the locations were identified as having stalk NO_3-N concentrations in the Excessive category, potentially a result of the high yield potential associated with the irrigated production system. When a field is identified in the Low category, this indicates that either corn utilized fertilizer-N very efficiently or not enough N was available to the corn crop. Based on the yield data at each location, FNRE was high.

The analysis of variance indicated significant differences among locations for mean stalk NO_3-N ($P < 0.0001$). Of the eleven verification fields in this study, five locations were identified in the Low category and six in the Optimal category (Table 1). No significant difference was identified in mean stalk NO_3-N among locations categorized in the Low category. For locations that were interpreted in the Optimal category, only the Clay-1 location was significantly different than the other locations, which was a result of the large variability in NO_3-N within stalk samples collected from the ten sampling positions for fields. The Clay-1 location had the highest mean stalk NO_3-N concentration of 1907 ppm, with all ten sampling positions having NO_3-N concentrations within the Optimal category. Fields having Optimal stalk NO_3-N typically had mean stalk NO_3-N concentrations that were closer to the lower limit (251 ppm) rather than the upper limit (2000 ppm). Three locations that had mean stalk NO_3-N concentrations that bordered near the lower limit of the Optimal category resulted in no significant difference in mean NO_3-N than all locations in the Low category.

For locations that were identified in the Optimal category, a wide range in NO_3-N was recovered between the ten sampling positions compared to the locations in the Low category (Table 1). Fields identified in the Low category had a range in stalk NO_3-N of 2 to 945 ppm among the ten sampling positions; however, three of the Low category fields had a range of less than 12 ppm NO_3-N among the 10 field samples. Conversely, fields in the Optimal category had a range of 1814 to 3927 ppm NO_3-N within a location. The wide range in stalk NO_3-N among sampling positions indicates the potential for a few sampling positions to contain high stalk NO_3-N concentrations within a location and control the category in which the location is classified. These results identify the potential to modify the NO_3-N concentration limits established for the upper-Midwest, to determine what would be considered Low, Optimal or Excessive for an Arkansas production system.

PRACTICAL APPLICATIONS

Variability in cornstalk NO_3-N concentration among sampling sites within a location was observed, however the sources of variability among CSNT values could be different than variability identified in the upper Midwest. A potential way to identify sources of spatial variability within a field would be to compare spatial variability in yield with spatial variability in CSNT values. Since Arkansas uses different management practices such as irrigation and split-N application times (compared to a single preplant application in some other states), further research is needed to identify differences in the interpretation of stalk nitrate concentrations for the Arkansas production system through the use of N response trials. Further research is required to ensure the adaptability of the CSNT to Arkansas corn production before this test can be implemented effectively on a wide-scale.

ACKNOWLEDGMENTS

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Table 1. Field average yield and stalk NO_3-N concentrations from eleven fields enrolled in the Arkansas Corn Verification Program in 2014 and 2015.

Year	County	Yield	NO_3-N Mean stalk[†]	NO_3-N Range stalk[‡]	Interpretation[§]
		(bu/acre)	(ppm)	(ppm)	
2014	Mississippi	208	0 c[¶]	0 - 2	Low
	Arkansas	246	3 c	0 - 12	Low
	Lonoke	188	807 b	3 - 3930	Optimal
	Jefferson	246	477 bc	1 - 2047	Optimal
	Clay	227	190 bc	1 - 585	Low
	Lee	201	711 b	1 - 3280	Optimal
2015	Lee	200	250 bc	1 - 946	Low
	St. Francis	187	326 bc	2 - 2067	Optimal
	Clay-1	205	1907 a	493 - 3398	Optimal
	Clay-2	197	2 c	1 - 3	Low
	Lincoln	227	542 bc	7 - 1821	Optimal

[†] Mean stalk NO_3-N measured by averaging the NO_3-N values from all ten sampling positions.

[‡] Minimum and maximum NO_3-N concentrations measured among the ten sampling positions within each location.

[§] Determined from Purdue University mean NO_3-N concentration limits Low (≤250 ppm), Optimal (251 to 2000 ppm), and Excessive (>2000 ppm).

[¶] Means followed by the same letter are not significantly different from one another at a significance level of 0.05 (LSD = 628).

Biomass Accumulation and Nitrogen Uptake by Rye and Tillage Radish Cover Crops in Arkansas

K.L. Hoegenauer, T.L. Roberts, N.A. Slaton, W.J. Ross, C.E. Greub, and J.T. Davidson

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Utilizing cover crops has recently become very important for Arkansas row-crop systems as concern about soil health and turbidity and sedimentation of surface waters has increased. Cover crops serve as integral tools for row-crop agriculture by reducing nutrient and sediment loss via erosion and runoff (Kaspar et al., 2001; Carrera et al., 2004). Cover crops also act as catch crops to sequester and recycle residual soil nutrients for subsequent cash crop use (Doran and Smith, 1991). A popular cover crop among Arkansas producers is cereal rye (*Secale cereal*), which is known for producing high amounts of biomass and scavenging excess nutrients (Dean and Weil, 2009). Cereal rye is a winter hardy cover crop, meaning it undergoes dormancy during the coldest part of winter and resumes growth as temperatures increase in late winter. When rye reaches maturity, the carbon (C) to nitrogen (N) ratio of the residue is typically high, which can cause the N sequestered by the rye to be immobilized and temporarily unavailable to the following cash crop (Kuo and Sainju, 1998).

Another cover crop gaining popularity among Arkansas row-crop farmers is tillage radish (*Raphanus sativus* L.), also known as forage or daikon radish. This brassica cover crop is named for its enlarged taproot that is capable of penetrating some restrictive soil layers (Dean and Weil, 2009; Chen and Weil, 2010). After decomposition of the radish, the taproot leaves large channels for improved water infiltration and preferential root growth for subsequent crops (Williams and Weil, 2004). Research in the mid-Atlantic region of the U.S. has also shown that tillage radish is also effective in scavenging residual soil nitrate (Dean and Weil, 2009; Chen and Weil, 2010). Research on the nutrient sequestering abilities of rye and tillage radish in Arkansas is relatively nonexistent; therefore, the objective of this study was to evaluate the total-N uptake of rye and tillage radish cover crops in a monoculture and as a blend.

PROCEDURES

Research was conducted at the University of Arkansas System Division of Agriculture's Vegetable Research Station, near Kibler, Ark. This study was established in fall 2014 on a Roxanna silt loam, which had been fallow since fall 2013. Soil samples collected at cover crop planting were analyzed for pH, Mehlich-3 extractable nutrients, total N, total C, and soil organic matter by weight loss on ignition (Table 1). Cover crop treatments included radish monoculture, radish-rye mixture, and rye monoculture (Southern Soil Solutions, LLC, Hazen, Ark.). Fertilizer-N rate treatments, including 0, 30, 60, and 90 lb N/acre, were randomly assigned to microplots within each cover crop treatment. Four replications of each treatment combination were included, and each microplot measured 6 ft wide by 8 ft long.

Cover crops were planted on 24 September 2014 in 9-in. wide rows using a no-till drill. Radish was seeded at rates of 9 lb/acre in the radish monoculture and 4.5 lb/acre in the radish-rye mix. Rye was seeded at rates of 35 lb/acre in the rye monoculture and 17.5 lb/acre in the radish-rye mix. Urea fertilizer enriched with ^{15}N and treated with the urease inhibitor, N-(n-butyl) thiophosphoric triamide (NBPT) was applied to the cover crops 2 weeks after planting. Cover crop biomass samples were collected in a 9 ft^2 section from each plot on 31 March 2015. Entire radish biomass was collected and separated into shoots and roots, while only the aboveground biomass of rye was collected. Plant samples were dried, weighed, ground, and analyzed for total-N using automated dry combustion. The experimental design was a 3 (cover crop) × 4 (N rate) factorial arrangement with four replications. Analysis of variance (ANOVA) was completed and significant differences among mean biomass and total-N measurements were determined in JMP Pro 12 using Tukey's honest significant difference (HSD) pairwise comparisons and a significance level of 0.05.

RESULTS AND DISCUSSION

The ANOVA indicated a significant cover crop by N rate interaction ($P = 0.003$) for cover crop biomass accumulation. Maximum biomass accumulation was much lower for the radish monoculture at 1273 lb/acre compared to 4676 and 6104 lb/acre for the radish-rye mix and rye monoculture treatments, respectively (Table 2). The biomass data collected for radish is likely an underestimation of the total radish biomass accumulated since many of the radishes had winterkilled and started decomposing at the time of sampling. Biomass in the radish monoculture was numerically highest when 0 or 30 lb N/acre was applied and lowest when 60 or 90 lb N/acre was applied.

The numerical decrease in biomass at the higher N rates can likely be attributed to a greater amount of the taproot being exposed (aboveground) which resulted in more winterkill. In the radish-rye mix the total biomass was dominated by the rye with very little contribution from the radishes (<20% of total biomass). The greatest overall biomass was produced by application of 90 lb N/acre to the rye monoculture. Although there was a numerical increase in total biomass accumulation with each incremental addition of N within the radish-rye and rye treatments, there was a sufficient amount of biomass produced in all N rates of these treatments, including the 0 lb N/acre, to provide the benefits of erosion control and weed suppression.

Total-N uptake by cover crops was also significantly affected by cover crop treatment and N rate interaction ($P = 0.001$). Maximum N uptake was much higher for the radish-rye mix and the rye monoculture at 93 and 109 lb N/acre, respectively, than for the radish monoculture at 38 lb N/acre (Table 2). Differences in N uptake among cover crop treatments can be attributed to differences in biomass, with greater biomass accumulation resulting in higher N uptake. Cereal rye is a winter hardy grass, meaning it will enter dormancy temporarily in the winter and then resume growth in late winter, which typically results in higher biomass accumulation and nutrient uptake than cover crops that winterkill. Due to decomposition of radish residue prior to sampling, some N extracted by radishes was likely leached from the residue resulting in underestimation of total-N uptake by the radish, particularly at the highest N rate (90 lb N/acre). Total-N uptake in the radish monoculture at the 30 lb N/acre rate was significantly higher than uptake of radish fertilized with 90 lb N/acre. Conversely, total-N uptake in the radish-rye mix and rye monoculture tended to increase numerically and sometimes significantly with increasing fertilizer-N rate.

PRACTICAL APPLICATIONS

Adequate biomass production by cover crops is necessary for effective control of soil erosion and nutrient runoff and to aid in weed suppression and crusting prevention. Rye consistently produced more biomass than radish at all N rates, indicating that rye could provide greater surface cover and potentially more erosion control than radish. Tillage radish has the potential to winterkill in most locations in Arkansas, while rye is dormant for only a portion of the winter and continues growth in early spring. Continued growth of rye in early spring could provide extended erosion control and N scavenging. The results of this trial indicate the ability of winter cover crops to scavenge soil residual nutrients and provide adequate residue to prevent soil erosion losses with little to no fertilizer-N input.

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Table 1. Soil test analysis for Roxanna silt loam at 0- to 6-in. depth taken at cover crop planting located at the Vegetable Research Station, near Kibler, Ark. Soil samples were collected in September 2014.

pH	OM[†]	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	NO_3-N + NO_2-N	NH_4-N	Total N	Total C
	(%)	(ppm)											(%)	
7.4	0.5	72	130	1396	254	6	15	195	88	4.0	16.8	1.9	0.06	0.46

[†] OM-organic matter determined by weight loss on ignition.

Table 2. The effect of the significant interaction between cover crop and N rate on total biomass and total-N accumulation by cover crops at the Vegetable Research Station, near Kibler, Ark. Data were collected in March 2015.

	Total Biomass			Total-N Uptake		
N Rate	Radish	Mix	Rye	Radish	Mix	Rye
(lb N/acre)	(lb/acre)			(lb N/acre)		
0	1048 D[†]	3559 C	3422 C	30 de[‡]	68 bc	57 cd
30	1273 D	3701 BC	4480 BC	38 de	68 bc	73 bc
60	930 D	3834 BC	4990 AB	29 de	78 bc	91 ab
90	597 D	4676 BC	6104 A	19 e	93 ab	109 a

[†] Means with a different uppercase letter are statistically significant across cover crop × N rate interaction for total biomass accumulation.

[‡] Means with a different lowercase letter are statistically significant across cover crop × N rate interaction for total N uptake.

Environmentally Smart Nitrogen Fertilizer is a Suitable Alternative to Urea for Cotton and Corn in Arkansas

M. Mozaffari and N.A. Slaton

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Nitrogen (N) fertilization will increase cotton (*Gossypium hirsutum* L.) and corn (*Zea mays* L.) yields in many Arkansas soils. Relatively high fertilizer-N rates are required to produce economically sustainable crop yields in Arkansas because the soil organic matter content of many agricultural soils is often low (< 2.0%). Additionally, several biogeochemical and transport processes such as runoff, leaching, and denitrification contribute to the loss of soil- and fertilizer-N. Reducing fertilizer-N loss to the environment will increase profit margins and reduce potential environmental risks associated with N fertilization.

A polymer-coated urea (44% N, Agrium Wholesales, Denver, Colo.) fertilizer has become available to Arkansas producers and is marketed 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 and moisture. The objective of this research was to evaluate cotton and corn yield response to ESN and urea in typical Arkansas agricultural soils.

PROCEDURES

Cotton Experiment

A field experiment was conducted to evaluate the effect of preplant application of urea, ESN, and their combination on cotton yield in a Memphis silt loam at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station (LMCRS) in Marianna, Ark. Before applying any fertilizer, soil samples were collected from the 0- to 6-in. depth and composited by replication. Soil samples were oven-dried and crushed, and soil pH, soil organic matter, NO_3-N, and Mehlich-3 extractable nutrients were measured. Average soil properties in the 0- to 6-in. depth were: 1.8% organic matter, 28 ppm NO_3-N, 46 ppm phosphorus (P), 93 ppm potassium (K), and 7.5 pH. Selected agronomic information is presented in Table 1. Current University of Arkansas System Division of Agriculture Cooperative Extension Service soil-test-based N fertility guidelines for irrigated-cotton recommend application of 70 lb N/acre for this soil.

