Wayne E. Sabbe

Arkansas Soil Fertility Studies 2018

Development of accurate soil-test-based, fertilizer-K recommendations is a component of seven of the eight research reports in this publication

Nathan A. Slaton, Editor

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Cover: Potassium (K) deficiency is the most common yield-limiting mineral deficiency of soybean and other row crops grown on silt and sandy loam soils in Arkansas. The photo of K-deficient soybean on the front cover was taken during the summer of 2018 from long-term plots at the Pine Tree Research Station. The plots were established in 2001, are cropped to a 2-year rotation of rice followed by soybean, and have received the same rates of fertilizer K every year. The cover photo shows severe, late-season K deficiency of soybean and the increased incidence of opportunistic diseases that often afflict K-deficient plants. Research with the objectives of characterizing the availability of K in Arkansas soils, characterizing crop yield response to K fertilization, and development of accurate soil-test-based, fertilizer-K recommendations is a component of seven of the eight research reports in this publication.

Photograph by Nathan Slaton, Assistant Director Arkansas Agricultural Experiment Station, University of Arkansas System Division of Agriculture, Department of Crop, Soil, and Environmental Sciences.

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WAYNE E. SABBE ARKANSAS SOIL FERTILITY STUDIES – 2018 –

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Department of Crop, Soil, and Environmental Sciences

Arkansas Agricultural Experiment Station
University of Arkansas System
Division of Agriculture
Fayetteville, Arkansas 72704

DEDICATED IN MEMORY OF

Wayne E. Sabbe

Wayne E. Sabbe was born June 17, 1937 in Rugby, North Dakota. He received his B.S. degree in soil science from North Dakota State University in 1959, and his Ph.D. from Oklahoma State University in 1963. Dr. Sabbe started work with the University of Arkansas in 1963 as a crop physiologist with the United States Department of Agriculture, Agricultural Research Service. In 1966, he was appointed assistant professor and in 1975, he advanced to professor. Dr. Sabbe spent his complete academic career with the university until he retired from the Department of Crop, Soil, and Environmental Sciences in 1999. During his career in the department, he was the leader and mainstay for soil testing in Arkansas. Evident of the respect and admiration of his colleagues is the fact that he was elected by the college faculty to serve as the first faculty chair in the 1990s. He also served as an interim head of the department, chair of the Dean's Faculty Advisory Council, chair of the Promotion and Tenure Committee, and in numerous other important committee positions. As both a crop physiologist and a soil scientist, Dr. Sabbe's broad, practical view was important to researchers, farmers, and extension personnel as well as students. During his career, he was advisor to 16 M.S. and 10 Ph.D. candidates, and some 90 others asked him to serve on their graduate committees.

Dr. Sabbe extended the Soil Testing and Diagnostic laboratories at Arkansas to include services other than soil testing, such as manure, forage, water, and plant analyses. His expertise in soil and plant analysis extended regionally, nationally, and internationally. In 1997, Dr. Sabbe was recognized with the prestigious J. Benton Jones Award given at the International Soil Testing Symposium by the Soil Testing and Plant Analysis Council. This recognition was prefaced by years of service to groups ranging from the Arkansas Plant Food Association to the Southern Regional Soil Testing Work Group and the Board of Directors of Council for Agricultural Science and Technology (CAST), as well as the American Society of Agronomy (ASA), Soil Science Society of America (SSSA), Certified Crop Adviser (CCA), the Soil Testing and Plant Analysis Council, and the European Society of Agronomy.

From 1991 to 2000, 52 presentations on his research were given at regional, national, and international meetings. His publications on soil amendments for plant nutrition were and still are important for the producer and researcher alike. Several of his publications explored the possibilities of using exchange resins to substitute for the time- and labor-intensive greenhouse approach to evaluate season-long nutrient release. The SSSA requested that he be lead author on two chapters in their Soil Testing and Plant Analysis publication and on a monograph on cotton. Internationally, he worked with plant-soil nutrition, and hosted scientists on short-term visits to Arkansas. In 1992, he fulfilled an off-campus sabbatical to Australia to expand the use of Near Infrared Spectroscopy for analysis of nitrogen and starch in cotton leaves.

Dr. Sabbe edited this research series when it was titled Arkansas Soil Fertility Studies from the publication's inception in 1989 until his retirement in 1999. In recognition of Dr. Sabbe's contributions to soil testing and fertility, this publication was renamed the Wayne E. Sabbe Arkansas Soil Fertility Studies in his memory starting with the 2001 publication.

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 2018 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 2017. 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 https://arkansas-ag-news.uark.edu/research-series.aspx

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Arkansas Soil-Test Summary for Samples Collected in 2017

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

Abstract

Soil-test data from samples submitted to the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory (STRL) in Marianna in 2017 were categorized according to geographic area (GA), county, soil association number (SAN), and selected cropping systems. Descriptive statistics of the soil-test data were calculated for categorical ranges for pH, phosphorus (P), potassium (K), zinc (Zn), and magnesium (Mg). In 2017, 184,948 client soil samples were analyzed by the STRL. Of the total samples, 48,483 were submitted as field-average samples, representing 1,034,184 acres for an average of 22 acres/sample. Grid soil samples accounted for 131,703 or 71% of all submitted samples. Soil samples from the Bottom Lands and Terraces, and Loessial Plains, GA with row-crop agriculture, represented 45% of the total field-average samples and 73% of the total acreage. Soil association numbers show that most samples were taken from soils common to row-crop and pasture production areas. Crop codes indicate that land used for i) row-crop production accounted for 77% and 46%, ii) hay and pasture for 17% and 18%, and iii) home lawns and gardens accounted for 1% of sampled acreage and 22% of submitted samples, respectively. This report includes a summary of soil-test Mg. The SANs having the lowest median soil-test Mg values were Arkansas Valley and Ridges and highest soil-test Mg was in the Bottom Lands and Terraces. The lowest median Mg values were for previous crops turf and hay and highest in row-crop categories.

Introduction

The University of Arkansas System Division of Agriculture has a rich history in agricultural services including soil testing. The Fertilizer Tonnage Fee was established in the 1950s with the funds used to provide Arkansas citizens with low cost soil-testing services for nutrient management and research. The Arkansas Soil Testing Program has grown over the years and is now believed to be the second largest public soil-test laboratory in regard to the number of soil samples analyzed annually. Although some proportion of agricultural soil samples, primarily grid samples collected from row-crop fields, are sent to private laboratories, the majority of soil samples are believed to be submitted to and analyzed by the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory (STRL), located in Marianna, Arkansas. The large number of soil samples analyzed annually by the STRL creates a tremendous database that can be used to assess soil chemical properties for different land use systems within Arkansas.

Each calendar year we summarize data from soil test results to examine how selected soil chemical properties are distributed across the Arkansas landscape with focus on soil pH, and Mehlich-3 extractable soil nutrients phosphorus (P), potassium (K), and zinc (Zn) because these properties are the ones used most frequently for nutrient management. This report summarizes soil pH and P, K, and Zn availability indices from samples submitted during 2017 and includes a special summary of soil-test Mg.

Procedures

Soil-test data from samples submitted to the STRL in Marianna between 1 January 2017 and 31 December 2017 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).

Soil samples are categorized as either field-average or grid samples based on how the soil submission form is completed. Because grid soil samples are frequently submitted in high volume, selected information, such as GA, SAN, previous crop and crop to be grown, is often not completed on the forms. Field-average samples are defined as samples that had all or nearly all information fields completed. Some proportion of the field-average samples may be grid samples that had all information fields completed. The information tables presented in this report may contain slightly different sample or acreage numbers for field-average samples. The differences in values is because some information was omitted from the sample form.

Descriptive statistics of the soil-test data were calculated for categorical ranges for pH, P, K, and Zn. Soil pH and Mehlich-3 extractable (analyzed using inductively coupled argon plasma spectroscopy, ICAP) soil nutrient (i.e., P, K, and Zn) availability index values indicate the relative level of soil fertility. Mehlich-3 extractable Mg was also summarized for this year’s report since plant Mg deficiencies occur sometimes in some landscapes.

Results and Discussion

Between 1 January 2017 and 31 December 2017, there were 202,078 soil samples analyzed by the STRL in Marianna. After removing 17,130 standard solution and check soil samples

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measured for quality assurance, the total number of client (e.g., researchers, growers, and homeowners) samples was 184,948 comprising 730 research samples and 184,218 samples from the public (Table 1). A total of 48,483 of the submitted soil samples were collected using the field-average sampling technique, representing 1,090,943 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 131,703 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 Crittenden (21,155 samples, 80% of county grid samples); Craighead (12,638, 61%); Clay (8421, 43%); St. Francis (6487, 74%); and Little River (6268, 62%) counties submitted the most grid soil samples for analyses and accounted for 42% of the total grid sample numbers. Thus, the total 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. The large number of grid samples submitted through these counties explains why the acres per sample values in Table 1 are often very low for some counties.

Soil samples from the Bottom Lands and Terraces, and Loessial Plains, primarily row-crop areas, represented 45% of the total field-average samples and 73% of the total acreage (Table 2). The average number of acres represented by each field-average soil sample from the ten geographic areas ranged from 7 to 38 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), 24 (Sharkey-Alligator-Tunica), 13 (Enders-Mountainburg-Nella-Steprock), and 18 (Carnasaw-Sherwood-Bismarck). However, the soil associations representing the largest acreage were 44, 45 (Crowley-Stuttgart), 24, 32 (Rilla-Hebert), and 22 (Foley-Jackport-Crowley) which represented 26%, 13%, 11%, 6%, and 6% 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 46% of submitted samples, ii) hay and pasture production accounted for 17% of the sampled acreage and 18% 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 were collected following soybean in the crop rotation. The cumulative acreage soil sampled following soybean represents about 14% of the annual soybean acreage, which totaled 3.5 million harvested acres in 2017, respectively (USDA-NASS, 2017).

Information in Tables 5, 6, and 7 pertains to the fertility status of Arkansas soils as categorized by GA, county, and the crop grown prior to collecting field-average soil samples (i.e., grid samples not included, except by county), respectively. The soil-test levels and median nutrient availability index values relate to the potential fertility of a soil, but not necessarily to the productivity of the soil. The median is the value that has an equal number of higher and lower observations and may be a better overall indicator of a soil's fertility status than a mean value. Therefore, it is not practical to compare soil-test values among SAN without knowledge of factors such as location, topography, and cropping system. Likewise, soil-test values among counties cannot be realistically compared without knowledge of the SAN and a profile of the local agricultural production systems. Soil-test results for cropping systems can be carefully compared by recognizing that specific agricultural production systems often indicate past fertilization practices or may be unique to certain soils that would influence the current soil-test values. The median pH of most soils in Arkansas ranges from 5.9 to 7.6 (Table 5). However, the predominant soil pH range varies among Arkansas counties (Table 6) and cropping systems (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 in Arkansas are 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 concentrations occur in soils following rice, winter wheat, soybean, and corn. Soils collected following cotton production have the highest median P and K concentrations. The median soil-test 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 and Zn occur in soils used for fruit production and non-agricultural purposes (e.g., lawn, turf, garden, and landscape/ornamental).

Tables 8-11 summarize Mehlich-3 extractable Mg in Arkansas soils using the percentage of sampled acres as distributed among five soil-test levels by county, GA, SAN (median only), and previous crop, respectively. Fertilizer recommendations for a Very Low Mg soil-test level is available for previous row and hay and pasture crops. The median values for Mg by county were lowest for Columbia and Calhoun counties, which have soils that are mostly low cation exchange capacity Coastal Plains soils and Van Buren County in the Boston Mountains. Soil-test Mg was highest in Crittenden, Lafayette, and Chicot counties, where clayey soils are common. The SAN having the lowest median soil-test Mg values were 11 (Falkner-Wrightsville) representing Arkansas Valley and Ridges, 38 (Amy-Smithton-Pheba) representing Coastal Plain, and 36 (Wrightsville-Louin-Acadia) representing the Bottom Lands and Terraces. The highest soil test Mg was found in SAN 33 (Billyhaw-Perry), 28 (Commerce-Sharkey, Crevasse, and Robinsonville), and 24 (Sharkey-Alligator-Tunica) in the

Bottom Lands and Terraces (Table 10). Soils in the Sharkey series, high cation exchange capacity clayey soils, tended to be consistently high in Mg. The lowest median Mg values for previous crop were turf, native warm-season grass hay, and small fruit and were highest in irrigated grain sorghum, rice, and soybean categories (Table 11).

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 soil samples submitted in 2017, 69% of the samples and 94% of the represented acreage had commercial agricultural/farm crop codes.

Acknowledgments

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Table 1. Sample number (includes grid samples) and total acreage by county for soil samples submitted to the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna from 1 January 2017 through 31 December 2017.

County	Acres sampled	% of total acres	No. of samples	% of total samples	Acres/ sample	County	Acres sampled	% of total acres	No. of samples	% of total sample	Acres/ sample
Arkansas	109,776	10	3730	2	29	Lee	110,571	10	4114	2	27
Ashley	7301	1	387	0	19	Lincoln	1489	0	216	0	7
Baxter	2440	0	341	0	7	Little River	8413	1	10,056	6	0
Benton	12,208	1	1219	1	10	Logan	4533	0	429	0	11
Boone	11,151	1	657	0	17	Lonoke	67,164	6	5438	3	12
Bradley	670	0	82	0	8	Madison	7571	1	488	0	16
Calhoun	371	0	46	0	8	Marion	2221	0	180	0	12
Carroll	16,257	2	806	0	20	Miller	4962	1	413	0	12
Chicot	10,601	1	677	0	16	Mississippi	6800	1	7079	4	0
Clark	3177	0	335	0	10	Monroe	6207	1	1189	1	5
Clay	24,559	2	19,697	11	1	Montgomery	1345	0	124	0	11
Cleburne	3543	0	374	0	10	Nevada	679	0	118	0	6
Cleveland	1015	0	3683	2	0	Newton	1903	0	167	0	11
Columbia	1738	0	223	0	8	Ouachita	461	0	150	0	3
Conway	14,032	1	479	0	29	Perry	3237	0	198	0	16
Craighead	24,050	2	20,608	11	1	Phillips	5015	1	1338	1	4
Crawford	17,898	2	911	1	20	Pike	1476	0	81	0	18
Crittenden	14,358	1	26,465	14	0	Poinsett	101,750	9	4746	3	21
Cross	35,218	3	1271	1	28	Polk	8984	1	595	0	15
Dallas	706	0	81	0	9	Pope	6263	1	609	0	10
Desha	16,533	2	10,558	6	2	Prairie	50,873	5	2135	1	24
Drew	2894	0	1159	1	3	Pulaski	2340	0	1025	1	2
Faulkner	6225	1	741	0	8	Randolph	8721	1	1917	1	5
Franklin	5039	1	292	0	17	Saline	3220	0	2315	1	1
Fulton	4180	0	418	0	10	Scott	1990	0	120	0	17
Garland	3829	0	2070	1	2	Searcy	2439	0	162	0	15
Grant	1236	0	152	0	8	Sebastian	4187	0	578	0	7
Greene	21,649	2	7635	4	3	Sevier	3801	0	165	0	23
Hempstead	5016	1	509	0	10	Sharp	5183	1	388	0	13
Hot Spring	1209	0	224	0	5	St. Francis	4478	0	8741	5	51
Howard	8239	1	455	0	18	Stone	2828	0	451	0	6
Independence	6607	1	431	0	15	Union	2038	0	211	0	10
Izard	3281	0	252	0	13	Van Buren	3788	0	278	0	14
Jackson	122,675	11	1635	1	75	Washington	14,511	1	2546	1	6
Jefferson	41,505	4	5803	3	7	White	5959	1	929	1	6
Johnson	7084	1	440	0	16	Woodruff	3321	0	481	0	7
Lafayette	10,889	1	1209	1	9	Yell	7643	1	373	0	21
Lawrence	33,420	3	7620	4	4	Sum or Average	1,090,943		184,218		6

Table 2. Sample number and total acreage by geographic area for soil samples submitted to the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna from 1 January 2017 through 31 December 2017.

Geographic area	Acres sampled	% of total acres	No. of samples	% of total samples	Acres/ sample
Ozark Highlands - Cherty Limestone and Dolomite	68,729	9	6719	17	10
Ozark Highlands - Sandstone and Limestone	8608	1	662	2	13
Boston Mountains	19,420	3	1890	5	10
Arkansas Valley and Ridges	52,268	7	4794	12	11
Ouachita Mountains	27,683	7	4175	11	7
Bottom Lands and Terraces	264,669	34	9483	24	28
Coastal Plain	31,666	4	2837	7	11
Loessial Plains	308,880	39	8170	21	38
Loessial Hills	7186	1	826	2	9
Blackland Prairie	2214	0	84	0	26
Sum or Average	791,323		39,640		20

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 field-average soil samples submitted to the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna from 1 January 2017 through 31 December 2017.

