Wayne E. Sabbe ARKANSAS SOIL FERTILITY STUDIES • 2016 •

Nathan A. Slaton, Editor

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Cover: Soybean is planted on more than 3 million acres in Arkansas each year with approximately 85% of the Arkansas acreage produced with irrigation. Irrigation water can be a primary source of chloride salts. The cover photograph shows chloride toxicity symptoms on the middle and bottom leaves of soybean plants in a production field in southeast Arkansas. Chloride toxicity symptoms often do not appear until late in the growing season, but may include scorching along the margins of lower and middle leaves, premature plant senescence, and yield loss. For more information on soybean response to chloride see the report on page 21. Photograph by Nathan Slaton, Professor, University of Arkansas System Division of Agriculture, Department of Crop, Soil, and Environmental Sciences.

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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 – 2016 –

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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 2016 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 2015. This set of data includes information for counties, soil associations, physiographic areas, and selected cropping systems.

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

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

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

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

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Soil-Test and Fertilizer Sales Data: Summary for the 2016 Growing Season

R.E. DeLong[1], N.A. Slaton[1], C.G. Herron[2], and D. Lafex[2]

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 2015 and 31 December 2015 were categorized according to geographic area (GA), county, soil association number (SAN), and selected cropping systems. The GA and SAN were derived from the General Soil Map, State of Arkansas (Base 4-R-38034, USDA, and University of Arkansas Agricultural Experiment Station, Fayetteville, Ark., December, 1982). Descriptive statistics of the soil-test data were calculated for categorical ranges for pH, phosphorus (P), potassium (K), and zinc (Zn). Soil pH and Mehlich-3 extractable (analyzed using inductively coupled plasma spectroscopy, ICAP) soil nutrient (i.e., P, K, and Zn) availability index values indicate the relative level of soil fertility.

Results and Discussion

Crop Acreage and Soil Sampling Intensity

Between 1 January 2015 and 31 December 2015, 159,514 soil samples were analyzed by the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna. After removing the 13,338 standard solution and check soil samples measured for quality assurance, the total number of client (e.g., researchers, growers, and homeowners) samples was 146,176, comprising 1391 research samples and 144,785 samples from the general public (Table 1). A total of 41,950 of the submitted soil samples were collected using the field-average sampling technique, representing 934,128 acres for an average of 22 acres/sample, and had complete data for county, total acres, and soil pH, P, K, and Zn. 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. The remaining 102,835 samples were grid samples collected primarily from row-crop fields.

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 2.5 to 5.0 acres and most grid samples are collected and submitted by a consultant or soil sampling service. Single clients from Craighead (9283, 41%); Crittenden (8138, 57%); Little River (7650, 76%); Lawrence (7474, 72%); and Cleveland (6536, 87%) counties submitted the most grid soil samples for analyses. Thus, the soil sample numbers for these counties and selected others probably represent soil samples from numerous counties that are submitted through a single Extension office that is conveniently located.

Soil samples from the Bottom Lands and Terraces and Loessial Plains, primarily row-crop areas, represented 48% of the total field-average samples and 75% of the total acreage (Table 2). The average number of acres represented by each field-average soil sample from the 10 geographic areas ranged from 8 to 42 acres/sample. Soil association numbers show that most samples were taken from soils common to row-crop and pasture production areas (Table 3). The soil associations having the most samples submitted were 44 (Calloway-Henry-Grenada-Calhoun), 4 (Captina-Nixa-Tonti), 45 (Crowley-Stuttgart), and 32 (Rilla-Hebert). However, the soil associations representing the largest acreage were 44, 45, 22 (Foley-Jackport-Crowley), and 32, which represented 23%, 17%, 9%, and 8% 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 77% of the sampled acreage and 47% of submitted samples, ii) hay and pasture production accounted for 21% of the sampled acreage and 24% of submitted samples, and iii) home lawns and gardens accounted for 1% of sampled acreage and 22% of submitted samples (Table 4). In row-crop producing areas, 60% of the soil samples are collected following soybean in the crop rotation. The cumulative acreage soil sampled following soybean represents 14% 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

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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 5.5 to 7.2; 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 soybean. Soils 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, 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).

Ten-Year Trends for Selected Crops and Soil Test Variables

Routine and timely soil sampling and testing are used by farmers to determine which fertilizer nutrients and soil amendments are needed to optimize crop growth and yield. For crops grown on well-buffered soils, the annual change in soil pH and soil-test P and K values can be relatively small and be overwhelmed by fluctuations from spatial and temporal variability. One advantage of public soil-testing programs is that annual soil nutrient summaries allow for trends across time to be tracked and the data represents a relatively large number of samples each year. The trends in median soil pH and Mehlich-3 extractable P, K, and Zn for soil cropped to corn, cotton, rice, soybean, and warm-season grass for hay production are shown in Figs. 1 through 4. The number of field-average soil samples and acres represented by each annual median value are given in Table 8.

The average number of composite soil samples used for these trends ranged from a low of 2210 (± 692) for corn to 13,248 (± 2621) for soybean. Warm-season grasses for hay had the lowest mean annual acreage (46,315 acre ± 18,701) and samples collected following soybean represented the greatest acreage (628,678 acres ±153,563). Soil pH was constant for samples collected from fields cropped to warm-season grass hay or increasing by 0.034 to 0.047 units per year for soil used for row-crop production (Fig. 1 and Table 9). The slow increase in soil pH in row-crop fields is at least partially due to the use of ground water high in calcium and magnesium bicarbonates for irrigation. Mehlich-3 extractable soil P is declining by 0.33 to 3.36 ppm/year for all five cropping systems with the trend for the greater rates of decline in soils with the greatest median soil-test P values (warm-season grasses and cotton, Fig. 2). Similar results were found for Mehlich-3 extractable K (Fig. 3) with the exception that soils used for warm-season grass hay production initially had intermediate soil-test K values but after 10 years had the lowest median K values due to the greatest rate of soil-test K decline. Decreasing soil-test P and K values on soils used for warm-season grass production is likely due to restrictions on the use of poultry litter on these soils and limited use of commercial fertilizers containing P and K to fertilize pastures and hay fields. The slow decline of soil-test P and K in soils used for row-crop production may be related to variable rate fertilization, greater nutrient export from high crop yields, increased nutrient loss, or combinations of these and other factors. The fertilizer tonnage of P and K fertilizers sold in Arkansas has fluctuated some but, on average, has not declined appreciably during this 10-year period (data not shown). The trend could also be due to a bias in the data as the number of field-average soil samples submitted during this time has declined since 2006 as more farmers are using grid soil samples which are not represented in this data (Table 8).

Mehlich-3 extractable Zn is also declining across time for all five of the crops represented in this summary. Possible reasons for soil-test Zn to decline include reduced application of poultry litter to soils used for warm-season grass hay production and the marketing of row-crop fertilization strategies that use relatively low Zn rates including in-furrow bands, seed treatments, and Zn coating on macronutrient fertilizers rather than broadcast application of granular Zn fertilizers.

Practical Applications

The results of annual soil-test summaries, or more specific summaries assembled for selected cropping systems, soils or geographic areas, can be used in county- or commodity-specific nutrient management education programs. Comparisons of annual soil-test information can document trends in fertilization practices or areas where nutrient management issues may need to be addressed. For the soil samples submitted in 2015, 78% of the samples and 99% of the represented acreage had commercial agricultural/farm crop codes. The 10-year analysis of soil chemical property trends for five selected crops suggest that soil P, K, and Zn availability are slowly declining. The decline in soil nutrient availability should continue to be monitored to determine the rate of change and trend across time. Long-term research plots that monitor these same changes in soil chemical properties should be initiated to determine why the soil-test values are declining. In the meantime, educational programs to show growers the potential benefits of fertilizer use or to aid growers in monitoring the net nutrient balance in selected fields may be needed to aid in our understanding of why soil-test P and K values are declining despite continued fertilizer use.

Acknowledgments

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Table 1. Sample number (includes grid and field-average samples) and total acreage by county for soil samples submitted to the Soil Testing and Research Laboratory in Marianna from 1 January through 31 December 2015. Note that the percentage of total acres and samples are rounded to whole numbers and the sum may be slightly greater than 100%.

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	89,780	10	1728	1	52	Lee	54,022	6	4364	3	12
Arkansas, Stuttgart	14,893	2	477	0	31	Lincoln	772	0	61	0	13
Ashley	7434	1	417	0	18	Little River	5452	1	10,077	7	1
Baxter	2095	0	423	0	5	Logan, Booneville	73	0	5	0	15
Benton	15,323	2	1193	1	13	Logan, Paris	5806	1	391	0	15
Boone	11,560	1	666	1	17	Lonoke	98,989	11	4051	3	24
Bradley	1011	0	82	0	12	Madison	7691	1	490	0	16
Calhoun	391	0	50	0	8	Marion	1339	0	158	0	9
Carroll	16,217	2	887	1	18	Miller	2505	0	164	0	15
Chicot	20,673	2	443	0	47	Mississippi	4922	1	7043	5	1
Clark	3567	0	278	0	13	Monroe	28,811	3	1399	1	21
Clay, Corning	8639	1	5665	5	2	Montgomery	1684	0	125	0	14
Clay, Piggott	6620	1	6260	4	1	Nevada	165	0	38	0	4
Cleburne	5706	1	412	0	14	Newton	3802	0	278	0	14
Cleveland	550	0	7552	5	0	Ouachita	472	0	148	0	3
Columbia	1012	0	186	0	5	Perry	915	0	90	0	10
Conway	10,112	1	335	0	30	Phillips	5071	1	196	0	26
Craighead	14,424	2	22,578	16	1	Pike	3389	0	169	0	20
Crawford	8131	1	563	0	14	Poinsett	45,023	5	4539	3	10
Crittenden	2935	0	14,250	10	0	Polk	8973	1	478	0	19
Cross	63,511	7	1123	1	57	Pope	9944	1	688	1	15
Dallas	619	0	102	0	6	Prairie, Des Arc	34,374	4	564	0	61
Desha	14,713	2	3066	2	5	Prairie, De Valls Bluff	1581	0	60	0	26
Drew	17,978	2	535	0	34	Pulaski	3931	0	1468	1	3
Faulkner	6043	1	734	1	8	Randolph	10,041	1	2522	2	4
Franklin	7789	1	354	0	22	Saline	1733	0	887	1	2
Fulton	3921	0	279	0	14	Scott	4124	0	181	0	23
Garland	1747	0	1035	1	2	Searcy	2402	0	230	0	10
Grant	806	0	141	0	6	Sebastian	9227	1	808	1	11
Greene	19,420	2	5455	4	4	Sevier	1542	0	114	0	14
Hempstead	5137	1	425	0	12	Sharp	3677	0	285	0	13
Hot Spring	640	0	93	0	7	St. Francis	6529	1	2384	2	3
Howard	5684	1	213	0	27	Stone	2492	0	275	0	9
Independence	7823	1	800	1	10	Union	2037	0	232	0	9
Izard	4431	1	321	0	14	Van Buren	1467	0	214	0	7
Jackson	6951	1	1259	1	6	Washington	15,253	2	2548	2	6
Jefferson	54,035	6	4469	3	12	White	7955	1	907	1	9
Johnson	3343	0	273	0	12	Woodruff	6072	1	140	0	43
Lafayette	1068	0	62	0	17	Yell, Danville	6964	1	382	0	18
Lawrence	54,987	6	10,399	7	5	Yell, Dardanelle	1188	0	49	0	24
						Sum[a] or Average	934,128		144,785		7

[a] Sum total sample number does not include 1391 research samples.

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 through 31 December 2015.

Geographic area	Acres sampled	% of total acres	No. of samples	% of total samples	Acres/ sample
Ozark Highlands - Cherty Limestone and Dolomite	73,538	9	6742	19	11
Ozark Highlands - Sandstone and Limestone	8130	1	566	2	14
Boston Mountains	16,646	2	1679	5	10
Arkansas Valley and Ridges	47,854	6	3795	11	13
Ouachita Mountains	25,431	3	2478	7	10
Bottom Lands and Terraces	283,436	35	8941	26	32
Coastal Plain	26,127	3	2262	7	12
Loessial Plains	318,862	40	7539	22	42
Loessial Hills	6645	1	861	3	8
Blackland Prairie	556	0	41	0	14
Sum or Average	807,225		34,904		23

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 through 31 December 2015.

							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	11,268	1	728	2	16	6.2	88	145	6.7
2.	Gepp-Doniphan-Gassville-Agnos	6627	1	790	2	8	6.7	57	138	6.1
3.	Arkana-Moko	24,049	3	1468	4	16	6.2	91	146	9.4
4.	Captina-Nixa-Tonti	30,920	4	3729	11	8	6.4	98	155	8.8
5.	Captina-Doniphan-Gepp	134	0	6	0	22	6.1	21	150	2.7
6.	Eden-Newnata-Moko	540	0	21	0	26	6.1	23	132	2.3
7.	Estate-Portia-Moko	299	0	25	0	12	5.6	113	105	9.0
8.	Brockwell-Boden-Portia	7831	1	541	2	15	6.3	37	103	3.7
9.	Linker-Mountainburg-Sidon	3311	0	258	1	13	6.1	67	119	5.0
10.	Enders-Nella-Mountainburg-Steprock	13,335	2	1421	4	9	6.1	102	122	6.9
11.	Falkner-Wrightsville	119	0	9	0	13	6.2	51	130	4.4
12.	Leadvale-Taft	19,526	2	1874	5	10	6.0	59	114	6.5
13.	Enders-Mountainburg-Nella-Steprock	6557	1	415	1	16	5.8	51	85	4.1
14.	Spadra-Guthrie-Pickwick	1836	0	101	0	18	5.8	103	118	7.9
15.	Linker-Mountainburg	19,816	2	1396	4	14	5.9	50	109	4.7
16.	Carnasaw-Pirum-Clebit	5837	1	371	1	16	5.8	89	110	7.2
17.	Kenn-Ceda-Avilla	6728	1	547	2	12	5.8	90	112	7.4
18.	Carnasaw-Sherwood-Bismarck	8632	1	1110	3	8	5.7	81	104	5.4
19.	Carnasaw-Bismarck	581	0	30	0	19	5.8	24	68	2.9
20.	Leadvale-Taft	2690	0	353	1	8	5.8	78	97	7.2
21.	Spadra-Pickwick	963	0	67	0	14	5.6	75	127	5.7
22.	Foley-Jackport-Crowley	71,231	9	1836	5	39	6.4	23	108	3.1
23.	Kobel	10,608	1	403	1	26	6.4	35	121	3.5
24.	Sharkey-Alligator-Tunica	46,284	6	1593	5	29	6.6	43	173	3.7
25.	Dundee-Bosket-Dubbs	31,395	4	915	3	34	6.4	37	122	3.2
26.	Amagon-Dundee	9041	1	283	1	32	6.3	47	119	4.1
27.	Sharkey-Steele	1820	0	437	1	4	7.2	50	267	3.0
28.	Commerce-Sharkey-Crevasse-Robinsonville	531	0	26	0	20	6.4	58	168	4.2
29.	Perry-Portland	21,114	3	443	1	48	6.3	35	139	3.4
30.	Crevasse-Bruno-Oklared	680	0	15	0	45	6.5	39	193	1.7
31.	Roxana-Dardanelle-Bruno-Roellen	15,512	2	328	1	47	6.4	37	147	3.5
`32.	Rilla-Hebert	60,859	8	2280	7	27	6.4	35	122	2.9
33.	Billyhaw-Perry	1194	0	36	0	33	7.7	24	75	2.3
34.	Severn-Oklared	5067	1	95	0	53	6.1	43	126	3.4
35.	Adaton	582	0	14	0	42	6.1	24	155	2.6
36.	Wrightsville-Louin-Acadia	7370	1	221	1	33	6.1	29	122	3.4
37.	Muskogee-Wrightsville-McKamie	148	0	16	0	9	5.6	110	156	8.7
38.	Amy-Smithton-Pheba	1266	0	167	0	8	5.9	96	107	4.9
39.	Darco-Briley-Smithdale	0	0	0	0	0	0	0	0	0
40.	Pheba-Amy-Savannah	1498	0	103	0	15	5.6	37	95	3.2
41.	Smithdale-Sacul-Savannah-Saffell	8884	1	724	2	12	5.8	86	94	6.5
42.	Sacul-Smithdale-Sawyer	12,027	1	1090	3	11	6.0	44	92	4.6
43.	Guyton-Ouachita-Sardis	2452	0	178	1	14	5.8	61	91	5.8
44.	Calloway-Henry-Grenada-Calhoun	184,675	23	4519	13	41	6.8	26	94	3.4
45.	Crowley-Stuttgart	134,187	17	3020	9	44	6.5	28	113	3.1
46.	Loring	1301	0	63	0	21	5.9	56	114	5.1
47.	Loring-Memphis	5076	1	785	2	7	6.1	34	112	4.2
48.	Brandon	268	0	13	0	21	7.2	32	90	2.8
49.	Oktibbeha-Sumter	556	0	41	0	14	6.1	95	128	6.0
	Sum or Average	807,225		34,904		21	6.2	57	124	4.8

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 2015 through 31 December 2015.