The cotton experiment was a randomized complete block design with a factorial arrangement of four preplant-applied, urea-ESN combinations that included five rates ranging from 30 to 150 lb N/acre in 30 lb N/acre increments and a no-N control. The four urea and ESN-N combinations were: 100% urea-N; 50% urea-N plus 50% ESN-N; 25% urea-N plus 75% ESN-N, and 100% ESN-N. Each treatment was replicated five times. We applied muriate of potash and triple superphosphate to supply 90 lb K_2O and 46 lb P_2O_5/acre to the entire experimental area. All fertilizers including the N-fertilizer treatments were hand-applied onto the soil surface and mechanically incorporated into the top 2- to 3-in. of soil. After fertilizers were incorporated, the beds were pulled with a hipper and the cotton was planted on top of the beds. Each cotton plot was 40 ft long and 12.6 ft wide allowing for four rows of cotton planted in 38-in. wide rows. Cotton was furrow-irrigated as needed and management closely followed the Cooperative Extension Service recommendations. The two center rows of cotton in each plot were harvested with a spindle-type picker equipped with an electronic weight measuring and recording system.

Corn Experiment

The corn experiment was conducted at the LMCRS on a Calloway silt loam in 2015. The corn experiment treatments, structure, design, and preplant soil sampling were similar to the cotton experiment. The average soil chemical properties of the 0- to 6-in. depth were: 1.8 % organic matter, 7.2 pH, 15 ppm NO_3-N; 40 ppm P, and 106 ppm K.

The experimental treatments included a no-N control and the preplant-applied, N rates ranged from 60 to 300 lb N/acre and increased in 60-lb N/acre increments. Each treatment was replicated six times. Applications of muriate of potash, triple superphosphate, and $ZnSO_4$ were made to supply 90 lb K_2O, 60 lb P_2O_5, 10 lb zinc (Zn), and 5.0 lb sulfur (S)/acre. All fertilizers, including the N treatments, were hand-applied onto the soil surface, incorporated into the top 2- to 3-in. of soil, beds were pulled with a hipper, and corn was planted (34,000 seeds/acre) on top of the beds. Selected agronomic information is listed in Table 1.

Corn was furrow-irrigated as needed and the Cooperative Extension Service recommended management practices were closely followed. The plots were 25 ft long and 12.6 ft wide allowing for four rows of corn planted in 38-in. wide rows. At harvest the corn grain in the center two rows of each plot was harvested with a plot combine. Grain yields were adjusted to 15.5% moisture content for statistical analysis.

Monthly precipitation was recorded by a weather station at the LMCRS. Long-term average precipitation data were obtained from the Arkansas Variety Testing Site (http://www.arkansasvarietytesting.com/crop/data/2). Analysis of variance (ANOVA) was performed by crop using the GLM procedure of SAS (SAS Institute, Inc., Cary, N.C.). The data from the no-N control (0 lb N/acre) were not included in the ANOVA. When appropriate, means were separated by the least significant difference (LSD) method and interpreted as significant when $P \leq 0.10$.

RESULTS AND DISCUSSION

At both locations, the precipitation from June to September was below the long-term average suggesting that field conditions were not conducive for N loss via leaching, runoff, or denitrification (Table 2). Nitrogen loss could have occurred during irrigation events.

Cotton Experiments

Averaged across N sources, N application rate significantly increased seedcotton yield (Table 3). However, the main effect of N source and the N source × N rate interaction did not significantly influence seedcotton yield ($P > 0.10$, Table 3). The significant effect of N rate is consistent with our previous findings (Mozaffari and Slaton, 2014; Mozaffari et al., 2013, 2015), and non-significant N source or N source × N rate interaction is consistent with our 2013 results (Mozaffari and Slaton, 2014) perhaps because June to September precipitation in 2015 was below average (Table 2). Seedcotton yield for the cotton that received no fertilizer-N was 2524 lb/acre, which was numerically (14.9%) lower than the yield of cotton that received the lowest fertilizer-N rate of 30 lb N/acre, averaged across N sources (Table 3). Averaged across N sources, the yield of cotton fertilized with 150 lb N/acre was significantly greater than all other treatments. Averaged across the five N rates, cotton fertilized with 100% ESN-N produced a numerically greater yield than cotton fertilized with 100% urea (Table 3). Similar to the 2014 growing season, we observed that at N rates of 60 to 120 lb N/acre, ESN-fertilized cotton appeared more vigorous than urea-fertilized cotton during the growing season.

Corn Experiment

The grain yield of corn that was not fertilized with N averaged 93 bu/acre (Table 4), which indicates relatively low native soil-N availability and increased yield potential with N fertilization. The N source × N rate interaction did not significantly influence corn grain yield, which agrees with our 2014 findings at LMCRS (Mozaffari et al., 2015). Corn grain yield was significantly influenced by the main effects of N rate, averaged across all N source combinations, and N source, averaged across N rates (Table 4). These significant main effects are consistent with our 2012 results (Mozaffari et al., 2013). Averaged across all N rates, corn fertilized with 100%-ESN-N produced significantly greater grain yield than corn fertilized with 100%-Urea-N or 50% urea-N plus 50% ESN-N. Averaged across all four N sources, application of 120 to 300 lb N/acre produced maximal corn grain yields that were greater than corn fertilized with 60 lb N/acre.

PRACTICAL APPLICATIONS

The amount of precipitation during most of the 2015 growing season (June to September) was below the long-term average at the study site. Seedcotton yield was maximized by application of 150 lb N/acre. Averaged across all fertilizer-N rates, corn yield was maximized by application of 120 lb N/acre and corn fertilized with 100% ESN-N produced significantly greater grain yield than corn fertilized with 100% urea-N or a 50:50 blend of urea and ESN. These results support our previous assertion that preplant-incorporated ESN is a suitable alternative to urea for furrow-irrigated cotton and corn grown in Arkansas. Future research should compare the effect of the timing and rate of application of urea and ESN.

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Table 1. Selected agronomic information for cotton and corn N-fertilization trials established at the Lon Mann Cotton Research Station (LMCRS) during 2015.

Crop	Previous crop	Soil series	Cultivar or hybrid	Planting date	N application date	Harvest date
Cotton	soybean	Memphis silt loam	ST4946[a]	8 May	30 April	7 Oct
Corn	soybean	Calloway silt loam	Terral 23BHR	2 May	9 April	15 Aug

[a] ST = Stoneville.

Table 2. Actual rainfall received by month in 2015 and the long-term (1960-2007) average monthly mean rainfall at Lon Mann Cotton Research Station (LMCRS) in Marianna, Ark.

		Precipitation					
Site ID	Precipitation	May	June	July	August	September	Total
		(inches)					
LMCRS[a]	2015	6.4	3.4	2.9	0.0	0.6	13.1
	Average[b]	5.9	3.9	3.9	2.8	3.2	19.7

[a] Cotton was planted on 8 May and harvested on 7 Oct. Corn was planted on 2 May and harvested on 15 August.

[b] Long-term average for 1960-2007.

Table 3. Seedcotton yield as affected by the significant ($P < 0.10$) N rate (averaged across N sources) main effect, the non-significant (NS) N source (averaged across N rates), and the non-significant N source × N rate interaction for a cotton fertilization experiment conducted at the Lon Mann Cotton Research Station in Lee County, Ark., during 2015.

	N-fertilizer source						
N rate	100% Urea-N	50% Urea-N 50% ESN-N[a]	25% Urea-N 75% ESN-N	100% ESN-N	N rate yield mean	N-fertilizer source N source	Yield mean
(lb N/acre)	Seedcotton yield (lb/acre)						(lb/acre)
0		2524[b]				None	2524[b]
30	2891	3111	2946	2939	2966	100% Urea-N	3092
60	2873	3024	3062	3125	3028	50%Urea-N, 50%ESN-N	3056
90	2967	3078	3234	3354	3158	25% Urea-N,75% ESN-N	3113
120	3226	2993	2831	3232	3071	100% ESN-N	3227
150	3464	3080	3494	3484	3381		
LSD 0.10		NS[c] (interaction)			185[d]	LSD 0.10	NS
P-value		0.5988			0.0030	*P*-value	0.3029

[a] ESN = Environmentally Smart N, polymer-coated urea.

[b] The no-N control is listed for reference only as it was not included in the analysis of variance.

[c] NS = not significant.

[d] LSD compares the yield of treatments that received N, averaged across N sources.

Table 4. Corn grain yield as affected by the significant ($P < 0.10$) N rate main effect, the significant N source main effect, and the non-significant (NS) N source × N rate interaction for a corn fertilization experiment conducted at the Lon Mann Cotton Research Station in Lee County, Ark., during 2015.

	N-fertilizer source						
N rate	100% Urea-N	50% Urea-N 50% ESN-N[a]	25% Urea-N 75% ESN-N	100% ESN-N	N rate yield mean	N-fertilizer source N source	Yield mean
(lb N/acre)	Corn yield (lb/acre)						(lb/acre)
0		93[b]				None	93[b]
60	129	141	133	155	140	100% Urea-N	147
120	161	152	161	158	158	50%Urea-N, 50%ESN-N	149
180	143	152	151	159	151	25% Urea-N,75% ESN-N	153
240	148	155	164	157	156	100% ESN-N	158
300	156	145	158	162	155		
LSD 0.10		NS[c] (interaction)			8[d]	LSD 0.10	7
P-value		0.3183			0.0013	*P*-value	0.00695

[a] ESN = Environmentally Smart N, polymer-coated urea.

[b] The no-N control is listed for reference only as it was not included in the analysis of variance.

[c] NS = not significant.

[d] LSD compares the yield of treatments that received N, averaged across N sources.

Corn Responds Positively to Soil-Applied Phosphorus and Potassium at Multiple Locations in Arkansas

M. Mozaffari, N.A. Slaton, A. Davis, Y.D. Liyew, S. Hayes, and J. Hedge

BACKGROUND INFORMATION AND RESEARCH PROBLEM

During the last decade, corn (*Zea mays* L.) has become a major row crop in the mid-South. Approximately 435,000 acres of corn were harvested in Arkansas during 2015. The equivalent of 60 lb P_2O_5 and 45 lb K_2O/acre are removed from the soil by a grain yield of 175 bu/acre (International Plant Nutrition Institute, 2012). Between 1992 and 2013, the average corn grain yield in Arkansas increased from 130 to 187 bu/acre, which represents a substantial increase in phosphorus (P) and potassium (K) export from the soil nutrient reserves. Deficiency of P, K, or both may limit corn yield in many agricultural soils if the nutrients removed by the harvested grain are not replenished by fertilization.

Phosphorus transport from agricultural soils has been implicated as one of the factors contributing to the hypoxic zone in the Gulf of Mexico. Applying the right rate of P and K will enable growers to maximize the net returns from corn production and minimize P loss into the surrounding landscape. Reliable soil-test based fertilizer recommendations are the key to applying the right P and/or K fertilizer rate.

Historically, corn acreage in Arkansas has fluctuated greatly from year-to-year. The lack of sustained corn acreage has resulted in limited research describing corn response to P or K fertilization. In 2010, we initiated replicated field experiments to evaluate corn response to P and K fertilization in Arkansas. Multiple site-years of research are needed to increase the reliability and applicability of soil-test correlation and calibration curves. The specific objective of this research was to evaluate corn grain yield response to soil-applied fertilizer-P or -K rates at multiple locations on soils typically used for corn production in Arkansas.

PROCEDURES

Phosphorus Experiments

Three P-fertilization trials were conducted in 2015 with one trial located at the University of Arkansas System Division of Agriculture's Pine Tree Research Station (PTRS) in St. Francis County (SFZE57) and two trials were located in commercial production fields in Greene County (GRZ51, GRZ53). The soil series and selected agronomic information for each site are listed in Table 1. The previous crop was soybean at the GRZ51 and GRZ53, and corn at SFZE57.

Prior to P application, a composite soil sample was taken from the 0- to 6-in. depth of each replication. Each composite soil sample consisted of a total of 6 to 8 cores with an equal number of cores collected from the top of the bed and bed shoulder. Soil samples were oven-dried, crushed, extracted with Mehlich-3 solution, and the concentrations of elements in the extracts were measured by inductively coupled plasma atomic emission spectroscopy. Soil pH was measured in a 1:2 (volume: volume) soil-water mixture. Mean soil chemical properties are listed in Table 2.

Phosphorus application rates ranged from 0 to 160 lb P_2O_5/acre in 40 lb P_2O_5/acre increments applied as triple superphosphate. The experimental design was a randomized complete block where each treatment was replicated four (GRZ51) or five (GRZ53 and SFZE57) times. Phosphorus treatments were applied onto the soil surface in a single application 1 to 14 days before planting and mechanically incorporated into the top 3- to 4-in. of the soil. The beds were then repulled with a hipper and corn was planted on the top of the bed. Blanket applications of muriate of potash and $ZnSO_4$ supplied 90 to 120 lb K_2O, ~5 lb sulfur (S), and ~10 lb zinc (Zn)/acre. All experiments were fertilized with a total of 260 to 290 lb nitrogen (N)/acre as urea in a single or split application (e.g., preplant, 3- to 6-lf stage and/or pre-tassel) depending on the location. Corn was grown on beds and furrow irrigated as needed either by research station staff or the cooperating producer. Each plot was 25-ft long and 10- to 12.6-ft wide allowing for four rows of corn spaced 30 in. apart. Corn management closely followed University of Arkansas Cooperative Extension Service (CES) recommendations.

The middle two rows of each plot were harvested either with a plot combine (SFZE57) or by hand (GRZ51 and GRZ53) with ears placed through a combine following hand harvest. The calculated grain yields were adjusted to a uniform moisture content of 15.5% before statistical analysis.

Potassium Experiments

Six replicated field experiments were conducted in 2015 including trials at the Pine Tree Research Station (SFZE52, SFZE54) in St. Francis County, the Rohwer Research Station in Desha County (DEZ52, DEZ54), and commercial production fields in Greene (GRZ52, GRZ54) County. The K trials in Greene County were located adjacent to the aforementioned P-rate trials, the two trials in Desha County were located in the same field. The DEZ52 trial was established in 2014 and the same K-fertilizer rates were applied to the same plots in 2015. At the SFZE52, the same K rates were applied to the same plots in 2013 and 2014 and the same rates were repeated a third consecutive year in 2015. All the other K experiments were new trials established in 2015. The previous crop at both DEZ sites and SFZE52 was corn. The agronomic information for K trials is listed in Table 1. Composite soil samples were collected from each replication for the new trials and for each 0 lb K_2O/acre plot from multi-year trials as described for the P trials. Soil property means are listed in Table 3.