							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	11,784	2	752	1	16	6.1	63	114	5.6
2.	Gepp-Doniphan-Gassville-Agnos	8225	2	864	1	10	6.4	47	127	5.0
3.	Arkana-Moko	26,296	4	1615	3	16	6.1	126	163	11.9
4.	Captina-Nixa-Tonti	34,730	9	3695	4	9	6.2	89	146	8.2
5.	Captina-Doniphan-Gepp	292	0	16	0	18	5.6	23	66	2.7
6.	Eden-Newnata-Moko	409	0	39	0	11	6.2	67	126	5.5
7.	Estate-Portia-Moko	295	0	17	0	17	5.6	134	137	19.1
8.	Brockwell-Boden-Portia	7923	2	646	1	12	6.0	27	102	2.9
9.	Linker-Mountainburg-Sidon	4290	1	349	1	12	6.0	60	102	5.4
10.	Enders-Nella-Mountainburg-Steprock	12,437	4	1499	1	8	6.0	71	109	5.7
11.	Falkner-Wrightsville	94	0	15	0	6	6.5	63	168	4.5
12.	Leadvale-Taft	29,487	5	2088	3	14	5.9	53	109	5.8
13.	Enders-Mountainburg-Nella-Steprock	5946	1	337	1	18	6.0	39	93	3.3
14.	Spadra-Guthrie-Pickwick	3272	1	177	0	19	5.6	68	108	6.8
15.	Linker-Mountainburg	18,319	4	1407	2	13	5.8	52	108	4.9
16.	Carnasaw-Pirum-Clebit	3792	1	330	0	12	5.8	88	106	6.4
17.	Kenn-Ceda-Avilla	9419	2	690	1	12	5.6	105	113	8.4
18.	Carnasaw-Sherwood-Bismarck	4467	3	1138	1	4	5.8	66	99	5.1
19.	Carnasaw-Bismarck	215	0	21	0	10	5.8	85	67	6.9
20.	Leadvale-Taft	1629	1	306	0	5	5.9	84	106	6.6
21.	Spadra-Pickwick	1394	0	88	0	16	5.6	44	114	4.9
22.	Foley-Jackport-Crowley	69,267	5	1970	7	35	6.4	24	112	3.4
23.	Kobel	15,885	1	537	2	30	6.2	24	100	3.1
24.	Sharkey-Alligator-Tunica	197,374	11	4403	21	45	6.6	33	224	3.6
25.	Dundee-Bosket-Dubbs	21,929	3	1061	2	21	6.3	33	113	3.3
26.	Amagon-Dundee	7872	1	338	1	23	6.4	46	128	3.6
27.	Sharkey-Steele	1751	1	296	0	6	6.4	29	148	3.3
28.	Commerce-Sharkey-Crevasse-Robinsonville	1474	0	105	0	14	5.7	46	139	2.4
29.	Perry-Portland	12,864	1	388	1	33	6.4	34	168	3.5
30.	Crevasse-Bruno-Oklared	2228	0	39	0	57	6.7	55	193	4.8
31.	Roxana-Dardanelle-Bruno-Roellen	5903	1	210	1	28	6.2	54	131	5.3
32.	Rilla-Hebert	45,056	3	1288	5	35	6.3	37	136	2.7
33.	Billyhaw-Perry	422	0	17	0	25	5.8	32	104	5.8
34.	Severn-Oklared	3543	0	101	0	35	6.2	64	127	6.6
35.	Adaton	28	0	2	0	14	5.3	14	55	2.7
36.	Wrightsville-Louin-Acadia	10,616	1	268	1	40	6.2	31	120	3.4
37.	Muskogee-Wrightsville-McKamie	134	0	5	0	27	6.4	55	185	13.0
38.	Amy-Smithton-Pheba	780	0	111	0	7	5.6	68	71	3.7
39.	Darco-Briley-Smithdale	104	0	25	0	4	7.3	8	270	2.1
40.	Pheba-Amy-Savannah	2036	0	165	0	12	5.6	39	99	3.9
41.	Smithdale-Sacul-Savannah-Saffell	7467	2	763	1	10	5.6	76	95	6.4
42.	Sacul-Smithdale-Sawyer	12,197	4	1423	1	9	5.9	51	92	4.6
43.	Guyton-Ouachita-Sardis	3994	1	199	0	20	5.7	112	106	8.8
44.	Calloway-Henry-Grenada-Calhoun	153,623	13	5001	16	31	6.6	28	99	3.2
45.	Crowley-Stuttgart	188,133	9	3503	20	54	6.5	28	117	3.3
46.	Loring	587	0	65	0	9	6.3	43	96	7.2
47.	Loring-Memphis	8210	2	848	1	10	6.2	33	116	3.9
48.	Brandon	267	0	14	0	19	6.0	16	63	2.0
49.	Oktibbeha-Sumter	571	0	34	0	17	5.9	63	155	6.6
	Sum or Average	959,030		39,268		24	6.1	54	121	5.3

Table 4. Sample number and total acreage by previous crop for soil samples submitted to the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna from 1 January 2017 through 31 December 2017.

Previous crop	Acres sampled	% of total acres	No. of samples	% of total samples	Acres/ sample
Corn	76,319	7	2586	5	30
Cotton	44,432	4	2700	6	17
Grain sorghum, non-irrigated	460	0	21	0	22
Grain sorghum, irrigated	5736	1	90	0	64
Rice	123,010	12	3363	7	37
Soybean	545,821	53	13,211	27	41
Wheat	3200	0	103	0	31
Cool-season grass hay	5942	1	344	1	17
Native warm-season grass hay	2814	0	269	1	11
Warm-season grass hay	31,442	3	1761	4	12
Pasture, all categories	132,178	13	6400	13	21
Home garden	4498	0	3965	8	1
Turf	1134	0	835	2	1
Home lawn	8353	1	6640	14	1
Small fruit	809	0	653	1	1
Ornamental	1762	0	1206	3	2
Miscellaneous[a]	46,274	5	4285	9	11
Sum or Average	1,034,184		48,423		21

[a] Miscellaneous includes all crop codes not specifically listed in the table and may include row crops, commercial vegetable codes, and turf-related codes (playgrounds) among others.

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 University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna from 1 January 2017 through 31 December 2017.

	Soil pH[a]						Mehlich-3 soil P[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[c]
	---(% of sampled acreage)--						--(% of sampled acreage)--					(ppm)
Ozark Highlands - Cherty Limestone and Dolomite	6	11	23	32	28	6.5	5	8	9	11	67	83
Ozark Highlands - Sandstone and Limestone	6	18	26	34	16	6.3	18	23	16	12	31	31
Boston Mountains	12	20	28	25	15	6.1	7	9	9	12	63	71
Arkansas Valley and Ridges	17	23	24	25	11	6.0	11	13	12	13	51	52
Ouachita Mountains	15	23	26	29	7	6.0	7	11	14	15	53	52
Bottom Lands and Terraces	5	11	20	40	24	6.5	10	17	19	21	33	39
Coastal Plain	18	26	26	21	9	5.9	16	10	9	10	55	61
Loessial Plains	6	12	18	29	35	6.6	19	32	21	16	12	25
Loessial Hills	20	17	19	29	15	6.2	21	16	10	14	39	39
Blackland Prairie	2	5	16	13	64	7.6	26	14	5	4	51	52
Average	11	17	23	28	21	6.4	14	15	12	13	46	51

	Mehlich-3 soil K[b] (ppm)						Mehlich-3 soil Zn[b] (ppm)					
Geographic area	<5.4	61-90	91-130	131-175	>175	Md[c]	<1.6	1.6-3.0	3.1-4.0	4.1 8.0	>8.0	Md[c]
	---(% of sampled acreage)--					(ppm)	--(% of sampled acreage)--					(ppm)
Ozark Highlands - Cherty Limestone and Dolomite	9	15	20	18	38	144	4	13	9	27	47	8.0
Ozark Highlands - Sandstone and Limestone	23	25	23	14	15	94	14	31	15	23	17	3.6
Boston Mountains	19	20	20	14	27	111	5	18	12	29	36	5.8
Arkansas Valley and Ridges	18	21	23	17	21	109	7	24	14	26	29	4.9
Ouachita Mountains	16	23	27	17	17	103	3	23	15	29	30	5.1
Bottom Lands and Terraces	6	15	23	19	37	143	7	37	21	26	9	3.4
Coastal Plain	30	20	19	13	18	91	10	21	10	21	38	5.8
Loessial Plains	11	32	34	14	9	97	10	38	18	26	8	3.2
Loessial Hills	12	20	25	22	21	117	8	26	14	29	23	4.4
Blackland Prairie	7	8	14	18	53	183	6	21	10	14	49	8.3
Average	15	20	23	17	25	119	7	25	14	25	29	5.0

[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 6. The percentage of sampled acres as distributed within five soil-test levels and median soil chemical property values by county for soil samples submitted to the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna from 1 January 2017 through 31 December 2017.

	Soil pH[a]						Mehlich-3 soil P[b] (ppm)					
County	<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[c]
	------ (% of sampled acreage) -----						---- (% of sampled acreage) ------					(ppm)
Arkansas	10	11	15	28	36	6.6	11	29	27	21	12	29
Ashley	4	7	11	40	38	6.8	17	32	15	8	28	26
Baxter	3	6	10	20	61	7.2	7	8	8	12	65	82
Benton	5	12	25	34	24	6.4	3	6	7	11	73	100
Boone	3	9	27	37	24	6.4	2	9	11	15	63	71
Bradley	13	15	27	31	14	6.2	7	9	7	7	70	133
Calhoun	9	37	30	17	7	5.8	7	9	9	22	53	55
Carroll	4	13	27	38	18	6.4	1	4	4	7	84	138
Chicot	2	5	8	44	41	6.8	10	19	26	26	19	34
Clark	17	24	27	19	13	6.0	18	17	10	6	49	48
Clay	4	11	28	47	10	6.4	12	23	21	21	23	32
Cleburne	11	22	27	25	15	6.1	7	13	14	16	50	50
Cleveland	10	15	21	38	16	6.4	15	19	17	18	31	35
Columbia	29	28	25	16	2	5.7	17	8	12	11	52	54
Conway	15	27	21	29	8	6.0	25	10	6	10	49	50
Craighead	4	7	18	44	27	6.6	6	13	15	22	44	46
Crawford	24	20	20	22	14	6.0	8	15	14	13	50	49
Crittenden	4	7	16	42	31	6.7	12	30	26	20	12	28
Cross	3	3	5	18	71	7.3	17	25	21	21	16	29
Dallas	27	22	16	15	20	6.1	25	11	7	10	47	44
Desha	4	10	21	46	15	6.5	6	17	19	24	34	40
Drew	6	13	23	34	24	6.5	8	12	23	31	26	38
Faulkner	19	23	24	25	9	6.0	17	16	16	12	39	37
Franklin	16	35	30	15	4	5.8	19	15	8	12	46	44
Fulton	7	25	28	29	11	6.2	15	26	20	13	26	29
Garland	13	19	26	34	8	6.1	4	13	16	19	48	50
Grant	28	20	22	19	11	5.9	5	9	7	11	68	84
Greene	9	14	24	38	15	6.4	12	18	17	19	34	38
Hempstead	15	23	27	25	10	6.1	40	7	9	8	36	31
Hot Spring	20	26	29	22	3	5.9	8	11	10	8	63	75
Howard	15	24	22	21	18	6.0	6	4	5	5	80	153
Independence	11	19	26	25	19	6.2	14	22	14	15	35	35
Izard	15	12	24	31	18	6.3	9	16	13	15	47	45
Jackson	3	13	34	39	11	6.3	20	26	16	16	22	27
Jefferson	11	17	26	37	9	6.2	10	20	24	26	20	34
Johnson	13	26	24	27	10	6.1	6	14	16	14	50	50
Lafayette	5	7	14	30	44	6.8	15	22	22	22	19	31
Lawrence	3	9	22	41	25	6.5	26	28	20	16	10	24
Lee	3	5	11	46	35	6.8	7	18	23	28	24	36
Lincoln	11	19	31	33	6	6.1	12	10	20	20	38	40
Little River	1	8	20	40	28	6.6	11	22	20	22	25	34
Logan	14	27	28	23	8	5.9	15	18	11	9	47	46
Lonoke	10	20	28	35	7	6.2	22	27	19	15	17	26
Madison	3	15	31	31	20	6.3	1	5	3	7	84	151
Marion	2	3	16	36	43	6.8	2	13	9	13	63	67
Miller	18	26	22	20	14	6.0	13	15	11	16	45	46
Mississippi	1	5	22	55	17	6.5	2	10	20	31	37	44
Monroe	3	7	15	41	34	6.7	36	31	15	12	6	19
Montgomery	17	27	26	19	11	5.9	5	15	14	17	49	50
Nevada	14	20	22	25	19	6.2	9	7	13	14	57	57
Newton	3	31	33	20	13	6.0	7	10	10	13	60	65
Ouachita	16	25	37	15	7	5.9	5	11	7	6	71	103
Perry	19	35	24	19	3	5.8	10	16	11	11	52	53
Phillips	11	13	19	47	10	6.4	8	22	22	22	26	35
Pike	20	21	22	21	16	6.1	12	7	7	1	73	115
Poinsett	2	3	10	31	54	7.0	16	35	25	16	8	25
Polk	21	32	23	20	4	5.8	4	7	7	8	74	116
Pope	13	24	26	24	13	6.0	10	8	6	9	67	84
Prairie	5	13	20	36	26	6.5	24	34	20	14	8	23
Pulaski	18	18	17	28	19	6.3	8	9	8	13	62	71
Randolph	6	18	25	27	24	6.3	20	27	22	19	12	27

continued

Table 6. Continued.

	Soil pH[a]						Mehlich-3 soil P[b] (ppm)					
County	**<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[c]**
	------ (% of sampled acreage) -----						---- (% of sampled acreage) ------					(ppm)
Saline	17	20	26	29	8	6.1	6	10	12	18	54	54
Scott	13	28	36	21	2	5.9	19	9	13	11	48	49
Searcy	5	14	25	33	23	6.4	11	11	19	21	38	43
Sebastian	13	25	24	20	18	6.1	8	14	11	14	53	56
Sevier	12	34	35	17	2	5.9	7	7	6	9	71	115
Sharp	6	18	24	36	16	6.4	14	22	15	13	36	34
St. Francis	5	10	21	46	18	6.5	6	14	20	27	33	41
Stone	28	20	22	20	10	5.8	4	9	6	14	67	78
Union	18	31	24	21	6	5.8	17	8	7	12	56	60
Van Buren	15	28	26	23	8	5.9	12	11	9	12	56	62
Washington	5	9	22	32	32	6.6	4	6	8	11	71	89
White	18	118	27	26	11	6.1	15	15	15	12	43	40
Woodruff	9	19	32	32	8	6.1	10	23	20	19	28	33
Yell	10	32	38	17	3	5.9	9	8	5	8	70	97
Average	11	19	23	29	18	6.3	12	15	14	15	44	56

	Mehlich-3 soil K[b] (ppm)						Mehlich-3 soil Zn[b] (ppm)					
County	**<61**	**61-90**	**91-130**	**131-175**	**>175**	**Md[c]**	**<1.6**	**1.6-3.0**	**3.1-4.0**	**4.1-8.0**	**>8.0**	**Md[c]**
	------ (% of sampled acreage) -----					(ppm)	---- (% of sampled acreage) ------					(ppm)
Arkansas	3	28	40	17	0	107	9	27	20	37	7	3.9
Ashley	21	33	20	4	22	86	8	31	21	25	15	3.6
Baxter	7	10	23	19	41	147	3	9	10	20	58	10.9
Benton	10	14	18	20	38	146	2	9	9	28	52	8.8
Boone	7	15	18	14	46	162	4	16	11	26	43	6.9
Bradley	18	20	23	18	21	106	0	21	10	22	47	7.4
Calhoun	24	30	17	9	20	81	20	33	11	17	19	2.7
Carroll	6	10	14	16	54	200	1	5	6	18	70	12.5
Chicot	2	4	13	21	60	223	17	58	18	7	0	2.4
Clark	21	21	27	16	15	99	11	36	10	14	29	3.6
Clay	8	23	33	21	15	113	8	34	21	32	5	3.5
Cleburne	23	27	19	14	17	91	10	23	10	31	26	4.7
Cleveland	10	20	26	20	24	119	14	38	17	26	5	3.1
Columbia	46	22	18	9	5	65	17	17	11	19	36	5.1
Conway	21	23	23	14	19	98	16	22	9	27	26	4.5
Craighead	5	13	22	23	37	148	6	39	27	28	0	3.4
Crawford	25	23	21	16	15	92	3	34	19	30	14	3.8
Crittenden	2	8	16	17	57	199	8	33	31	28	0	3.4
Cross	5	31	39	13	12	101	4	33	25	34	4	3.6
Dallas	37	25	16	7	15	76	27	20	9	15	29	3.5
Desha	7	16	22	18	37	141	9	36	22	31	2	3.4
Drew	15	20	21	18	26	117	12	46	28	12	2	2.9
Faulkner	17	23	28	13	19	103	12	27	14	22	25	4.1
Franklin	22	26	24	15	13	92	13	19	13	25	30	4.6
Fulton	13	26	26	15	20	107	19	42	9	15	15	2.6
Garland	11	26	32	19	12	104	2	25	19	34	20	4.6
Grant	22	24	15	16	23	103	5	19	11	25	40	6.0
Greene	10	24	32	21	13	110	10	38	21	29	2	3.2
Hempstead	48	15	14	9	14	66	17	25	8	18	32	4.5
Hot Spring	33	22	15	12	18	83	8	22	13	29	28	4.5
Howard	12	11	21	17	39	142	3	7	7	18	65	13.9
Independence	17	19	23	17	24	110	11	36	12	21	20	3.4
Izard	23	21	28	16	12	101	12	33	11	22	22	3.7
Jackson	5	20	38	22	15	114	7	43	22	28	0	3.1
Jefferson	6	22	30	18	24	117	20	47	17	13	3	2.5
Johnson	15	26	24	18	17	10	4	30	19	26	21	4.1
Lafayette	2	13	16	17	52	183	26	6	10	4	0	2.0
Lawrence	14	26	29	17	14	101	11	40	17	24	8	3.1
Lee	1	14	33	25	27	133	20	54	16	10	0	2.3
Lincoln	9	15	19	7	50	165	4	30	17	26	23	4.3
Little River	4	17	34	20	25	124	19	51	16	14	0	2.4
Logan	30	20	23	8	19	90	6	33	11	20	30	4.4
Lonoke	11	25	31	17	16	106	24	50	13	11	2	2.2

continued

Table 6. Continued.