Crop	Acres sampled	% of total acres	No. of samples	% of total samples	Acres/ sample
Corn	48,059	6	1542	4	3
Cotton	26,583	3	1555	4	17
Grain sorghum, non-irrigated	1731	0	71	0	24
Grain sorghum, irrigated	1242	0	346	1	36
Rice	114,040	14	2940	8	39
Soybean	435,427	53	10,324	28	42
Wheat	7481	1	417	1	18
Cool-season grass hay	5354	1	310	1	17
Native warm-season grass hay	3496	0	185	1	19
Warm-season grass hay	35,631	4	1587	4	23
Pasture, all categories	129,256	16	6573	18	20
Home garden	5522	1	4090	11	1
Turf	5013	1	941	3	5
Home lawn	4899	1	4056	11	1
Small fruit	544	0	433	1	1
Ornamental	1596	0	1265	3	1
Sum or Average	825,874		36,635		23

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 2015 through 31 December 2015.

Geographic area	Soil pH[a]						Mehlich-3 soil P[b] (ppm)						Mehlich-3 soil K[b] (ppm)						Mehlich-3 soil Zn[b] (ppm)					
	<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	9	16	25	29	21	6.3	4	8	8	11	69	89	9	14	19	18	40	150	3	14	9	24	50	8.3
Ozark Highlands - Sandstone and Limestone	10	19	25	27	19	6.2	18	18	10	14	40	38	19	23	24	15	19	103	12	29	16	24	19	3.8
Boston Mountains	15	22	26	28	9	6.1	6	8	7	8	71	98	15	18	22	14	31	121	7	18	10	27	38	6.6
Arkansas Valley and Ridges	21	25	22	22	10	5.9	13	12	11	12	52	55	16	21	25	17	21	110	9	20	12	24	35	5.6
Ouachita Mountains	27	30	23	18	2	5.7	8	9	8	9	66	82	19	20	25	15	21	106	6	19	12	26	37	6.0
Bottom Lands and Terraces	7	13	22	35	23	6.4	11	19	21	21	28	35	7	17	26	20	30	131	10	38	19	24	9	3.2
Coastal Plain	26	22	21	21	10	5.8	15	13	9	11	52	48	27	21	18	12	22	86	13	21	11	21	34	4.5
Loessial Plains	8	12	16	27	37	6.7	17	29	25	17	12	27	10	27	37	14	12	102	13	35	16	28	8	3.3
Loessial Hills	17	17	24	27	15	6.1	21	17	12	14	36	34	11	25	26	19	19	111	9	27	16	29	19	4.2
Blackland Prairie	17	24	17	7	35	6.1	10	7	12	5	66	95	12	2	39	27	20	128	7	20	15	15	43	6.0
Average	16	20	22	24	18	6.1	12	14	12	12	50	60	15	19	26	17	23	115	9	24	14	24	29	5.2

[a] Analysis by electrode in 1:2 soil volume:deionized water volume.
[b] Analysis by inductively coupled 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 2015 through 31 December 2015.

	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	6	14	23	54	7.1	7	26	32	24	11	31	2	19	48	22	9	114	2	20	19	50	9	4.8
Arkansas, Stuttgart	9	15	21	36	19	6.5	19	24	22	18	17	28	8	26	27	19	20	113	17	36	20	23	4	3.0
Ashley	12	12	18	29	29	6.6	16	17	15	12	40	38	13	20	22	15	30	123	16	31	13	20	20	3.4
Baxter	3	6	12	21	58	7.2	5	7	5	12	71	88	5	8	21	24	42	158	2	8	5	22	63	12.0
Benton	9	16	25	33	17	6.3	3	6	7	10	74	103	10	15	20	17	38	144	2	11	11	27	49	8.7
Boone	9	16	28	35	12	6.2	3	8	8	10	71	92	9	9	16	18	48	170	2	15	7	24	52	9.4
Bradley	20	22	16	20	22	6.1	2	4	9	4	81	178	21	10	16	20	33	141	4	10	4	28	54	9.8
Calhoun	20	14	20	34	12	6.2	10	6	4	8	72	108	18	32	26	6	18	89	10	2	18	20	32	4.5
Carroll	5	20	32	31	12	6.2	1	3	4	7	85	138	8	8	14	15	55	191	1	5	4	19	71	14.3
Chicot	7	6	13	43	31	6.7	8	19	20	17	36	37	8	12	20	13	47	164	8	37	22	23	10	3.4
Clark	25	25	25	19	6	5.8	12	14	9	13	52	52	21	18	22	14	25	106	10	35	15	22	18	3.4
Clay, Corning	6	12	26	45	11	6.4	13	28	27	21	11	28	3	23	42	23	9	113	12	23	10	33	22	4.8
Clay, Piggott	6	11	26	51	6	6.4	5	13	17	26	39	43	5	22	41	20	12	111	8	39	25	28	0	3.3
Cleburne	20	28	21	25	6	5.9	12	14	11	9	54	61	23	23	22	14	18	96	16	27	10	18	29	3.9
Cleveland	18	22	23	25	12	6.0	12	13	15	23	37	42	5	12	18	18	47	166	4	36	28	32	0	3.5
Columbia	26	23	21	18	12	5.9	14	11	9	11	55	58	40	21	22	8	9	71	25	22	7	13	33	3.8
Conway	21	19	21	27	12	6.1	13	17	22	18	30	35	16	20	23	18	23	115	12	25	14	27	22	4.1
Craighead	6	10	21	38	25	6.5	10	18	17	20	35	39	6	15	25	21	33	138	7	34	25	28	6	3.5
Crawford	12	15	30	31	12	6.2	17	12	13	13	45	45	11	14	21	19	35	137	4	23	19	36	18	4.5
Crittenden	8	12	24	37	19	6.4	12	25	25	23	15	31	2	7	15	16	60	207	9	30	26	35	0	3.6
Cross	3	4	9	22	62	7.2	13	28	26	20	13	29	11	36	32	10	11	93	5	49	22	23	1	3.0
Dallas	40	21	23	16	0	5.6	10	9	8	10	63	78	27	17	27	14	15	102	16	27	14	26	17	3.7
Desha	3	6	15	27	49	6.9	12	18	19	21	30	37	5	8	15	17	5	201	8	39	25	27	1	3.3
Drew	20	13	18	32	17	6.3	21	29	16	15	19	26	13	20	19	14	34	129	13	35	21	18	13	3.2
Faulkner	25	22	21	24	8	5.9	16	17	11	10	46	45	21	26	21	15	17	96	14	27	12	20	27	4.0
Franklin	27	35	26	12	0	5.6	11	11	3	9	66	89	16	16	29	17	22	118	5	15	10	25	45	7.5
Fulton	19	22	17	28	14	6.1	15	19	13	18	35	37	10	22	30	18	20	112	14	39	15	15	17	3.0
Garland	25	26	25	22	2	5.8	4	9	10	11	66	72	15	22	30	16	17	105	4	20	14	28	34	5.6
Grant	35	18	20	20	7	5.8	11	6	6	9	68	85	25	19	20	14	22	102	16	16	11	21	36	5.9
Greene	11	16	26	34	13	6.3	12	19	16	18	35	38	8	22	30	24	16	117	8	34	21	30	7	3.5
Hempstead	29	29	18	20	4	5.8	36	14	8	8	34	27	43	20	11	12	14	71	22	25	9	11	33	3.5
Hot Spring	25	17	23	29	6	6.0	14	8	5	11	62	88	23	20	15	8	34	102	15	15	9	16	45	7.4
Howard	31	36	21	12	0	5.6	4	5	4	5	82	176	12	13	26	19	30	129	3	9	5	15	68	15.7
Independence	23	22	18	22	15	6.0	15	25	19	14	27	30	16	27	31	15	11	98	19	26	6	19	30	4.1
Izard	10	25	26	29	10	6.1	12	17	15	16	40	41	21	30	25	14	10	89	18	36	13	19	14	2.9
Jackson	10	15	15	33	27	6.5	16	20	15	21	28	36	6	22	33	20	19	118	14	41	16	15	14	2.9
Jefferson	9	19	25	33	14	6.2	8	17	24	27	24	36	7	17	22	16	38	140	15	46	22	17	0	2.8
Johnson	15	19	25	25	16	6.1	8	9	14	15	54	60	5	17	28	19	31	132	8	19	15	25	33	5.6
Lafayette	16	21	23	18	22	6.0	19	19	8	16	38	38	13	15	26	18	28	129	26	24	19	19	12	3.0
Lawrence	8	16	26	36	14	6.3	31	32	17	11	9	21	13	25	31	18	13	105	9	42	16	25	8	3.1
Lee	8	11	24	41	16	6.4	5	12	18	28	37	43	2	11	32	26	29	137	25	49	16	10	0	2.2
Lincoln	23	30	16	21	10	5.8	7	12	7	8	66	77	15	16	21	18	30	119	12	13	13	25	37	5.7
Little River	7	12	23	29	29	6.4	17	19	16	20	28	34	3	14	28	20	35	141	21	44	17	18	0	2.5

continued

Table 6. Continued.

Geographic area	Soil pH[a]						Mehlich-3 soil P[b] (ppm)						Mehlich-3 soil K[b] (ppm)						Mehlich-3 soil Zn[b] (ppm)					
	<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	40	40	20	6.6	20	20	40	0	20	26	0	20	0	0	80	344	0	20	20	40	20	5.8
Logan, Paris	27	35	26	12	0	5.7	19	12	7	6	56	77	30	19	15	15	21	93	7	21	10	24	38	3.0
Lonoke	12	18	27	36	7	6.2	19	25	21	16	19	28	10	20	32	17	21	114	25	49	13	12	1	2.2
Madison	7	20	35	31	7	6.1	2	5	6	5	82	174	10	16	19	13	42	146	1	11	7	19	62	12.0
Marion	6	8	20	30	36	6.6	8	12	11	14	55	57	6	19	30	15	30	127	7	17	7	25	44	7.0
Miller	22	22	18	21	17	6.0	6	13	13	18	50	50	17	22	22	14	25	105	9	22	17	31	21	4.5
Mississippi	4	9	24	49	14	6.4	2	10	15	25	48	49	2	11	28	27	32	144	3	30	27	34	6	3.8
Monroe	7	9	20	33	31	6.6	27	25	21	14	13	25	4	24	30	23	19	119	23	43	12	17	5	2.3
Montgomery	19	23	27	22	9	6.0	6	5	12	12	65	108	14	14	22	14	36	130	7	14	11	18	50	9.5
Nevada	29	29	18	18	6	5.7	8	26	0	3	63	64	40	34	16	8	2	66	5	18	24	26	27	5.0
Newton	11	21	28	25	15	6.1	5	9	8	13	65	76	15	14	19	16	36	136	4	19	16	23	38	5.6
Ouachita	29	23	25	10	13	5.7	15	12	11	8	54	62	31	26	13	10	20	76	10	17	12	33	28	5.2
Perry	24	34	26	14	2	5.7	23	16	12	4	45	31	22	17	23	13	25	107	10	26	26	24	14	3.7
Phillips	10	11	18	38	23	6.5	8	25	16	15	36	37	4	17	31	16	32	128	14	32	15	20	19	3.4
Pike	38	35	13	13	1	5.5	7	6	5	9	73	96	39	24	16	11	10	76	7	10	10	28	45	7.8
Poinsett	4	8	17	28	43	6.8	22	31	21	16	10	25	13	22	23	12	30	114	9	29	20	26	16	3.9
Polk	34	39	17	10	0	5.5	5	7	4	7	77	131	18	18	18	16	30	121	6	13	9	23	49	8.0
Pope	20	25	21	25	9	6.0	9	11	10	11	59	67	11	20	32	16	21	112	6	19	14	24	37	6.2
Prairie, Des Arc	6	16	19	28	31	6.5	36	36	17	13	8	20	28	23	23	16	10	88	7	27	22	41	3	4.0
Prairie, De Valls Bluff	22	8	13	15	42	6.8	22	32	15	3	28	25	7	42	23	13	15	91	5	27	20	30	18	4.1
Pulaski	24	17	19	25	15	6.1	8	12	9	14	57	61	13	24	30	17	16	104	5	14	12	31	38	6.4
Randolph	12	23	26	29	10	6.1	21	32	22	13	12	24	15	23	29	18	15	104	7	19	14	27	33	5.5
Saline	24	20	20	24	12	6.0	6	8	11	16	59	64	11	17	29	20	23	123	5	21	16	32	26	4.9
Scott	33	32	15	20	0	5.6	20	16	11	12	41	39	37	23	17	8	15	74	8	22	12	27	31	5.3
Searcy	9	12	18	42	19	6.5	4	17	14	15	50	51	9	19	24	19	29	126	9	29	13	24	25	4.1
Sebastian	14	22	25	23	16	6.1	10	9	11	10	60	66	13	16	26	19	26	123	2	10	8	27	53	9.0
Sevier	28	25	27	28	0	5.8	3	4	9	9	75	125	25	20	17	15	23	98	4	11	4	23	58	9.8
Sharp	6	20	21	28	25	6.3	13	18	8	17	44	43	15	20	29	17	19	110	16	24	16	23	21	3.8
St. Francis	9	14	22	41	14	6.4	11	16	18	27	28	38	2	8	17	22	51	180	21	42	17	19	1	2.5
Stone	36	25	23	12	4	5.6	6	5	5	10	74	89	18	26	20	14	22	99	4	26	17	29	24	5.0
Union	26	19	26	22	7	5.9	12	10	8	12	58	63	32	27	19	12	10	81	9	14	7	21	49	7.9
Van Buren	15	27	22	22	14	6.1	7	8	7	13	65	80	18	18	25	13	26	112	10	21	13	29	27	4.5
Washington	8	15	24	26	27	6.4	3	7	8	11	71	94	6	13	19	19	43	160	2	10	9	27	52	8.6
White	17	19	21	34	9	6.2	13	14	10	13	50	51	15	23	26	16	20	107	13	24	14	26	23	4.2
Woodruff	11	17	28	23	21	6.1	19	27	22	19	13	27	8	29	41	15	7	99	11	46	18	22	3	2.9
Yell, Danville	26	43	22	9	0	5.6	17	11	5	8	59	76	20	19	20	15	26	113	8	17	13	27	35	6.2
Yell, Dardanelle	12	18	16	33	21	6.3	4	4	8	14	70	89	8	14	33	20	25	124	4	20	10	27	39	6.2
Average	16	19	22	27	16	6.2	12	15	13	14	46	60	14	19	24	16	27	122	10	25	15	24	26	5.2

[a] Analysis by electrode in 1:2 soil volume:deionized water volume.
[b] Analysis by inductively coupled 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 2015 through 31 December 2015.