Potassium application rates ranged from 0 to 200 lb K_2O/acre in 40 lb K_2O/acre increments at all sites except SFZE52 where the rate increased in 50 lb K_2O/acre increments. All K treatments were applied as muriate of potash onto the soil surface from 1 day before planting to 18 days after planting (Table 1). All preplant-applied K fertilizer was mechanically incorporated, then the beds were repulled with a hipper and corn was planted on top of the bed. Triple superphosphate and $ZnSO_4$ were broadcast-applied to supply 40 to 80 lb P_2O_5, ~10 lb Zn, and ~5 lb S/acre. Nitrogen fertilizer management was the same as described for the P trials.

At DEZ52 and DEZ54, the plots were 40-ft long and 12.6-ft wide allowing for four rows of corn planted in 38-in. wide rows. At the other locations, plots were 25-ft long and 10-ft wide allowing for four rows of corn planted in 30-in. rows. All experiments had a randomized complete block design and each treatment was replicated five (SFZE52, SFZE54, GRZ52, GRZ54) or six (DEZ52, DEZ54) times.

Analysis of variance was performed for each individual P or K trial using the GLM procedure of SAS (SAS Institute, Inc., Cary, N.C.). When appropriate, significant differences among means were separated by the least significant difference (LSD) test with significance interpreted at the 0.10 level.

RESULTS AND DISCUSSION

Phosphorus Experiments

The soil pH ranged from 5.3 to 7.1 and all soils were mapped as silt loam soils (Table 2). Mehlich-3 extractable P ranged from 17 to 28 ppm. According to the current University of Arkansas CES interpretation, the soil-test P level was Low (16 to 25 ppm) at GRZ51 and SFZE57, and Medium (26 to 35 ppm) at GRZ53. According to the current University of Arkansas CES soil-test based P fertilization guidelines, for corn with a yield goal of >200 bu/acre, the Low and Medium soil-test P levels receive recommendations of 110 and 80 lb P_2O_5/acre, respectively.

Phosphorus fertilization significantly influenced ($P \leq 0.10$) corn grain yield (Table 4) at the two sites with Low (GRZ51 and SFZE57) Mehlich-3 extractable soil-P levels (Table 2). Lack of P response at GRZ53, rated as having a Medium soil-test P level, is consistent with our previous results and our current interpretation of Mehlich-3 extractable soil-test P for corn production in Arkansas. At the two P-responsive sites, grain yields of corn that did not receive fertilizer-P ranged from 170 to 193 bu/acre and the grain yield of corn fertilized with P ranged from 198 to 239 bu/acre. Maximal corn yields were produced by application of 40 to 80 lb P_2O_5/acre. The application of rates greater than 80 lb P_2O_5/acre did not serve to increase yield but likely would have increased soil-test P for subsequent crops.

Potassium Experiments

Soil pH ranged from 5.4 to 7.3 and Mehlich-3 extractable P ranged from 9 to 40 ppm, in the six K trials (Table 3). The average Mehlich-3 extractable K ranged from 49 to 83 ppm among the six sites. According to the CES soil-test interpretation, soil-test K was Very Low (< 61 ppm) at GRZ54 and SFZE52 and Low (61 to 90 ppm) at the other four sites. Current fertilization guidelines for corn with a yield goal of >200 bu/acre would have recommended 160 and 115 lb K_2O/acre for the Very Low and Low soil-test K levels, respectively.

Potassium fertilization significantly ($P \leq 0.10$) affected corn grain yield at all sites except DEZ54 and GRZ52 (Table 5). The positive yield response to K fertilization at four sites is consistent with current CES recommendations for soil-test based fertilizer-K. However, the lack of response to K fertilization at DEZ54 and GRZ52 was unexpected considering the Low soil-test K level and relatively low variability in corn grain yields (CV = 4.5% to 6.0%). Grain yield of corn that did not receive fertilizer-K ranged from 146 to 224 bu/acre and grain yield of corn that received K ranged 173 to 245 bu/acre. At the K-responsive sites, the minimum K rate needed to produce maximal corn yields ranged from 40 to 120 lb K_2O/acre.

PRACTICAL APPLICATIONS

The 2015 results show that P fertilization did not increase corn grain yield when Mehlich-3 extractable P in the 0- to 6-in. depth was within the Medium level. At the two P-responsive sites, corn receiving 40 to 80 lb P_2O_5/acre produced the numerically greatest corn grain yields. Potassium fertilization significantly increased corn grain yield at four sites with Very Low to Low soil-test K levels, but failed to influence corn yield at two sites with Low soil-test K. The data from these studies will be added to a database on corn response to P or K fertilization to evaluate the utility of existing soil-test thresholds and recommended fertilizer-P and -K rates needed to produce maximal corn yield. Additional single-year and long-term trials on soils with a wide array of soil-test P and K values are needed to increase the reliability of soil-test based P and K fertilizer recommendations for irrigated-corn production having relatively high yield potential in eastern Arkansas.

ACKNOWLEDGMENTS

Research was funded by the Arkansas Corn Check off Program funds administered by the Arkansas Corn and Grain Sorghum Promotion Board, Fertilizer Tonnage Fees, and the University of Arkansas System Division of Agriculture. The assistance of the staff of the University of Arkansas Soil Testing and Research Laboratory in Marianna with laboratory analyses is greatly appreciated.

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Table 1. Site identification code, test nutrient(s), soil series, corn hybrid, planting, fertilizer application, and harvest dates for trials conducted in Desha (DEZ52, DEZ54), Greene (GRZ51-54), and St. Francis (SFZE52, SFZE54, SFZE57) counties during 2015.

Site code	Test nutrient	Soil series	Hybrid	Planting date	Fertilizer application date	Harvest date
DEZ52	K	Hebert silt loam	Mycogen 2D848	30 April	18 May	8 Sep
DEZ54	K	Hebert silt loam	Mycogen 2D848	30 April	27 April	8 Sep
GRZ51, GRZ52	P, K	Calloway silt loam	DeKalb 6208	23 April	22 April	31 Aug
GRZ53, GRZ54	P, K	Calloway silt loam	DeKalb 6687	25 April	21 April	31 Aug
SFZE52, SFZE54	K	Calloway silt loam	Agri Gold 6659	7 May	27 May	17 Sep
SFZE57	P	Crowley silt loam	Dyna Grow 56V646	7 May	5 May	16 Aug

Table 2. Selected chemical property means of soil samples collected from the 0- to 6-in. depth before P-fertilizer application for three P-fertilization trials established in Greene (GRZ51, GRZ53) and St. Francis (SFZE57) counties during 2015.

		Mehlich-3-extractable nutrients						
Site ID	Soil pH[a]	P	SD P[b]	K	Ca	Mg	Cu	Zn
		(ppm)						
GRZ51	5.7	17	±7	89	696	174	0.8	10.7
GRZ53	5.3	28	±9	68	479	106	1.8	15.5
SFZE57	7.1	23	±3	104	1252	220	0.9	8.1

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

[b] SD, Standard deviation of Mehlich-3 extractable soil-test P means.

Table 3. Selected chemical property means of soil samples taken from the 0- to 6-in. depths before fertilizer-K application for six trials conducted in Desha (DEZ52, DEZ54), Greene (GRZ52, GRZ54), and St. Francis (SFZE52, SFZE54) counties during 2015.

		Mehlich-3-extractable nutrients						
Site ID	Soil pH[a]	P	K	SD K[b]	Ca	Mg	Cu	Zn
		(ppm)						
DEZ52	6.0	40	64	±11	727	111	1.0	5.1
DEZ54	6.7	31	73	±8	759	112	0.8	1.5
GRZ52	5.9	9	79	±4	755	203	1.0	8.1
GRZ54	5.4	17	51	±7	489	102	1.5	14.4
SFZE52	7.3	22	49	±4	1527	254	1.5	2.5
SFZE54	6.9	27	83	±8	1474	251	1.1	3.3

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

[b] SD, Standard deviation of Mehlich-3 extractable soil-test K means.

Table 4. Effect of P-fertilization rate on corn grain yield for three trials conducted in Greene (GRZ51, GRZ53), and St. Francis (SFZE57) counties during 2015.

	Grain yield		
Fertilizer-P rate	**GRZ51**	**GRZ53**	**SFZE57**
(lb P_2O_5/acre)		**---------------------(bu/acre)---------------------**	
0	193	170	170
40	198	163	239
80	222	187	201
120	215	169	233
160	222	187	201
C.V., %[a]	5.0	13.2	11.7
P value	0.0138	0.1293	0.0286
LSD 0.10[b]	16	NS[c]	37

[a] CV = Coefficient of variation.
[b] LSD = Least significant difference at *P* = 0.10.
[c] NS = not significant (*P* >0.10).

Table 5. Effect of K-fertilization rate on corn grain yield for six trials conducted in Desha (DEZ52, DEZ54), Green (GRZ52, GRZ54), and St. Francis (SFZE52, SFZE54) counties during 2015.

	Grain yield						Grain yield
Fertilizer-K rate	**DEZ52**	**DEZ54**	**GRZ52**	**GRZ54**	**SFZE54**	**K rate**	**SFZE52**
(lb K_2O/acre)			**------------------------------------(bu/acre)------------------------------------**			**(lb K_2O/acre)**	**(bu/acre)**
0	187	201	224	146	157	0	148
40	209	203	229	173	216	50	200
80	204	212	220	210	221	100	223
120	207	205	227	207	245	150	244
160	205	213	217	201	223	200	220
200	202	213	213	221	233	-	-
C.V., %[a]	4.5	4.5	6.0	13.1	7.4	C.V., %	12
P value	0.0049	0.1091	0.438	0.0300	<0.0001	*P*-value	0.0008
LSD 0.10[b]	9	NS[c]	NS	38	17	LSD 0.10	29

[a] CV = Coefficient of variation.
[b] LSD = Least significant difference at *P* = 0.10.
[c] NS = not significant (*P* > 0.10).

Comparison of Mehlich-3 Extractable Phosphorus and Potassium from Field-Moist and Oven-Dried Soil Samples

N.A. Slaton, T.L. Roberts, R.J. Norman, and R.E. DeLong

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Soil samples submitted for routine soil test procedures are usually oven-dried in preparation for grinding and nutrient extraction. The effect of soil drying on the amount of extractable soil potassium (K) has been known for many years (Attoe, 1947; Luebs et al., 1956). More recent research showed that analysis of field-moist soil resulted in more accurate predictions regarding corn and soybean yield response to fertilizer-K addition (Barbagelata and Mallarino, 2013). The amount of K extracted from the loamy-textured soils of Arkansas is also affected by drying but perhaps not to the same extent as soils from the midwest (Martins et al., 2015). Fertilization recommendations based on field-moist soil analysis are currently available only for K from Iowa State University (Malllarino et al., 2013). Phosphorus (P) recommendations are the same regardless of whether dry or field-moist soil is used for extraction. However, Martins et al. (2016) showed that the amount of P extracted from oven-dried and field-moist loamy soils of Arkansas was also different, especially for soils within the important agronomic concentration range (<50 ppm Mehlich-3 P). This report describes the relationship of P and K extracted from several long-term fertilization trials using oven-dried and field-moist soil samples.

PROCEDURES

Soil samples from the 0- to10-cm depth were collected in late winter of 2015 from six long-term P or K fertilization trials established at the University of Arkansas System Division of Agriculture's Pine Tree Research Station (PTRS) and Rice Research and Extension Center (RREC). These trials allowed us to collect numerous samples from the same soil series and crop management background which differed only in prior P or K fertilization rate. Two of the sampled trials on a Calhoun silt loam at the PTRS followed rice (*n* = 40) or soybean (*n* = 45) and have had 0 to 160 lb K_2O/acre applied annually since 2000 or 2001. The other four trials (30 plots/trial) were located at the RREC on a Dewitt silt loam and included two P and two K trials established in 2007 and cropped to either rice (n = 60) or soybean (*n* = 60) with rates of 0, 40, 80, 120, and 160 lb K_2O or P_2O_5/acre/year. All six of the research trials are managed using no-tillage and fertilizers are applied to the soil surface.

The composite soil samples were collected and transported to the lab; the whole sample was moist sieved as described by Gelderman and Mallarino (2015), and then divided into two samples of which one was oven-dried at 65 °C for 3 days and the other half was placed in a sealed plastic bag and stored in a 5 °C incubator until analysis was performed. The moisture content of the field-moist soil was determined as described by Martins et al. (2015) and an amount of soil equivalent to 2.0 g of oven-dried soil was weighed, and 20 mL of Mehlich-3 solution was added to extract nutrients. Oven-dried soil was ground to pass a 2-mm sieve and extracted using the standard procedures. The nutrient concentration of the extracts from both oven-dried and field-moist samples were determined using inductively coupled plasma atomic emission spectroscopy (ICAP-AES, Spectro Arcos 160).

The oven-dried, soil-P or -K concentrations were regressed against the field-moist, soil-P or -K concentrations using the REG procedure of SAS v. 9.4 (SAS Institute, Inc., Cary, N.C.). In each linear regression model, the field-moist soil-P or -K concentration was the independent variable and oven-dried soil-P or -K concentration was the dependent variable.

RESULTS AND DISCUSSION

The minimum and maximum values for soil pH, Mehlich-3 extractable P and K (dry soil), and the ratio of field-moist soil nutrient/oven-dried soil nutrient soil properties for each of the six trials are summarized in Table 1. The difference between field-moist and oven-dried soil K ranged from -31 (dry < moist) to 50 (dry > moist) ppm K for the Dewitt soil (RREC) and -12 (dry < moist) to 21 (dry > moist) ppm K for the Calhoun soil (PTRS). Regressing oven-dried soil K against field-moist soil K for the Calhoun (Fig. 1) and Dewitt (Fig. 2) soils resulted in significant, linear relationships that had intercept coefficients that were greater than 0, and linear coefficients that were less than 1.0. Based on these relationships, field-moist soil K is lower than oven-dried soil K when extractable K is <100 ppm for the Calhoun soil and <136 ppm for the Dewitt soil. The equilibrium point is evident for each soil where the dry-to-moist soil-K ratio equals 1.0 (Fig. 3). The different equilibrium points for the two soils suggest that each soil is unique and an average relationship to convert dry-soil K to field-moist K would not be accurate for all soils. Should field-moist soil prove to be a more accurate predictor of crop yield response to K fertilization, soil-test labs will need to decide whether extraction will be performed on dry or moist soil.