County	Mehlich-3 soil K[b] (ppm)						Mehlich-3 soil Zn[b] (ppm)					
	<61	61-90	91-130	131-175	>175	Md[c]	<1.6	1.6-3.0	3.1-4.0	4.1 8.0	>8.0	Md[c]
	------ (% of sampled acreage) -----					(ppm)	---- (% of sampled acreage) ------					(ppm)
Madison	8	13	17	16	46	159	1	8	8	21	63	11.5
Marion	5	16	21	23	35	141	1	11	8	24	56	9.1
Miller	24	25	23	14	14	92	0	22	11	32	35	5.4
Mississippi	1	10	34	29	26	137	4	32	27	31	6	3.7
Monroe	5	28	39	19	9	104	14	53	21	12	0	2.6
Montgomery	28	20	22	13	17	94	5	28	14	17	36	4.8
Nevada	26	23	17	12	22	92	11	28	12	20	29	4.0
Newton	28	14	20	13	25	105	5	23	16	29	27	4.4
Ouachita	29	17	20	13	21	98	5	12	9	18	56	10.3
Perry	18	21	18	23	20	110	2	25	18	27	28	4.6
Phillips	6	20	35	25	14	116	34	42	13	10	1	2.0
Pike	28	19	16	19	18	93	5	19	9	19	48	10.2
Poinsett	9	23	17	11	40	135	5	33	29	28	5	3.6
Polk	24	23	18	13	22	96	4	19	9	19	49	8.3
Pope	16	20	23	17	24	115	7	18	9	24	42	6.9
Prairie	13	30	32	14	11	98	7	39	22	30	2	3.3
Pulaski	11	23	26	17	23	115	3	15	9	24	49	8.2
Randolph	10	27	28	20	15	107	5	22	19	41	13	4.6
Saline	10	15	22	22	31	137	4	19	18	40	19	4.9
Scott	33	18	15	16	18	88	8	20	12	23	37	5.3
Searcy	14	23	27	18	18	110	11	28	13	27	21	4.0
Sebastian	9	20	24	21	26	126	2	8	7	28	55	8.8
Sevier	26	16	15	13	30	108	9	9	3	15	64	11.0
Sharp	21	20	23	17	19	100	18	31	13	21	17	3.3
St. Francis	2	11	21	20	46	165	18	45	17	20	0	2.6
Stone	26	22	20	10	22	95	4	23	16	30	27	4.9
Union	37	26	18	10	9	75	13	21	10	21	35	4.8
Van Buren	30	21	17	12	20	88	18	26	13	23	20	3.6
Washington	7	13	21	19	40	151	2	9	8	31	50	8.5
White	22	23	26	14	15	97	14	24	13	28	21	4.1
Woodruff	15	25	33	14	13	101	8	58	15	16	3	2.6
Yell	17	17	16	15	35	131	3	9	11	26	51	8.6
Average	16	20	23	16	25	114	9	28	14	23	26	5.0

[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 7. The percentage of sampled acres as distributed within five soil-test levels and median soil chemical property values by previous crop for soil samples submitted to the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna from 1 January 2017 through 31 December 2017.

	Soil pH[a]						Mehlich-3 soil P[b] (ppm)					
Previous crop	**<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[c]**
	---(% of sampled acreage)--						--(% of sampled acreage)--					(ppm)
Corn	3	8	17	42	30	6.6	8	21	22	23	26	35
Cotton	2	3	12	51	32	6.7	3	10	16	23	48	48
Grain sorghum, non-irrigated	5	19	38	29	9	6.0	0	14	5	10	71	78
Grain sorghum, irrigated	0	2	7	21	70	7.1	12	13	17	22	36	41
Rice	8	14	18	28	32	6.6	28	33	22	13	4	22
Soybean	4	9	18	35	34	6.6	12	28	24	21	15	30
Wheat	7	20	30	28	15	6.2	14	27	18	7	34	29
Cool-season grass hay	11	27	37	23	2	5.9	8	16	14	14	48	49
Native warm-season grass hay	38	28	18	16	0	5.6	18	20	9	6	47	41
Warm-season grass hay	20	29	28	23	0	5.8	16	14	10	12	48	50
Pasture, all categories	11	25	29	29	6	6.0	14	12	10	11	53	55
Home garden	5	9	15	27	44	6.9	4	5	5	6	80	142
Turf	17	19	30	26	8	6.0	6	6	10	10	68	74
Home lawn	16	19	24	30	11	6.1	6	12	14	18	50	52
Small fruit	29	20	17	22	12	5.9	6	6	9	13	66	77
Ornamental	9	11	13	25	42	6.8	7	7	9	12	65	77
Average	12	16	22	28	22	6.3	10	15	13	14	48	56

	Mehlich-3 soil K[b] (ppm)						Mehlich-3 soil Zn[b] (ppm)					
Previous crop	**<5.4**	**61-90**	**91-130**	**131-175**	**>175**	**Md[c]**	**<1.6**	**1.6-3.0**	**3.1-4.0**	**4.1 8.0**	**>8.0**	**Md[c]**
	---(% of sampled acreage)--					(ppm)	--(% of sampled acreage)--					(ppm)
Corn	9	22	32	19	18	113	5	37	18	30	10	3.6
Cotton	2	8	17	24	49	173	12	45	22	18	3	2.9
Grain sorghum, non-irrigated	10	24	19	29	18	118	24	10	10	14	42	6.0
Grain sorghum, irrigated	1	7	16	18	58	216	3	34	22	39	2	3.9
Rice	8	28	28	15	21	109	10	46	19	22	3	2.9
Soybean	7	26	34	16	17	107	10	42	21	25	2	3.1
Wheat	11	33	24	20	12	99	22	37	13	14	14	2.5
Cool-season grass hay	32	21	18	8	21	83	11	32	11	22	24	4.0
Native Warm-season grass hay	54	23	9	8	6	57	13	45	17	13	12	2.9
Warm-season grass hay	42	24	14	11	9	69	10	29	12	23	26	4.2
Pasture, all categories	21	20	19	14	26	108	8	22	11	24	35	5.4
Home garden	6	13	19	18	44	160	2	7	6	18	67	14.0
Turf	21	18	22	17	22	108	4	15	14	36	31	5.8
Home lawn	7	19	27	23	24	125	2	18	17	39	24	5.1
Small fruit	13	22	32	15	18	107	4	20	13	28	35	5.5
Ornamental	12	20	24	18	26	118	4	9	6	21	60	11.3
Average	16	21	22	17	24	117	9	28	15	24	24	5.2

[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. The percentage of sampled acres as distributed within five soil-test levels and median Mehlich-3 extractable magnesium (Mg) by county for soil samples submitted to the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna from 1 January 2017 through 31 December 2017.

	Mehlich-3 soil Mg[a] (ppm)							Mehlich-3 soil Mg[a] (ppm)					
County	<31	31-50	51-140	141-500	>500	Md[b]	County	<31	31-50	51-140	141-500	>500	Md[b]
	(% of sampled acreage)					(ppm)		(% of sampled acreage)					(ppm)
Arkansas	0	2	32	60	6	199	Lee	0	0	6	86	8	283
Ashley	0	2	56	39	3	132	Lincoln	0	2	34	27	34	226
Baxter	0	0	16	63	21	284	Little River	0	3	42	35	20	154
Benton	0	2	55	40	3	128	Logan	0	4	61	32	7	108
Boone	1	4	52	38	5	123	Lonoke	1	4	52	33	10	130
Bradley	2	23	51	20	4	68	Madison	0	1	49	49	2	139
Calhoun	7	17	72	4	0	63	Marion	0	1	33	59	8	181
Carroll	0	1	22	73	4	208	Miller	2	10	52	28	8	109
Chicot	0	0	17	30	53	559	Mississippi	0	1	39	48	2	165
Clark	4	13	64	18	1	92	Monroe	0	0	6	78	16	309
Clay	0	1	30	63	6	187	Montgomery	0	5	64	31	0	108
Cleburne	5	14	58	21	2	86	Nevada	11	17	38	27	7	92
Cleveland	0	4	52	30	14	122	Newton	1	10	64	23	2	92
Columbia	10	29	50	11	0	60	Ouachita	3	20	56	19	2	77
Conway	7	5	50	33	5	112	Perry	2	3	51	39	5	132
Craighead	0	1	24	65	10	220	Phillips	0	2	35	57	6	174
Crawford	1	7	55	31	6	107	Pike	6	5	64	25	0	93
Crittenden	0	0	2	41	57	572	Poinsett	0	0	5	53	42	348
Cross	0	0	3	89	8	305	Polk	1	8	58	33	0	111
Dallas	9	24	57	11	0	74	Pope	1	7	53	36	3	122
Desha	0	2	38	37	23	176	Prairie	0	1	32	61	6	182
Drew	1	1	28	47	23	189	Pulaski	1	3	43	48	5	149
Faulkner	2	7	53	32	6	110	Randolph	0	0	23	63	14	215
Franklin	0	8	66	27	0	103	Saline	1	5	66	27	1	107
Fulton	0	2	49	43	6	134	Scott	2	5	52	39	2	127
Garland	0	2	69	28	1	107	Searcy	2	18	57	21	2	92
Grant	8	25	49	18	0	73	Sebastian	1	1	46	51	1	143
Greene	0	3	39	52	6	161	Sevier	2	8	58	32	0	111
Hempstead	2	15	59	24	0	75	Sharp	0	9	50	37	4	123
Hot Spring	7	17	62	14	0	74	St. Francis	0	0	10	65	25	284
Howard	2	8	54	35	1	123	Stone	12	19	48	20	1	74
Independence	1	8	37	42	12	158	Union	5	28	51	16	0	69
Izard	2	12	48	37	1	96	Van Buren	8	33	51	8	0	63
Jackson	1	11	49	34	5	104	Washington	1	3	57	38	1	122
Jefferson	0	2	38	46	14	171	White	4	15	63	18	0	86
Johnson	5	18	43	32	2	99	Woodruff	1	7	64	22	6	98
Lafayette	0	1	10	34	55	568	Yell	0	1	44	52	3	147
Lawrence	0	1	28	45	26	253	Average	2	7	44	38	9	158

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

Table 9. The percentage of sampled acres as distributed within five soil-test levels and median Mehlich-3 extractable magnesium (Mg) by geographic area for soil samples submitted to the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna from 1 January 2017 through 31 December 2017.

Geographic area	Mehlich-3 soil Mg[a] (ppm)					
	<31	31-50	51-140	141-500	>500	Md[b]
	(% of sampled acreage)					(ppm)
Ozark Highlands - Cherty Limestone and Dolomite	1	3	48	44	4	135
Ozark Highlands - Sandstone and Limestone	1	7	44	46	2	138
Boston Mountains	3	14	55	26	2	95
Arkansas Valley and Ridges	2	7	57	31	3	110
Ouachita Mountains	1	4	63	31	1	111
Bottom Lands and Terraces	1	2	31	45	21	206
Coastal Plain	4	15	56	23	2	89
Loessial Plains	0	1	28	66	5	202
Loessial Hills	0	2	19	75	4	240
Blackland Prairie	4	7	36	53	0	153
Average	2	6	44	44	4	148

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

Table 10. The median Mehlich-3 extractable magnesium (Mg) by soil association number (SAN) for soil samples submitted to the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna from 1 January 2017 through 31 December 2017.

SAN	Soil association	Mehlich-3 soil Mg[a], Md[b]	SAN	Soil association	Mehlich-3 soil Mg[a], Md[b]
		(ppm)			(ppm)
1.	Clarksville-Nixa-Noark	113	26.	Amagon-Dundee	169
2.	Gepp-Doniphan-Gassville-Agnos	189	27.	Sharkey-Steele	164
3.	Arkana-Moko	181	28.	Commerce-Sharkey-Crevasse-Robinsonville	523
4.	Captina-Nixa-Tonti	125	29.	Perry-Portland	209
5.	Captina-Doniphan-Gepp	105	30.	Crevasse-Bruno-Oklared	76
6.	Eden-Newnata-Moko	106	31.	Roxana-Dardanelle-Bruno-Roellen	196
7.	Estate-Portia-Moko	116	32.	Rilla-Hebert	214
8.	Brockwell-Boden-Portia	138	33.	Billyhaw-Perry	752
9.	Linker-Mountainburg-Sidon	89	34.	Severn-Oklared	242
10.	Enders-Nella-Mountainburg-Steprock	96	35.	Adaton	134
11.	Falkner-Wrightsville	59	36.	Wrightsville-Louin-Acadia	74
12.	Leadvale-Taft	119	37.	Muskogee-Wrightsville-McKamie	204
13.	Enders-Mountainburg-Nella-Steprock	90	38.	Amy-Smithton-Pheba	70
14.	Spadra-Guthrie-Pickwick	151	39.	Darco-Briley-Smithdale	75
15.	Linker-Mountainburg	101	40.	Pheba-Amy-Savannah	87
16.	Carnasaw-Pirum-Clebit	110	41.	Smithdale-Sacul-Savannah-Saffell	86
17.	Kenn-Ceda-Avilla	114	42.	Sacul-Smithdale-Sawyer	89
18.	Carnasaw-Sherwood-Bismarck	106	43.	Guyton-Ouachita-Sardis	111
19.	Carnasaw-Bismarck	88	44.	Calloway-Henry-Grenada-Calhoun	202
20.	Leadvale-Taft	137	45.	Crowley-Stuttgart	200
21.	Spadra-Pickwick	129	46.	Loring	166
22.	Foley-Jackport-Crowley	216	47.	Loring-Memphis	245
23.	Kobel	141	48.	Brandon	238
24.	Sharkey-Alligator-Tunica	339	49.	Oktibbeha-Sumter	153
25.	Dundee-Bosket-Dubbs	133		Average	158

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

Table 11. The percentage of sampled acres as distributed within five soil-test levels and median Mehlich-3 extractable magnesium (Mg) by previous crop for soil samples submitted to the University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory in Marianna from 1 January 2017 through 31 December 2017.

	Mehlich-3 soil Mg[a] (ppm)					
Previous crop	**<31**	**31-50**	**51-140**	**141-500**	**>500**	**Md[b]**
	-------------------- (% of sampled acreage) ------------------					**(ppm)**
Corn	0	1	34	59	6	171
Cotton	0	0	32	64	4	201
Grain sorghum, non-irrigated	5	10	43	42	0	98
Grain sorghum, irrigated	0	4	7	46	47	475
Rice	0	5	17	59	24	284
Soybean	0	2	27	59	12	208
Wheat	1	3	57	35	4	115
Cool-season grass hay	2	13	54	31	0	95
Native warm-season grass hay	3	13	67	15	2	75
Warm-season grass hay	5	11	60	23	1	93
Pasture, all categories	1	7	54	37	1	118
Home garden	1	3	36	54	6	170
Turf	9	24	56	11	0	69
Home lawn	0	3	65	31	1	113
Small fruit	9	18	43	28	2	89
Ornamental	0	3	40	53	4	156
Average	2	8	43	40	7	158

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

Variability in Soil-Test Phosphorus and Potassium in Several Arkansas Fields

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Abstract

A considerable amount of time and financial resources are spent in the collection of soil samples for variable-rate fertilization in Arkansas. A study was initiated in 2017 with the objectives of understanding the spatial dependence of phosphorus (P) and potassium (K) across fields with different soil properties and management histories, and how different interpolation methods affect the resulting fertilizer prescription maps. Soil samples have been collected in 1-acre grids on nearly 1800 acres with the majority of the samples collected with an automated soil sampler. The coefficients of variation (CV) for P ranged from 22% to 58% among the 11 fields, which is considerably higher than the CV range for K (17% to 33%). Results of the preliminary analysis show that, depending on the field, sampling densities between 1 and 16 acres would be required to characterize the spatial dependence of K. However, for P, grid sizes between 1 and 7 acres would be required. It is obvious that the size of a grid that accounts for the variability of P may be different from the grid size that accounts for the variability in K concentration across a field. The two interpolation methods used were kriging (Kr) and inverse distance (ID). The use of Kr resulted in more fertilizer applied for the majority of the fields for both, P and K. Also, Kr allocated more fertilizer to lower soil-test categories than ID. As more data is collected and analyzed, perhaps we can identify specific soil properties and management practices that have a heavier weight on variability of the nutrients of interest and use such information to provide guidance on how to sample fields with a specific set of conditions.

Introduction

A large portion of the soil samples analyzed by the University of Arkansas Soil Testing and Research Lab are collected with the objective of applying fertilizer in a variable-rate fashion. The overarching goal of this project is to evaluate the agronomic and economic benefits of variable-rate fertilization (VRF). However, successful VRF requires the proper characterization of the spatial dependence of the nutrients of interest. An additional component that may affect the characterization of nutrient variability is the interpolation method chosen to predict nutrient values of non-sampled locations. Currently in Arkansas, service providers take soil samples based on 2.5- or 5-acre grids, or they may use apparent electrical conductivity and perhaps yield maps to develop management zones. The choice of soil sampling method appears to be arbitrary and probably driven by convenience. The most common interpolation methods used by providers in Arkansas are inverse distance weighting (ID) and Kriging (Kr), without much knowledge behind the interpolation method of choice. Therefore, it is of critical importance to identify the density and/or method of soil sampling, and interpolation method that best describes the spatial dependence of the nutrient(s) of interest. There is a need to understand which soil factors and management practices have a bigger weight on the spatial variability of a nutrient in a particular field. Before an attempt is made to evaluate VRF, one needs to be certain that fertilizer is applied only to areas where a fertilizer recommendation would have been generated. While it is not realistic to expect that VRF will account for 100% of the variability in a field, there should be a reasonable expectation that VRF will better address the variability than the conventional fertilizer application method. The objective of this paper is to report on a preliminary evaluation of the spatial dependence of nutrients, particularly P and K in several fields in eastern Arkansas, and how different interpolation methods compare in the total amount of fertilizer to be applied and how such fertilizer is distributed in a field.

Procedures

Sample Collection

Soil samples were collected from 11 fields (nearly 1800 acres) located in Lee and Cross counties in Arkansas. Fields 1, 3, 4, and 5 were divided into 1-acre grids, with each grid center being geo-referenced. Once the center of each grid was located, 6 to 8 soil cores were collected from a 12-ft radius around the grid center point and composited. Fields 2, 6, 7, 8, 9, 10, and 11 were sampled with a Falcon automated soil sampler (Falcon Soil Technology, Monroe, N.C.). This machine uses a steel drum to collect cores every 15 feet. Each sample was a composite of 15 cores. When possible, the unit was pulled at a 45 degrees angle in each grid polygon.