	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	5	11	24	39	21	6.4	7	15	27	26	25	36	6	22	35	22	15	115	10	32	17	28	13	3.6
Cotton	8	13	31	42	6	6.3	2	8	14	27	49	50	1	6	17	21	55	189	12	38	25	26	0	3.2
Grain sorghum, non-irrigated	21	10	24	41	4	6.2	7	23	25	24	21	33	6	13	35	17	29	127	10	39	32	19	0	3.1
Grain sorghum, irrigated	8	11	21	38	22	6.4	14	15	26	27	18	33	4	23	33	20	20	118	11	54	17	18	0	2.5
Rice	7	14	18	31	30	6.5	23	34	22	15	6	23	7	21	29	16	27	118	11	45	19	23	2	2.9
Soybean	4	9	19	34	34	6.6	12	25	25	21	17	30	7	24	34	18	17	111	11	40	19	26	4	3.1
Wheat	25	13	19	34	9	6.1	21	13	16	18	32	37	7	24	40	20	9	109	25	40	19	15	1	2.4
Cool-season grass hay	17	30	24	26	3	5.9	5	12	9	15	59	61	24	20	17	16	23	102	9	23	17	30	21	4.7
Native warm-season grass hay	27	29	18	16	10	5.7	25	18	11	8	38	30	33	28	20	8	11	78	14	32	11	24	19	3.6
Warm-season grass hay	26	32	23	19	0	5.7	14	12	9	11	54	58	29	23	18	13	17	87	15	22	11	24	28	4.7
Pasture, all categories	17	28	28	21	6	5.9	12	11	8	11	58	62	17	17	19	14	33	124	8	22	11	21	38	5.7
Home garden	7	10	14	28	41	6.8	5	4	4	6	81	145	6	10	18	18	48	170	3	8	6	18	35	13.4
Turf	8	14	29	36	13	6.3	4	4	7	11	74	86	18	18	25	17	22	110	2	16	13	33	36	6.3
Home lawn	26	20	22	24	8	6.0	6	12	12	16	54	55	8	20	30	22	20	119	4	18	16	39	23	5.3
Small fruit	31	18	20	22	9	5.9	3	7	4	9	80	103	12	20	24	17	27	119	3	15	10	22	50	7.7
Ornamental	14	11	16	27	32	6.5	8	10	8	11	63	69	10	20	31	20	19	117	3	10	10	24	53	9.2
Average	16	17	22	30	15	6.2	11	14	14	16	45	57	12	19	27	17	25	120	9	28	16	24	23	5.1

[a] Analysis by electrode in 1:2 soil weight:deionized water volume.
[b] Analysis by inductively coupled plasma spectroscopy (ICAP) in 1:10 soil weight:Mehlich-3 volume.
[c] Md = median.

Table 8. Summary of annual soil sample numbers for each crop from 2006–2015 (calendar years), which which were used to examine the 10-year trends for selected, median soil chemical properties (Figures 1-4).

		Year									
Crop	**Statistic**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Corn	Samples	995	2057	2710	2053	1982	1951	3032	3318	2457	1542
	Acres	42,967	100,689	166,634	94,006	105,001	98,533	144,330	173,039	73,426	448,059
Cotton	Samples	8058	8089	4037	4416	4169	4041	3155	2118	613	1555
	Acres	280,084	284,081	114,501	148,674	176,283	227,693	133,428	22,171	4826	26,583
Rice	Samples	4931	3835	3511	3677	4408	3584	2526	2923	2471	2940
	Acres	194,710	156,051	149,505	168,719	191,107	155,944	91,732	120,142	98,970	114,040
Soybean	Samples	13,496	15,080	13,726	14,330	16,597	12,980	16,630	9711	9609	10,324
	Acres	576,677	701,330	696,144	640,817	861,602	623,962	807,510	356,247	587,060	435,427
WSG Hay[a]	Samples	4057	3427	2131	1942	1566	1911	2038	1915	1587	1587
	Acres	87,462	73,311	41,263	40,764	31,144	39,479	44,805	36,027	33,267	35,631

[a] WSG Hay, warm-season grass hay. Data obtained from DeLong et al., 2008-2016.

Table 9. Linear regression coefficients describing the trends in median annual soil pH and Mehlich-3 extractable P, K, and Zn for five crops from 2006-2015 (calendar years).

	Soil pH		Mehlich-3 P		Mehlich-3 K		Mehlich-3 Zn	
Crop	**Slope**	**R^2**	**Slope**	**R^2**	**Slope**	**R^2**	**Slope**	**R^2**
Corn	0.044	0.46	-1.60	0.86	-2.97	0.48	-0.13	0.38
Cotton	0.047	0.46	-2.16	0.75	-3.61	0.25	-0.16	0.56
Rice	0.034	0.66	-0.74	0.87	-1.23	0.26	-0.20	0.78
Soybean	0.045	0.65	-0.33	0.62	0.07	0.00	-0.18	0.57
WSG Hay[a]	0.016	0.18	-3.36	0.60	-3.77	0.57	-0.34	0.63

[a] WSG hay, warm-season grass hay.

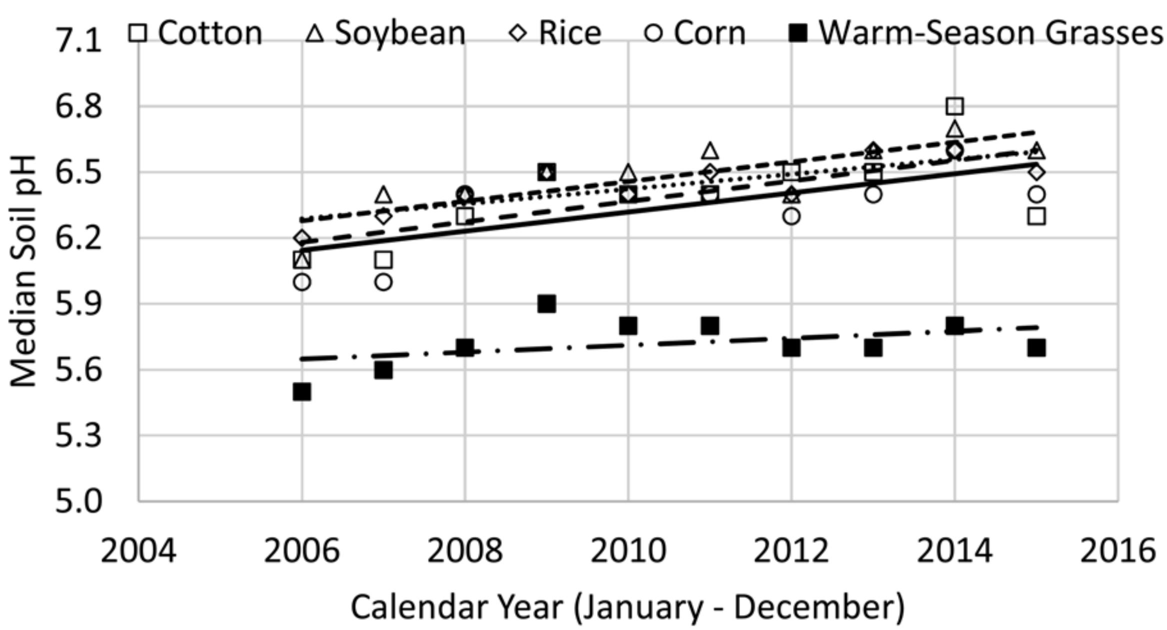

Fig. 1. Ten-year trend of median soil pH for Arkansas soils previously cropped to corn, cotton, rice, soybean, and warm-season grasses.

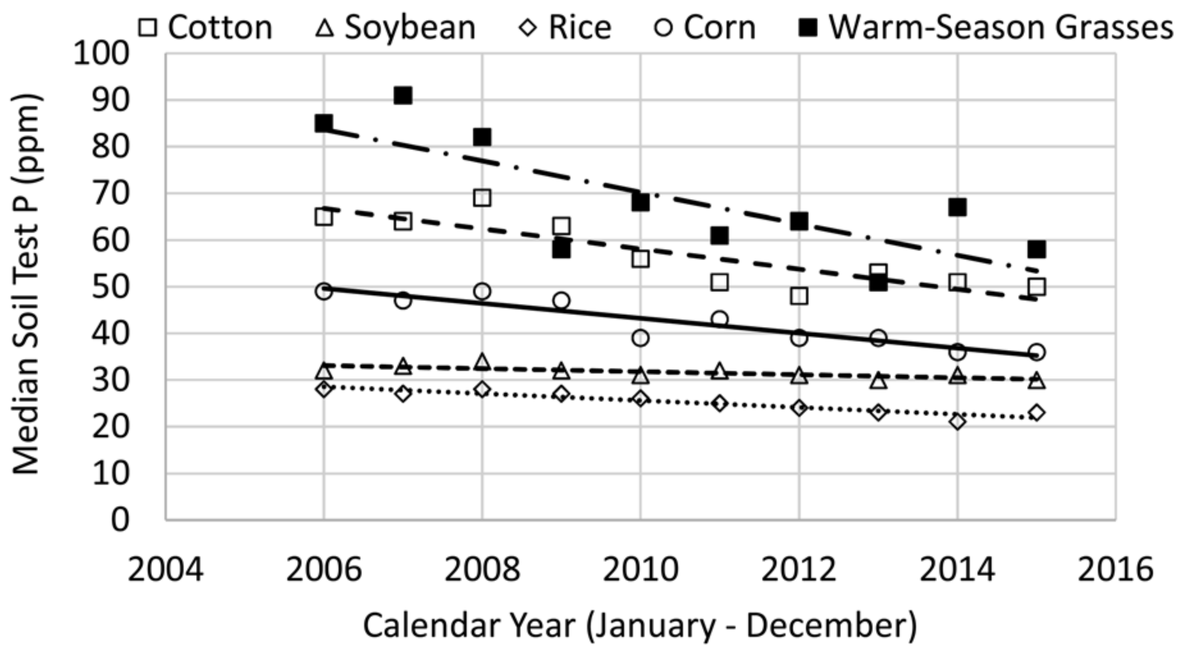

Fig. 2. Ten-year trend of median Mehlich-3 P for Arkansas soils previously cropped to corn, cotton, rice, soybean, and warm-season grasses.

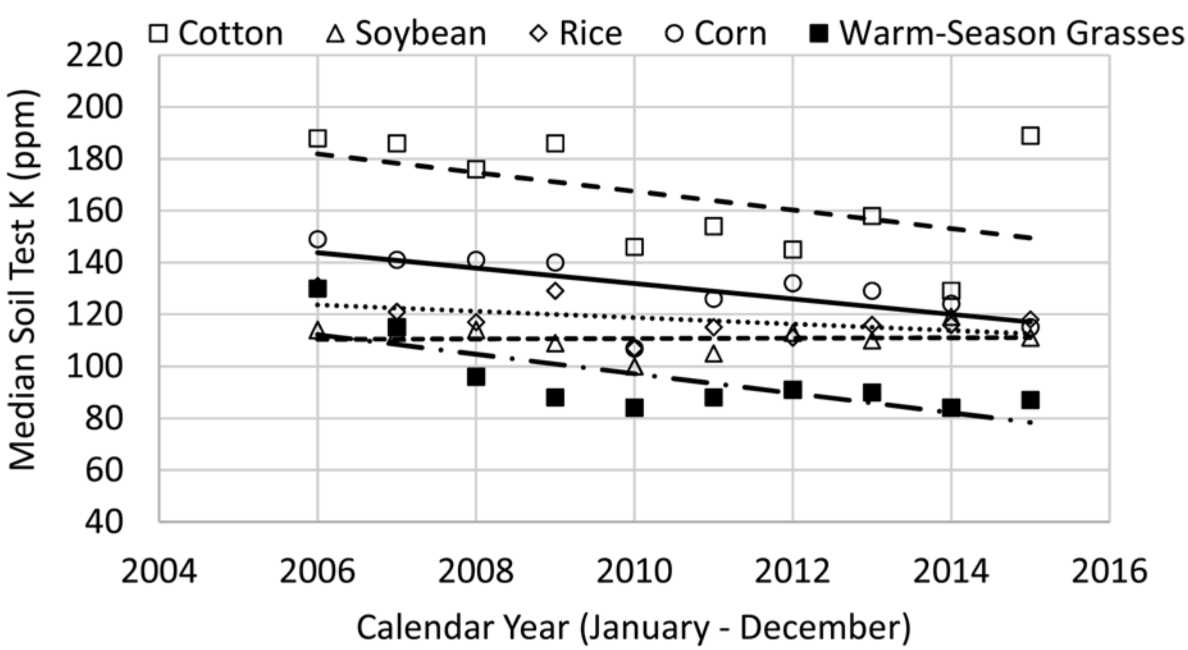

Fig. 3. Ten-year trend of median Mehlich-3 K for Arkansas soils previously cropped to corn, cotton, rice, soybean, and warm-season grasses.

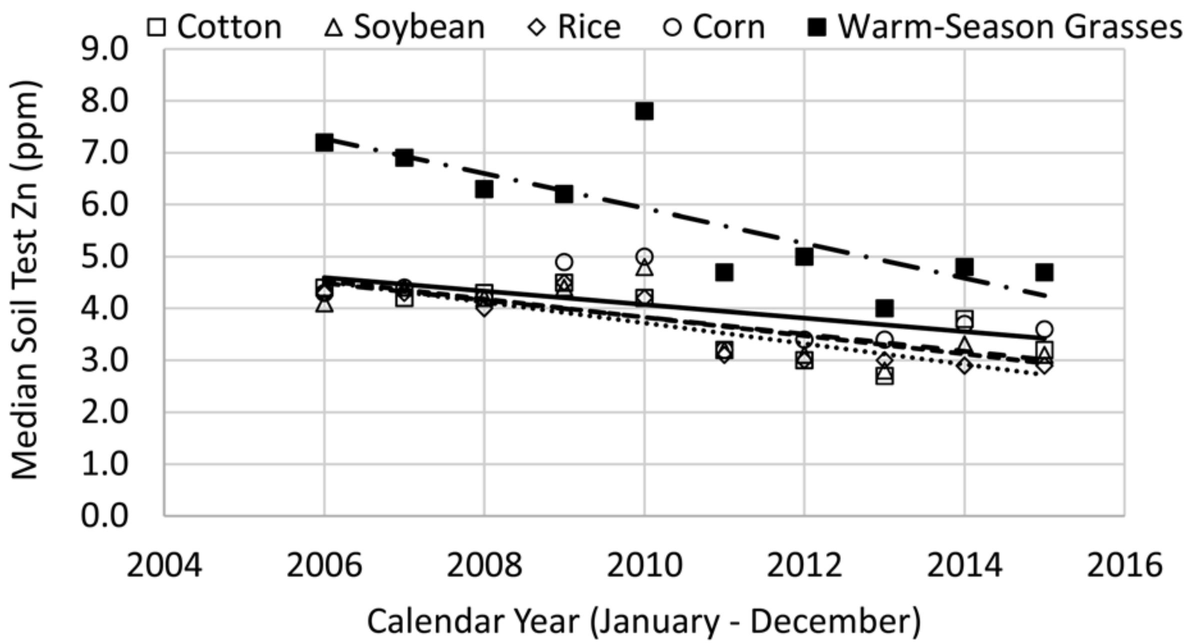

Fig. 4. Ten-year trend of median Mehlich-3 Zn for Arkansas soils previously cropped to corn, cotton, rice, soybean, and warm-season grasses.

Why Does Variability Exist Among Variety Soybean Chloride Ratings?

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Background Information and Research Problem

Research is conducted annually to assign a Cl trait rating of includer or excluder to commercial soybean varieties. The soybean variety screening program in Arkansas assigns a rating to soybean varieties based on the leaf-Cl concentration of five individual plants grown in the greenhouse that are subjected to relatively high Cl concentrations and compared to known Cl-includer and Cl-excluder check varieties (Green and Conatser, 2014). The information from this screening method sometimes produces inconsistent ratings from one year to the next, which is frustrating and sometimes costly for growers that may need a Cl-excluding variety.