The long-term P fertilization trials on the Dewitt soil at the RREC were the only sites sampled for P, which is not recognized as being affected by drying to the same extent as K. The difference between oven-dried and field-moist soil P concentrations ranged from -3 (dry < moist) to 12 (dry > moist) ppm P with only 2 of the 60 observations being negative (dry < moist; Fig. 4). The relationship was significant and linear with a slope that was 1.0, but the intercept was different than 0 indicating a consistent increase of 5 ppm P from oven drying for the Dewitt soil. The dry-to-moist soil P ratio shows that the difference has the greatest effect on soils that have < 50 ppm P, and especially < 20 ppm P which are within the most important soil-test range in regards to agronomic recommendations (Fig. 5). Additional soils are needed to examine whether the oven-drying effect described for the Dewitt soil is consistent for other soils.

PRACTICAL APPLICATIONS

Oven drying soil changes the amount of P and K extracted from soil with the differences generally being non uniform in that the relationships have an intercept greater than 0 and a slope less than 1.0. These differences would potentially increase two errors in soil-test-based recommendations including identification of soils that require fertilization as having adequate P or K (no fertilizer recommended) and soils that do not require fertilization as needing low to moderate amounts of fertilizer. Nearly all soil-test labs in the USA are set-up to process and extract dry soil samples. Adoption of moist soil analysis as the standard method would initially require substantial changes to processing and may have the disadvantage of having a greater labor requirement and increased processing time. The process of soil collection may also be affected as field-moist soil analysis may require collection of samples that are neither too wet nor too dry. Moist-soil analysis may potentially improve the accuracy of soil-test based fertilizer recommendations and warrants additional research.

ACKNOWLEDGMENTS

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Table 1. Previous crop grown (Prev Crop), observation number (*n*), minimum (min) and maximum (max) values of soil pH, and selected Mehlich-3 P and K expressions of oven-dried soil from six long-term fertilization trials used to evaluate the relationship between field-moist and oven-dried soil-test P and K.

			Soil pH		Mehlich-3 P		Moist/Dry P ratio		Mehlich-3 K		Moist/Dry K ratio	
Soil[a]	**Crop[b]**	**n**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
					----- (ppm)------				----- (ppm) ----			
PTRS-K1	R	40	7.4	8.2	18	35	1.07	1.89	38	103	1.06	1.58
PTRS-K2	S	45	8.0	8.3	18	45	1.14	1.56	30	112	0.93	1.71
RREC-K1	R	30	5.4	6.3	30	45	0.98	1.46	76	179	0.99	1.72
RREC-K2	S	30	5.2	5.8	29	48	1.09	1.52	76	240	0.84	1.38
RREC-P1	R	30	5.2	5.8	12	84	0.98	1.47	104	167	0.71	1.16
RREC-P2	S	30	5.3	6.2	9	81	0.96	2.09	86	127	0.88	1.17

[a] PTRS, Pine Tree Research Station (Calhoun silt loam); RREC, Rice Research Extension Center (Dewitt silt loam).

[b] Previous Crop abbreviations: R, rice; S, soybean.

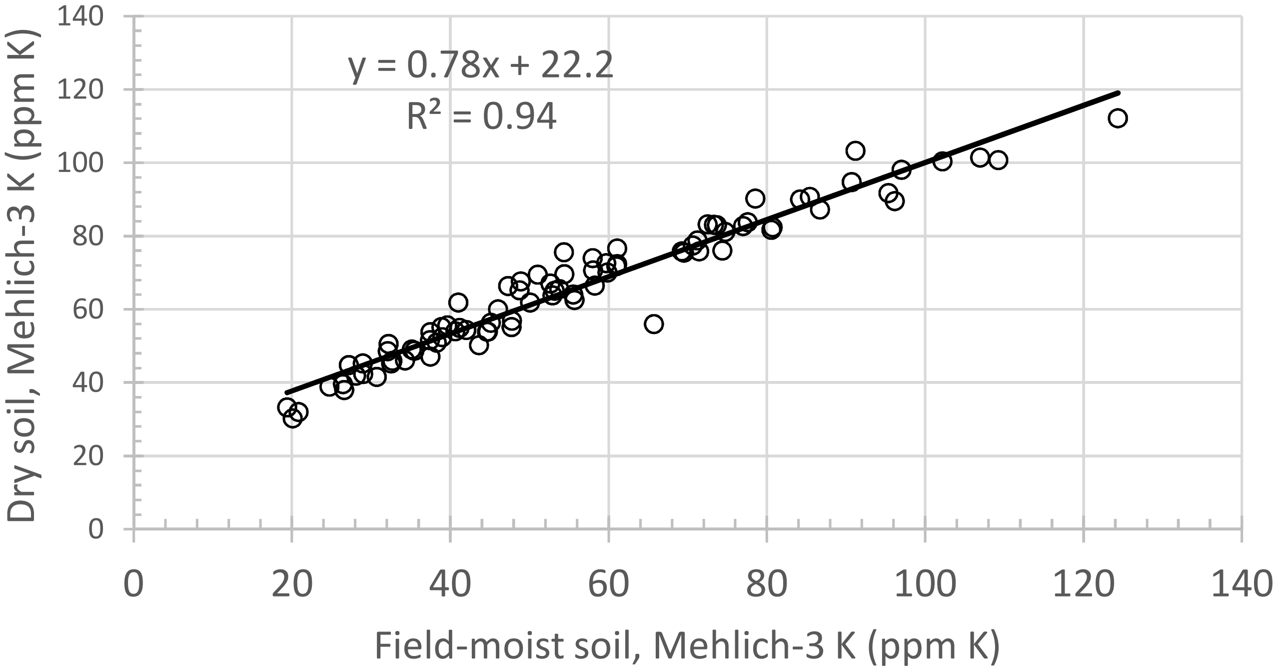

Fig. 1. The relationship between Mehlich-3 extractable oven-dried and field-moist soil K (0- to 10-cm depth) for a Calhoun silt loam that has received 0 to 160 lb K_2O/acre/year since 2000 at the Pine Tree Research Station. Soil samples were collected in winter 2015 following rice (*n* = 40) and soybean (*n* = 45).

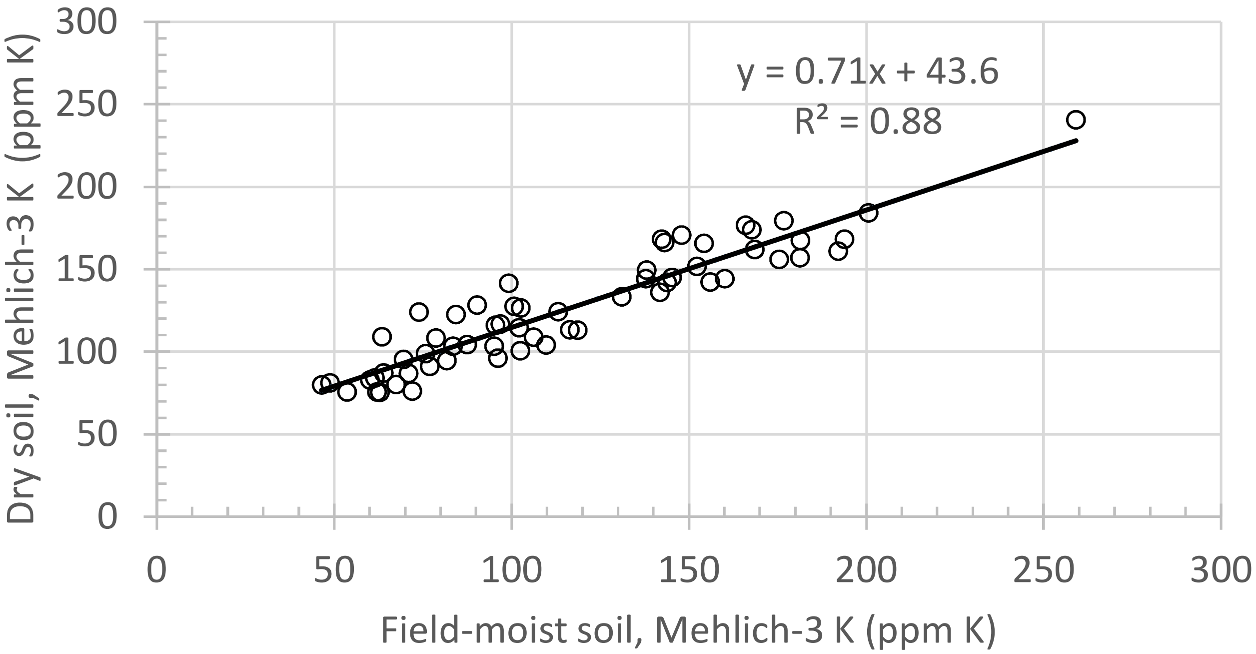

Fig. 2. The relationship between Mehlich-3 extractable oven-dried and field-moist soil K (0- to 10-cm depth) for a Dewitt silt loam that has received 0 to 160 lb K_2O/acre/year since 2007 at the Rice Research and Extension Center. Soil samples were collected in winter 2015 following rice (*n* = 30) and soybean (*n* = 30).

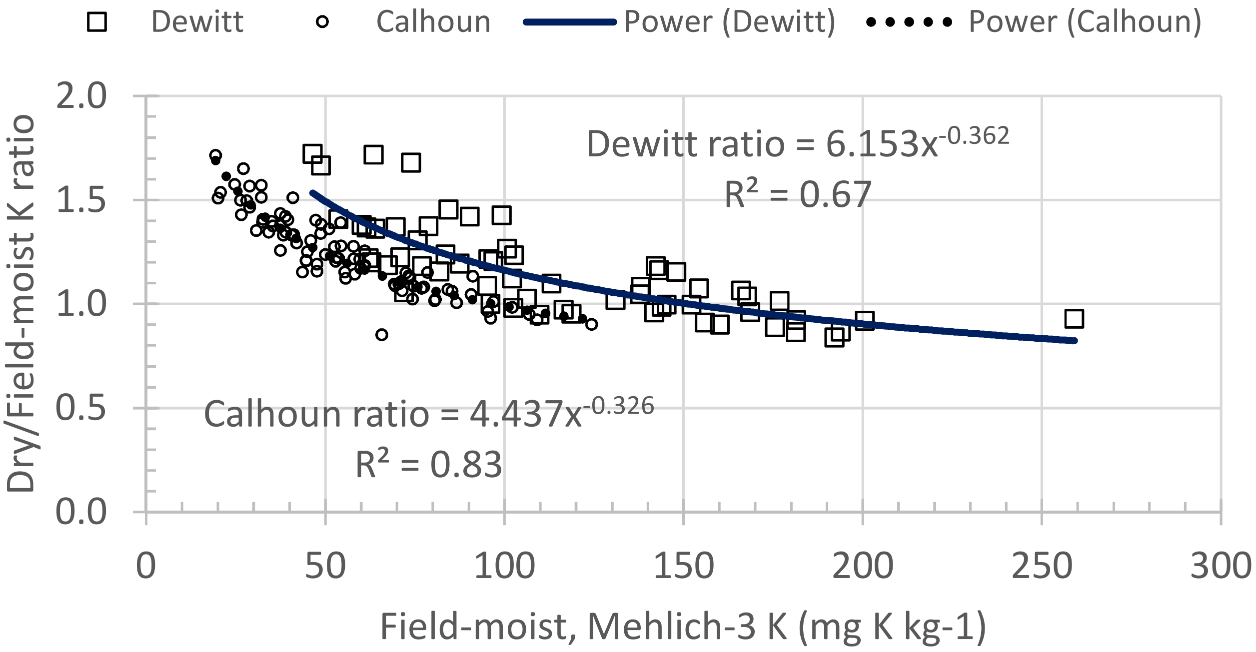

Fig. 3. The relationship between the dry/field-moist soil-K ratio regressed against Mehlich-3 extractable field-moist soil K (0- to 10-cm depth) for Calhoun and Dewitt silt loams that have received 0 to 160 lb K_2O/acre/year since 2000 or 2007, respectively.

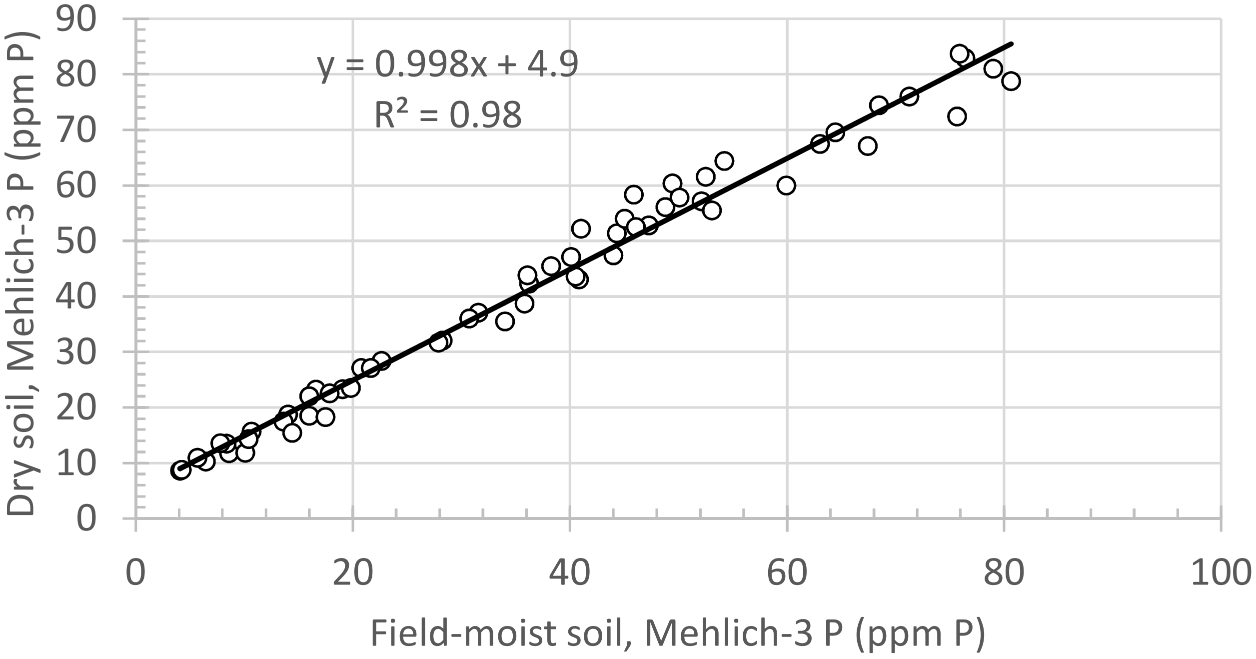

Fig. 4. The relationship between Mehlich-3 extractable oven-dried and field-moist soil P (0- to 10-cm depth) for a Dewitt silt loam that has received 0 to 160 lb P_2O_5/acre/year since 2007 at the Rice Research and Extension Center. Soil samples were collected in winter 2015 following rice (*n* = 30) and soybean (*n* = 30).