Field Descriptions

Eleven fields were sampled for the purpose of this study. Table 1 shows a description of the soil series present in each field. The fields were chosen as they included several soil series and historical data showed significant spatial variability in the concentration of nutrients. Fields 1, 2, 6, and 7 are furrow ir-

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rigated, while fields 3, 4, 5, 8, 9, 10, and 11 are irrigated with center pivots. Fields 1 and 2 were precision-leveled several years ago, while the rest of the fields have not received any significant land-forming practice. Fertilizers, particularly K, have been applied with variable-rate technology in fields 1 and 2 for 3 years and in fields 3, 4, 5, 8, 9, 10, and 11 intermittently for the last 8 years. Variable-rate technology has not been used in fields 6 and 7.

Statistical Analysis

Descriptive statistics were estimated with the Univariate procedure in SAS v.9.2 (SAS Institute, Cary, N.C.), including the Shapiro-Wilk statistic, which was used to test for normality. When the test for normality failed ($P < 0.05$), the data were log-transformed to stabilize the variance. Empirical semivariograms were fit to both raw and log-transformed data using ArcGIS Geostatistical Analyst (ESRI, Redlands, Calif.), with Stable, Gaussian and spherical (only for non-transformed data) models tested. The selection of the fitted model was mostly based on which model had resulting root mean squared standardized errors (RMSE) closest to one. A semivariogram describes the nature of spatial autocorrelation of soil samples at a specific distance and direction from each other. A semivariogram is composed of three parameters including the range, which defines the minimum separation between soil samples that will ensure the two samples are independent. Soil samples collected at distances closer than the range are assumed to be spatially auto-correlated. The *y*-axis (dependent variable) value corresponding to the range is called the sill. The sill represents the maximum semivariance between two sampling points and should approximate the population variance. Sill gives an indication of the degree of uncertainty when interpolating the points. Theoretically, the model should intercept at the 0 value, however, in real life, measurement errors prevent this from occurring. The point at which the line intercepts the *y*-axis is called the nugget and it is a measure of experimental and/or human error.

Two interpolation methods were compared in terms of the total amount of fertilizer applied, as well as distribution of fertilizer according to the soil-test level for soil samples collected every acre. Prescription maps were developed assuming corn (*Zea mays* L.) was the intended crop. The percent of the total fertilizer nutrient (K_2O or P_2O_5) amount falling into the currently used soil-test levels of very low (0–16 ppm for P; 0–60 ppm for K), low (16–25 ppm for P; 61–90 ppm for K), medium (26–35 ppm for P; 91–130 ppm for K), and optimum (36–50 ppm for P; 131–175 ppm for K) for each of the interpolation methods was estimated. An interpolation method is used to predict nutrient concentrations at non-sampled locations. The two interpolation methods evaluated were Kr and ID. Kriging interpolation is a geostatistical interpolation technique, which uses the statistical attributes of the known locations to predict values at non-sampled locations. Kriging uses semivariograms to account for spatial autocorrelation. The ID interpolation method is a deterministic (mathematical) technique. Inverse distance assumes that samples closest to the "prediction" location have more influence than those samples that are farther apart and assigns a weight to the number of locations chosen to predict values at non-sampled locations. This method assumes that the weight decreases with distance. The weights are proportional to the inverse of the distance.

Results and Discussion

Table 1 shows a description of the soil series within each field. All the fields have a mixture of two to five soil series. The size of the fields ranged from 75 to 354 acres. Crops grown in these fields include corn, cotton (*Gossypium hirsutum* L.), soybean (*Glycine max* L.), and rice (*Oryza sativa* L.).

The descriptive statistics for soil-test P and K for each of the 11 fields are shown in Table 2. The CV for P ranged from 22% to 58% among the 11 fields, which is considerably higher than the CV range for K (17% to 33%). Regardless of the level of variability exhibited by the P and K concentrations in each field, the median and average concentrations were fairly similar. Results in Table 2 show most of the median values for both P and K are lower than corresponding mean concentrations. This situation appears to be an indication that the variability observed is not necessarily due to outliers among the soil samples, but rather to intrinsic variability in a particular field, as proposed by Cambardella and Karlen (1999). The mean P and K concentrations for fields 1, 2, 6, and 7 are considerably lower than the rest of the fields sampled, and have relatively higher CV. These nutrient levels seem to correlate well with yield levels observed in those fields. Historical yields for fields 1, 2, 6, and 7 are close or lower than the state average for the particular crops. The distribution of soil-test P failed the normality test for each site, except field 10, based on the Shapiro-Wilk statistic ($P < 0.05$) (Table 3). In the case of K, fields 2, 3 and 10 were the only locations which showed normal distributions. Soil-test P and K concentrations for each field were log transformed to reduce the variance and calculate the semivariogram, when needed. The transformation reduced skewness by 5-fold in some fields. Skewness is a measure of the shape of the frequency distribution, as compared to a normal distribution.

The choice of the semivariogram model and other parameters will affect the outcome of the results, particularly the range. The root mean square error (RMSE) was used as a qualitative measure of appropriate model choice. Values for RMSE close to 1.0 are considered a sign of appropriate model choice. The spherical model was fitted for each one of the fields passing the normality test. For the rest, the stable model was used. There was considerable variability among the ranges calculated for each field, even for fields that have received similar management for years. The range values for field 1 are 2 to 2.65 times larger than the ranges for field 2. Fields 3, 4, and 5 have been planted to cotton during most years and show range values for K of 197, 436, and 525 ft, which approximate sampling grid sizes of 1, 2, and 3 acres, respectively. For P, approximate soil sampling would be every 1 to 7 acres. Fields 6 and 7 have been managed similarly, with reduced inputs.

Approximate range values are 7 and 5 acres for K and 6 and 3 acres for P. Average soybean yields in fields 6 and 7 are low (45 bu/acre). Variable-rate fertilization in these fields would not be recommended due to their very low fertility levels. Fields 8, 9, 10, and 11 have been managed similarly and are adjacent to each other. Curiously, the descriptive statistics (Table 2) show similar numbers for all the fields, with the exception of the K levels for field 11, which are lower than the rest of the fields. The calculated range for K for fields 8 and 10 are 2288 ft and 3414 ft, which corresponds to a grid size close to 11 and 16 acres, respectively. The calculated range values for fields 9 and 11 are 675 ft and 450 ft, which corresponds to a grid size close to 3 and 2 acres, respectively. A possible explanation for such discrepancy in the nature of the spatial dependence of K, is the larger proportion of mapped clayey soils in fields 8 (71%) and 10 (100%), compared to such in fields 9 (44%) and 10 (43%).

Soil survey data (Soil Survey Staff, 2017) showed that the calculated range values cross several soil series, which may indicate similar nutrient dynamics among different soil series. Other factors such as micro-topography may also affect the observed variability. It is possible that sampling based on elevation or the incorporation of apparent electrical conductivity (ECa) could improve the prediction of nutrient concentrations at non-sampled locations. The range values calculated for fields 2, 4, and 5 were numerically similar for P and K. Field 3 receives irrigation in only 70% of its area. This situation could be a contributing factor for the low range value calculated for K. Also, a clustering effect associated with previous history of VRF could contribute to the large range values for P.

In 8 out of the 11 fields, the Kr method recommended more fertilizer than the ID method, with such difference ranging from 259 to 1470 lb of K_2O corresponding to fields 3 and 10, respectively. The ID method also recommended the fewest units of P_2O_5 in the majority of the fields (7), with the difference ranging between 624 and 1818 lb of P_2O_5 for fields 10 and 5, respectively.

Figure 1 shows how the recommended K_2O was distributed according to the interpolation method used for selected fields. In field 2, most of the soil samples fell in the medium category for K. In fields 4 and 10, the majority of samples had soil-test K in the optimum category, as was the case for fields 3, 5, 8, 9, and 11. In fields 1, 6 (shown), and 7, the majority of samples had a low soil-test K level. In all fields except 1, 7, and 11, the Kr interpolation method recommended more fertilizer than ID. Regardless of the soil-test K distribution among the soil-test levels, the Kr method consistently allocated more K fertilizer to the lowest soil-test category present in a given field, as compared to ID. In field 2, the Kr method allocated almost twice as much of the total K fertilizer than the ID method to areas of the field identified with a low soil-test level (4410 vs 2270 lb K_2O). In field 4, the Kr method allocated 33% of the total K fertilizer to areas in the medium level category, while the ID method allocated only 9%. A similar trend is observed for fields 6 and 10. Even in fields where basically the same amount of fertilizer was recommended for either method, such as field 9, the Kr method allocated 877 lb of fertilizer K to areas with a medium soil-test K level compared to only 214 lb allocated by the ID method.

The allocation of the P fertilizer followed a similar trend to the allocation of K fertilizer (Fig. 2). The Kr method allocated more P fertilizer to lower soil-test categories, regardless of the total amount of P fertilizer for the whole field. In fields 2 and 4, more P fertilizer was recommended by the Kr method, while the contrary was true for fields 3 and 7. There was no clear relationship between the CV and fertilizer distribution pattern for both P and K. However, in those fields where the majority of the samples were in the very low soil-test level, such as fields 1 and 6, the choice of interpolation method affected neither the distribution nor the total amount of fertilizer recommended.

The difference in the allocation of fertilizer is mostly related to the approach each of the interpolation methods follows to predict soil-test values at non-sampled locations. Results from cross validation tests (data not shown), which provide a mean to compare both interpolation methods, did not provide a clear indication of the interpolation method, Kr or ID, that consistently had better predictive ability. However, conceptually, the probability of a yield response to fertilizer applications is higher in areas with suboptimum soil-test levels. In field 6, 4582 lb of K_2O was recommended by the Kr method for areas testing very low, compared with 2740 lb K_2O recommended by the ID method. Similarly with P, in field 2, the Kr method recommended 2650 lb of P_2O_5 for areas having a very low soil-test P level, while the ID method recommended only 1130 lb P_2O_5.

Using the interpolation method that results in prescription maps with the least amount of fertilizer is an appealing option, especially with current crop and fertilizer price scenarios. However, one may choose to use the Kr method as it reduces the risk of yield penalties associated with not applying enough fertilizer to areas with a good probability of a yield response to fertilizer applications.

Practical Applications

The objectives of this study were to assess the nature of the variability in P and K in some soils in eastern Arkansas, to eventually develop recommendations regarding the proper grid size to collect soil samples for VRF and to evaluate two interpolation methods in terms of total amount of fertilizer recommended and the distribution according to soil-test level. Soil-test P tends to show more variability across fields than soil-test K. The preliminary analysis shows that, depending on the field, sampling densities between 1 and 16 acres would be required to characterize the spatial dependence of K. However, for P, grid sizes between 1 and 7 acres would be required. Data collected show that those fields with significant proportions of clayey-textured soils had less variability in the soil-test K levels across a field and perhaps could be sampled at a larger density. It is obvious that the size of a grid that accounts for the variability of P may be different from that grid size that accounts for the variability in K concentration across a field. Perhaps one may consider other factors such as existing correlation and calibration relationships and the suitability of current soil testing methodology while deciding which nutrient to be applied with variable-rate technology. The observed variability in soil-test P and K could also have been affected by "outside" factors such as human and experimental error and previous fertilization history.

Of the two interpolation methods evaluated, the kriging method recommended greater fertilizer use for 8 of 11 fields for K and 7 of 11 fields for P than the inverse distance method. In all the fields, the kriging method allocated more fertilizer to lower soil-test categories. As more data is collected and analyzed, perhaps we can identify specific soil properties and management practices that have a heavier weight on variability of the nutrients of interest and use such information to provide guidance on how to sample fields with a specific set of conditions.

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Table 1. Number of acres, crop planted at the time of sampling, and mapped soil series associated with each of the fields sampled during 2017–2018.

			Soil series[a] (%)										
Field	Acres	Crop	Ar	Cb	He	Ds	Es	Sh	Du	Cw	Ne	Tn	Br
1	101	Corn	42	57									
2	130	Rice		55	45								
3	190	Cotton				17	44	39					
4	174	Cotton				51	14	9	27				
5	145	Cotton				13	48	39					
6	127	Soybean		38	54					8			
7	354	Soybean		46	33					21			
8	165	Corn				24		10			25	36	5
9	157	Corn				29		15	28		29		
10	79	Corn						34			30	36	
11	75	Corn				20			37		32	11	

[a] Ar = Arkabutla silt loam; Cb = Calloway silt loam; He = Henry silt loam; Ds = Dubbs loam; Es = Earle silty clay; Sh = Sharkey clay; Du = Dundee silt loam; Cw = Crowley silt loam; Ne = Newellton silty clay loam; Tn = Tunica clay; Br = Bruno fine sandy loam.

Table 2. Descriptive statistics for P and K concentrations in eleven fields sampled during 2017–2018.

	Field										
	1	2	3	4	5	6	7	8	9	10	11
Mean (ppm)											
P	21	24	43	37	42	14	21	38	36	38	36
K	73	103	190	211	187	65	79	201	172	191	158
Median (ppm)											
P	16	22	39	35	37	13	19	36	36	37	34
K	70	97	175	208	176	64	76	205	162	198	152
Maximum (ppm)											
P	51	61	51	74	123	47	133	75	75	60	66
K	139	149	151	395	434	112	157	362	283	282	228
Minimum (ppm)											
P	6	8	6	13	17	5	12	21	17	21	20
K	39	57	99	78	91	41	12	99	103	87	115
Coefficient of Variation (%)											
P	58	44	43	37	43	35	44	28	25	22	23
K	28	17	29	33	32	17	23	26	24	25	18

Table 3. Shapiro-Wilk statistic, resulting semivariogram range and approximate sampling grid size, and root mean square error (RMSE) associated with the fitted semivariogram model, for soil-test P and K, for 11 fields.

	Shapiro-Wilk Statistic		Range		Approximate sampling grid size		Root mean square error	
Field	P	K	P	K	P	K	P	K
	----------(*P*-value)----------		----------- (ft) -----------		------- (acres) ------		-------- (RMSE) -------	
1	<0.0001	0.0368	741	1627	4	8	0.91	0.93
2	<0.0001	0.5500	370	613	2	3	0.95	0.95
3	<0.0001	0.1134	1416	197	7	1	0.96	1.01
4	<0.0001	0.0451	290	525	1	3	0.97	0.91
5	<0.0001	0.0001	239	436	1	2	1.04	0.96
6	<0.0001	0.0007	1200	1463	6	7	1.08	1.08
7	<0.0001	<0.0001	638	994	3	5	1.59	0.98
8	<0.0001	0.0185	1050	2288	5	11	1.01	0.98
9	0.0030	<0.0001	1050	675	5	3	1.03	1.00
10	0.1200	0.0528	450	3414	2	16	1.03	0.98
11	<0.0001	0.0026	762	450	4	2	1.01	0.98

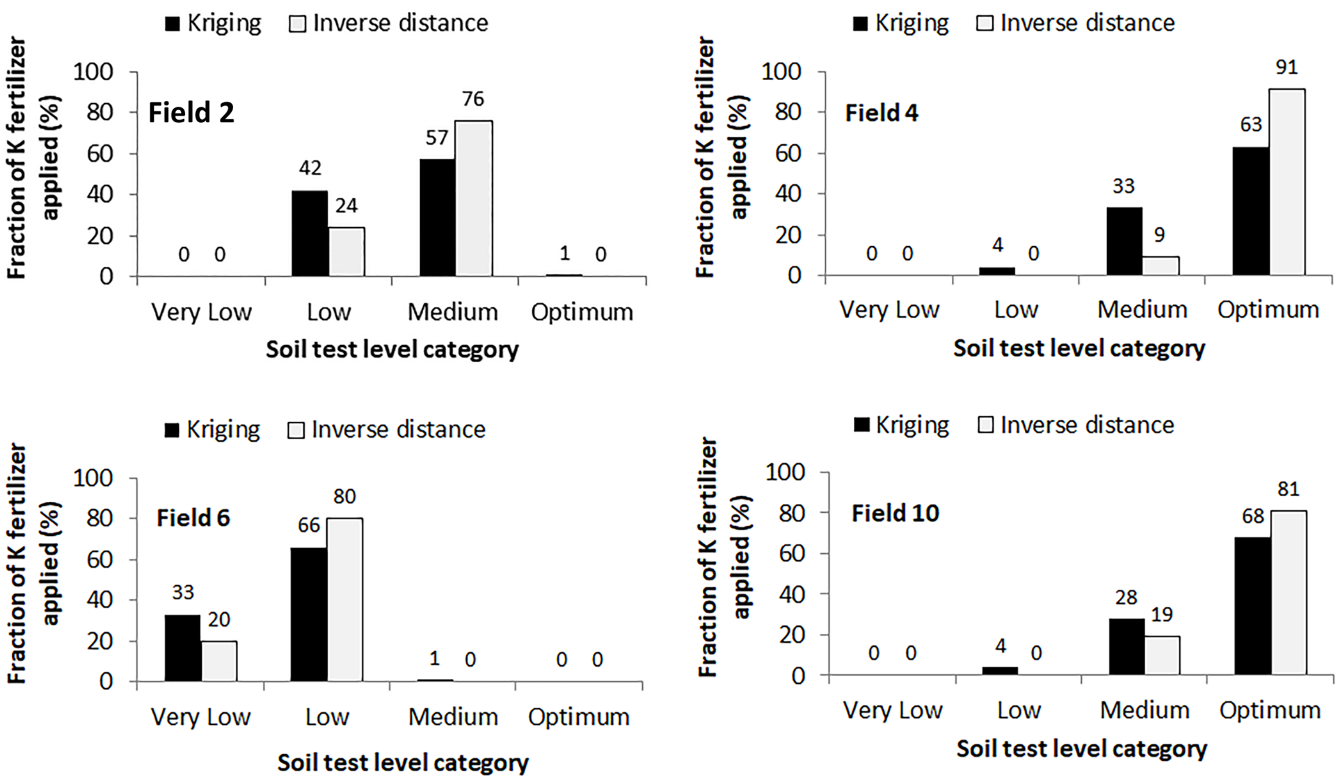

Fig 1. Distribution of K fertilizer according to soil-test category and interpolation method for selected fields.