Arkansas soybean growers possess limited tools for dealing with Cl toxicity, which highlights the importance of accurate Cl-trait ratings. Our research objective was to examine the leaf-Cl concentration of a population of individual plants from several varieties to better understand whether individual plants within each variety exhibit consistent Cl uptake (Cl inclusion or exclusion). We anticipated that most soybean varieties would be a population of Cl-includer and Cl-excluder plants rather than a pure population of plants that had similar leaf-Cl concentrations.

Procedures

A field trail was established at the University of Arkansas System Division of Agriculture's Pine Tree Research Station, near Colt, Ark., during 2016 on a Calloway silt loam. Selected mean soil chemical properties from composite soil samples (0- to 4-inch depth) included 6.3 pH, 88 µmhos/cm for soil electrical conductivity (1:2 soil weight to water volume mixture), 22 ppm Mehlich-3 P, 106 ppm Mehlich-3 K, 256 ppm Mehlich-3 Mg, 1161 ppm Mehlich-3 Ca, and 15.8 ppm water-soluble Cl. No fertilizers or soil amendments were added to the field prior to or during the growing season. The field had been fallow for at least two years.

The eleven varieties listed in Table 1 were selected for this study to represent maturity groups (4.7 to 5.3) commonly grown in Arkansas with some of the varieties having inconsistent Cl ratings (Table 1). From the most recent Cl ratings available for each variety, three varieties were rated as Cl excluders, three were rated as mixed, and five were rated as Cl includers. The Cl ratings for the selected varieties may not be consistent with company ratings or ratings given in previous years of the Arkansas Cl screening trial.

Each variety was planted (130,000 seed/acre) in an 8-row strip that was 500 ft long with rows on the top center of each bed spaced 30 inches apart. Beginning 100-ft inside the west border of the field, where polypipe was positioned for irrigation, three 50-ft blocks spaced 50-ft apart were established. Within each block at the V6 growth stage, 16 individual plants (total of 48 plants/variety) from the 2 middle rows of each strip were identified with a flag and plants on either side of the flagged plant were pulled to avoid confusion about which plant was selected for the study. Soybean management in regard to pest control and irrigation closely followed the University of Arkansas System Division of Agriculture Cooperative Extension Service production guidelines. Soybean was furrow irrigated with surface-water from a nearby pond (61 mg Cl/L when sampled on 2 August 2016).

Once plants reached the R2 to R3 growth stage, trifoliate leaf samples (leaf and petiole) were collected by removing the top four fully matured leaves and petioles from each plant. The sampled tissue was oven-dried, weighed, ground, extracted with water (Kalra, 1998), and extracts were analyzed for Cl concentration using inductively coupled plasma spectroscopy (Spectro Analytical Instruments Inc., Mahwah, N.J.).

The experiment was a strip trial design containing 11 varieties. The mean and standard deviation of leaf-Cl concentration were calculated for each variety using the MEANS procedure of SAS v. 9.4 (SAS Institute, Cary, N.C). The MIXED procedure was used to determine if location in the field (block) had a significant effect on leaf-Cl concentration to address the potential for spatial variability. For this analysis, variety and block were treated as fixed effects and significance was interpreted at the 0.10 level.

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Leaf-Cl concentrations were allocated into six categories including low (<500 ppm), moderately low (501 to 1000 ppm), moderate (1001 to 2000 ppm), moderately high (2001 to 3000 ppm), high (3001 to 4000 ppm), and very high (>4000 ppm Cl) to represent the range of leaf-Cl concentrations. Note that the Cl concentrations that define each category in this research are somewhat subjective (dependent on site and environment) and different Cl concentration ranges might be needed for an environment with different amounts of Cl. The percentage of plants within each Cl concentration category was summarized across all varieties and then by variety. Linear regression analysis was performed to evaluate the relationship between mean leaf-Cl concentration and individual leaf-Cl concentrations of each variety.

Results and Discussion

This study aimed to answer two questions; do individual, field-grown plants of a single variety have similar leaf-Cl concentrations, and, more comprehensively, why are variety Cl ratings inconsistent among years or screening times? The block main effect addressing leaf-Cl spatial variability was not statistically significant ($P = 0.33$) indicating that numerical differences in mean leaf-Cl concentration among blocks were due to the behavior of individual plants (n = 16) in each variety to accumulate Cl and not on location in the field, Cl movement with irrigation water, or soil properties.

Leaf-Cl concentrations averaged across plants within a single variety ranged from 221 to 3309 ppm Cl (Table 1). Across the 11 varieties in our trial, the leaf Cl categories in decreasing order of plant population percentage followed the order of moderately low, high, and very high (Table 2). The distribution of plants among Cl concentration categories was clearly variety dependent (Table 2). The all-variety distribution does not likely represent that of all commercially available varieties since many of these 11 varieties were picked for a specific reason.

Pioneer 49T80R, categorized as a Cl-excluder, had 100% of its plants with low leaf-Cl concentrations, which is behavior expected from a true Cl-excluding variety in this environment. Armor 47-R70 had over 90% of plants with leaf-Cl concentrations >1000 ppm Cl, which is consistent with the Cl-includer variety. Varieties labeled as mixed (Asgrow 5233, Progeny 4900RY, and Progeny 5333RY) had 43%, 85%, and 79% of plants with low leaf-Cl concentrations (<500 ppm) and 47%, 8%, and 17% of plants with leaf-Cl concentrations >1000 ppm, respectively. The remaining includer varieties (Armor 47-R13, Asgrow 4934, Dynagro S52RY75, and Pioneer 49T09BR) had no plants with low leaf-Cl concentrations (<500 ppm) and all, except Asgrow 4934, had >90% of the plants with leaf-Cl concentrations >1000 ppm. The two remaining excluder varieties (GoSoy 4914GTS and NK S48-D9) produced 13% and 50% of plants with leaf-Cl concentrations <500 ppm and 15% and 44% with >1000 ppm, respectively. The majority of the GoSoy 491GTS plants had moderately low Cl concentrations suggesting it behaved more like a Cl excluder.

A preliminary configuration for a new rating system was examined using plant mean leaf-Cl concentrations and Cl distribution data. We summarized the 11 varieties into 2 categories including the percentage of plants with low Cl (<500 ppm Cl) and plants having moderate and greater Cl (>1000 ppm Cl, Tables 1 and 2). The mean leaf-Cl concentration (dependent variable, Table 1) regressed against the percentage of plants having low leaf-Cl concentrations (independent variable, Table 2) showed a relatively weak relationship ($R^2 = 0.57$, not shown). However, the relationship between mean leaf-Cl concentration and the percentage of plants having moderate and higher leaf-Cl concentrations was positive, linear, and relatively strong (Fig. 1).

Based on the relationship shown in Fig. 1, a preliminary rating system on a 1 to 10 scale could be developed using composite leaf samples from field-grown variety trials. For example, varieties having less than 10% of its plants with leaf-Cl concentrations >1000 ppm for this field environment would be assigned a rating of 1 and represent a strong Cl excluder (e.g., 2 = 11% to 20%, 3 = 21% to 30%, 4 = 31% to 40%, etc…). Additional research is needed to confirm the consistency of these results using more varieties and different locations.

Practical Application

The results of our study showed that many soybean varieties are simply a mixture of plants with either the includer or excluder trait. The ratio of includer to excluder plants in the population of a single variety likely influences the overall performance of the variety in the presence of high Cl concentrations and the mean leaf-Cl concentration of field grown plants appears to be well correlated with the percentage of Cl-includer plants in the population. Our trial did not fully examine whether plants have a range of abilities to include or exclude Cl, but a wide range of leaf-Cl concentrations were measured. The fact that most varieties likely contain a mixture of includer and excluder plants may be the primary reason for a single variety having different Cl-trait ratings from the annual five-plant greenhouse screening. Research to characterize the ratio of includer and excluder plants of more varieties with different maturity groups and herbicide tolerance technologies is warranted and needed to develop a more robust and accurate Cl-trait rating system.

Acknowledgments

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Table 1. Varieties, Cl-rating category, leaf-Cl means and standard deviations, and percentage of plants in two categories for each variety from the field trial conducted at University of Arkansas System Division of Agriculture's Pine Tree Research Station near Colt in 2016.

Variety	Cl rating (Cl Screening Trials) 2013	2014	2015	Leaf-Cl concentration Mean	SD[a]	Percentage of plants <500 ppm	>1000 ppm
				------- (ppm Cl) -------		------------- (%) -------------	
Pioneer 49T80R	Excluder	Mixed	Excluder	221	55	100	0
Progeny 4900RY	.	Excluder	Mixed	400	670	85	8
Progeny 5333RY	Excluder	Excluder	Mixed	437	522	17	17
GoSoy4914GTS	Mixed	Excluder	Excluder	759	253	13	15
NK S48-D9	.	Includer	Excluder	875	837	50	44
Asgrow AG5233	Mixed	Mixed	Mixed	1045	906	43	47
Asgrow AG4934	Inlcuder	Includer	Includer	1319	456	0	66
Armor 47-R70	.	.	Includer	1693	513	0	96
Armor 47-R13	Includer	Includer	.	2225	1124	0	94
Pioneer 49T09BR	.	.	Includer	2350	1397	0	100
Dynagro S52RY75	.	Mixed	Includer	3309	2092	0	100

[a] SD, Standard deviation.

Table 2. Distribution of leaf-Cl concentration using all varieties from the 2016 soybean chloride population trial conducted at University of Arkansas System Division of Agriculture's Pine Tree Research Station near Colt in 2016.

Variety	Leaf Cl concentration range: Low 0-500 ppm	Moderately low 501-1000 ppm	Moderate 1001-2000 ppm	Moderately high 2001-3000 ppm	High 3001-4000 ppm	Very high >4000 ppm
	------------------------------	--------------------	(% of plants)	--------------------	--------------------	------------------------------
Pioneer 49T80R	100	0	0	0	0	0
Progeny 4900 RY	85	7	0	6	2	0
Progeny 5333RY	79	4	15	2	0	0
GoSoy4914GTS	13	72	15	0	0	0
NK S48-D9	50	6	33	11	0	0
Asgrow AG5233	43	11	32	13	2	0
Asgrow AG4934	0	34	62	4	0	0
Armor 47-R70	0	4	71	23	2	0
Armor 47-R13	0	6	50	27	8	8
Pioneer 49T09BR	0	0	44	48	4	4
Dynagro S52RY75	0	0	21	44	17	18
All varieties	34	13	31	16	3	3

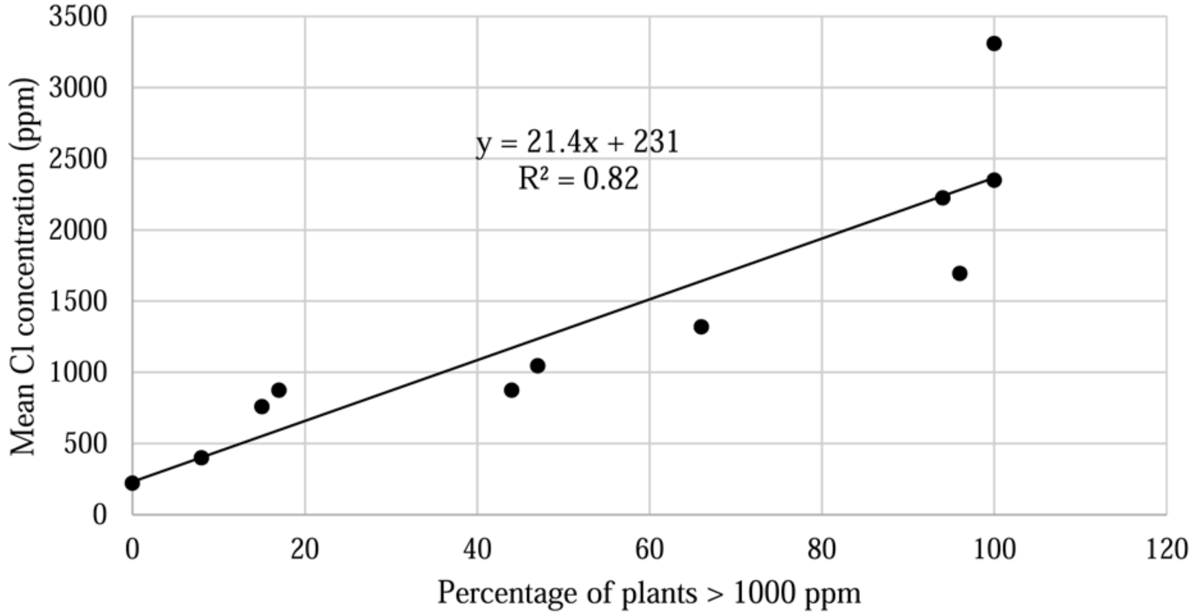

Fig. 1. Mean leaf-Cl concentration (*n* = 48) regressed across percentage of plants with leaf-Cl concentrations greater than 1000 ppm Cl. Data taken from soybean Cl population trial conducted at the University of Arkansas System Division of Agriculture's Pine Tree Research Station near Colt in 2016.

Grain Sorghum Yield Response to Phosphorus and Potassium Fertilizer Application Rates in Arkansas

M. Mozaffari[1], N.A. Slaton[2], Y. D. Liyew[3], S. Hayes[4], and M. Duren[1]

Background Information and Research Problem

During the last six years grain sorghum [*Sorghum bicolor* (L.) Moench] acreage in Arkansas has fluctuated from 40,000 to 450,000 acres. One bushel of grain sorghum removes 0.6 and 0.8 lb of P_2O_5 and K_2O, respectively. In the last five years, Arkansas producers have succeeded in increasing the state average sorghum yield from 72 to 100 bu/acre which represents substantial amounts of phosporus (P) and potassium (K) removal from the soil. Phosphorus and/or K deficiency will limit sorghum yield in many agricultural soils if the nutrients removed by the harvested crops are not supplied and/or replenished by fertilization. Reliable soil-test based fertilizer recommendations are the keys to applying the right rates of P and or K fertilizer. Very little information is available that describes grain sorghum response to P or K fertilization under the current high yielding Arkansas production practices. Such information is needed to evaluate and, if needed, revise the current soil-test based P and K fertilization recommendations for irrigated grain sorghum production in Arkansas. The objective of this study was to evaluate irrigated grain sorghum response to P or K fertilizer application rates in selected Arkansas soils.

Procedures

Phosphorus Experiments

Three P-fertilization trials were conducted in 2016 at the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center located at Keiser, Ark., in Mississippi County (MSSB61), Pine Tree Research Station (PTRS) at Colt, Ark., in St. Francis County (SFSB61), and Lon Mann Cotton Research Station (LMCRS) at Marianna, Ark., in Lee County (LESB61). The soil series and selected agronomic information for each site are listed in Table 1. The previous crop was soybean at MSSB61 and LESB61, and corn at SFSB61.

Prior to P application, a composite soil sample was taken from the 0- to 6-inch depth of each replication or zero P plot. At LESB61, the soil test results are based on samples collected in January 2015 on a 35 ft by 35 ft grid. Each composite soil sample consisted of a total of 6 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 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 six (LESB61, MSSB61) or five (SFSB61) times. Phosphorus treatments were applied onto the soil surface in a single application from 2 days before planting to 20 days after planting (Table 1). The preplant-applied P was mechanically incorporated into the top 3- to 4-inches of the soil. The beds were then pulled with a hipper and grain sorghum was planted on the top, center of the bed. Blanket applications of muriate of potash and $ZnSO_4$ supplied 90 lb K_2O, ~5 lb S, and ~10 lb Zn/acre. All experiments were fertilized with a total of 110 to 120 lb N/acre as urea in a single or split applications (e.g., preplant, 3- to 6-leaf stage and/or pre-tassel) depending on the location. Grain sorghum was grown on beds and furrow irrigated as needed by research station staff. Each plot was 25-ft long and 10-ft wide at SFSB61, and 40-ft long and 12.6-ft wide at other sites allowing for 4 rows of grain sorghum spaced 30 or 38 inches apart, respectively. Grain sorghum management closely followed University of Arkansas System Division of Agriculture's Cooperative Extension Service (CES) recommendations.