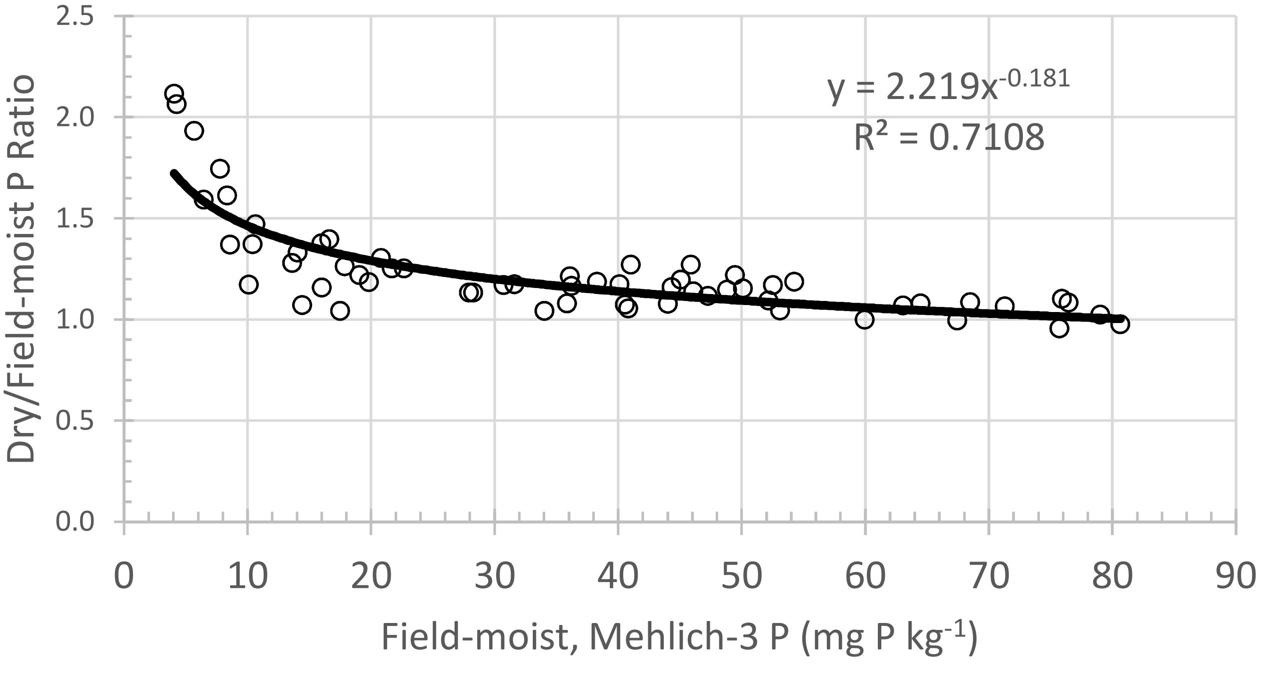

Fig. 5. The relationship between the dry/field-moist soil P ratio regressed against Mehlich-3 extractable field-moist soil P (0- to 10-cm depth) for Calhoun and Dewitt silt loams that have received 0 to 160 lb P_2O_5/acre/year since 2007 at the Rice Research and Extension Center.

Soil-Test Phosphorus and Potassium Fluctuations Following Rice and Soybean Harvest Yield Through Early Spring

N.A. Slaton, M. Fryer, T.L. Roberts, R.J. Norman, J.T. Hardke, J. Hedge, and D. Frizzell

BACKGROUND INFORMATION AND RESEARCH PROBLEM

The demand for routine soil analysis in Arkansas has increased exponentially over the last 40 years (Fig. 1). The time of year that soil samples are collected and submitted for analysis in Arkansas has changed in the last decade. The late winter and early spring months used to be the time that soil samples were submitted for analysis, but the greatest number of soil samples are now submitted in October and November suggesting that soil samples are collected within weeks after most summer crops are harvested (Fig. 2). The change in soil sample collection time raises several questions about how sample time (and submission for analysis) influences laboratory operations (e.g., the timeliness of soil analysis services) and whether soil chemical properties and the resulting fertilizer recommendations are affected by soil sample collection time. The soil-test based-P and -K fertilizer recommendations in Arkansas are based on soil samples collected from January until immediately before planting (e.g., early June). Knowledge of how soil-test P and K trend across time is important in relation to how fertilizer recommendations might be influenced.

The issue of soil sample collection methods (Keogh and Maples, 1967) and time (Keogh and Maples, 1972) have been addressed in prior Arkansas research. Soil chemical properties are known to fluctuate across time but the role of how previous crop [e.g., rice (*Oryza sativa* L.) and soybean [*Glycine max* (L.) Merr.)] influences this process has not been thoroughly characterized. In general, soil-test K typically increases from summer crop harvest until sometime in the winter or early spring with the increase in soil-test K being significantly correlated with K loss from harvested crop residue (Oltmans and Mallarino, 2015). Soil pH is known to fluctuate with soil moisture, salinity, and microbial activity with the greatest pH values usually occurring in the winter and the lowest pH values occurring in the summer (Keogh and Maples, 1972) when evapotranspiration and microbial activity are both high. Soil-test P fluctuates less numerically than soil-test K, but the more narrow agronomic range of soil-test P levels may still result in small soil-test P fluctuations having a substantial effect on fertilizer-P recommendations. The objectives of this research were to evaluate i) how Mehlich-3 P and K were affected by soil sample collection time and summer crop P and K fertilization rate and ii) the range of soil moisture contents under which soil samples can be collected from fall through early spring.

PROCEDURES

Selected field fertilization experiments conducted with rice and soybean in 2013 and 2014 were soil sampled periodically following summer-crop harvest until the following spring. The field trials were part of Matthew Fryer's thesis research (Fryer, 2015). Soil samples were collected following either rice (6 sites) or soybean (6 sites) in the rotation. In 2014, soil samples from selected sites were actually collected prior to harvest. All soil samples were collected from the 0- to 4-in. depth from the same plots of two fertilization treatments. The two fertilization treatments included the no fertilizer-P or -K control plots and another treatment that received both fertilizer-P and -K. Although each field trial contained six or more replications of each treatment, soil samples were collected from only four of the replicates.

The general agronomic information for each trial is listed in Table 1. A composite soil sample was collected from each plot (104 ft^2 for rice plots and 260 ft^2 for soybean plots) with no soil cores from the outside 0.5 ft of each plot's boundary. Each composite sample consisted of five soil cores which were placed in sealable plastic bags. The soil samples were transported to the University of Arkansas System Division of Agriculture's Agricultural Diagnostic Laboratory in Fayetteville, Ark., where the soil moisture content was determined and samples were dried for 48 hours at 150 °F, ground and mixed, and passed through a 2-mm sieve. A subsample of oven-dried soil was weighed to 2.00 g, extracted with 20 mL Mehlich-3 solution and the nutrient concentration of the extracts were determined by inductively coupled plasma atomic emission spectrophotometry. Soil pH was measured in a 1:2 soil:water mixture.

Each experiment was a randomized complete block design with a split-plot treatment structure where fertilizer treatment was the whole plot and sample time was the subplot. Each treatment was replicated four times. The mean soil-test P and K was calculated for each sample time, and the initial mean soil-test P and K from soil samples collected immediately before planting from plots that received no P or K fertilizer was subtracted to calculate P and K difference. A negative P or K difference indicates that soil-test P or K declined after cropping. The mean soil-test values represent a total of 20 soil cores per treatment on each sample day from a total area of 416 ft^2 for rice plots and 1040 ft^2 for soybean. We assumed that the original soil-test P and K mean was representative of all plots. The analysis of covariance (ANCOVA) was performed using the GLM procedure in SAS v. 9.4 (SAS Institute, Inc., Cary, N.C.). Phosphorus or K difference was regressed across days after harvest (DAH) including the linear and quadratic terms of DAH that were allowed to depend on fertilizer-P or -K rate applied to the previous crop and all possible interactions. The model was simplified by sequentially eliminating the most complex non-significant ($P \leq 0.10$) term until the simplest model was derived. This process was performed by the previous crop (rice or soybean) prior to post-harvest soil sampling (overall average response) and for each individual site-year. Lastly, several site-years cropped to soybean in 2014 were sampled once before harvest, where the harvest date was time 0 and the number of days before harvest was entered as a negative value.

RESULTS AND DISCUSSION

The post-harvest, soil-test P and K means, averaged across sample times, are listed in Table 2 for the two fertilizer rates applied at each of the 12 research sites. Soil moisture ranged from lows of 11% to 12% at multiple sites, which occurred most commonly after rice harvest or before soybean harvest, to high moistures of 27% to 28% usually following rice in January or early February. Soil samples were not collected on a few occasions because the soil was too wet to extract intact cores. The average (across sites) coefficient of variation (CV) of post-season soil-test results was slightly higher for P (18.1%) than for K (15.6%), but the CV for soil-test K was numerically greater at some locations. Soil-test K tended to be more variable following rice, but soil-test P always had greater numerical CV values following soybean. Soil that had fertilizer applied to the previous crop usually had numerically comparable CV values as soil that received no P or K fertilizer.

Averaged over all site-years, soil-test P across time was constant following rice (Fig. 3) and declined slightly following soybean (Fig. 4). Within each previous crop, the rate of fertilizer-P applied significantly influenced the magnitude (intercept value) of the difference. Following rice, the initial model simplified to a significant intercept term which depended on fertilizer-P rate, as the linear slope coefficient (-0.0098 ppm/DAH) was not significantly different than 0 ($P = 0.3154$, Fig. 3). Soil-test P declined by -10.0 ppm (±1.1, standard error) when 0 lb P_2O_5/acre was applied and by -5.4 ppm when 60 lb P_2O_5/acre was applied to the previous rice crop. Following soybean, soil-test P declined linearly at a uniform rate of 0.013 ppm/DAH (± 0.0046 standard error) with the intercept depending on fertilizer-P rate applied to the previous soybean crop [Fig. 4, -2.4 (±0.5) ppm for soybean fertilized with 0 lb P_2O_5/acre and 2.5 (±0.5) ppm for soybean fertilized with 60 lb P_2O_5/acre]. These results are somewhat logical since the flooded soil conditions used for rice production are known to suppress Mehlich-3 extractable P (Norman et al., 2003), and, given the average (across site-years) grain yields of each crop (205 and 206 bu/acre for rice and 55 and 61 bu/acre for soybean) and fertilizer-P rate, P removal by the harvested yield averaged 62 lb P_2O_5/acre for rice (calculated 0.30 lb P_2O_5/bu × 205 to 206 bu/acre) compared to 44 to 49 lb P_2O_5/acre removed by soybean (0.8 lb P_2O_5/bu × 55 to 61 bu/acre).

The derived soil-test K response trend was different following rice than following soybean (Figs. 5 and 6). Following rice, soil-test K increased at a uniform quadratic rate as the DAH increased peaking at 128 DAH (Fig. 5). The peak predicted soil-test K was -4 ppm less than the original (preplant) value for rice fertilized with 0 lb K_2O/acre and +3 ppm greater for rice fertilized with 90 to 120 lb K_2O/acre. The predicted peaks show that soil-test K increased by 22 ppm following rice harvest with the peak in late December to early January. The 22 ppm change in soil-test K following rice represents 28% of the initial average (across all rice site-years) soil-test K (80 ppm). The intercept was affected by the fertilizer-K rate applied to the prior rice crop with rice receiving no fertilizer-K [-25.7 (±3.8) ppm] having a lower (e.g., more negative) intercept than rice receiving 90 to 120 lb K_2O/acre [-18.8 (±3.8) ppm]. The observed quadratic soil-test K increase across time is likely from K slowly leaching from the dry rice straw following harvest (Oltmans and Mallarino, 2015). The overall average rice grain yield (205 and 206 bu/acre) resulted in an average removal of only 41 lb K_2O/acre (calculated 0.20 lb K_2O/bu × 205 or 206 bu/acre). The K that remains in the rice straw after harvest may account for up to 80% of the total aboveground K content during the season (Dobermann et al., 1996). Potassium exists exclusively in the cell solution and is not part of cell walls or other plant structures that require decomposition to be released, which allows K to leach from crop stover with adequate rainfall following harvest.

Following soybean, soil-test K did not change across time as the linear slope coefficient (-0.0192 ppm/DAH) was not significant ($P = 0.2369$, Fig. 6). The application of 90 to 120 lb K_2O/acre to the prior soybean crop maintained soil-test K at 1.8 ppm above the original (preplant) value; whereas application of no fertilizer-K to the soybean crop resulted in a net decrease of 17 ppm at soybean harvest. The average (across site-years) soybean grain yields (55 and 61 bu/acre) resulted in average removals of 66 (no K fertilizer) and 73 (K fertilized) lb K_2O/acre (calculated 1.2 lb K_2O/bu × 55 or 61 bu/acre). The lack of change in soil-test K across time following soybean (as compared to rice) may be because of the greater K removal by soybean and less total K in the stover that is returned to the field.