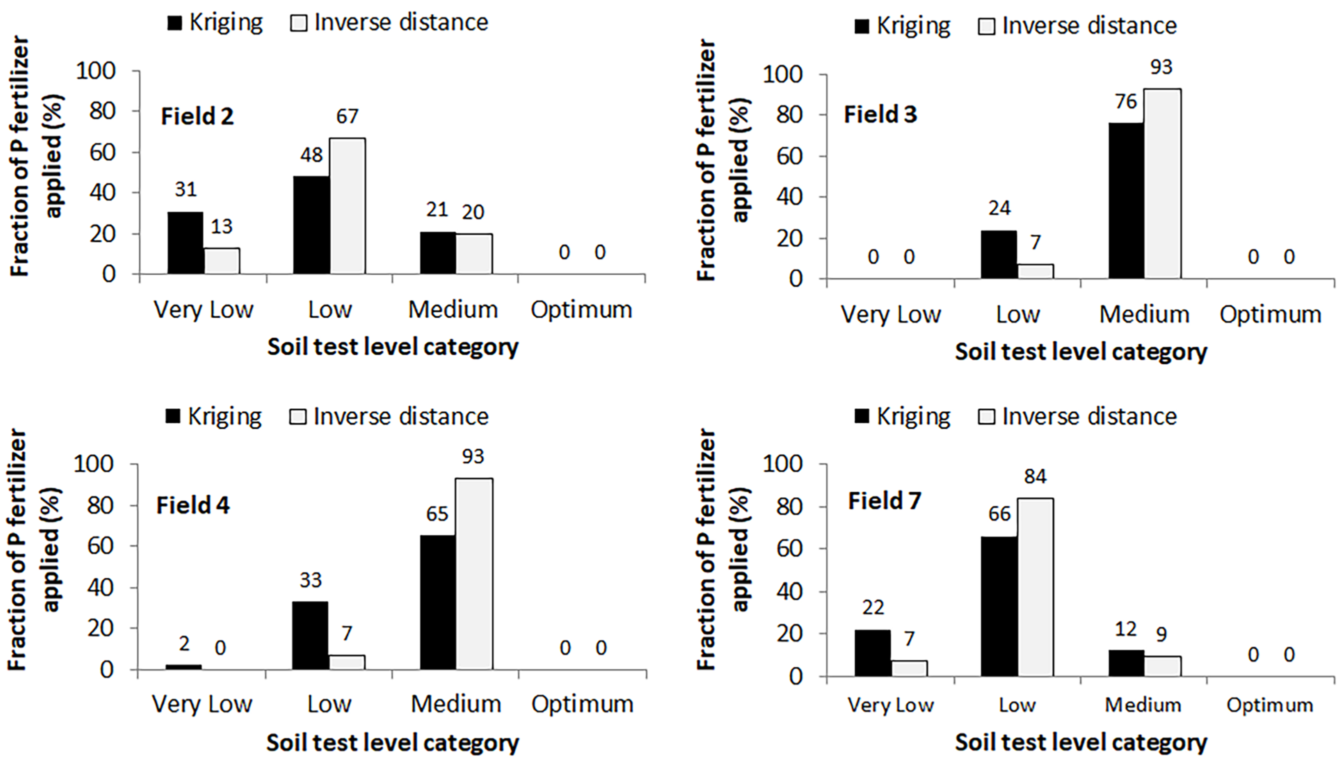

Fig 2. Distribution of P fertilizer according to soil-test category and interpolation method for selected fields.

Effect of Soil-Applied Phosphorus and Potassium on Corn Grain Yield in Arkansas

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Abstract

Corn (*Zea mays* L.) is an important crop in Arkansas. Reliable soil-test-based fertilizer recommendations are the most cost effective tool for sound nutrient management. Information from replicated experiments on corn response to P or K fertilization are the cornerstones of reliable soil testing. Replicated field experiments were conducted to evaluate corn response to P or K fertilizer rate on soils typically used for corn production. Phosphorus fertilization significantly influenced ($P < 0.10$) corn grain yield at two sites rated Low or Medium in Mehlich-3 extractable soil-P. At the two P responsive sites, the grain yield of corn that received no fertilizer P was 150 or 103 bu/acre, respectively, and the yield of corn fertilized with P ranged from 159 to 175 bu/acre or 114 to 138 bu/acre, respectively. Potassium fertilization significantly affected corn grain yield at two sites with Low and Medium soil-test K. The grain yield of corn that received no K fertilizer was 110 or 141 bu/acre and corn yields fertilized with K ranged from 149 to 174 or 170 to 192 bu/acre, respectively. Supplemental P or K fertilization did not influence corn grain yield when the soil-test P or K levels were Optimum. The results will be added to a database on high-yielding corn response to P or K fertilization in Arkansas. The database will be used to review and, if needed, revise the existing soil-test-based P and K fertility recommendations for corn production in Arkansas.

Introduction

Corn continues to be a major row crop in Arkansas. In 2017, approximately 620,000 acres of corn were planted in Arkansas. The equivalent of 60 lb P_2O_5 and 45 lb K_2O/acre are removed from the soil by a grain yield of 175 bu/acre (International Plant Nutrition Institute, 2012). Between 1992 and 2017, the average corn grain yield in Arkansas increased from 130 to 183 bu/acre, which represents a substantial increase in P and K removal from the soil nutrient reserves. Phosphorus and K play important roles in many plant physiological processes such as energy transfer and carbohydrate metabolism. The deficiency of either nutrient will limit corn yield and reduce the growers' profits. Failure to replace the nutrients removed by the harvested grain with adequate fertilizer rates contributes to soil nutrient depletion and eventually yield-limiting nutrient deficiencies.

Applying the right rates of P and K enables growers to maximize the net returns from corn production and minimize nutrient loss into the surrounding landscape. Reliable soil-test-based fertilizer recommendations are the most cost effective tool for applying the right P and or K fertilizer rates. Development of reliable soil-test-based P or K fertilizer recommendations requires data from a large number of sites and years. Multiple site-years of research are needed to increase the reliability and applicability of soil-test correlation and calibration curves. The specific objective of this research was to evaluate corn grain yield response to soil-applied fertilizer-P or -K rates at multiple locations on soils typically used for corn production in Arkansas.

Procedures

Phosphorus Experiments

Seven replicated P-fertilization trials were established in 2018 at the University of Arkansas System Division of Agriculture Research Stations in Pine Tree (PTRS: SFZ81, SFZ85, SFZ87, SFZ89), Marianna (LMCRS: LEZ81, LEZ85), and a commercial farm in Lonoke County (LOZ81). Selected agronomic information for completed P trials is listed in Table 1.

Prior to P application, a composite soil sample was taken from the 0-to 6-inch depth of each replication or the plot that would receive 0 lb P_2O_5/acre (SFZ81). Each composite soil sample consisted of a total of 5 or 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 atomic emission spectroscopy. Soil pH was measured in a 1:2 (volume: volume) soil-water mixture. Mean soil chemical properties are listed in Table 2.

Phosphorus application rates ranged from 0 to 160 lb P_2O_5/acre in 40 lb P_2O_5/acre increments applied as triple superphosphate. The experimental design was a randomized complete block where each treatment was replicated five times at all sites. Phosphorus treatments were applied onto the soil surface in a single application between 7 days before planting and 6 days after emergence. On sites where the P was applied before planting (LEZ81 and LEZ85), the treatments were

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mechanically incorporated into the top 3 to 4 inches of the soil. The beds were then re-pulled with a hipper and corn was planted on the top of the bed. Blanket applications of muriate of potash and $ZnSO_4$ supplied 90 to 120 lb K_2O, ~5 lb S, and ~10 lb Zn/acre. All experiments were fertilized with a total of 260 to 290 lb N/acre as urea and ammonium sulfate in a single or split application (e.g., preplant, 3-to 6-leaf stage and/or pre-tassel) depending on the location. Corn was grown on beds and furrow irrigated as needed either by research station staff or by the cooperating producer. Each plot was 25- or 40-ft long and 10- to 12.6-ft wide allowing for four rows of corn spaced 30 or 38 inches apart depending on the location. Corn management closely followed University of Arkansas System Division of Agriculture's Cooperative Extension Service (CES) recommendations. We were not able to collect reliable yield data from two of the seven tests at PTRS (SFZ85 and SFZ89) because they were damaged by wildlife.

The middle two rows of each plot were harvested either with a plot combine in Marianna or by hand at all other locations with ears placed through a combine following hand harvest. The calculated grain yields were adjusted to a uniform moisture content of 15.5% before statistical analysis.

Potassium Experiments

Six replicated field experiments were conducted in 2018 including trials at the PTRS (SFZ82, SFZ84), LMCRS (LEZ86), and commercial production fields in Chicot (CLZ82), Clay (CLZ82), and Lonoke (LOZ82) Counties. Agronomic information for the completed K trials is listed in Table 1. Soil sampling, K-fertilization and other practices were similar to the P studies. At sites CHZ82 and CLZ82, the beds were repulled after K fertilizer application and corn was planted on the top of the bed. At LEZ86 and LOZ82, K was applied on the soil surface. The K test in Lonoke County (LOZ82) was located adjacent to the P fertility trial described earlier. Soil property means are listed in Table 3. Potassium application rates ranged from 0 to 200 lb K_2O/acre in 50 lb K_2O/acre increments using muriate of potash. Triple superphosphate and $ZnSO_4$ were broadcast to supply 80 to 90 lb P_2O_5, ~10 lb Zn, and ~5 lb S/acre. Nitrogen fertilizer management was the same as described for the P trials. We were not able to collect reliable yield data from two of the tests in PTRS (SFZ82 and SFZ84) because the tests were damaged by wildlife.

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 Square Means procedure with significance interpreted at the 0.10 level.

Results and Discussion

Phosphorus Experiments

The soil pH ranged from 6.6 to 7.9 and Mehlich-3 extractable P ranged from 19 to 43 ppm (Table 2). The soil test data for trials that were damaged by wildlife are not reported in Table 2. According to the current CES interpretation, the soil-test P level was Low (16 to 25 ppm) at SFZ87; Medium (26 to 35 ppm) at LEZ81, LOZ81, and SFZ81; and Optimum (26 to 35 ppm) at LEZ85. According to the current CES soil-test-based P fertilization guidelines, for corn with a yield goal of >200 bu/acre, the Low, Medium, or Optimum soil-test levels receive recommendations of 110, 80, and 0 lb P_2O_5/acre, respectively.

Phosphorus fertilization significantly influenced ($P < 0.10$) corn grain yield (Table 3) at only two sites, which had either Low (SFZ87) or Medium (LEZ81) Mehlich-3 extractable soil-P levels (Table 2). At LEZ81, the grain yield of corn that did not receive any P was 150 bu/acre and the yield of corn fertilized with P ranged from 159 to 175 bu/acre and corn fertilized with 120 lb P_2O_5/acre produced the greatest numerical grain yield. At SFZ87, the yield of the corn that received no fertilizer P averaged 103 bu/acre and the yields of corn receiving P ranged from 114 to 138 bu/acre with the response to P fertilization being inconsistent among the fertilizer-P rates. Phosphorus application rate did not significantly influence corn grain yield at the remaining three sites.

Potassium Experiments

Soil pH and Mehlich-3 extractable P ranged from 6.4 to 7.2 and 20 to 59 ppm, respectively (Table 4). The soil-test information for trials that were damaged by wildlife is not reported in Table 4. The average Mehlich-3 extractable K ranged from 64 to 120 ppm among the four sites. According to the CES soil-test interpretation, soil-test K was Low (61 to 90 ppm) at CHZ82 and LOZ82, and Medium (91 to 130 ppm) at CLZ82 and LEZ86. Current fertilization guidelines for corn with a yield goal of >200 bu/acre would have recommended 115 and 80 lb K_2O/acre for the Low and Medium soil-test K levels, respectively.

Potassium fertilization significantly ($P < 0.10$) affected corn grain yield at CHZ82 and CLZ82, the two sites with Low and Medium soil-test K levels (Table 5). At CHZ82, the grain yield of corn that did not receive K fertilizer was 110 bu/acre and that of corn fertilized with K ranged from 149 to 174 bu/acre with the numerically highest yield produced by corn receiving 200 lb K_2O/acre. At CLZ82, the grain yield of corn that was not fertilized with K was 141 bu/acre and that of corn receiving K fertilizer ranged from 170 to 192 bu/acre. At both responsive sites, the grain yields of corn fertilized with the different K rates were not significantly different (Table 5). The positive response to K fertilization at CHZ82 is consistent with current CES recommendations for soil-test-based K fertilizer recommendations.

Practical Applications

The 2018 results show that P fertilization increased corn grain yield when Mehlich-3 extractable P in the 0- to 6-inch depth at one site was Low and at a second site with Medium soil-test P. However, P fertilization did not significantly influence corn grain yield at another site with Medium soil-test P. As expected when the soil-test P was Optimum, P fertilization did not significantly influence corn grain yield. At the P-responsive sites, corn receiving 40 or 120 lb P_2O_5/acre produced the numerically greatest grain yields. Potassium fertilization significantly increased corn grain yield at two sites which had Low or Medium K levels. Potassium fertilization did not increase the corn grain yield at the other two sites rated Low or Medium in Mehlich-3 extractable K. The results from these studies will be added to a database on modern corn hybrid response to P or K fertilization to evaluate the utility of existing soil-test thresholds and recommended P- and K-fertilization rates needed to produce maximal corn yield.

Acknowledgements

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Table 1. Site identification code, test nutrient(s), soil series, corn hybrid, row spacing, and planting, fertilization and harvest dates for corn P- and/or K-fertilizer rate trials completed in Chico (CHZ82), Clay (CLZ82), Lee (LMCRS: LEZ81, LEZ85, LEZ86), Lonoke (LOZ81, LOZ82), and St. Francis (PTRS: SFZ81, SFZ87) counties during 2018.

Site code	Test nutrient	Soil series	Hybrid	Row spacing	Planting date	Fertilization date	Harvest date
				(inches)	----------------	(day-month)	----------------
CHZ82	K	Henry silt loam	AgVenture 8714	38	1-May	25-April	19-Sep
CLZ82	K	Beulah fine sandy loam	Pioneer 1197	30	11-April	4-April	9-Sep
LEZ81, LEZ85	P	Convent silt loam	Croplan 6265SS	38	4-May	26-April	9-Sep
LEZ86	K	Memphis silt loam	Croplan 6265SS	38	4-May	14-May	9-Sep
LOZ81, LOZ82	P, K	Immanuel silt loam	Agri Gold 6659	30	18-April	27-April	11-sep
SFZ81	P	Calhoun silt loam	Dyna-gro D57	30	3-May	9-May	10-Aug
SFZ87	P, P	Calhoun silt loam	Croplan 6265	30	4-May	9-May	11-Aug

Table 2. Selected chemical property means of soil samples collected from the 0- to 6-inch depth before P-fertilizer application for five P-fertilization trials completed in Lee (LMCRS: LEZ81, EZ85), Lonoke (LOZ81), and St. Francis (SFZ81, SFZ87) counties during 2018.

Site ID	Soil pH	Mehlich-3-extractable nutrients							Soil organic matter
		P	SD P[†]	K	Ca	Mg	Cu	Zn	
		----------------	----------------	----------------	(ppm)	----------------	----------------	----------------	(%)
LEZ81	6.6	26	±5	69	1129	304	2.0	2.1	--
LEZ85	7.2	43	±3	102	1287	325	2.3	1.3	--
LOZ81	6.4	29	±6	81	865	108	1.5	1.9	2.1
SFZ81	7.9	22	±4	88	2592	303	2.0	11.2	--
SFZ87	6.5	19	±6	75	1486	263	1.7	1.8	2.0

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

Table 3. Effect of P-fertilization rate on corn grain yield for five trials conducted in Lee (LMCRS: LEZ81 and LEZ85) Lonoke (LOZ81) and St. Francis (PTRS: SFZ81 and SFZ87) Counties during 2018.

	Grain yield				
P rate	LEZ81	LEZ85	LOZ81	SFZ81	SFZ87
(lb P_2O_5/acre)	(bu/acre)				
0	150 b†	122	196	129	103 c
40	163 ab	136	212	145	131 a
80	173 a	124	229	151	114 bc
120	175 a	134	211	131	138 a
160	159 ab	139	209	140	130 ab
C.V., %‡	5.8	8.2	6.1	10.4	8.6
P-value	0.0959	0.1494	0.2659	0.7521	0.0238

† Means followed by the same letter are not significantly different at *P* = 0.10.
‡ C.V., Coefficient of variation.

Table 4. Selected chemical property means of soil samples taken from the 0-to 6 inch depths before K fertilizer application for four trials conducted in Chicot (CHZ82), Clay (CLZ82), Lee (LEZ86), and Lonoke (LOZ82) counties during 2018.

		Mehlich-3-extractable nutrients							Soil organic
Site ID	Soil pH	P	K	SD K†	Ca	Mg	Cu	Zn	matter
		(ppm)							(%)
CHZ82	7.2	55	64	9	1197	270	1.8	2.2	2.3
CLZ82	6.8	59	120	20	594	97	2.4	3.8	1.0
LEZ86	7.2	42	113	11	1295	340	2.2	1.3	--
LOZ82	6.4	20	78	9	828	107	1.6	1.5	1.98

† SD, Standard deviation of Mehlich-3 extractable soil-test K in the 0- to 6-inch depth.

Table 5. Effect of K-fertilization rate on corn grain yield for four trials conducted in Chicot (CHZ82), Clay (CLZ82), Lee (LEZ82), and Lonoke (LOZ82) counties during 2018.

	Grain yield			
K rate	CHZ82	CLZ82	LEZ86	LOZ82
(lb K_2O/acre)	(bu/acre)			
0	110 b†	141 b	115	178
50	149 a	192 a	113	197
100	160 a	188 a	115	198
150	-	170 a	117	182
200	174 a	183 a	111	196
C.V., %‡	9.7	7.6	9.2	7.9
P-value	0.0593	0.0054	0.8626	0.3758

† Means followed by the same letter are not significantly different at *P* = 0.10.
‡ C.V., Coefficient of variation.