The middle two rows of each plot were harvested with a plot combine. The calculated grain yields were adjusted to a uniform moisture content of 14% before statistical analysis.

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[3] Research Program Technician, Pine Tree Research Station, near Colt.
[4] Program Associate, Rohwer Research Station, Rohwer.

Potassium Experiments

Six replicated field experiments were conducted in 2016 at the PTRS (SFSB62, SFSB64, SFESB62) in St. Francis County, Rohwer Research Station (RRS) in Desha County (DESB62, DESB64), and LMCRS in Lee County (LESB62). The two K trials in Desha County were located in the same field as the aforementioned P trial. The DEZ62 trial was established in 2014 and the same fertilizer-K rates were applied to the same plots in 2014, 2015 and 2016. The DESB64 trial was established in 2015 and the same fertilizer-K rates were applied to the same plots in 2015. At the SFESB62, the same rates of K have been applied to the same plots annually since 2013 and the same rates were applied again in 2016. The previous crop at the two DESB sites and all SFSB and SFESB sites was corn. The test at LESB62 was a new trial established in 2016 where the previous crop was irrigated soybean.

The agronomic information for K trials is listed in Table 1. Composite soil samples were collected from each replication of the new trials and from each 0 lb K_2O/acre plot from multi-year trials and processed 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 SFESB62 where the rate increased by 50 lb K_2O/acre increments. All K treatments were applied as muriate of potash onto the plot surface in the same window of time as the P trials (Table 1). All of the preplant-applied K fertilizer was mechanically incorporated, the beds were re-pulled with a hipper, and grain sorghum was planted on the top, center of the bed. Triple superphosphate and $ZnSO_4$ fertilizers were broadcast 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.

The trials at St. Francis County (SFSB62, SFSB64 and SFESB62) were 25-ft long and 10-ft wide allowing for 4 rows of grain sorghum planted in 30-inch rows. Plot dimensions for all the other trials were 40-ft long and 12.6-ft wide allowing for 4 rows of grain sorghum planted in 38-inch wide rows. All experiments had a randomized complete block design and each treatment was replicated five times in St. Francis County and six times at all the other sites.

Analysis of variance was performed for each individual P or K trial using the GLM procedure of SAS. 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 6.5 to 7.7 and all soils were mapped as silt loam soils, except at MSSB61 where the soil is mapped as Sharkey-Steel complex (Table 1). Mehlich-3 extractable P ranged from 14 to 27 ppm. According to the current CES soil-test interpretation, the soil-test P level was Very Low (<16 ppm) at SFSB61 and Medium (26 to 35 ppm) at all the other sites. According to the current CES soil-test based P fertilization guidelines for grain sorghum with a yield goal of >130 bu/acre, the Very Low and Medium soil-test P levels receive recommendations of 110 and 70 lb P_2O_5/acre, respectively.

Experimental plots at SFSB61 were damaged by wildlife and meaningful data could not be collected. Phosphorus fertilization did not significantly influence grain sorghum yield at the two sites that had a Medium soil-test P (Table 4). We have observed similar results in our research with corn. If this trend continues in the future research, then our current interpretation of Mehlich-3 extractable soil-test P for grain sorghum may need to be revisited. Numerically, grain yields of crops fertilized with any P ranged from 94 to 106 bu/acre and the yields of grain sorghum that did not receive any P ranged from 94 to 99 bu/acre.

Potassium Experiments

Soil pH and Mehlich-3 extractable P ranged from 6.0 to 6.8 and 16 to 40 ppm, respectively (Table 3). The average Mehlich-3 extractable K ranged from 48 to 88 ppm among the six sites. According to the current CES soil-test interpretation, soil-test K was Very Low (<61 ppm) at DESB62 and SFESB62 and Low (61 to 90 ppm) at the other four sites. Current fertilization guidelines for grain sorghum with a yield goal of >130 bu/acre would have recommended 150 and 100 lb K_2O/acre for the Very Low and Low soil-test K levels, respectively.

Potassium fertilization significantly ($P \leq 0.10$) affected grain sorghum yield at all sites except DESB64 (Table 5). A positive response to K fertilization at the five sites with Very Low and Low soil-test levels is in agreement with current CES recommendations for soil-test based fertilizer-K. However, the lack of response to K fertilization at DESB64 was unexpected considering the Low soil-test K level and relatively low variability in grain yields. We have observed a similar result at this site with corn in 2015. The yields of grain sorghum that were not fertilized with any K ranged from 79 to 116 bu/acre and grain yields of sorghum that received K ranged 90 to 138 bu/acre. At the K-responsive sites, maximal sorghum yields were produced with the application of 80 to 200 lb K_2O/acre.

Practical Applications

The 2016 results show that P fertilization did not increase grain sorghum yield when Mehlich-3 extractable P in the 0- to 6-inch depth was within the Medium level. Potassium fertilization significantly increased grain sorghum yield at five sites with Very Low to Low soil-test K levels, but failed to influence sorghum yield at one site with Low soil-test K. Reliability and applicability of such information will increase if research is conducted on a range of soils with various levels of Mehlich-3 extractable P (or K), clay content, pH and other conditions. We will use the information from this and future research to construct databases on grain sorghum response to P and K fertilization under Arkansas crop production conditions.

The database will be used to evaluate and, if needed, revise our current soil-test based recommendations for P and/or K fertilization of grain sorghum in Arkansas.

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

Table 1. Site identification code, test nutrient(s), soil series, grain sorghum hybrid; planting, fertilizer application, and harvest dates for trials conducted in Desha (DESB62, DESB64), Lee (LESB61, LESB62), Mississippi (MSSB61), and St. Francis (SFSB61, SFSB62, SFSB64, SFESB62, and SFSB61) counties during 2016.

Site code	Test nutrient	Soil series	Hybrid	Planting date	Fertilizer application date	Harvest date
DESB, 62, 64	K	Hebert silt loam	AgVenture7R21	25 April	27 May	8 Sep
LESB61, 62	P, K	Calloway silt loam	DeKalb DKS51-01	20 April	18 April	3 Sep
MSSB61	P	Sharkey-Steel Complex	DeKalb DKS51-01	18 April	7 April	2 Sep
SFSB62, SFSB64, SFESB62	K	Calloway silt loam	DeKalb DKS53-67	15 April	5 May	27 Sep
SFSB61	P	Crowley silt loam	Dyna Grow 56V646	15 April	5 May	28 Sep

Table 2. Selected chemical property means of soil samples collected from the 0- to 6-inch depth before P-fertilizer application for four grain sorghum P-fertilization trials established in Lee (LESB61), Mississippi (MSSB61) and St. Francis (SFSB61) counties during 2016.

Site ID	Soil pH[a]	Mehlich-3-extractable nutrients						
		P	SD P[b]	K	Ca	Mg	Cu	Zn
		(ppm)						
LESB61	7.1	27	±6	63	1193	299	1.7	2.2
MSSB61	6.5	26	±4	204	2970	600	4.1	4.0
SFSB61	7.7	14	±3	120	2613	290	1.2	2.2

[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-inch depths before fertilizer-K application for six grain sorghum trials conducted in Desha (DESB62, DESB64), Lee (LESB62), and St. Francis (SFSB62, SFSB64, and SFESB62) counties during 2016.

Site ID	Soil pH[a]	Mehlich-3-extractable nutrients						
		P	K	SD K[b]	Ca	Mg	Cu	Zn
		(ppm)						
DESB62	6.0	40	48	±6	720	99	1.0	3.2
DESB64	6.3	21	66	±9	759	106	1.1	1.5
LESB62	6.0	16	70	±5	1025	241	1.5	1.9
SFSB62	6.8	27	78	±6	489	102	1.5	14.4
SFSB64	6.4	28	88	±20	1514	269	1.6	8.1
SFESB62	6.7	37	58	±6	1615	274	1.1	3.1

[a] Soil pH was measured in a 1:2 (weight: volume) soil-water mixture.
[b] SD, Standard deviation of Mehlich-3 extractable soil-test K in the 0- to 6-inch depth.

Table 4. Effect of P-fertilization rate on grain sorghum yield for two trials conducted in Lee (LESB61), and Mississippi (MSSB61) counties during 2016.

	Grain yield	
P rate	LESB61	MSSB61
(lb P_2O_5/acre)	-------- (bu/acre) --------	
0	94.1	98.5
40	94.3	99.2
80	98.4	105.8
120	99.9	94.2
160	98.6	95.2
C.V., %[a]	6.3	9.1
P-value	0.4989	0.2212
LSD 0.10[b]	NS[c]	NS

[a] C.V., 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 grain sorghum yield for six trials conducted in Desha (DESB62, DESB64), Lee (LESB62), and St. Francis (SFSB62, SFSB64, and SFESB62) counties during 2016.

	Grain yield						Grain yield
K rate	DESB62	DESB64	LESB62	SFSB62	SFSB64	K rate	SFESB62
(lb K_2O/acre)	--------------------------------------(bu/acre)--------------------------------------					(lb K_2O/acre)	(bu/acre)
0	79.5	96.9	82.5	104.8	116.2	0	87.2
40	90.5	96.0	93.2	121.8	113.3	50	104.2
80	97.0	92.6	89.8	135.3	116.6	100	111.6
120	101.0	97.2	96.8	124.1	131.2	150	117.6
160	97.8	100.4	99.8	129.9	131.0	200	113.4
200	101.8	100.3	100.5	125.3	137.5	-	-
C.V., %[a]	7.0	5.9	6.6	7.4	6.4		10.0
P-value	0.0025	0.4481	0.0075	<0.0187	0.0030		0.0033
LSD 0.10[b]	8	NS[c]	7.6	12.8	10.3		11.9

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

Evaluation of Mehlich-3 Extraction of Field-Moist and Oven-Dried Soil from Long-Term Fertilization Trials

N. A. Slaton[1], J. Hardke[2], T.L. Roberts[1], and R.J. Norman[1]

Background Information and Research Problem

Soil-test phosphorus (P) and potassium (K) are known to be affected by the soil moisture status at the time of analysis. Luebs et al. (1956) was among the first to show that soil-test K in Iowa soils can be substantially changed by drying soil samples, which causes soil-test K to increase on soils with very low amounts of exchangeable K and to decrease on soils that have high soil-test K values. Barbagelata and Mallarino (2013) recently demonstrated that moist-soil analysis provides a more accurate assessment of corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] response to K fertilization. In Arkansas, Martins et al. (2015) showed that Mehlich-3 extractable P and K tend to be greater from oven-dried soil as compared with field-moist soil with the difference being potentially great enough to influence the interpretation of the resulting soil-test value. The effect of soil drying on extractable K appears to be independent of extraction method and the magnitude of difference varies among soils.

Last year we reported the soil-test P and K relationships between oven-dried and field-moist soils from long-term fertilization trials on Calhoun and Dewitt silt loam soils (Slaton et al., 2016). The objective of this report is to determine the relationship between field-moist and oven-dried soil from the same long-term P and K fertilization experiments to see if the relationships defined from soil samples collected in 2015 were similar to relationships defined from soil samples collected from the same plots in 2016.

Procedures

Soil samples (0- to 4-in depth) were collected in early- to mid-January 2016 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). The sampled trials on a Calhoun silt loam at the PTRS followed rice (n = 45) or soybean (n = 40) 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 or soybean 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. These are the same plots sampled, analyzed and reported by Slaton et al. (2016) with the only differences being one additional year of cropping and fertilization and crop rotation. The procedures used to collect, process, and analyze the soil samples were the same as outlined by Slaton et al. (2016) with soil moisture determined as described by Kalra and Maynard (1991) and field-moist soil processed as described by Gelderman and Mallarino (2015). The minimum and maximum values of selected soil properties for each of the individual trials are listed in Table 1.

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. No replicate data were omitted from the analysis regardless of the observations Cook's D statistic or studentized residual value (all values < ± 3.4). The regression coefficients and standard errors for each year are listed in Table 2.

Results and Discussion

The relationships between K extracted using oven-dried soil and field-moist soil are shown for the Calhoun soil (Fig. 1) and Dewitt soil (Fig. 2) for soil samples collected in 2015 and 2016 from the same plots. Although the regression slope coefficients were numerically different between years, the qualitative relationships were similar in that the slope was less than 1.0. The Dewitt soil exhibited greater variability in 2016 with the slope coefficient being numerically lower than in 2015 (Table 2). The oven-dried K/field-moist K ratio showed that the equilibrium point where the ratio equals 1.0 was numerically similar (~100 ppm) for each year on the Calhoun soil (Fig. 3). However, the Dewitt soil showed slightly different numerical relationships as the oven-dried K/field-moist K ratio equilib-

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rium point being about 160 ppm in 2015 and 120 ppm in 2016 (not shown). For both soils, the ratio was greater than 1.0 below the equilibrium point and less than 1.0 as field-moist soil K concentrations increased.

For P, the data between years showed no discernible visual patterns (Fig. 4) with the slope and intercept coefficients being numerically similar for each of the two years (Table 2). The intercept value for each year indicated that oven-drying resulted in a consistent increase of 4 ppm P compared to analysis of field-moist soil. The oven-dried P/field-moist P ratio also showed similar trends although the ratio remained above 1.0 for the majority of the data points in 2016 (Fig. 5).

Practical Applications

Analysis of soil samples in 2016 continued to show that oven-drying soil samples influences the amounts of P and K extracted from field-moist soil and the differences tend to be soil dependent. The Calhoun soil showed similar numerical relationships between methods and years for K and the Dewitt soil showed the same for P. The relationship was somewhat different between years for K on the Dewitt soil, which may be attributed to the seasonal and annual fluctuations that sometimes occur with K. Despite the effect of oven-drying on soil-test K, research by Fryer (2015) showed that the current recommendations that use K extracted from oven-dried soil are relatively accurate at identifying soybean yield response to K fertilization. Analysis of field-moist soil may not provide for increased accuracy in soil-test P and K recommendations, but should continue to be examined in correlation and calibration trials as the results of oven-drying on extractable K are irreversible.

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 and Nutrient[a]	Prev Crop[b]	n	Soil pH		Mehlich-3 P		Moist/Dry P ratio		Mehlich-3 K		Moist/Dry K ratio	
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
					(ppm)							
Calhoun-K1	R	40	7.9	8.4	24	55	1.06	1.37	34	101	0.96	1.37
Calhoun-K2	S	45	7.7	8.3	25	57	1.10	1.95	49	125	0.86	1.54
Dewitt-K1	R	30	5.8	6.4	32	53	0.76	1.39	76	207	0.86	2.16
Dewitt-K2	S	30	5.2	5.6	31	53	1.00	1.33	78	158	0.74	1.24
Dewitt-P1	R	30	5.3	6.0	13	93	1.00	1.44	102	145	0.87	1.08
Dewitt-P2	S	30	5.5	6.1	9	98	1.00	1.80	100	219	0.79	1.87

[a] Soil and nutrient. PTRS, Pine Tree Research Station (Calhoun silt loam); RREC, Rice Research Extension Center (Dewitt silt loam) sampled in January 2016. Ranges for 2015 soil samples are given by Slaton et al. (2016).
[b] Previous crop abbreviations: R, rice; S, soybean.

Table 2. Linear regression coefficients and standard errors (SE) for 2015 and 2016 describing the relationship between Mehlich-3 extractable P or K from oven-dried soil regressed against Mehlich-3 extractable P or K from field-moist soil using soil samples collected from six long-term P and K trials (data combined into 3 analyses, by ignoring previous crop) in 2015 or 2016.