PRACTICAL APPLICATIONS

Soil samples collected after soybean represent the largest proportion of soil samples submitted to the University of Arkansas System Division of Agriculture's Soil Test Laboratory, but soil samples are also collected following other crops including rice. Although the previous crop was not formerly compared in the regression analyses presented here, the trends provide strong evidence that the crop grown prior to soil sampling and the time after harvest can influence soil-test results and should be considered when collecting soil samples, interpreting the soil-test results, or both. Based on these results, collecting soil samples following soybean in the rotation offers the most consistent soil-test results which are least affected by sample time (early fall to early spring).

ACKNOWLEDGMENTS

Research was funded by the Soybean Check-off Program administered by the Arkansas Soybean Promotion Board, Rice Check-off Program administered by the Arkansas Rice Research and Promotion Board, Fertilizer Tonnage Fees, and the University of Arkansas System Division of Agriculture.

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Table 1. Selected agronomic information from 12 field trials where soil samples were collected from fall through spring 2013-14 and 2014-15.

Site ID	Location-(field ID) and year[a]	Crop grown	Soil series	Soil pH	P	K	Yield[b] (no P or K)	Yield[b] (fertilized)	Yield p-value	Fertilizer rate[b]
					------(ppm)	-----	(bu/acre)			(lb P_2O_5–K_2O)
1	PTRS-MC 2013	Rice	Calhoun	7.1	16	70	210	210	0.92	60 – 90
2	PTRS-D12 2013	Rice	Loring	7.0	23	108	251	244	0.39	60 – 120
3[c]	PTRS-F18 2014	Rice	Calhoun	7.8	13	55	227	240	0.09	60 – 120
4	PTRS-JC 2014	Rice	Calhoun	7.6	61	90	183	183	0.91	60 – 120
5	PTRS-I10 2014	Rice	Calloway	6.6	27	72	208	210	0.68	60 – 120
6	RREC 2014	Rice	Dewitt	7.0	13	85	151	146	0.39	60 – 120
7	PTRS-C4 2013	Soybean	Calloway	6.9	18	88	50	55	<0.01	60 – 120
8	CBS 2013	Soybean	Convent	5.7	23	83	58	69	0.02	60 – 120
9	PTRS-D20 2013	Soybean	Calloway	7.0	8	94	44	52	<0.01	60 – 120
10	PTRS-D12 2014	Soybean	Calloway	7.6	19	76	62	63	0.47	60 – 120
11	PTRS-I10 2014	Soybean	Calloway	7.2	1 7	57	52	64	<0.01	60 – 120
12	RREC 2014	Soybean	Dewitt	6.2	16	72	53	57	0.05	60 – 120

[a] PTRS, Pine Tree Research Station; RREC, Rice Research and Extension Center; and CBS, (Lon Mann Cotton Research Station) Cotton Branch Station.

[b] Two fertilizer treatments were sampled at each site-year including soil that received 'no-P or -K' and soil that received P and/or K fertilizer (fertilized). See footnote 'c' below for the one exception.

[c] For site-year 3, the no-P or -K treatment received 60 lb P_2O_5 with 0 lb K_2O; the results were excluded from regression analyses.

Table 2. The mean (*n* = 32-43), standard deviation (SD), and coefficient of variation (C.V., or relative standard deviation) of Mehlich-3 soil-test P and K from the 0- to 4-in. depth in soil samples before planting (initial) and late season (post-harvest) between September (near crop maturity or harvest) and the following early spring (March).

Site ID	Location-(field ID) and year[a]	Initial Soil P	Initial Soil K	Soil moisture at sampling Mean	Soil moisture at sampling SD	Soil moisture at sampling CV	Post-harvest soil-test P Mean	Post-harvest soil-test P SD	Post-harvest soil-test P CV	Post-harvest soil-test K Mean	Post-harvest soil-test K SD	Post-harvest soil-test K CV
		----- (ppm) -----		------- (%) ------			-----(ppm)----		(%)	-------(ppm) ----		(%)
1	PTRS-MC 2013	16	70	19.5	3.2	16	11.5	1.6	14	68	15	22
		--[b]	--	19.4	3.1	16	16.3	2.9	18	73	15	20
2	PTRS-D12 2013	23	108	20.6	4.2	20	18.2	2.3	13	97	26	27
		--	--	20.5	3.8	18	22.5	2.5	11	110	24	22
3	PTRS-F18 2014	13	55	23.9	2.2	9	9.3	1.7	19	59	8	13
		--	--	24.2	2.1	9	10.5	2.1	20	66	11	16
4	PTRS-JC 2014	61	90	22.4	1.6	7	42.2	4.2	10	72	10	14
		--	--	23.5	7.4	32	49.4	4.8	10	74	10	14
5	PTRS-I10 2014	27	72	22.8	1.2	5	17.8	1.5	9	57	7	13
		--	--	22.5	3.0	13	19.8	1.5	7	68	10	14
6	RREC 2014	13	85	21.5	1.3	6	5.9	2.2	38	75	6	8
		--	--	21.2	1.4	6	7.7	3.0	39	79	7	9
7	PTRS-C4 2013	18	88	19.6	1.9	10	14.7	2.4	16	71	11	15
		--	--	19.5	1.8	9	19.7	3.4	17	90	13	14
8	CBS 2013	23	83	21.6	1.4	7	20.5	2.9	14	64	6	9
		--	--	21.3	1.4	7	22.8	2.6	12	86	10	12
9	PTRS-D20 2013	8	94	17.2	2.6	15	7.8	1.4	18	70	7	10
		--	--	16.8	2.8	17	11.5	4.0	35	94	11	12
10	PTRS-D12 2014	19	76	21.1	3.1	15	16.0	3.3	21	58	11	19
		--	--	21.6	3.1	14	19.2	6.2	21	69	13	18
11	PTRS-I10 2014	17	57	21.7	2.4	11	13.9	1.5	11	48	7	16
		--	--	21.8	2.1	10	20.6	4.9	24	61	10	16
12	RREC 2014	16	72	17.6	4.7	27	12.1	1.5	13	52	11	21
		--	--	17.8	4.3	24	18.2	4.5	25	79	16	21

[a] PTRS, Pine Tree Research Station; RREC, Rice Research and Extension Center; and CBS, (Lon Mann Cotton Research Station) Cotton Branch Station.

[b] Soil samples were not collected from the plots that received P and K fertilizer but were assumed to have similar mean values as soil that received no fertilizer-P or -K.

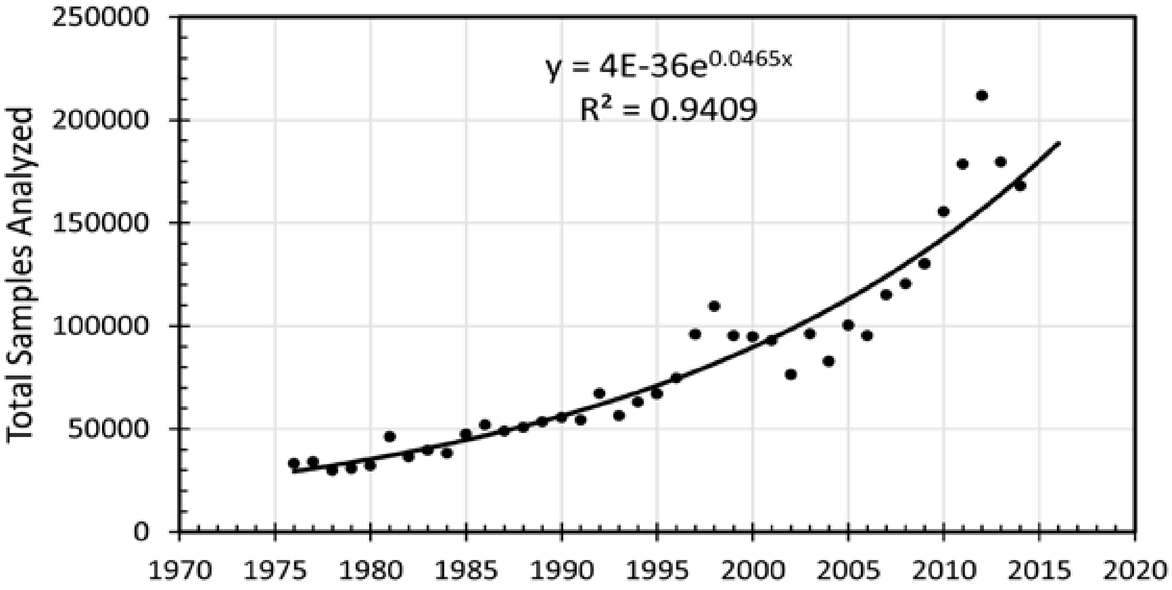

Fig. 1. The number of soil samples analyzed by calendar year at the University of Arkansas System Division of Agriculture's Marianna Soil Test Laboratory from 1976 through 2014.

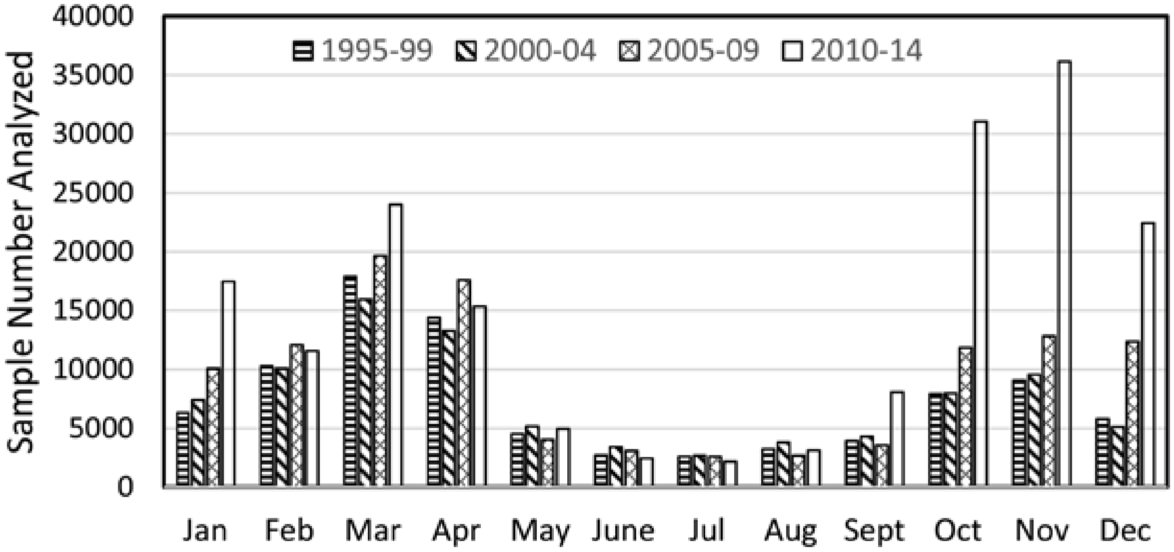

Fig. 2. The number of samples analyzed by month since 1995 expressed as five-year averages at the University of Arkansas System Division of Agriculture's Marianna Soil Test Laboratory.

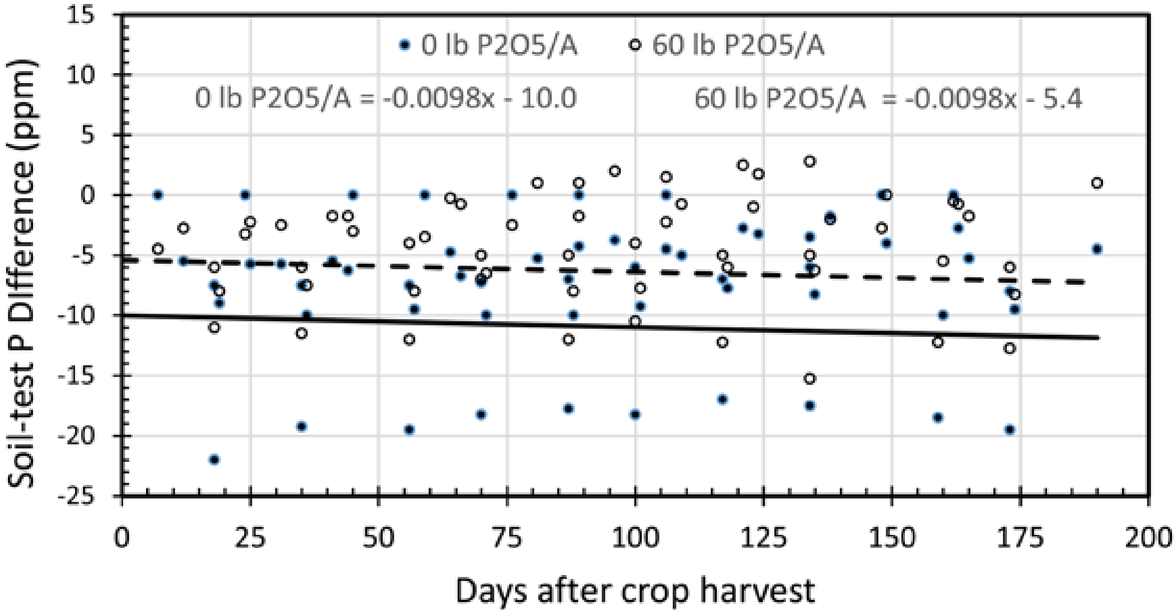

Fig. 3. The difference in soil-test P (Post-harvest – Preplant) as affected by time after rice harvest and fertilizer-P rate applied to the previous rice crop in five loamy-textured fields (R^2 = 0.18). Trend line legend: The solid line represents 0 lb P_2O_5/acre and the dashed line represents the 60 lb P_2O_5/acre.