Toward Developing an Improved Agricultural Limestone Recommendation for Arkansas Soils

M. Mozaffari[1], H.C. Hays[1], and Z.M. Hays[1]

Abstract

Soil pH is an important chemical property that controls the availability of plant nutrients. Soil samples were collected from agricultural soils across Arkansas. Chemical characterization, laboratory incubation, soil pH, and buffer tests were conducted. For 82 soils, the soil clay content, soil organic matter (SOM), and estimated cation exchange capacity (ECEC, as estimated from summation of Mehlich-3 extractable cations) ranged from 5% to 62% and 0.75% to 8.4%, respectively, and ECEC was 1.55 to 23.55 cmol/kg. Mehlich-3 extractable K, Ca, Mg, and soil clay content were significantly ($P < 0.1$) and moderately to somewhat strongly correlated with each other ($r = 0.31$ to 0.90). The lime requirement to raise the soil water pH1:2 to 6.0 was measured by the single addition of calcium hydroxide [$Ca(OH)_2$, SALR] and Sikora Buffer (SBLR). For a subset of the samples, the lime requirement to raise the soil water pH to 6.0 (LILR) was determined in a laboratory incubation study. The LILR was significantly and weakly correlated with soil clay content ($n = 41$, $P < 0.1$, $R^2 = 0.22$) and significantly and moderately correlated with SALR ($n = 40$, $P < 0.1$, $R^2 = 0.66$). There was a significant correlation between SALR and SBLR ($n = 29$, $P < 0.1$, $R^2 = 0.80$).

Introduction

Proper management of soil pH is crucial for improving nutrient use efficiency and ensuring economically optimal crop yields. Most agricultural crops require a pH range between 5.5 and 6.5 for optimal growth and development. Various factors such as soil parent material, climate, and crop production practices such as root respiration and intensive N fertilization lower the soil pH. The University of Arkansas System Division of Agriculture's Cooperative Extension Service soil-test-based fertility guidelines currently considers soil pH of less than 5.8 as below optimum for most plants and recommends application of 2000 to 7000 lb/acre of agricultural lime depending on soil pH and clay content. Agricultural limestone application rates in Arkansas are based on soil pH (1:2 soil: water ratio) and soil Mehlich-3 extractable Ca, while many states in the region use a buffer solution. Growers, consultants, and other interested parties have questioned the foundation and requested scientific data that support existing lime recommendations. The authors could not find published information supporting the logic of the existing recommendations. The research reported here is part of a larger effort to develop research-based lime recommendations for the diverse array of soil and cropping systems in Arkansas. The specific objectives of this report are to evaluate 1) the relationship between Mehlich-3 extractable basic cations and soil clay content, and 2) the effectiveness of two laboratory methods of lime requirements and relate that to experimentally determined lime requirement. This information is crucial for evaluating and, if needed, revising the existing Arkansas soil-test-based lime recommendation.

Procedures

Five gallons of bulk soil were collected from the 0- to 6-inch depth from 100 locations across Arkansas. Soil samples were dried thoroughly, mixed in a clean cement mixer and ground to pass a 2-mm sieve. Soil samples were tested for pH (w/w, 1:1 water, 1:2 water, and 0.01 *M* $CaCl_2$; Sikora and Kissel, 2014), soil organic matter (SOM, Zhang and Wang, 2014), Mehlich-3 extractable nutrients (Zhang et al., 2014), and particle size analysis by the hydrometer method (Huluka and Miller, 2014). Mehlich-3 extractable K, Ca, Mg, and Na concentrations were used to calculate the cmolc/kg soil of each basic cation and the estimated soil cation exchange capacity (ECEC) was derived by summing the charge of Mehlich-3 extractable basic cations. The initial soil characterization data were used to select a cross section of soils with a wide range of soil physical and chemical properties for a 90-day laboratory incubation study. A similar 120-day incubation study with different $CaCO_3$ lime application rates (Mozaffari, 2018) has been previously reported. The incubation study reported here evaluated soil pH response to seven rates of pure $CaCO_3$ equivalent to 0 to 3500 lb/acre assuming 2,000,000 lb soil/acre in an acre furrow slice. Of the 100 soil samples collected, the pH (w/w, 1:2 water) of 18 soils was above 5.5 and those soils were discarded. Soil characterization and lime buffer data for 82 soils and incubation data for 43 soils are presented in this report.

Each experimental unit consisted of one 300-mL round bottom plastic container. A 220-gram sample of each soil plus the appropriate amount of $CaCO_3$ was mixed thoroughly and added to the plastic container. Deionized water was added to each container to obtain a gravimetric moisture content equivalent to gravimetric field capacity. Soil particle size analysis was used to estimate gravimetric soil moisture content at field capacity using the SPAW program developed by USDA (https://hrsl.ba.ars.usda.gov/SPAW/SPAWDownload.html). The top of each container was covered with plastic film and 8 to 10 pinholes were made in the plastic film to allow for air exchange. Each treatment was replicated 3 times. Containers were arranged on shelves in a randomized complete block configuration and incubated at room temperature (68° to 77° F). The containers were periodically checked (every 2 to 3 weeks) and if the soil

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appeared completely dry, the container weight was recorded and deionized water was added to bring the weight of the container plus soil to the container weight at day 1. The soil was allowed to go through at least 5 wet-drying cycles to simulate field conditions. At the end of the 90-day incubation, the soil samples were removed from the containers, dried, ground, and subsamples were taken for measurement of soil pH. The lime requirement was measured in the laboratory by single addition of calcium hydroxide lime recommendation (SALR; Kissel and Sonan, 2014) and Sikora Buffer Lime Recommendation (SBLR; (Sikora, 2014b).

Descriptive statistics were used to determine the range of soil chemical and physical properties. The incubation data and the buffer results were used to calculate the soil lime requirement to raise the soil pH to target pH of 6.0 (w/w, 1:2 water).Descriptive statistics and regression analysis were used to characterize soil properties and evaluate the relation among lime requirement methods.

Results and Discussion

Soil organic matter ranged from 0.75% to 8.40% and clay content ranged from 5% to 62%, respectively (Table 1). Soil water pH1:2 ranged from 4.2 to 7.5 and salt pH ranged from 3.75 to 6.72. Mehlich-3 extractable Ca and Mg were the two most abundant soil cations. Soil clay content, ECEC, Mehlich-3 extractable Ca, and Mg were significantly and weakly or moderately correlated with each other (r = 0.20 to 0.90, Table 2). Calcium was a better predictor of ECEC and clay content than Mg. The amount of calcium carbonate needed to raise the soil pH to 6.0 by SALR and SBLR ranged from 225 to 5830 lb/acre and 2000 to 12,000 lb/acre, respectively. The SALR was significantly ($P < 0.1$) but not strongly correlated with SOM ($r = 0.41$) and soil clay content ($r = 0.37$); however, it did not correlate with ECEC or any of the cations. The SBLR was significantly correlated with SOM ($r = 0.37$), clay content ($r = 0.52$) and Mehlich-3 extractable Ca ($r = 0.23$) or Mg ($r = 0.24$).

For the subset of samples used in the incubation study, the laboratory incubation lime recommendation (LILR) was significantly, albeit weakly ($R^2 = 0.22$) correlated with soil clay content (Fig. 1). The lack of a strong correlation was somewhat surprising and may have implications for accurate lime recommendation via LILR and needs further evaluation. There was a significant and moderately strong relationship between the SALR and LILR lime requirement ($P < 0.10$, $R^2 = 0.66$, Fig. 2) which suggests that SALR is a potentially good predictor of lime requirement for the soils in this study. Similarly there was a strong relationship between the lime requirement as predicted by SBLR and SALR (Fig. 3, $n = 29$, $P < 0.1$, $R^2 = 0.80$). The results suggest that if the current work cannot demonstrate the suitability of using ECEC and soil pH to predict lime requirement with reasonable accuracy, then SALR or SBLR may be a suitable alternative.

Practical Applications

The lime requirement needed to raise soil pH1:2 to 6.0 by methods used in Georgia (SALR) and Kentucky (SBLR) were tested and were correlated with each other. The lime requirement, as determined via linear regression of laboratory incubation data (LILR) was weakly correlated with the soil clay content. However, the LILR was significantly correlated with the SALR and SBLR lime requirement methods. For the soils evaluated in this study, the SALR appears to be a better predictor of the soil lime requirement than the SBLR.

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Table 1. Descriptive statistics for soil organic matter (SOM), Mehlich-3 extractable K, Ca, Mg, estimated cation exchange capacity (ECEC), clay content, soil pHw1:1, soil pHw1:2, soil pHCaCl$_2$, the amount of calcium carbonate required to raise the soil pH to 6 by a single addition of calcium hydroxide (SALR) or Sikora Buffer (SBLR) for the 82 soils used in the soil characterization and lime buffer measurements component of the study.

Soil property	*n*	Mean	Std Dev (±)	Minimum	Maximum
SOM (%)	80	3.03	1.60	0.75	8.4
K (cmol/kg)	82	0.44	0.24	0.08	1.21
Ca (cmol/kg)	82	4.32	3.30	0.74	15.68
Mg (cmol/kg)	82	2.10	2.21	0.27	13.41
ECEC (cmol/kg)	82	7.54	5.09	1.55	23.47
Clay (%)	82	22.8	12.43	5.0	62.0
$pH_{w1:1}$	82	5.08	0.51	4.18	6.98
$pH_{w1:2}$	82	5.26	0.44	4.30	7.50
$pH_{CaCl_2,1:1}$	82	4.72	0.51	3.75	6.72
SALR $CaCO_3$ (lb/acre)	75[a]	1770	1249	225	5830
SBLR $CaCO_3$ (lb/acre)	58[b]	1770	1249	2000	12000

[a] The results for eight samples were unrealistic or erroneous SALR values or did not call for lime application and had to be discarded.
[b] We were not able to calculate SBLR for 24 samples because their SBLR values were unrealistic, erroneous values or were out of the range of those provided in Table 2 of Sikora (2014a).

Table 2. Pearson correlation coefficient (r) and *p*-values (*P*) describing the correlation among soil organic matter (SOM), Mehlich-3 extractable Ca and Mg, estimated cation exchange capacity (ECEC), clay content (*n* = 80), the amount of calcium carbonate required to raise the soil pH to 6.0 by a single addition of calcium hydroxide (SALR, *n* = 73) or Sikora Buffer (SBLR, *n* = 57) for the soils reported here.

Parameter		SOM	Ca	Mg	ECEC	Clay	SALR	SBLR
SOM	*r*	1.0	0.35	0.20	0.34	0.23	0.41	0.38
	P	-	0.001	0.06	0.002	0.037	<0.0003	0.003
Ca	*r*	0.35	1.0	0.41	0.91	0.54	0.06	0.23
	P	0.01	-	0.0001	<0.0001	<0.0001	0.63	0.07
Mg	*r*	0.24	0.41	1.0	0.74	0.33	0.17	0.18
	P	0.07	<0.0001	-	<.0001	0.0038	0.15	0.19
ECEC	*r*	0.34	0.90	0.74	1.0	0.55	0.10	0.24
	P	0.002	<0.0001	<0.0001	-	<0.0001	0.38	0.06
Clay	*r*	0.23	0.54	0.32	0.55	1.0	0.37	0.52
	P	0.04	<0.0001	0.002	<0.0001	-	0.001	0.001
SALR	*r*	0.41	0.06	0.17	0.10	0.37	1.0	0.78
	P	0.0003	0.63	0.15	0.39	0.001	-	<0.0001
SBLR	*r*	0.38	0.24	0.17	0.24	0.52	0.78	1.0
	P	0.0036	0.07	0.19	0.06	<0.0001	<0.0001	-

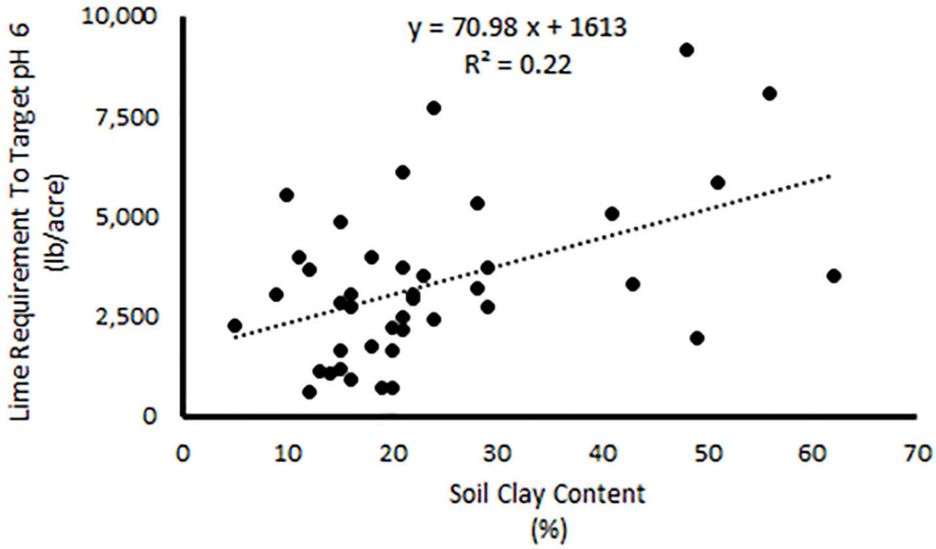

Fig. 1. Relationship between the soil clay content, as measured by the hydrometer method, and the amount of $CaCO_3$ required to raise the soil $pH_{w1:2}$ to target pH of 6.0, as calculated from a 90-day laboratory incubation study, for 41 soils from Arkansas.

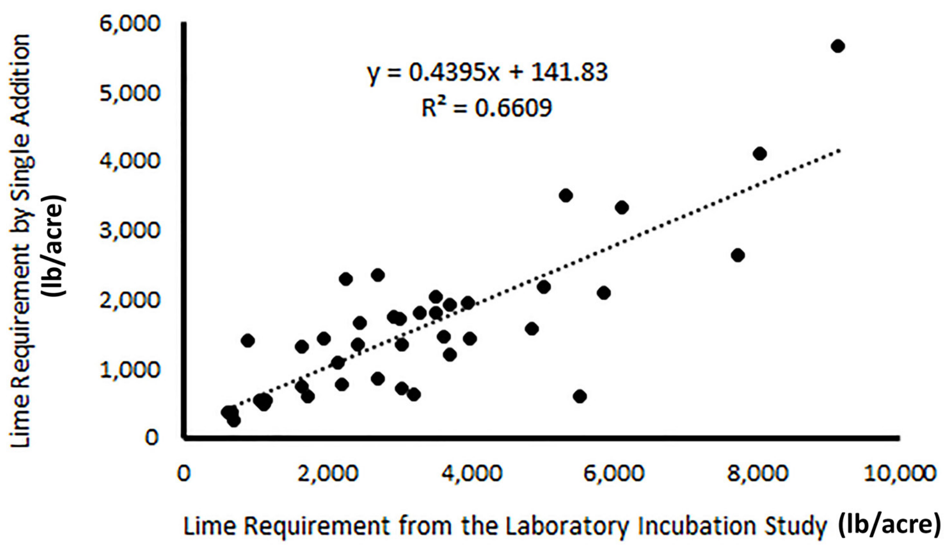

Fig. 2. Relationship between the amount of $CaCO_3$ required to raise the soil $pH_{w1:2}$ to 6.0 as determined by a 90-day laboratory incubation study and the single addition of $Ca(OH)_2$ for 40 soils from across Arkansas.

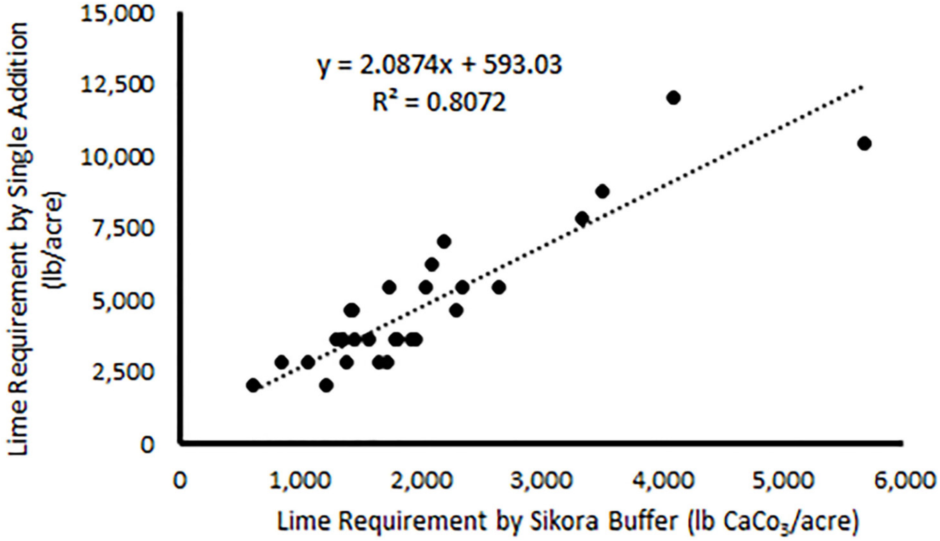

Fig. 3. Relationship between the amount of $CaCO_3$ required to raise the soil $pH_{w1:2}$ to 6.0 as determined by the Sikora Buffer (SBLR) and single addition of $Ca(OH)_2$ (SALR) methods for 29 Arkansas soils.

Economic Optimum Fertilizer Potassium Rate for Irrigated Soybeans

J.A. Richard[1], K.J. Bryant[2], T.B. Mark[3], and N.A. Slaton[4]

Abstract

A Linear Response Stochastic Plateau (LRSP) yield response model as documented in the literature is used to estimate soybean (*Glycine max* L.) yield in Arkansas for a given soil-applied fertilizer-K rate and a given soil-test K. This yield response to K fertilization is coupled with soybean price and fertilizer-K price to estimate an economic optimum fertilizer-K recommendation. Data used to fit the model are from 99 research trials conducted throughout Arkansas to examine irrigated soybean response to K fertilization rate. These tests were conducted from 2004 to 2016. Results show the economic soil-applied fertilizer-K recommendations decrease as soil-test K increases. Also, as the market situation becomes more favorable as marked by a higher soybean price and a lower fertilizer-K price, the economic recommendation is to apply more fertilizer K at all soil-test K levels. Soil-test K values can now be used to make economically informed decisions, where previously only agronomic insight was available to soybean producers.