			2015					2016				
Soil	Nutrient	n	Intercept	SE	Slope	SE	R^2	Intercept	SE	Slope	SE	R^2
Calhoun	K	85	22.3	1.2	0.78	0.02	0.95	17.4	1.8	0.87	0.03	0.92
Dewitt	K	60	43.6	4.4	0.71	0.04	0.87	44.5	6.4	0.63	0.05	0.70
Dewitt	P	60	4.9	0.8	1.00	0.02	0.98	4.3	1.0	1.03	0.02	0.98

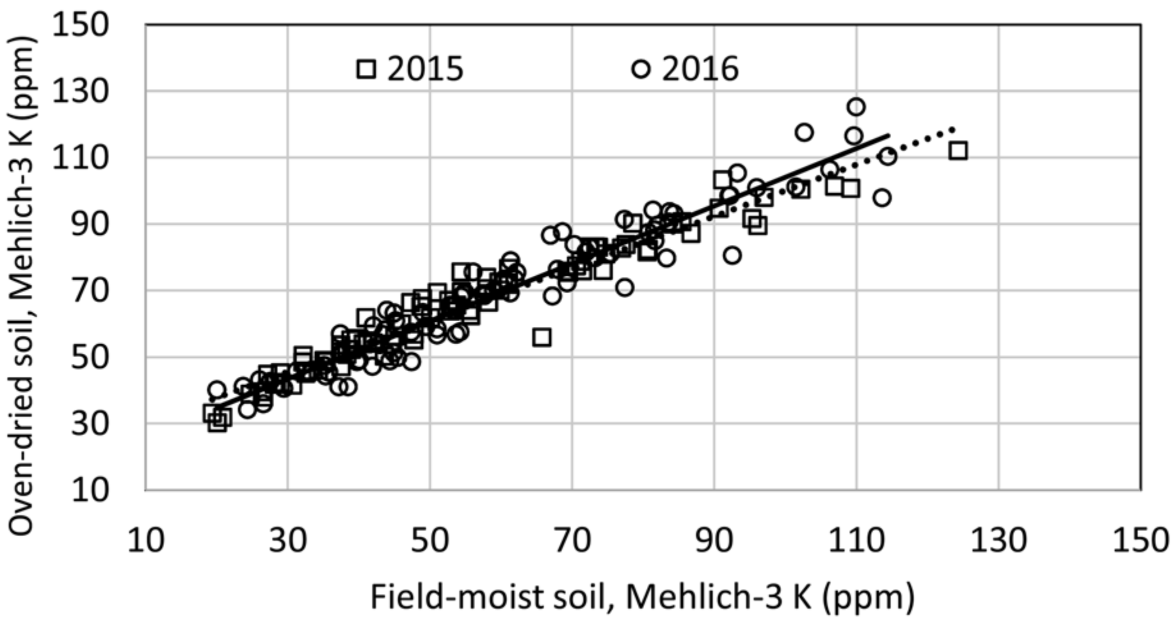

Fig. 1. The relationship between Mehlich-3 extractable oven-dried and field-moist soil K from soil samples (0- to 4-inch depth, *n* = 85) collected in 2015 and 2016 from a long-term K trial located on a Calhoun silt loam. See Table 2 for coefficients that describe each linear regression line.

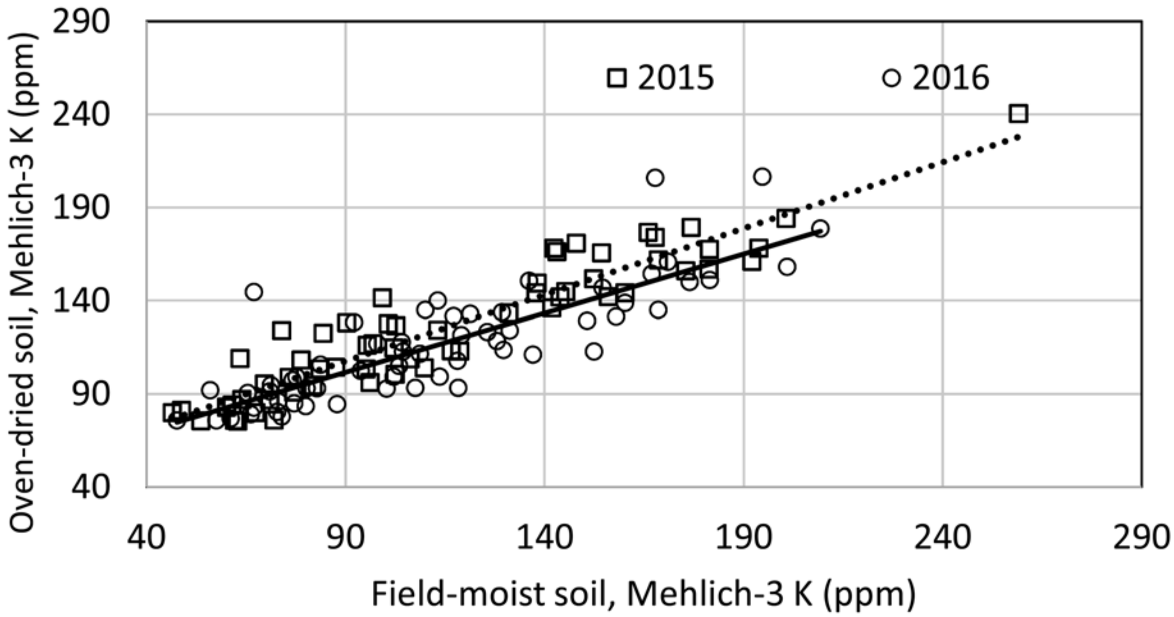

Fig. 2. The relationship between Mehlich-3 extractable oven-dried and field-moist soil K from soil samples (0- to 4-inch depth, *n* = 60) collected in 2015 and 2016 from a long-term K trial located on a Dewitt silt loam. See Table 2 for coefficients that describe each linear regression line.

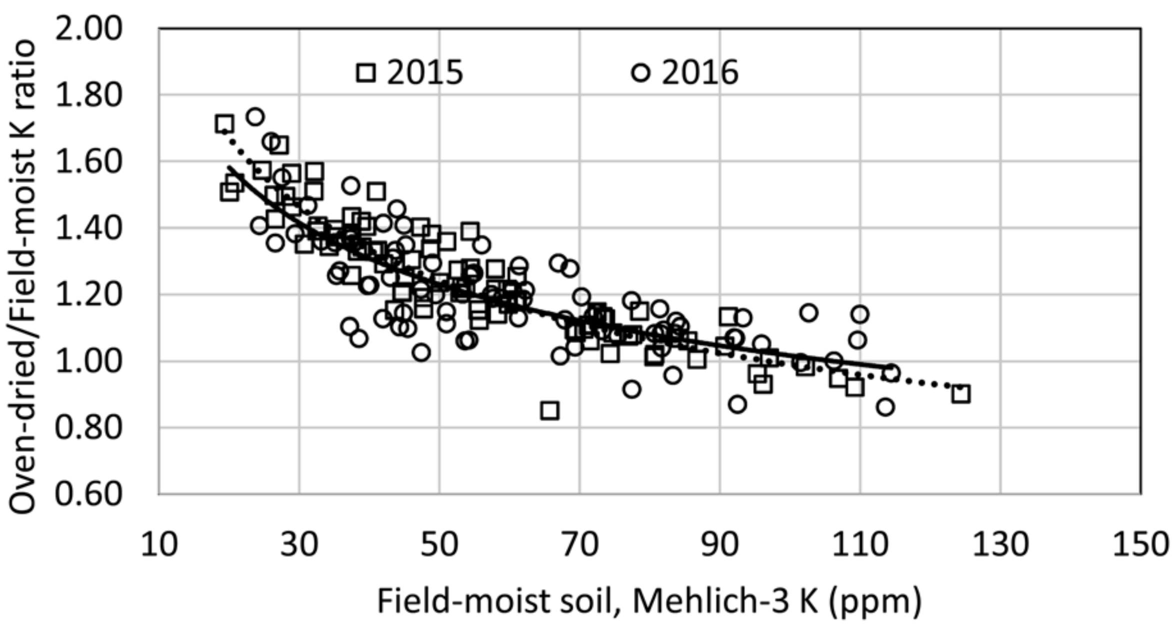

Fig. 3. The relationship between the dry/field-moist soil K ratio regressed against Mehlich-3 extractable field-moist soil K (0- to 4-inch depth) from soil samples (0- to 4-inch depth, *n* = 85) collected in 2015 and 2016 from a long-term K trial located on a Calhoun silt loam.

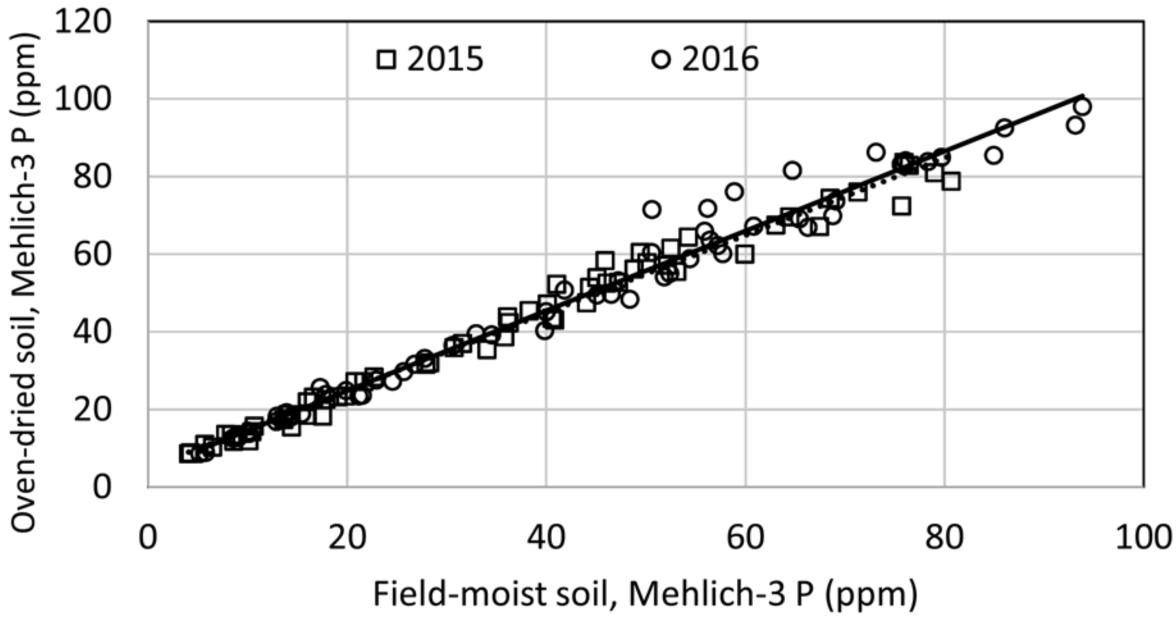

Fig. 4. The relationship between Mehlich-3 extractable oven-dried and field-moist soil P from soil samples (0- to 4-inch depth, *n* = 60) collected in 2015 and 2016 from a long-term P trial located on a Dewitt silt loam. See Table 2 for coefficients that describe each linear regression line.

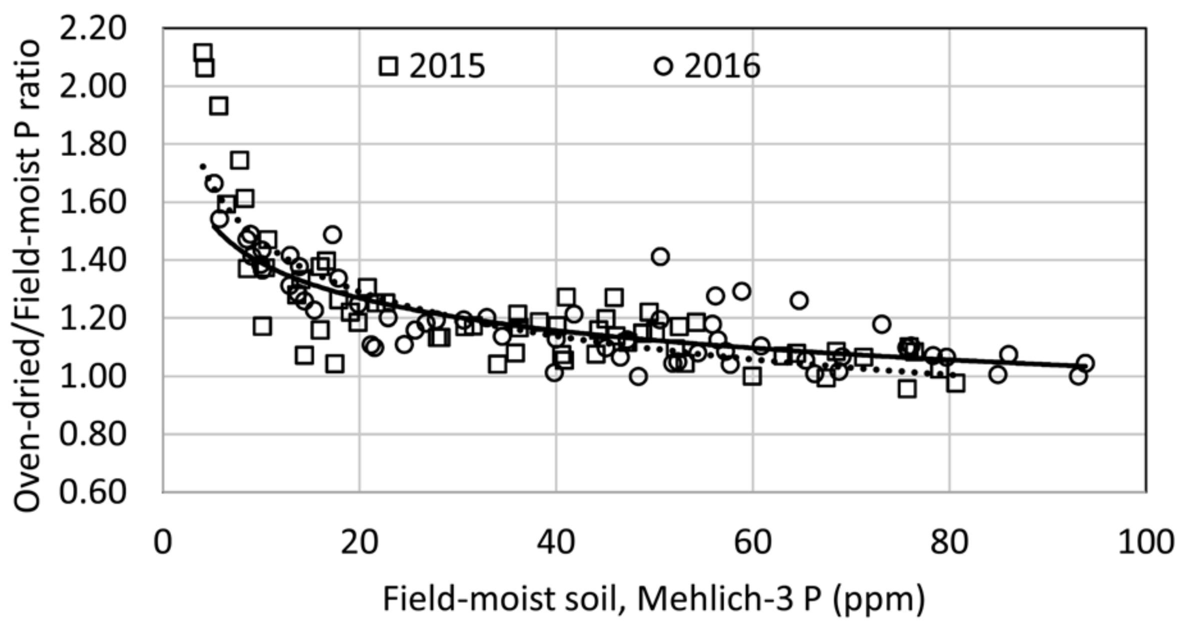

Fig. 5. The relationship between the dry/field-moist soil K ratio regressed against Mehlich-3 extractable field-moist soil P (0- to 4-inch depth) from soil samples (0- to 4-inch depth, *n* = 60) collected in 2015 and 2016 from a long-term P trial located on a Calhoun silt loam.

Corn Yield Response to Injected Urea Ammonium Nitrate With and Without Instinct II

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Background Information and Research Problem

Nitrification inhibitors have not been used extensively as N-fertilizer additives in mid-South grain-crop production systems. The two nitrification inhibitors used in the USA are nitrapyrin and dicyandiamide (DCD). Research suggests that both are legitimate nitrification inhibitors but their use provides inconsistent yield benefits (Franzen, 2011). Corn (*Zea mays* L.) and other fertilizer-N requiring grain and fiber crops typically are managed with a proportion of the total-N requirement applied preplant (25% to 40%) and the remainder applied in one or more post-emergence applications made near the growth stage that rapid plant growth begins. Interest in the use of efficacious N additives remains high because of the need to reduce N loss via runoff and leaching, incentives that encourage farmers to use N additives, and the fact that the number of acres managed by an individual farmer is increasing (USDA-NASS, 2016) which requires farmers to manage resources (e.g., time, labor, equipment, etc.) efficiently. The objective of this field experiment was to evaluate whether the encapsulated form of nitrapyrin sold as Instinct II provided any growth, grain yield and soil-N benefits for corn grown on a poorly drained clayey soil.

Procedures

A replicated field trial was established on a soil mapped as a Sharkey and Desha clay at the University of Arkansas System Division of Agriculture's Rohwer Research Station. Selected mean (n = 4) soil properties include an estimated cation exchange capacity of 39 $cmol_c$/kg soil, 7.7 pH, 3.6% organic matter, 64 ppm Mehlich-3 P, 3.7 ppm Mehlich-3 Zn, 7 ppm Mehlich-3 S, and 353 ppm Mehlich-3 K. Soybean [*Glycine max* (L.) Merr.] was grown in 2015. Based on soil-test results, no other fertilizers were applied.

The trial included a total of five fertilizer-N treatments (Table 1). The N fertilizer source for all treatments was 32% urea ammonium nitrate (UAN). Instinct II (1.58 lb a.i./gal) was mixed with UAN applied at the V2 stage to selected treatments to supply 37 oz Instinct II/acre. The preplant application was made on 7 April and the sidedress application was made on 28 April. Corn hybrid Mycogen 2Y744 (113 relative maturity) was planted on 7 April 2016 on beds spaced 38 inches apart. The UAN was injected 4 inches deep into the shoulder on one side of each bed, 10 inches from the center of the bed. Each corn plot was 4-rows wide for the length of the field (~900 ft). An estimate of stand density was made on 7 June by counting a 100-ft length of the two center rows of each no fertilizer-N control plot, which showed an average of 33,045 plants/acre (789 standard deviation). The trial was furrow irrigated with the first irrigation occurring on 20 May and additional irrigations on 9 June, 15 June, 23 June., 28 June, 12 July, 18 July, and 25 July.