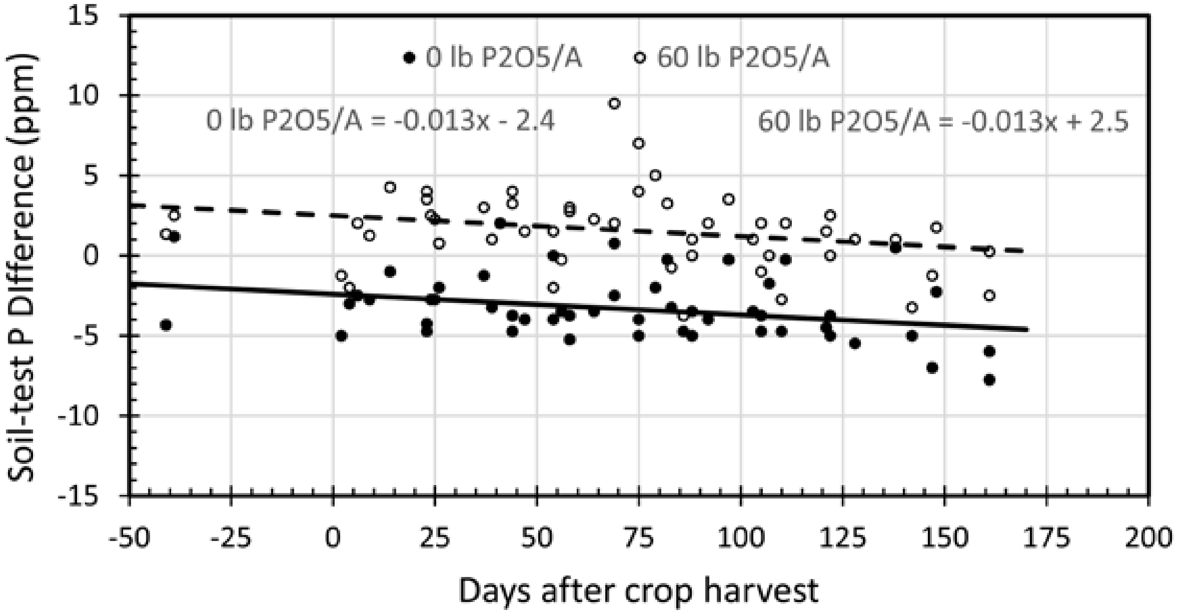

Fig. 4. The difference in soil-test P (Post-harvest – Preplant) as affected by time after soybean harvest and fertilizer-P rate applied to the previous soybean crop in six loamy-textured fields (R^2 = 0.56). Trend line legend: The solid line represents 0 lb P_2O_5/acre and the dashed line represents the 60 lb P_2O_5/acre.

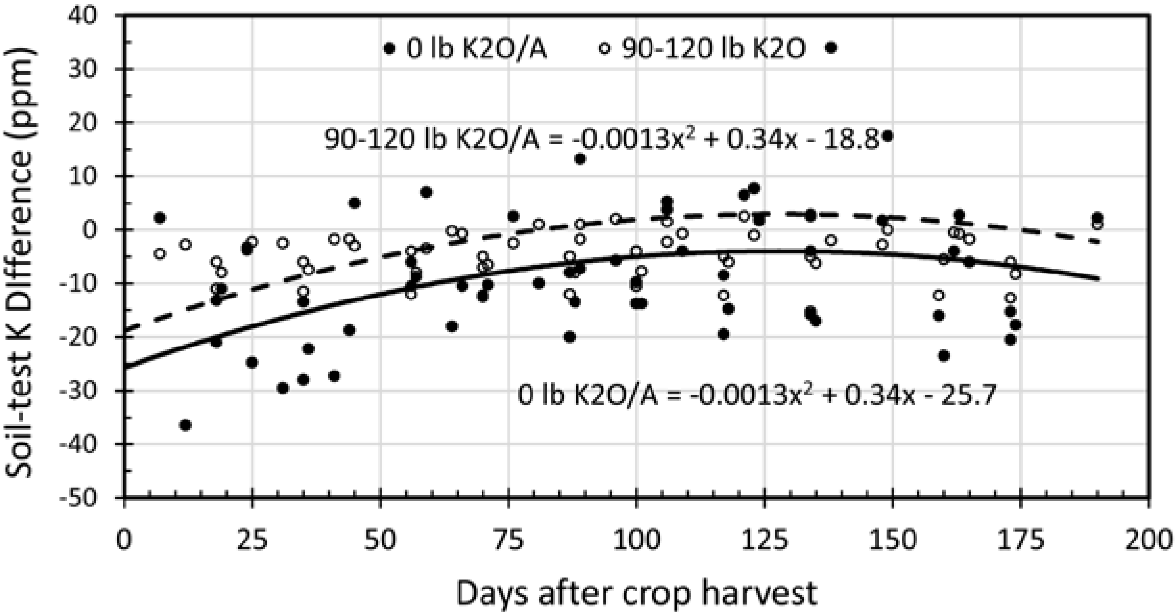

Fig. 5. The difference in soil-test K (Post-harvest – Preplant) as affected by time after rice harvest and fertilizer-K rate applied to the previous rice crop in five loamy-textured fields (R^2 = 0.25). Trend line legend: The solid line represents 0 lb K_2O/acre and the dashed line represents the 90-120 lb K_2O/acre.

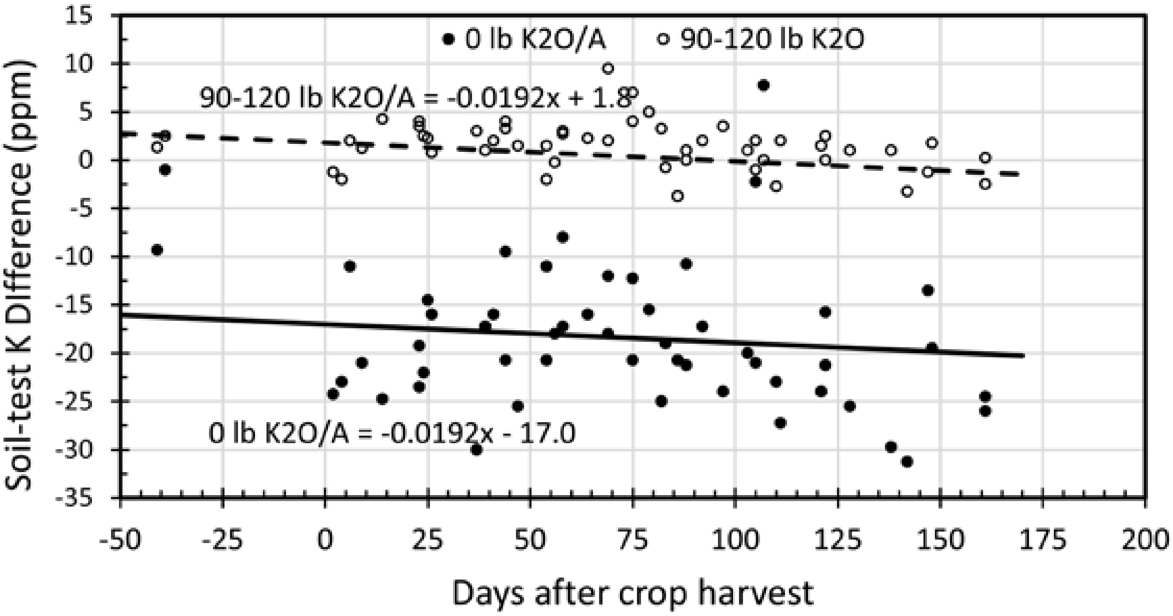

Fig. 6. The difference in soil-test K (Post-harvest – Preplant) as affected by time after soybean harvest and fertilizer-K rate applied to the previous soybean crop in six loamy-textured fields (R^2 = 0.60). Trend line legend: The solid line represents 0 lb K_2O/acre and the dashed line represents the 90-120 lb K_2O/acre.

Soybean Root and Shoot Chloride Concentration as Affected by Chloride Rate and Cultivar Chloride Includer/Excluder Rating

N.A. Slaton, R.E. DeLong, and M. Fryer

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Soybean [*Glycine max* (L.) Merr.] cultivar sensitivity to chloride (Cl) toxicity is determined by greenhouse screening methods that involve exposing young soybean plants to a concentrated Cl solution and visual observation of the amount and rapidity of 'leaf scorch' and seedling mortality (Lee et al., 2008; Valencia et al., 2008). Based on this test, cultivars are categorized as Cl-Includer, a mixed population, and Cl-Excluder cultivars. The definition of a Cl-Excluder cultivar is usually communicated as a cultivar that takes up Cl and retains the Cl in the root system rather than transporting it to the aboveground plant structures (Abel, 1969; Valencia et al., 2008). This suggests that Cl entry into the root system of soybean cultivars is the same, regardless of cultivar Cl category; and Cl translocation from the root to the shoot is under genetic control. Abel and MacKenzie (1964) and Valencia et al. (2008) both showed that root Cl concentration was not consistently greater in Cl-Excluder cultivars compared to Cl-Includer cultivars despite Cl-Includer cultivars having consistently greater leaf-Cl concentrations than Cl-Excluder cultivars. Logic suggests that if the amount of total Cl uptake was equal and Cl-Includer cultivars have much greater Cl concentrations in the aboveground portions of the plant, then the root-Cl concentration of Cl-Excluder cultivars would be consistently greater than that of Cl-Includer cultivars. The exception to this would be if root system growth of Cl-Excluder cultivars was stimulated (or not reduced) and the Cl concentration in the root is diluted. Valencia et al. (2008) showed that root dry weight between Cl-Includer and Cl-Excluder cultivars was different only when relatively high rates of Cl salts were added. Another possible mechanism of exclusion is that Cl is 'excluded' at the root-soil interface. The objective of this small research project was to measure the Cl concentration in the aboveground (shoot) and belowground (root) portion of two soybean cultivars with different Cl ratings.

PROCEDURES

This experiment was performed within a larger Cl rate × soybean cultivar trial established at the University of Arkansas System Division of Agriculture's Pine Tree Research Station (PTRS) during 2015 on an alkaline Calloway silt loam that followed corn in rotation. Soybeans were planted on beds spaced 30 in. apart at a population of 155,000 on 10 June 2015. Soybean management and pest control at all sites closely followed recommendations from the University of Arkansas Cooperative Extension Service for furrow-irrigated (well water) soybean production. The 2015 experiment from which samples were collected was managed similarly to the experiment reported by Slaton et al. (2015) and is described in another report included in this publication.

For this experiment, two Cl rates, 0 and 750 lb Cl/acre, were used. The Cl solutions were applied on 7 July, 15 July, 19 July, 4 August, and 11 August. Briefly, the Cl was applied as a combination of $CaCl_2$•$2H_2O$ and $MgCl_2$•$6H_2O$ salts (Bulk Reef Supply Co., Golden Valley, Minn.) in a 3:1 molar ratio, which approximated the molar ratio of Mehlich-3 exchangeable Ca and Mg in the soil. The 750 lb Cl/acre was applied in five separate applications (Table 2) with the salts dissolved in 3 gal of deionized water (57 gal/acre at PTRS). The salt solution was delivered using a 4-nozzle boom with drop nozzles (Teejet XR8004VS at the PTRS Teejet Technologies, Wheaton, Ill.) that applied two rows simultaneously or, later in the season when the canopy closed, a single-nozzle boom was used to direct spray onto the side of each bed to minimize Cl runoff from furrow irrigation.

Two cultivars, Pioneer 48T53R (Includer) and 47T36R (Excluder), were sampled at the R5.5 (25 August) growth stage, after all Cl had been applied. Aboveground and belowground tissue samples were collected from one of the outside (non-harvest) rows in each of the first three replicates of soybean receiving 0 and 750 lb Cl/acre. Samples were collected by digging up two whole soybean plants in each plot. The plants were labeled and transported to a nearby laboratory where they were carefully spray washed to remove dust from the leaves and soil from the root system and rinsed a second time in deionized water. The root system was removed from the stem at the soil line, the roots and nodules of each sample were placed in a plastic bag and stored on ice for 24 hours. The nodules on each fresh root system and pods on the aboveground portion were counted and summed, the root and shoot samples were oven-dried, weighed, ground to pass a 1-mm sieve, digested with concentrated HNO_3 and 30% H_2O_2 (Jones and Case, 1990), extracted with water (Liu, 1998), and analyzed for Cl by inductively coupled plasma spectroscopy (ICPS, Spectro

Analytical Instruments Inc., Mahwah, N.J.). The roots and shoots were also digested with concentrated nitric acid and analyzed for other essential mineral nutrients.

For all measured parameters, analysis of variance (ANOVA) was conducted with the MIXED procedure in SAS v. 9.4 (SAS Institute, Inc., Cary, N.C.; Table 1). The experiment was a randomized complete block with a split-plot treatment structure where Cl rate was the whole plot and cultivar (Cl rating) was the subplot factor. When appropriate, mean separations were performed using Fisher's protected least significant difference (LSD) method at a significance level of 0.05. When the interaction was significant, an LSD that allowed any two treatments to be compared was calculated and used to evaluate treatment differences.

RESULTS AND DISCUSSION

The soybean root systems were sampled using shovels and the recovery was incomplete and possibly different from plot-to-plot. However, the process was performed as uniformly and completely as possible and the measurements of dry weight and nodule numbers have merit for comparative purposes. That said, the primary reason for sampling the roots was to assess the Cl concentration of this often ignored plant part. Root dry weight was affected by a significant interaction (Table 1). With the limited number of treatments it is difficult to determine whether the differences are an artifact of sampling error or a true response (Table 2). The nodule number present on the root system was affected only by cultivar Cl rating (Table 1). The Cl-Excluder cultivar roots (121 nodules) had more nodules than the Cl-Includer cultivar roots (88 nodules). Pod number and pod and shoot dry weight were not affected by the main effects or their interaction (Table 1).

Root Cl concentration was affected only by Cl rate (Table 1). Averaged across cultivars, root Cl concentration averaged 5922 ppm for soybean receiving 750 lb Cl/acre and 2209 ppm for the soybean receiving no Cl. The root Cl concentration differed by less than 100 ppm between the Cl-Includer and Cl-Excluder cultivars within each Cl rate (not shown). Shoot Cl concentration was affected by the interaction between Cl rate and cultivar-Cl rating (Table 1). The interaction showed that the Cl-Includer that received 750 lb Cl/acre contained greater Cl concentrations than all other treatment combinations, which were not statistically different from one another (Table 2). Numerically, the Cl-Excluder cultivar receiving 750 lb Cl/acre had greater shoot Cl concentration that the Cl-Includer that received no Cl. The Cl-Excluder cultivar that received no Cl had the lowest numerical shoot Cl concentration.