Introduction

Linear plateau yield response models can be used in fertilizer economic analyses to develop expectations for crop yield, given various levels of fertilizer applied to a field. The yield response model is then used in conjunction with input and output prices to determine an economically optimum fertilizer recommendation. A linear plateau model implies that yield increase is linear as more fertilizer is applied up until yield is maximized. Once the yield maximizing level of fertilizer input has been reached, there should no longer be a yield response expected (i.e., yield plateaus). Further, specifying the plateau as stochastic, allows modeling the uncertainty inherent in crop yield response to fertilizer application.

Tembo et al. (2008) documented the long history of research aimed at developing crop input response modeling techniques. Linear response plateau models have been very popular. Many articles compare results across various functional forms and many find the linear response plateau as a top performing method. Specific examples where the plateau is allowed to vary with plot, site and year are provided by Babcock and Blackmer (1994), Bäckman et al. (1997), and Cerrato and Blackmer (1990). Sumelius (1993) also introduces year effects, but only in the form of annual dummy variables.

Tembo et al. (2008) was a significant advancement in the literature when modeling crop yield response to a fertilizer input as it made improvements over prior efforts. The Tembo et al. study used wheat (*Triticum aestivum* L.) yield response to nitrogen fertilizer as its empirical example. The current study adapts the Tembo et al. technique to study soybean yield response to fertilizer-K rate. This adaptation requires including information available from a soil-test value for K into the yield response model.

Numerous researchers have demonstrated the ability of information from Tembo et al. (2008) to be used to develop economic recommendations for fertilizer use. Boyer et al. (2015) demonstrated the ability of the Tembo et al. (2008) model to test the normality assumption of the year random effect, as applied in the determination of downside risk measures for crop insurance programs. Harmon (2016) introduced an estimation of the value of soil-test information by including testing costs in the net revenue function, thereby validating the recommendation to test fields regularly. More articles specifically in the context of developing producer recommendations include Roberts et al. (2011), Harmon et al. (2017), McFadden et al. (2017), and Ouedraogo and Brorsen (2018).

Data used to fit the model for the current study are from 99 K fertilization rate trials conducted in Arkansas. Fertilizer was applied as muriate of potash, in the spring, where a Mehlich-3 soil-test documented the initial soil-test K. These tests were conducted from 2004 to 2016. The data were reduced to only site-years where there were at least three rates of fertilizer-K being compared.

Procedures

By adopting and modifying the methodology of Tembo et al. (2008), the following equation determines the yield response function:

$$Y_{il} = min(\beta_0 + \beta_1 x_{1il} + \beta_2 x_{2il}, \mu_m + v_i) + \tau_i + \varepsilon_{il} \quad \text{Eq. 1}$$

where Y_{il} is the yield of the i^{th} site and the l^{th} potassium treatment level, x_{1il} is the soil-applied K rate, x_{2il} is the soil-test K, μ_m is the average plateau yield, $v_i \sim N(0, \sigma_v^2)$ is the plateau site random effect, $\tau_i \sim N(0, \sigma_\tau^2)$ is the site random effect,

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$\varepsilon_{il} \sim N(0, \sigma_\varepsilon^2)$ is a random error term, and β_0, β_1, and β_2 are intercept and slope parameters to be estimated. The three error terms in the model are assumed to be independent. Inclusion of the soil-test K variable ($\beta_2 x_{2il}$) in Eq. 1, is an extension of the methods developed in Tembo et al. (2008.)

To better understand μ_m, it is defined as

$$\mu_m = \beta_0 + \beta_1 x_m \quad \text{Eq. 2}$$

where x_m is the level or rate of soil-applied K needed to reach the plateau.

Now a profit maximizing objective function can be specified for the risk neutral producer:

$$E(\pi_{ik} \mid x_{1i}) = pE(y_{ik}) - r\, x_{1i} \quad \text{Eq. 3}$$

where subscripts follow the definitions above, $E(\pi_{ik} \mid x_{1i})$ is the expected profit conditional on the level of soil-applied K, $E(y_{ik})$ is the expected yield, and p and r are soybean prices and K prices, respectively.

Using the relationships defined in Eqs. 1 through 3, and following the estimation procedure outlined in Tembo et al. (2008), the optimal soil-applied, fertilizer-K rate is directly estimated for three market scenarios. Soybean prices of \$15.00, \$9.40, and \$7.00 per bushel are combined with prices of \$0.20, \$0.29, and \$0.38 per pound of K_2O to represent a best, current, and worst-case market scenario. The price ratios are compared to the current agronomic K rate recommendations for soybean in Arkansas, which include the soil-test categories of Very Low (≤60 ppm), Low (61–90 ppm), Medium (91–130 ppm), Optimum (131–175 ppm), and above Optimum (>175 ppm) based on Mehlich-3 soil-test K.

Results and Discussion

The model estimates for the economic optimum soil-applied fertilizer-K rate are presented in Fig. 1. As the soil-test K level increases from Very Low to Optimum, the recommended soil-applied fertilizer-K rate decreases, as expected. As the market situation becomes more favorable as marked by a higher soybean price and a lower fertilizer-K price, the recommendation is to apply more fertilizer K at each soil-test K level.

Figure 1 compares the current Arkansas fertilizer-K rate recommendations (Slaton et al., 2015), which are developed irrespective of cost and returns, to the different economic optimum soil-applied, fertilizer-K rates predicted for three price ratios. In the three price ratios presented, the economic optimum K rate calls for less soil-applied K than the Arkansas recommendations for soybean in each soil-test K level except the Medium level.

Practical Applications

This analysis evaluated the decision of how much fertilizer-K should be applied to a field intended for soybean production. Starting with a compilation of agronomic and soil-test information from field research, economic variables were introduced, and the crop response was modeled by a linear response stochastic plateau. Three market scenarios were evaluated, demonstrating the sensitivity of the economic optimum to input and output prices.

This research will increase decision-making capability using information already being collected and monitored. Soil-test levels can now be used to make economically informed decisions, where previously only agronomic insight was available to soybean producers. Future research should make better use of the data set. For the current study, yield was only reported at the treatment mean level. Using the plot level yield data would provide additional information for the model as well as be more consistent with Tembo et al. (2008) and much of the other research cited in this article.

Acknowledgments

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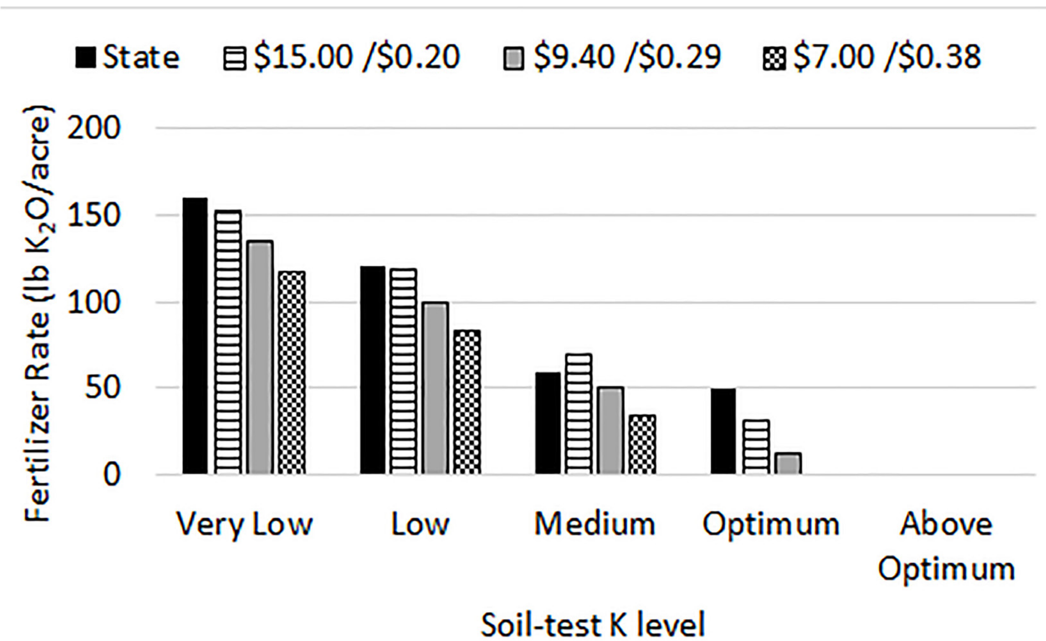

Fig. 1. Economic Optimum K fertilizer application rate across various market scenarios compared to the current agronomic K fertilizer rate recommendation. In the figure legend, 'State' refers to the current University of Arkansas System Division of Agriculture's Cooperative Extension Service K rate recommendation, irrespective of price ratio; legend price ratios are the bushel price for soybean / price per pound of K_2O).

Monitoring Potassium Losses in Runoff on Arkansas Discovery Farms: Findings from 2017 and 2018

A.N. Sharpley[1], M.B. Daniels[2], N.A. Slaton[1], L. Berry[1], L. Riley[2], and J. Burke[1]

Abstract

The Arkansas Discovery Farm Program has been in place since 2010. The Program focuses on documenting nutrient and sediment runoff from private working farms, using state-of-the-art water sampling equipment to quantify the effects of conservation practices on water quality. Currently, there are 12 Discovery Farms across Arkansas. There is little information on the loss of potassium (K) in runoff, which has the potential to hinder K-use efficiency and farm profitability by increasing K fertilizer needs. Thus, research described in this report was conducted to quantify K losses in edge-of-field runoff for row crop and livestock Discovery Farms and the spatial distribution of K in soils across fields. After monitoring for 15 months, mean K concentrations ranged from 4.75 to 16.35 mg/L, with the lowest concentrations measured in runoff from cotton (*Gossypium hirsutum* L.) with cereal rye (*Secale cereale* L.) cover crop and highest from conventionally tilled corn (*Zea mays* L.) fields. The loss of K in runoff from four poultry houses (41.0 lb/acre) decreased after passing through the 984-ft long grassed waterway (29.6 lb/acre). A better understanding of the fate and transport of K in soils with respect to decreasing loss in runoff has the potential to reduce K fertilizer inputs and thereby increase farm profitability.

Introduction

Arkansas Discovery Farms are real working farms that allow documentation of runoff of nutrients and sediments at the edge-of-field, using state-of-the-art automated water sampling devices, coupled with collection flumes that allow quantification of runoff volume. In 2017, we initiated monitoring of K losses in agricultural runoff from our Discovery Farm sites. While there is little information on K fate and transport in agricultural runoff, minimizing any losses is important to profitability and sustainability.

The goal of this project is to increase farm profitability by better understanding K dynamics in soil. Specific objectives are to: (a) quantify K losses in edge-of-field runoff for row crop and livestock Discovery Farms, and (b) quantify the spatial distribution of K in soils across fields and with depth. Data given in this report is from May 2017 (project initiation) through October 2018. As this project was initiated in May 2017, the information in this report is preliminary and few conclusions and interpretations can be drawn from 15 months of sample collection and analysis.

Procedures

Objective 1

Discovery Farms Description

Currently, there are 12 Discovery Farms located across Arkansas (Fig. 1). This report summarizes field K loss via runoff water results from multiple fields monitored on 5 Discovery Farms. More detail on site monitoring is given in Sharpley et al. (2018).

The Marley Farm is a poultry–beef grazing operation in the Beaver Lake–Upper White River Watershed. There are 10 poultry houses, with 1200 acres of pasture and about 1000 acres of woodland. We are monitoring runoff from 4 poultry houses that flow into a 3-acre pond and from 2 poultry houses where runoff flows through a pasture (cut for hay) into an ephemeral creek, connected to the White River.

The Morrow Farm is a beef rotational grazing operation in the Illinois River Watershed in Northwest Arkansas. We are monitoring runoff from grazed pasture, and two locations on a stream where it enters and exits the farm.

The Moore Farm is a poultry operation with 8 houses, 4 of which were newly constructed. There are 200 acres of corn grown on the farm. We worked with the farmer to design the new houses with a low nutrient footprint and install best management practices (BMPs) such as grassy waterways and larger concrete pads at the house entrance.

The Maus farm is a 940-acre row-crop farm in the Mississippi River Basin Healthy Watersheds Initiative (MRBI) focus watershed of Point Remove–Lake Conway, in Pope County. There are about 200 acres of wheat (*Triticum aestivum* L.), 240 acres of rice (*Oryza sativa* L.), 200 acres of corn, and 400 acres of soybean [*Glycine max* (L.) Merrill.]. We are monitoring runoff from 4 fields that have management ranging from cover crop, no cover crop, conservation tillage, and conventional tillage under a rotation of corn and soybean.

The Stevens Farm is a row-crop operation (about 1500 acres) concentrating on cotton and corn production and is located near Dumas in the Bayou Macon Watershed in Desha County. We are monitoring runoff from 4 cotton fields that benefit from a cereal rye cover crop and conservation tillage on nutrient runoff.

Only the Stevens Farm received K fertilizer every year (Table 1). At the other farms, nutrients were generally applied as poultry litter to meet forage requirements of mixed cool- and warm-season grasses (Table 1).

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[2] Professor and Technician I, respectively, Department of Crop, Soil, and Environmental Sciences, Little Rock.

Runoff-Water Collection and Analysis

Fifteen fields were monitored for runoff volume and quality. At the lower end of each field, automated, runoff water quality monitoring stations are in place to: 1) measure runoff flow volume; 2) collect water samples of runoff for water quality analysis; and 3) measure precipitation. A water sample is collected and processed in the field for preservation and shipped in insulated shipping vessels to keep samples chilled to meet EPA guidelines for sample collection, handling, preparation, and analysis. Samples are filtered (<0.45 µm) and the concentration of water-soluble K determined by the Arkansas Water Resources Laboratory (certified by the Arkansas Department of Environmental Quality, https://arkansas-water-center.uark.edu/water-quality-lab.php). More details of sample collection and treatment is available in Sharpley et al. (2018).

Results and Discussion

Runoff event dates, volume, concentration of K, and K loss from sites at the Marley, Morrow, Moore, Maus and Stevens Farms are presented in Tables 2, 3, 4, 5, and 6, respectively. The runoff, mean concentration of K, and total loss of K in runoff since the project began, are summarized in Table 7. Mean K concentrations ranged from 4.75 to 16.35 mg K/L, with the lowest concentrations measured in runoff from the Stevens cotton with cereal rye cover crop field and highest from the Moore cornfield (Table 7). Potassium concentrations varied little among fields at the Maus (5.27 to 6.88 mg K/L) and Stevens Farms (3.72 to 6.13 mg K/L), which were managed similarly.

The concentration and unit area loss of K in runoff from the 4 poultry houses (10.34 mg/L and 41.0 lb/acre, respectively) decreased after passing through the 984-ft long grassy waterway (8.62 mg/L and 29.6 lb/acre, respectively). At the Moore Farm, the average water-soluble K concentration was appreciably lower in runoff from the new poultry houses designed with a lower environmental footprint (9.97 mg K/L) than from the original poultry houses (16.22 mg K/L). Given that runoff from the new houses was less than half that from the original houses, the loss of K in runoff was lower from the new than original houses (58.2 and 10.2 lb K/acre, respectively; Table 7). Even with the paucity of information on K runoff, concentrations from the 5 Discovery Farms reported here are of a similar range to that in runoff from native grass (dominantly little bluestem, *Andropogon scoparius* Michx.) and wheat watersheds at El Reno, Okla. (<1 to 15 mg K/L; Sharpley et al., 1988).

Practical Applications

A better understanding of the dynamics of K in soils with respect to decreasing loss in runoff has the potential to reduce K fertilizer inputs and thereby increase farm profitability. Even though K loss is not considered a water quality concern, we need to acknowledge that altering management to minimize N and P losses in runoff can have unintended consequences on soil K and positively or negatively influence the overall soil fertility framework.

Acknowledgments

The authors acknowledge the financial support of the Arkansas Fertilizer Tonnage Fees, and the University of Arkansas System Division of Agriculture, making this research possible.

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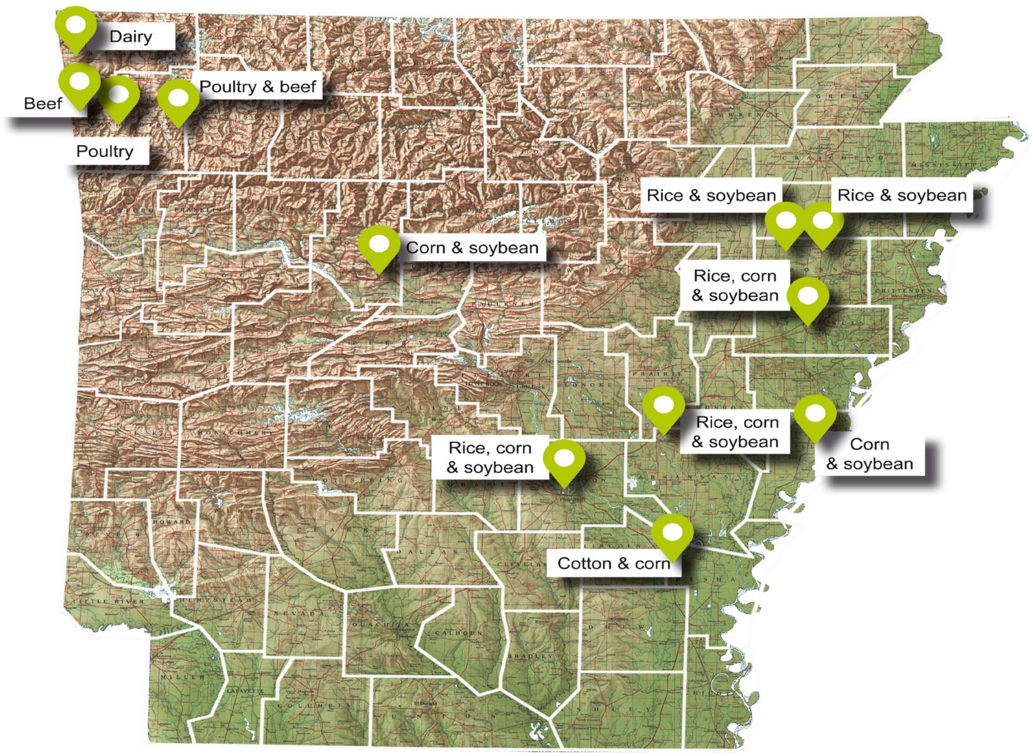

Relief map courtesy Arkansas Geological Survey

Fig. 1. Locations of Arkansas Discovery Farms.