Chlorophyll meter (SPAD) readings were made on 7 (1233 growing degree units, tassel emergence) and 21 (1639 growing degree units, R1 stage) June. The SPAD readings were made from the two middle corn rows in a 100-ft section of each treatment starting approximately 60 ft from the field edge where irrigation pipe was located. The SPAD readings on 7 June were taken from the most recent (highest on plant) fully emerged leaf (visible leaf collar) on the plant at a point 0.5 inch from the leaf edge and three-quarters of the distance from the collar to the leaf tip. At the R2 stage (21 June), SPAD readings were taken from the uppermost ear leaf at the same leaf position as previously described. The SPAD values (n = 6) from each plot and sample time were averaged and recorded.

The experiment was a randomized complete block design with four blocks. Leaf SPAD readings were analyzed by sample time using ARM 2016.4 (Gyling Data Management, Inc., Brookings, S.D.). The analysis of variance on corn grain yield included only the four treatments that received fertilizer-N because the mean yield for corn that received no fertilizer-N was only 3 bu/acre (standard deviation ± 1 bu/acre), which is clearly different than that of corn that received fertilizer-N (range of mean yields 163 to 188 bu/acre). Numerical differences among treatments were interpreted as statistically significant using Fishers protected least significant difference test when the treatment factor P-value was ≤ 0.10.

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Results anad Discussion

Monthly rainfall amounts (after planting) totaled 4.6 inches in April, 2.8 inches in May, 3.6 inches in June, 3.7 inches in July, and 5.3 inches in August. The wettest early season (pre-irrigation) period was from 27 April to 3 May when 2.5 inches of rain was measured in six different events with the greatest proportion of precipitation (1.7 inches) on 29 April. Overall, the field environmental conditions were not considered to be highly conducive for early-season denitrification and runoff.

Leaf chlorophyll or SPAD readings at both measurement times were numerically greatest for corn fertilized with split applications of UAN plus Instinct II (Treatment 5, Table 2). Among the four treatments receiving fertilizer-N, three of the four treatments on each measurement date were similar with the numerical ranking changing somewhat between the two sample times. When Instinct was added to the UAN, the SPAD readings were either numerically (7 June) or statistically (21 June) higher than the same UAN treatment without Instinct (e.g., compare Treatments 2 vs 3 or 4 vs 5), which confirmed our visual observations on each SPAD measurement date that corn receiving Instinct II had a greener leaf color. Corn receiving no fertilizer-N had SPAD readings that were always significantly lower than corn receiving fertilizer-N.

Corn grain yield followed similar numerical rankings as the SPAD readings taken on 7 June in that the yield of corn receiving Instinct II was always numerically higher than the same N application strategy without Instinct II (Table 5). Significant yield differences occurred only for corn receiving 250 lb N/acre at the V2 stage with no Instinct II (Treatment 2) which produced lower yields than corn fertilized with treatments 3, 4, and 5. The yield data suggests that N applied at the V2 stage on this poorly drained soil is susceptible to N loss and that the nitrification inhibitor marketed as Instinct II added to injected UAN has potential yield benefits for furrow-irrigated corn. The yield data also suggests the suboptimal N rate used in this trial on a very N deficient clayey soil increased early-season vigor and corn yield potential.

Practical Applications

The results from this single trial suggest that the nitrification inhibitor marketed as Instinct II may provide some benefit to corn when added to 32% UAN applied preplant or early sidedress. Slaton et al. (2014) reported significant yield benefits from nitrapyrin (Instinct I) applied with 32% UAN applied at a sub-optimal N rate on a clayey soil. Cumulatively, the results suggest that the nitrification inhibitor nitrapyrin may be a valid UAN-N management tool for corn produced in the mid-South. However, the 2016 trial and results of Slaton et al. (2014) are not consistent regarding the need for preplant N on clayey soils. This may be due to the 2016 trial being more N deficient and requiring supplemental N as compared to results reported by Slaton et al. (2014). Additional research may be needed to determine on what soils preplant fertilizer-N is needed to maximize corn yield potential.

Acknowledgments

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Table 1. Summary of five fertilizer-N treatments used in a field trial at the University of Arkansas System Division of Agriculture's Rohwer Research Station in 2016. Note in treatment numbers 3 and 5, Instinct was added only to urea ammonium nitrate applied at the V2 stage.

Treatment†	Total N rate	Preplant N rate	V2 stage N rate	Instinct II rate
	(lb N/acre)			(oz/acre)
1 (no fertilizer-N)	0	0	0	0
2 (V2)	250	0	250	0
3 (V2+INS)	250	0	250	37
4 (PP & V2)	250	100	150	0
5 (PP & V2+INS)	250	100	150	37

† Abbreviations: PP (preplant); V2 (Vegetative stage 2, corn with 2-leaf collars); and INS (Instinct II formulation of nitrapyrin).

Table 2. Summary of five fertilizer-N treatments (Table 1) used in a field trial at the University of Arkansas System Division of Agriculture's Rohwer Research Station in 2016. Note in treatment numbers 3 and 5, Instinct II (INS, 37 oz/acre) was added only to urea ammonium nitrate applied at the V2 stage.

Treatment number†	SPAD (7 June)	SPAD (21 June)	Grain yield
			(bu/acre)
1 (no fertilizer-N)	26.2 c	25.5 c	3‡
2 (V2)	52.7 b	57.8 ab	166 b
3 (V2+INS)	54.3ab	59.1 ab	179 a
4 (PP & V2)	56.4 a	57.3 b	182 a
5 (PP & V2+INS)	57.1 a	60.0 a	188 a
$LSD_{0.10}$	3.0	2.4	11
C.V., %	2.4	1.9	6.0
P-value	<0.0001	<0.0001	<0.0001

† Total N rate of treatments 2 to 5 was 250 lb N/acre. When N was split, 100 lb N/acre was applied preplant and 150 lb N/acre was applied at V2 stage. Abbreviations: PP (preplant); V2 (Vegetative stage 2, corn with 2-leaf collars); and INS (Instinct II formulation of nitrapyrin).

‡ Yield of corn receiving no fertilizer-N was excluded from analysis of variance.

Evaluation of a Rapid, In-Field Method for Assessing Soybean Potassium Nutritional Status

N.A. Slaton[1], D.A. Sites[1], D.D. Cox[1], T. Richmond[1], J. Hardke[2], T.L. Roberts[1], and J. Hedge[3]

Background Information and Research Problem

Plant tissue analysis in production agriculture has historically been used to diagnose nutrient-related maladies or eliminate nutrients as a possible cause after plants express symptoms. The now defunct (in Arkansas) cotton (*Gossypium hirsuturm* L.) petiole monitoring program was one of the few examples of a weekly tissue analysis program to monitor a crop for the nutritional status of selected nutrients (NO_3-N, P, K, and S; Sabbe and Zelinski, 1990). Traditional plant tissue analysis methods usually require at least 24 hours for sample preparation, analysis, and result reporting with more time needed if samples must be mailed. In-field nutrient assessments are an alternative to traditional plant analysis but these rapid tests have limited application since research has been conducted primarily in production systems involving high value crops like vegetables and potatoes (*Solanum tuberosurm* L.; Rosen et al. 1996; Hochmuth, 2015).

The rapid, in-field methods require that sap be extracted from plant tissue, usually petioles. After extraction, the sap is placed on a small handheld instrument; the first instrument used for this purpose is known as the 'Cardy meter'. The original Cardy meter is no longer available but Horiba Scientific (Kyoto, Japan) has developed a series of ion-specific, handheld instruments including one for K. One limitation for the use of in-field sap analysis as a crop nutrition monitoring tool is that not all crops are well-suited for sap extraction. The objectives of this experiment were to evaluate weekly petiole sap analysis as a tool for monitoring soybean [*Glycine max*. (L.) Merr.] K nutrition and to compare petiole sap-K, petiole-K, and trifoliolate leaf-K concentrations during the growing season.

Procedures

Soybean grown in two long-term K rate trials and two K application timing trials were used to achieve the objectives of this experiment. The long-term trials included a 16-year trial at the University of Arkansas System Division of Agriculture's Pine Tree Research Station (PTRS-LTK, Calhoun series) and a 10-year trial at the Rice Research and Extension Center (RREC-LTK, Dewitt series), which each included annual rates of 0, 40, 80, 120 and 160 lb K_2O/acre and are cropped to a rice-soybean rotation. The RREC-LTK trial was drill-seeded (7.5-inch row spacing) into a no-till seedbed on 17 May with Armor 47-R13 soybean. The PTRS-LTK was drill-seeded (15-inch row spacing) into a no-till seedbed on 11 May with Pioneer 49T09 soybean. The two K timing trials were both located at the PTRS in fields that will be referred to as I-10 (Calloway series) and F3 (Calhoun series). Only two treatments in each trial were used for the objectives of this report and included preplant applications of 0 and 180 lb K_2O/acre. A summary of soil chemical properties including pH (1:2 soil-water mixture) and selected Mehlich-3 extractable nutrients before fertilizer treatment application is listed in Table 1. Selected data from these four trials will be used in this report.

No yield data from these trials will be given in this report since we were interested only in examining seasonal trends in sap-K concentration among the different levels of K nutrition and comparing sap-K concentration (mg K/L) as determined with the Horiba B-731 LAQUAtwin Compact K Ion Meter (Horiba Instruments, Inc., Kyoto, Japan) with leaf-K and petiole-K concentrations determined via traditional analytical methods (Jones and Case, 1990).

Tissue samples consisting of 2 sets of 10 petioles and trifoliolate leaves were collected on 5 or 6 different weeks from each trial (Table 2). The first set of tissue was used for traditional analysis and the petioles were removed from the trifoliolate leaves and each tissue was placed in a labeled paper bag, dried, ground in a Wiley mill, digested with concentrated HNO_3 and 30% H_2O_2, and analyzed for nutrient content by inductively coupled plasma spectroscopy. The second set of tissue was used for sap extraction from petioles following the removal of trifoliolate leaves. The 10 petioles were cut into 0.5-inch long pieces, placed in a handheld garlic press to extract the sap into a 3-mL plastic vial, and the vials were frozen until the analysis was conducted in the lab. This procedure generally extracted 0.50 to 0.75 mL of sap.

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The Horiba instrument was calibrated with a series of six standards made with reagent grade KCl and water ranging from 500 to 8000 mg K/L. A seventh standard of 150 mg K/L was prepared but was seldom used as the results were inconsistent. It is interesting to note that standards made with purchased stock solution of 10,000 mg K/L in a 2% HNO_3 matrix with a similar range of solution-K concentrations did not work in the Horiba instrument, presumably because the Horiba instrument is sensitive to solutions with pH below 2.0. The accuracy and precision of the Horiba instrument was checked after 6 to 15 samples (e.g., corresponds to the number of samples from each sample time for each trial) using two standard solutions that bracketed the K concentration in the unknown samples (e.g., 2000 and 4000 mg K/L). The frozen sap solutions were thawed, each 3-mL vial was placed on a vortex mixer for 15 seconds, and a disposable pipette was used to place 0.5 mL of sap onto the sensor. The sensor was rinsed with deionized water after each sample.

The replicate K concentration data (n = 54) from petiole sap, petiole analysis, and leaf analysis from PTRS-LTK were regressed against the number of days after planting (DAP) using a model that initially included linear and quadratic terms of DAP which were allowed to depend on fertilizer-K rate. The relationship was refined by sequentially removing the most complex non-significant model terms and running the new model until a final model was reached. Model terms were eliminated when their P-value was >0.15. The relationships among the three K concentrations (petiole sap, petiole, and leaf) were determined by regression to evaluate linear and quadratic models using data from all four trials (n = 81 or 96) that were available at the time this report was prepared.

Results and Discussion

The tissue-K concentrations from soybean leaves, petioles, and sap collected from the PTRS-LTK trial showed some similarities as each decreased linearly across time (Figs. 1-3). Petiole-sap K (Fig. 1) and petiole-K (Fig. 2) concentrations each decreased at a uniform rate across time with differences among the intercepts depending on K application rate. Leaf-K concentration (Fig. 3) also decreased linearly across time but both the intercepts and slopes depended on K application time. The coefficient of determination for each of the three relationships was greatest for petiole-K (R^2 = 0.89, CV = 14.2%), intermediate for leaf-K (R^2 = 0.74, CV = 15.8%), and lowest for petiole-sap K (R^2 = 0.60, CV = 30.8%). The results indicate that sap-K is the most variable of the three measurements, which is not surprising since this is the first time we have extracted sap from tissue. The sap extraction process yielded different volumes of sap from one sample time to another and may be related to soil moisture and plant hydration differences and the fact that the size of petioles changes during the season. A more efficient tool for extracting sap may improve the relationship and increase the speed and ease of sap extraction from petioles.

Data (n = 81 or 96) from all sample times and all four K trials were used to evaluate the relationships among sap-K, trifoliolate-leaf K, and petiole-K concentrations. Among the three K measurements, the relationship between trifoliolate-leaf K and petiole-K concentrations was the strongest with an R^2 value of 0.79 and described by a linear relationship of %K = 2.45x – 0.68 where x is the trifoliolate-leaf K concentration with units of %K. The relationship indicates that petiole-K concentration is approximately two times greater than the K concentration in the upper leaves. Predictions were least accurate when K concentrations were very low, such as late (R5.5 stage) in the growing season. Petiole-K concentration (R^2 = 0.45; mg sap K/L = 0.067x + 0.020 where x is % petiole-K) was a slightly better predictor of sap-K concentration than trifoliolate-leaf K concentration (R^2 = 0.42; mg sap K/L = 0.15x – 00.014 where x is % leaf-K). Although the linear relationships involving sap-K were significant, the strength of the relationships was relatively weak. Further statistical analysis with more data, partitioning data into crop growth stages, and/or examining alternative methods of measuring the sap-K (e.g., dilution with deionized water before measurement) are needed before the Horiba K meter can be used to assess soybean K nutrition across growth stages. Rosen et al. (1996) reported that diluted sap provided stronger relationships for K concentration than undiluted sap. However, the need to dilute sap increases the complexity of the measurement and opportunity for error, especially for making in-field measurements.

Practical Applications

Preliminary information regarding a rapid method of assessing soybean K nutritional status using the handheld Horiba instrument was successful in showing the general trend for sap-K to decline across time and differences among K rates. Petiole-sap K concentrations were more variable than the traditional plant tissue analysis methods but it also has the potential advantage of being done in the field and providing a rapid and economical indication of the plant's K nutrition status. Additional research will show whether the rate of petiole-sap K concentration decline across time is predictable and uniform across research locations. Despite the greater variability in petiole-sap K concentrations, the method shows promise for use to monitor the K nutritional status of soybean plants.

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Table 1. Selected soil test information for four sites used for evaluating petiole-sap K trends across time.

Site[a]	Trial[b]	K Rate	pH	P	K	Ca	Mg
		(lb K_2O/acre)		---------- (ppm) ----------			
Pine Tree	PTRS-LTK	0	8.0	35	60	2720	544
		40	7.9	35	64	2586	545
		80	7.9	33	85	2322	511
		120	8.0	33	92	2616	541
		160	7.9	31	111	2352	515
Pine Tree	PTRS-I10	0	7.6	13	64	1664	298
Pine Tree	PTRS-F3	0	8.1	10	46	2022	324
Rice Research	RREC-LTK	0	5.4	44	85	998	109
		40	5.5	41	97	987	108
		80	5.3	43	111	928	103
		120	5.3	41	123	898	97
		160	5.4	44	148	920	99

[a] PTRS, Pine Tree Research Station; RREC, Rice Research and Extension Center.
[b] LTK, Long-term potassium, and I-10 and F3 are abbreviations for field names.