PRACTICAL APPLICATIONS

The results of this preliminary trial suggest that root Cl concentration was not different between the two selected cultivars that possessed different Cl inclusion/exclusion traits, but shoot Cl concentration was clearly affected. The root Cl concentrations were most affected by Cl application rate which also had the greatest effect on shoot Cl concentration. The objective of this small experiment was to provide additional evidence about the mechanism of Cl inclusion/exclusion. The literature suggests that Cl is taken up equally by cultivars having each trait, but Cl Includers transport Cl to the shoot; whereas Cl Excluders limit Cl transport from the root to the shoot. Based on this description, the roots of Cl Excluder cultivars would have greater root Cl concentrations. These preliminary results suggest that the root system of Cl-Excluder cultivars may limit Cl uptake, as our results showed no Cl accumulation in the root system. The trend for greater numerical Cl concentrations in the shoot of Cl-Includer cultivars does suggest that transport of Cl from the root to the shoot also may be limited,

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Table 1. Summary of analysis of variance *P*-values for selected measurements as affected by Cl rate and cultivar Cl rating and their interaction.

Source of Variation	Nodule number	Pod number	Pod dry weight	Root		Shoot	
				Dry weight	Cl concentration	Dry weight	Cl concentration
Cl Rate	0.3757	0.2943	0.9816	0.2863	0.0099	0.4744	0.0749
Cl Rating	0.0168	0.6526	0.8135	0.9378	0.8340	0.7428	0.0033
Interaction	0.5642	0.3102	0.5630	0.0414	0.9855	0.4325	0.0098

Table 2. Soybean root dry weight and shoot Cl concentration as affected by the significant Cl rate × Cl rating (includer/excluder) interaction at the Pine Tree Research Station.

	Root dry weight		Shoot Cl Concentration	
Cl rate	Excluder	Includer	Excluder	Includer
(lb Cl/acre)	----------------(grams†)---------------		-----------------(ppm†)----------------	
0	6.3 b	8.1 ab	464 b	1078 b
750	8.5 a	6.8 ab	2563 b	6673 a

† Lowercase letters among the four means for each measurement represents the least significant difference to compare any two means.

Soybean Yield as Affected by Chloride Rate and Cultivar Chloride Includer/Excluder Rating

N.A. Slaton, D. Cox, T.L. Roberts, J. Ross, R.E. DeLong, M. Fryer, and J. Hedge

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Chloride (Cl) toxicity, also known as 'leaf scorch' of soybean [*Glycine max* (L.) Merr.], is primarily a problem in the southern United States. Chloride toxicity is relatively common in Arkansas and the symptoms are similar to that described by Parker et al. (1983). Soybean cultivars are categorized as Cl-Includers, segregators (mixed population), or Cl-Excluders based on greenhouse screening techniques (Lee et al., 2008; Valencia et al., 2008). Chloride toxicity occurs to varying degrees in Arkansas soybean fields each year, but tends to be worst in fields having poorly drained soil and in years with minimal summer rainfall. Season-long use of irrigation water from ground or surface sources results in Cl accumulation in soybean beds during the season. As a general observation, soybeans grown on beds and furrow-irrigated tend to show more Cl toxicity than flat-planted soybeans that are flood irrigated. Proper cultivar selection is the first step of managing Cl toxicity.

Diagnosis of Cl toxicity has relied on visual recognition of the leaf scorch symptoms. The visual diagnosis is often confirmed by tissue analysis that shows scorched leaves contain very high Cl concentrations. Despite our knowledge that soybean cultivars possess different Cl accumulation traits, soil and plant information to monitor or diagnose Cl toxicity during the season has not been developed. Diagnostic leaf-Cl concentrations might enable us to identify potential Cl problems before the visual symptoms appear and assess to what extent soybean acreage is affected by Cl toxicity. Limited field research has been conducted with Includer and Excluder soybean cultivars. Our research goal was to compare six cultivars, three Cl-Includers and three Cl-Excluders, to eventually develop soil- and leaf-Cl concentrations that would enable us to eventually diagnose Cl toxicity before symptoms occur. The results presented in this report are simply to examine yield of cultivars categorized as Includers and Excluders as affected by cumulative Cl rate.

PROCEDURES

Trials were established at the University of Arkansas System Division of Agriculture's Pine Tree Research Station (PTRS) and Rohwer Research Station during 2015, but the Rohwer Research Station trial was abandoned in early July after being damaged by flooding. Specific soil, agronomic, and research management information for the PTRS is listed in Tables 1 and 2. Management of the PTRS trial with respect to seeding rate, irrigation, and pest control closely followed recommendations for furrow-irrigated soybean from the University of Arkansas System Division of Agriculture's Cooperative Extension Service.

Three companies provided one late maturity group IV Includer and one Excluder cultivar for the field trial. The six cultivars were intended to represent the range of Includer and Excluder cultivars available to Arkansas farmers. The six cultivars were seeded in random positions as described by Slaton et al. (2015). Individual plots were 30-ft long and 4-rows wide. Cultivar yields from variety trials conducted in 2013 and 2014 are listed in Table 1.

Each Cl rate strip was separated by four border rows of soybean to ensure Cl from one strip did not influence soybean growth in the adjacent treatment. Phosphorus (50 lb P_2O_5/acre) and K (70 lb K_2O/acre) was applied preplant before the final beds were formed. The PTRS field-average soil chemical properties ($n = 4$ composite soil samples from 0- to 4-in. depth) included a mean pH of 7.1, 2.2% soil organic matter, 24 (±2 standard deviation) ppm Mehlich-3 phosphorus (P), 61 (±10) ppm Mehlich-3 potassium (K), 250 ppm Mehlich-3 magnesium (Mg), and 1556 ppm Mehlich-3 calcium (Ca). Corn (*Zea mays* L.) was grown the previous year.

Chloride treatments were made using a combination of $CaCl_2{\bullet}2H_2O$ and $MgCl_2{\bullet}6H_2O$ salts (Bulk Reef Supply Co., Golden Valley, Minn.) applied in a 3:1 molar ratio, which approximated the molar ratio of Mehlich-3 exchangeable Ca and Mg in the soil. Four season-total Cl rates (0, 250, 500, and 750 lb Cl/acre) were applied in five separate applications (Table 2). The Ca and Mg salts for each rate were preweighed for each replicate and Cl rate, dissolved in 3 gallons of deionized water (57 gal/acre at PTRS) and applied to the plots on the dates indicated in Table 2. The salt solution was delivered using a 4-nozzle boom with drop nozzles (Teejet XR8004VS at the PTRS, Teejet Technologies, Wheaton, Ill.) that applied two rows simultaneously. Later in the season when the canopy closed, a single-nozzle boom that allowed the solution to be sprayed directly onto the side of each bed was used to prevent the Cl solution from contacting the foliage.

Fifteen fully expanded trifoliolate leaves from the third node from the top of the plant were collected at six different times during the season to monitor leaf-Cl concentrations (Table 2). All plant samples were dried to a constant moisture, ground to pass a 1-mm sieve, digested with concentrated HNO_3 and 30% H_2O_2 (Jones and Case, 1990), extracted with water (Liu, 1998), and analyzed for Cl by inductively coupled plasma spectroscopy (ICPS, Spectro Analytical Instruments Inc., Mahwah, N.J.). The two middle rows of the plot were harvested with a small-plot combine equipped with a moisture meter and scale.

The analysis of variance was conducted with the MIXED procedure in SAS v. 9.4 (SAS Institute, Inc., Cary, N.C.). The experiment was a randomized complete block with a split-plot treatment structure where Cl rate was the whole plot and the subplot factor was Cl rating (Includer or Excluder averaged across cultivars). When appropriate, mean separations were performed using Fisher's protected least significant difference (LSD) method at a significance level of 0.10.

RESULTS AND DISCUSSION

Rainfall at the PTRS totaled 2.2 inches in June, 6.1 inches in July, 1.6 inch in August, and 1.1 inch in September with daily rain events greater than 1 inch occurring twice in June and once in July. None of the individual rainfall events that occurred between 6 July and 31 August, the period of Cl salt application to the plots, were greater than 0.5 inches, but the field was irrigated weekly with irrigation performed 36 to 48 hours before salt application. Rainfall or irrigation events may flush Cl and other soluble salts from the soil and reduce Cl toxicity.

The primary questions addressed by this research are i) how does yield between the two cultivar Cl ratings compare within each Cl level and ii) is the yield of Excluder cultivars more stable than Includer cultivars when exposed to high Cl? Our hypothesis is that the yield of Includer cultivars would decrease at a faster rate than the yields of Excluder as Cl rate increased, which would result in a significant Cl rate × cultivar Cl rating interaction.

Trifoliolate leaf-Cl concentration at the R5 stage following application of Cl was affected by the significant interaction ($P < 0.0001$) between Cl rate and cultivar Cl rating (Table 3). The mean leaf-Cl concentration of the Excluder cultivars increased as Cl rate increased but differed by only 256 ppm Cl and were different from one another. The leaf-Cl concentration of Includer cultivars also increased as Cl rate increased but the range was 3522 ppm Cl and the difference was statistically significant with each incremental Cl rate increase. The leaf-Cl concentration within each Cl rate was always lower for the Excluder cultivars with leaf-Cl ratios of 10.2 to 12.9 (Includer/Excluder). Based on the preliminary relationship from Slaton et al. (2015) yield losses of ~1% and 10% would have been expected for the Excluder and Includer cultivars receiving 750 lb Cl/acre.

The weight of 1000-seed was affected only by cultivar Cl rating with the mean seed weight of the Excluder cultivars (138 g) being greater than that of the Includer cultivars (129 g). Soybean yield was affected only by Cl application rate ($P = 0.0085$) as neither Cl rating ($P = 0.5395$) and the interaction ($P = 0.4317$) were statistically significant (Table 4). Soybean yield declined numerically as Cl rate increased, but only the mean yields produced by soybean receiving 0 and 750 lb Cl/acre were statistically different. Although not significant, the yield difference between soybean receiving the 0 and 750 lb Cl/acre was numerically larger for the Includer cultivars than the Excluder cultivars.

PRACTICAL APPLICATIONS

The Cl rates used in this trial are not indicative of how much Cl is required to cause Cl-toxicity and should be considered only as supplemental Cl applied as an attempt to induce Cl toxicity. The amount of Cl needed to induce Cl toxicity in soybeans will likely vary among years, fields, irrigation systems, and cultivars. The second year of this research showed that, as a group, Excluder cultivars showed a non-significant trend to produce greater yields than Includer cultivars at the highest level of Cl addition. Leaf-Cl concentrations at the R5 stage were 10 to 12 times greater for Includer cultivars than Excluder cultivars suggesting that leaf analysis from field trials may be sufficient for classifying new cultivars as Includers or Excluders. The data collected in 2015 will be helpful in refining the preliminary relationships between leaf Cl and soybean yield. The methods of this research may need to be adjusted in 2016 to accentuate yield loss from Cl addition.

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Table 1. Grain yield and selected characteristics for six soybean cultivars used in field Cl rate trials as reported by the Arkansas Soybean Variety Testing Program in 2013 and 2014.

			Arkansas Performance Test Yields			
Cultivar	**MG**†	**Cl-R**‡	**RRS 2013**§	**RRS 2014**§	**AS 2013**§	**AS 2014**§
			(bu/acre)			
Armor 48-R66	4.8	Includer	58.7	64.6	67.1	63.3
Armor 49-R56	4.8	Excluder	62.2	66.5	68.2	68.9
NK S45-V8	4.5	Includer	50.1	59.7	64.3	62.9
NK S46-L2	4.6	Excluder	59.6	61.2	65.8	60.2
Pioneer 47T36R	4.7	Excluder	64.4	75.5	64.8	69.6
Pioneer 48T53R	4.8	Includer	58.5	69.0	62.7	70.1

† MG = Maturity Group.

‡ Cl-R = Soybean Cl rating.

§ Yield data from Bond et al. (2013) and Bond et al. (2014) and preliminary data http://arkansasvarietytesting.com/home/soybean/. RRS = Rohwer Research Station irrigated yield mean and AS = All-Site yield mean.

Table 2. Selected management information for the soybean Cl trial conducted in 2015.

Information or event	**Pine Tree Research Station**
Soil series	Calloway silt loam
Previous crop	Corn
Bed width (inches)	30
Seed rate (seed number/acre)	155,000
Seeding date	10 June
Chloride application dates	
1	7 July (V6 w/bloom clusters)†
2	15 July (R0-R1)
3	29 July (R2)
4	4 August (R3)
5	11 August (R4-5)
Tissue sample dates	
1	22 July (R1-2)
2	29 July (R2)
3	4 August (R3)
4	11 August (R4-5)
5	19 August (R5.0-5.5)
6	4 September (R6.5)
Soil sample date	20 August
Harvest date	14 October

† Date and growth stage of Cl solution application or tissue sample collection.

Table 3. Soybean trifoliolate leaf Cl concentration as affected by the significant interaction between two cultivar Cl rating groups (Includer and Excluder) and cumulative Cl rate at the Pine Tree Research Station in 2015.

Cl Rate	Excluder	Includer
(lb Cl/acre)	----------------- (bu/acre)	----------------
0	111 a[†]	1128 b
250	235 a	2750 c
500	304 a	3908 d
750	367 a	4650 e

[†] Means followed by different lowercase letters indicate significant difference at 0.10 as indicated by a single LSD value (0.10) comparing any two means.

Table 4. Soybean grain yield for two cultivar Cl rating groups (Includer and Excluder) as affected by Cl rate at the Pine Tree Research Station in 2015.

Cl Rate	Excluder	Includer	Mean
(lb Cl/acre)	------------------------	(bu/acre)	-----------------------
0	49	51	50 a[†]
250	51	49	50 ab
500	48	47	48 ab
750	47	45	46 b

[†] Means, averaged across Cl-rating group, followed by different lowercase letters indicate significant difference at 0.10 as indicated by a single LSD value (0.10) comparing any two means.

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