Table 2. Planting date, sample dates and average soybean growth stage when tissue samples were collected for petiole-sap K extraction at four fields in 2016.

Event	Growth stage[a]	Field			
		PTRS-LTK	PTRS-I10	PTRS-F3	RREC_LTK
		---------- (Month / day) ----------			
Plant date	--	May 11	May 7	May 5	May 17
Sample 1	R2	July 12	--	--	July 12
Sample 2	R2-3	July 19	July 19	July 19	July 20
Sample 3	R2-4	July 26	July 27	July 26	July 26
Sample 4	R4-5	Aug 2	Aug 2	Aug 2	Aug 3
Sample 5	R5	Aug 10	Aug 10	Aug 10	Aug 10
Sample 6	R5.5	Aug 17	Aug 17	Aug 17	Aug 18

[a] The listed growth stage represents the stage range for all four sites.

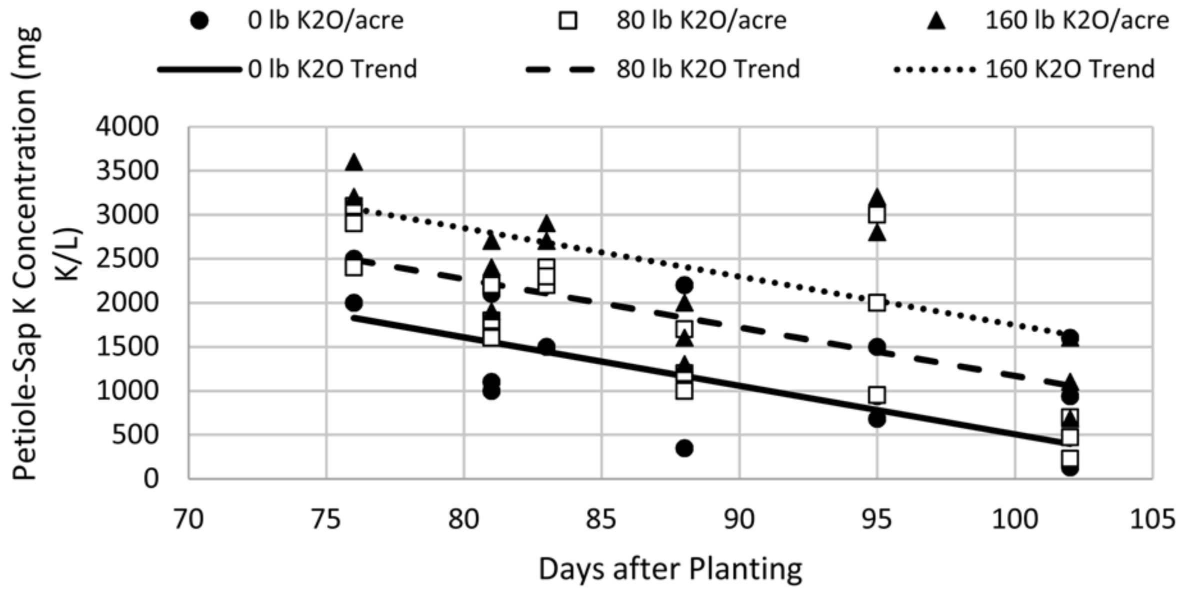

Fig. 1. Petiole-sap K concentration during reproductive growth of soybean receiving three different annual fertilizer-K rates from a long-term trial at the University of Arkansas System Division of Agriculture's Pine Tree Research Station in 2016.

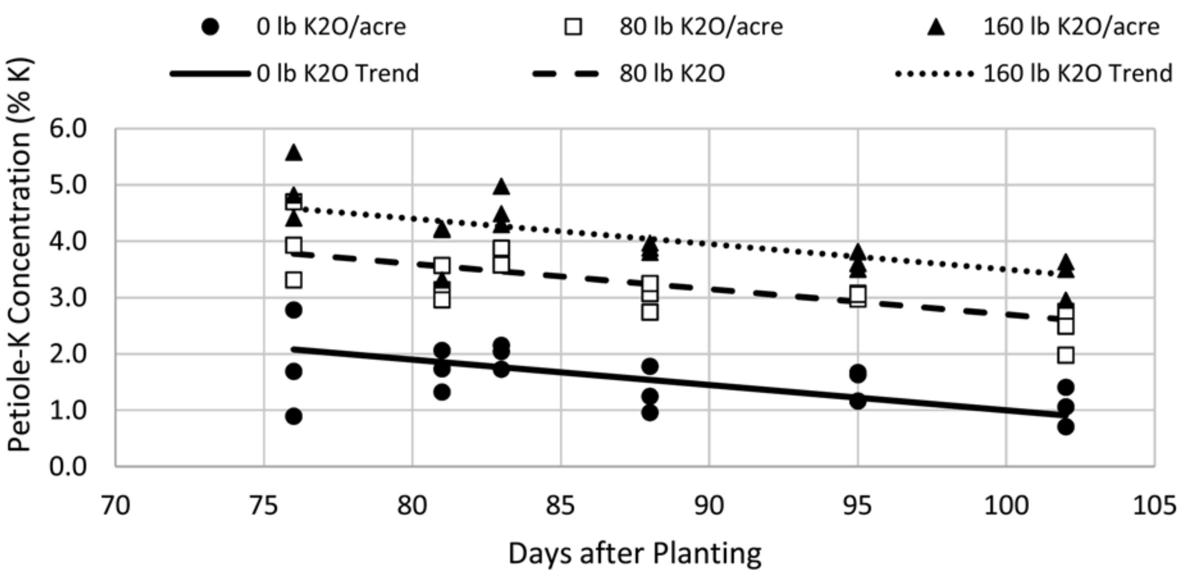

Fig. 2. Petiole-K concentration, as determined by traditional digestion and lab analysis, during reproductive growth of soybean receiving three different annual fertilizer-K rates from a long-term trial at the University of Arkansas System Division of Agriculture's Pine Tree Research Station in 2016.

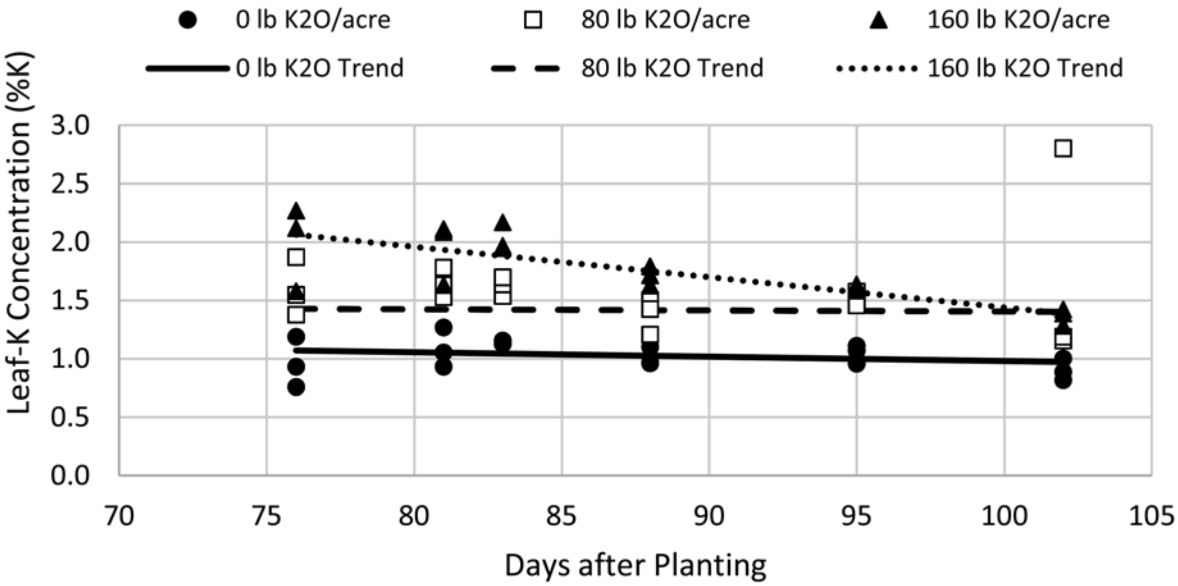

Fig. 3. Leaf-K, as determined by traditional digestion and lab analysis, concentration during reproductive growth of soybean receiving three different annual fertilizer-K rates from a long-term trial at the University of Arkansas System Division of Agriculture's Pine Tree Research Station in 2016.

Soybean Yield Response to Muriate of Potash Application Timing

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Background Information and Research Problem

Potassium (K) deficiency is the most common yield limiting nutrient for soybean [*Glycine max* (Merr.) L.] grown on silt loam soils in Arkansas. The published diagnostic tissue-K concentrations are specific for the R2 growth stage. Trifoliolate-leaf K concentrations less than 1.5% are considered deficient and concentrations between 1.5 and 1.8% K are considered low and likely to limit the yield of soybeans with good yield potential. Our research has developed preliminary trifoliolate-leaf and petiole-K concentrations that allow us to interpret tissue-K concentrations throughout reproductive growth (Parvej et al., 2016). Research is underway to validate and refine these continuous critical tissue-K concentrations before the information is promoted for continuous monitoring of the soybean plants' K nutritional status. While the development of these critical K concentrations is important, they alone are not of great use unless we also know whether agronomic and/or economic yield increases can be obtained with mid- to late-season K fertilization should tissue analysis verify that K is yield limiting.

Limited information is available regarding soybean yield response to K application time. Nelson et al. (2005) reported soybean yields were increased by foliar application of a K solution as late as the R4 stage. Potassium uptake by soybean peaks around the R6.0 to 6.5 stage (Bender et al., 2015; Parvej, 2015) suggesting that yield might respond to K fertilization beyond the R4 stage. The research objective was to examine seed yield response of irrigated soybean to granular K fertilizer application timing.

Procedures

Field trials were established in 2015 (Calloway silt loam) and 2016 (Calhoun silt loam) at the University of Arkansas System Division of Agriculture's Pine Tree Research Station. Selected mean soil properties (0- to 4-inch depth) of the 2015 trial include 7.7 pH and Mehlich-3 extractable K of 43 ppm for analysis with oven-dried soil and 31 ppm for analysis with field-moist soil. The 2016 trial soil properties included 8.1 pH and 46 ppm Mehlich-3 extractable K for analysis with oven-dried soil and 23 ppm for analysis with field-moist soil.

The 2015 trial included ten treatments including a no-K control, 60 lb K_2O/acre applied preplant, 120 lb K_2O/acre applied preplant, and 7 post-emergence applications of 60 lb K_2O/acre applied on the dates and times listed in Table 1. The 2016 trial included 13 treatments including a no-K control, 60 lb K_2O/acre applied preplant, 120 lb K_2O/acre applied preplant, 180 lb K_2O/acre applied preplant, and 9 post-emergence applications of 60 or 120 lb K_2O/acre applied on the dates and times listed in Table 2. Muriate of potash was the K fertilizer used in each trial and all fertilizer-K, regardless of application time, was applied to the soil surface. In the absence of adequate rainfall, plots were flood-irrigated on a weekly basis.

The 2015 trial was planted into an untilled seedbed on 9 June with Pioneer 47T36R and the 2016 trial was planted into a conventionally tilled seedbed on 5 May with Armor 47-R70. Each individual plot was 30-ft long, contained five rows of soybean with 15-inch wide rows, and was separated from adjacent plots by a 24- to 30-inch wide alley on each side. At maturity, four of the five soybean rows in each plot were harvested with a small-plot combine equipped to measure grain weight and moisture content. Grain yield was adjusted to 13% grain moisture for statistical analysis.

Each study was a randomized complete block design with six (2015) or five (2016) blocks that contained each treatment. Statistical analysis was performed by trial using the MIXED procedure in SAS v. 9.4 (SAS Institute, Inc., Cary, N.C.). Differences were interpreted as significant when $P \leq 0.10$ and, when appropriate, yield means were separated using Fisher's least significant difference test.

Results and Discussion

The SoyMap program predicted the R1 stage would occur on 17 July (± 2 days) and the R8 stage would occur on 30 September for the 2015 trial. Soybean in the 2016 trial

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was predicted to reach the R1 and R8 stages on 14 June (± 6 days) and 11 September (± 4 days), respectively. For soybean receiving no fertilizer-K, the trifoliolate-leaf K concentration at the R2 stage (for samples collected 29 July 2015 and 29 June 2016) averaged 0.97% K in 2015 and 1.06% K in 2016 (data not shown). The presence of early-season K deficiency symptoms during vegetative growth and the leaf-K concentrations at the R2 stage indicated that soybean at both sites would benefit from K fertilization. It is interesting to note that the marginal leaf chlorosis associated with K deficiency mostly disappeared between the R2 and R5 stages, which corresponds to the approximate time that weekly irrigation was initiated.

Grain yield results from both sites showed that preplant K fertilization with the highest K rates produced the greatest numerical yields in both trials with yield increases above the no-K control of 19 bu/acre in 2015 (Table 1) and 29 bu/acre in 2016 (Table 2). Compared to the no-K control, significant yield increases of 4 to 8 bu/acre were measured from K fertilization through the last actual K application time, which corresponded to the R5.5 to R6.0 stages. The magnitude of yield increase from the fertilizer-K rate that was repeated across time started to decline following the R4 stage. Although both trials showed excellent and consistent responses to K fertilization time, neither of the trials answered the question of how late fertilizer-K could be applied and maximum yield be produced because soybean yields were maximized by a preplant application rate greater than the rate repeated across time. This issue was recognized following the 2015 trial and we increased the post-emergence K rate from 60 to 120 lb K_2O/acre, which failed to produce maximum yield in the 2016 trial. The inclusion of several 60 lb K_2O/acre rates at three of the post-emergence application times did suggest that soybeans were still responsive to K rate at both the R2 and R4 stages (Table 2).

Practical Applications

Granular K fertilizer can be applied to K-deficient irrigated soybeans until mid- to late-reproductive growth resulting in significant yield increases. The significant yield increases from K fertilization during early reproductive growth is not surprising since flowering and pod set are ongoing. However, yield increases from K fertilization during late-reproductive growth are somewhat surprising since pod number has largely been decided by this stage, leaving seed number (e.g., abortion) and seed weight as the only yield components that can be influenced. These results show that an accurate K monitoring program may benefit soybean production by identifying K as a potential yield-limiting factor, especially when the production environment is conducive to high yields. Additional research is needed to formally characterize the rate of yield decline to fertilizer timing, evaluate at what stage maximum yield potential can no longer be attained, and identify the most appropriate K rate. These results provide no information to support or refute whether foliar application of low-solution K rates would be capable of producing the same yield responses.

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Table 1. Soybean grain yield as affected by K application times and dates for a trial on a Calloway silt loam in 2015.

Growth stage	Application date	K rate	Grain yield
	(Month - day)	(lb K_2O/acre)	(bu/acre)
Preplant	April 22	120	64 a
Preplant	April 22	60	58 b
V4.0	July 07	60	60 b
R1.0	July 21	60	60 b
R2.0	July 29	60	59 b
R4.0	August 11	60	55 c
R5.0	August 19	60	57 bc
R5.5	August 25	60	50 d
R6.0	September 1	60	49 d
No-K Control	--	0	45 e
P-value	--	--	<0.0001

Table 2. Soybean grain yield as affected by K application times and dates for a trial on a Calhoun silt loam in 2016.

Growth stage	Application date	K rate	Grain yield
	(Month - day)	(lb K_2O/acre)	(bu/acre)
Preplant	May 5	60	61 bc
Preplant	May 5	180	71 a
Preplant	May 5	120	64 b
V4.0	June 14	120	64 b
R2.0	June 29	120	64 b
R2.0	June 29	60	59 cd
R2.0	July 11	120	64 b
R4.0	July 26	120	61 bc
R4.0	July 26	60	56 de
R5.0	August 3	120	55 ef
R5.5	August 18	120	52 f
R5.5	August 18	60	53 f
No-K control	--	0	42 g
P-value	--	--	<0.0001

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