Table 1. Field management and application of potassium for 2017 and 2018.

			Potassium management					
			Amount		Date		Method	
Farm	Field size	Management	2017	2018	2017	2018	2017	2018
	(acres)		-------- (lb) ---------					
Marley 1	17.4	Four poultry houses	- -	- -	- -	- -	- -	- -
Marley 2	3.6	Four poultry houses	- -	- -	- -	- -	- -	- -
Marley 3	7.9	Poultry houses after grassy waterway	68[a]	68[a]	Feb. 3	Mar. 10	Broadcast	
Morrow 1	24.0	Grazed pasture	68[a]	68[a]				
Morrow 2	35.2	Ephemeral stream flow entering farm	- -	- -	- -	- -	- -	- -
Morrow 3	158.0	Ephemeral stream flow leaving farm	- -	- -	- -	- -	- -	- -
Moore 1	30.7	Corn field	68[a]	68[a]	April 4	May 2	Broadcast	
Moore 2	2.4	Rear of original poultry houses	- -	- -	- -	- -	- -	- -
Moore 3	2.5	Front of original poultry houses	- -	- -	- -	- -	- -	- -
Moore 4	3.3	Front of new poultry houses	- -	- -	- -	- -	- -	- -
Maus 1	18.0	Corn with cover crop	135[b]	90[c]	June 16	Nov. 27	Broadcast	
Maus 2	19.0	Corn with cover crop	135[b]	90[c]	June 16	Nov. 27	Broadcast	
Maus 3	14.0	Corn with cover crop	135[b]	90[c]	June 16	Nov. 27	Broadcast	
Maus 4	20.0	Corn with cover crop	135[b]	90[c]	June 16	Nov. 27	Broadcast	
Stevens 1	37.0	Cotton w/cereal rye cover crop	81[d]	90[d]	May 10	May 29	Broadcast	
Stevens 2	22.0	Cotton w/cereal rye cover crop	81[d]	90[d]	May 10	May 29	Broadcast	
Stevens 3	37.0	Cotton w/cereal rye cover crop	81[d]	60[d]	May 10	May 29	Broadcast	
Stevens 4	42.0	Cotton without cover crop	81[d]	90[d]	May 10	May 29	Broadcast	

[a] Source of K applied was poultry litter at 1.5 tons/acre with assumed 2.25% K concentration.
[b] Source of K applied was poultry litter at 3 tons/acre with assumed 2.25% K concentration.
[c] Source of K applied was poultry litter at 2 tons/acre with assumed 2.25% K concentration.
[d] Source of K applied was custom blended fertilizer.

Table 2. Runoff, potassium concentrations, and loss in runoff from the Marley Farm, Elkins, Ark.

			Potassium in runoff		
Date sampled	Total runoff	Unit area runoff	Conc.	Loss	Load
	(gal)	(gal/acre)	(mg/L)	(lb/acre)	(lb)
Marley 1 – 17.4 acres – Runoff from four poultry houses					
5/22/2017	685,600	39,402	3.69	1.2	21.2
5/27/2017	205,600	11,816	6.64	0.7	11.5
6/5/2017	156,800	9011	7.68	0.6	10.1
6/18/2017	62,900	3615	12.39	0.4	6.5
7/4/2017	474,600	27,276	12.84	2.9	51.1
7/4/2017	238,100	13,684	5.52	0.6	11.0
8/14/2017	219,500	12,615	9.06	1.0	16.7
8/17/2017	262,900	15,109	6.78	0.9	15.0
2/21/2018	591,500	33,994	7.69	2.18	37.9
2/24/2018	810,100	46,557	5.02	1.95	33.9
2/27/2018	211,200	12,138	3.86	0.39	6.8
3/29/2018	550,600	31,644	2.18	0.58	10.0
4/14/2018	293,700	16,879	5.57	0.78	13.6
4/21/2018	191,200	10,989	2.34	0.21	3.7
5/3/2018	711,800	40,908	6.92	2.36	41.0
5/16/2018	221,200	12,713	7.84	0.83	14.4
6/24/2018	40,700	2339	9.49	0.19	3.2
7/30/2018	284,100	16,328	6.28	0.85	14.9
8/15/2018	207,400	11,920	7.31	0.73	12.6
8/19/2018	379,600	21,816	4.23	0.77	13.4
Marley 2 – 3.6 acres – Runoff from four poultry houses					
5/22/2017	339,090	94,192	3.42	2.7	9.7
5/27/2017	77,100	21,417	5.98	1.1	3.9
6/5/2017	38,710	10,753	10.00	0.9	3.2
7/4/2017	58,810	16,336	10.32	1.4	5.1
7/4/2017	58,970	16,381	5.94	0.8	2.9
8/15/2017	44,050	12,236	16.80	1.7	6.2
8/17/2017	91,280	25,356	8.31	1.8	6.4
2/21/2018	165,110	45,864	13.49	5.16	18.6
2/24/2018	208,680	57,967	8.32	4.02	14.5
3/29/2018	136,610	37,947	3.60	1.14	4.1
4/14/2018	130,050	36,125	13.23	3.98	14.3
4/21/2018	57,240	15,900	5.34	0.71	2.5
5/3/2018	560,090	155,581	4.75	6.16	22.2
5/16/2018	64,200	17,833	13.43	2.00	7.2
7/30/2018	60,920	16,922	36.02	5.08	18.3
8/19/2018	153,590	42,664	6.49	2.31	8.3
Marley 3 – 7.9 acres – Poultry houses after grass waterway					
5/22/2017	763,100	96,595	4.19	3.4	26.7
5/27/2017	117,700	14,899	7.3	0.9	7.2
6/5/2017	79,900	10,114	8.99	0.8	6.0
7/4/2017	76,300	9658	9.92	0.8	6.3
7/4/2017	7026	889	6.33	0.1	0.4
8/17/2017	158,700	20,089	7.40	1.2	9.8
2/21/2018	360,000	45,570	24.82	9.43	74.4
2/24/2018	453,500	57,405	11.55	5.53	43.6
2/27/2018	148,200	18,759	8.98	1.40	11.1
3/29/2018	236,800	29,975	3.27	0.82	6.5
5/3/2018	797,400	100,937	3.90	3.28	25.9
8/19/2018	279,100	35,329	6.79	2.00	15.8

Table 3. Runoff, potassium concentrations, and loss in runoff from the Morrow Farm, Wedington, Ark.

Date sampled	Total runoff	Unit area runoff	Potassium in runoff		
			Conc.	Loss	Load
	(gal)	(gal/acre)	(mg/L)	(lb/acre)	(lb)
Morrow 1 – 24 acres – Runoff from grazed pasture					
5/22/2017	132,220	5509	8.13	0.4	9.0
5/27/2017	46,482	1937	9.24	0.2	3.6
6/5/2017	68,650	2860	15.72	0.37	9.0
6/19/2017	22,610	942	19.28	0.2	3.6
2/21/2018	51,150	2131	8.67	0.15	3.7
2/24/2018	244,390	10,183	4.07	0.35	8.3
2/27/2018	19,320	805	4.48	0.03	0.7
3/29/2018	56,210	2342	2.46	0.05	1.2
5/3/2018	78,010	3250	4.84	0.13	3.1
8/19/2018	28,310	1180	10.96	0.11	2.6
Morrow 2 – 87 acres – Ephemeral stream flow entering Morrow Farm					
5/22/2017	3,045,260	35,003	5.33	1.6	135.4
5/27/2017	19,932	229	8.22	0.02	1.4
6/5/2017	19,920	229	9.20	0.02	1.5
8/14/2017	849,940	9769	8.26	0.7	58.5
8/17/2017	1,169,850	13,447	7.55	0.9	73.7
2/21/2018	1,466,330	16,854	7.48	1.05	91.4
2/24/2018	5,391,620	61,973	6.74	3.48	302.8
2/27/2018	516,450	5936	7.44	0.37	32.0
3/29/2018	1,110,260	12,762	6.03	0.64	55.8
5/3/2018	1,895,400	21,786	6.08	1.10	96.0
8/19/2018	186,000	2138	8.73	0.16	13.5
Morrow 3 – 158 acres – Ephemeral stream flow leaving Morrow Farm					
5/22/2017	4,813,650	30,466	6.50	1.6	260.9
5/27/2017	23,160	147	46.67	0.06	9.0
6/5/2017	218,491	1383	8.43	0.1	15.4
8/14/2017	127,829	809	11.77	0.1	12.5
8/17/2017	165,515	1048	8.72	0.1	12.0
2/21/2018	1,590,600	10,067	7.63	0.64	101.1
2/24/2018	7,255,870	45,923	7.10	2.72	429.2
2/27/2018	844,690	5346	7.27	0.32	51.2
3/29/2018	1,644,310	10,407	5.76	0.50	78.9
4/14/2018	279,760	1771	7.75	0.11	18.1
5/3/2018	3,522,500	22,294	6.52	1.21	191.3
8/19/2018	319,590	2023	8.14	0.14	21.7

Table 4. Runoff, potassium concentrations, and loss in runoff from the Moore Farm, Lincoln, Ark.

Date sampled	Total runoff	Unit area runoff	Potassium in runoff		
			Conc.	Loss	Load
	(gal)	(gal/acre)	(mg/L)	(lb/acre)	(lb)
Moore 1 – 30.7 acres – Runoff from corn field					
5/22/2017	797,443	25,975	18.38	4.0	122.4
6/5/2017	121,351	3953	17.70	0.6	17.9
7/4/2017	273,188	8899	30.96	2.3	70.6
8/6/2017	195,172	6357	17.44	0.9	28.4
8/14/2017	607,908	19,802	12.81	2.1	65.1
8/17/2017	590,368	19,230	14.30	2.3	70.5
2/21/2018	642,707	20,935	20.57	3.59	110.1
2/24/2018	2,632,017	85,733	15.38	10.99	337.3
2/27/2018	7574	247	12.82	0.03	0.8
3/29/2018	674,869	21,983	9.85	1.81	55.4
5/3/2018	1,049,516	34,186	9.59	2.73	83.9
Moore 2 – 2.4 acres – Runoff from rear of original poultry houses					
5/22/2017	98,487	41,036	6.35	2.1	5.1
6/5/2017	16,511	6880	8.43	0.5	1.1
7/4/2017	53,465	22,277	22.65	4.1	9.8
8/6/2017	64,785	26,994	18.23	4.0	9.6
8/14/2017	129,750	54,063	8.87	3.9	9.3
8/17/2017	94,965	39,569	7.52	2.4	5.8
2/21/2018	136,306	56,794	8.07	3.82	9.2
2/24/2018	215,847	89,936	6.99	5.24	12.6
3/29/2018	80,258	33,441	6.61	1.84	4.4
4/14/2018	7579	3158	10.40	0.27	0.7
5/3/2018	218,500	91,042	5.36	4.07	9.8
8/15/2018	91,701	38,209	9.54	3.04	7.3
8/19/2018	83,255	34,690	7.26	2.10	5.0
Moore 3 – 2.5 acres – Runoff from front of original poultry houses					
5/22/2017	95,595	38,238	9.14	3.0	7.4
6/5/2017	255,242	102,097	11.35	9.8	24.4
7/4/2017	48,803	19,521	37.65	6.2	15.5
8/6/2017	37,262	14,905	20.08	2.5	6.3
8/14/2017	59,705	23,882	9.54	1.9	4.8
2/21/2018	79,609	31,844	23.41	6.22	15.5
2/24/2018	227,874	91,150	14.32	10.88	27.2
2/27/2018	51,998	20,799	13.13	2.28	5.7
3/29/2018	38,567	15,427	10.81	1.39	3.5
5/3/2018	129,487	51,795	13.33	5.76	14.4
8/15/2018	90,904	36,362	11.08	3.36	8.4
8/19/2018	70,749	28,300	20.77	4.90	12.2
Moore 4 – 3.3 acres – Runoff from front of new poultry houses					
5/22/2017	176,231	53,403	5.16	2.4	7.8
6/5/2017	26,483	8025	6.54	0.5	1.5
6/19/2017	16,481	4994	9.73	0.4	1.4
8/6/2017	1993	604	5.87	0.03	0.1
8/14/2017	19,024	5765	6.43	0.3	1.1
2/27/2018	18,387	5572	11.17	0.52	1.7
4/14/2018	20,069	6082	10.51	0.53	1.8
4/21/2018	49,932	15,131	5.21	0.66	2.2
5/3/2018	211,711	64,155	2.95	1.58	5.2
6/24/2018	8659	2624	31.00	0.68	2.2
7/30/2018	10,943	3316	17.96	0.50	1.6
8/15/2018	120,730	36,585	7.05	2.15	7.1

Table 5. Runoff, potassium concentrations, and loss in runoff from the Maus Farm, Atkins, Ark.

Date sampled	Total runoff	Unit area runoff	Potassium in runoff Conc.	Potassium in runoff Loss	Potassium in runoff Load
	(gal)	(gal/acre)	(mg/L)	(lb/acre)	(lb)
Maus 1 – 18 acres – Runoff from corn field with cover crops					
5/28/2017	61,041	3391	3.22	0.09	1.64
6/4/2017	701,166	38,954	2.01	0.65	11.76
7/16/2017	298,825	16,601	4.39	0.61	10.94
8/14/2017	456,695	25,372	2.90	0.61	11.05
9/1/2017	150,978	8388	2.29	0.16	2.88
8/31/2017	10,836	602	4.20	0.02	0.38
9/7/2017	68,297	3794	3.61	0.11	2.06
9/15/2017	129,915	7218	3.26	0.20	3.53
9/22/2017	132,403	7356	3.54	0.22	3.91
10/2/2017	65,876	3660	4.16	0.13	2.29
2/17/2018	160,301	8906	5.30	0.06	1.10
4/16/2018	255,543	14,197	6.03	0.11	1.99
5/4/2018	87,292	4850	2.68	0.02	0.30
5/25/2018	411,993	22,889	2.05	0.06	1.09
6/2/2018	290,374	16,132	2.50	0.05	0.94
6/14/2018	40,435	2246	7.79	0.02	0.41
7/11/2018	106,906	5939	6.86	0.05	0.95
7/17/2018	540,696	30,039	2.75	0.11	1.92
7/18/2018	78,911	4384	2.59	0.01	0.26
7/21/2018	179,869	9993	3.97	0.05	0.92
8/2/2018	74,818	4157	7.21	0.04	0.70
8/10/2018	99,286	5516	7.33	0.05	0.94
8/14/2018	381,700	21,206	6.20	0.17	3.06
8/17/2018	248,764	13,820	5.63	0.10	1.81
9/22/2018	140,747	7819	21.69	0.22	3.95
10/10/2018	61,109	3395	15.00	0.07	1.19
Maus 2 – 19 acres – Runoff from corn field with cover crops					
5/28/2017	409,070	21,530	4.77	0.86	16.3
6/4/2017	925,461	48,708	3.05	1.24	23.5
6/27/2017	69,949	3682	4.48	0.14	2.6
7/3/2017	30,680	1615	5.47	0.07	1.4
7/16/2017	77,498	4079	5.40	0.18	3.5
8/14/2017	616,148	32,429	4.12	1.11	21.2
8/11/2017	302,562	15,924	5.31	0.70	13.4
9/1/2017	742,179	39,062	9.89	3.22	61.2
8/31/2017	52,852	2782	7.89	0.18	3.5
9/7/2017	38,028	2001	6.07	0.10	1.9
2/17/2018	251,283	13,225	4.62	0.08	16.27
4/16/2018	2,774,250	146,013	8.89	1.77	23.53
4/26/2018	270,970	14,262	4.66	0.09	2.61
5/4/2018	142,673	7509	4.47	0.05	1.40
5/16/2018	32,475	1709	5.13	0.01	3.49
7/1/2018	35,213	1853	7.00	0.02	21.16
7/6/2018	51,030	2686	10.41	0.04	13.39
7/12/2018	106,961	5630	8.15	0.06	61.20
7/12/2018	35,728	1880	11.33	0.03	3.48
7/17/2018	831,777	43,778	5.26	0.31	1.92
7/18/2018	671,546	35,345	4.66	0.22	1.59
7/21/2018	469,026	24,686	6.45	0.22	33.69
8/10/2018	373,703	19,669	3.76	0.10	1.72
8/14/2018	1,066,858	56,150	9.89	0.76	0.87
8/16/2018	659,615	34,717	7.48	0.35	0.23
9/21/2018	799,699	42,089	21.52	1.24	0.34
10/9/2018	190,100	10,005	17.22	0.24	0.73
10/13/2018	1,577,646	83,034	5.34	0.61	1.19
10/16/2018	200,633	10,560	4.23	0.06	0.55
10/25/2018	65,212	3432	4.36	0.02	5.98
10/31/2018	8571	451	5.24	0.00	4.27
11/2/2018	221,208	11,643	3.78	0.06	4.13

continued

Table 5. Continued.

Date sampled	Total runoff	Unit area runoff	Potassium in runoff		
			Conc.	Loss	Load
	(gal)	(gal/acre)	(mg/L)	(lb/acre)	(lb)
Maus 3 – 14 acres – Runoff from corn field with cover crops					
6/27/2017	24,492	1749	4.54	0.1	0.9
7/16/2017	260,927	18,638	4.62	0.7	10.1
8/14/2017	779,234	55,660	3.48	1.6	22.6
8/11/2017	182,614	13,044	3.76	0.4	5.7
9/1/2017	196,053	14,004	3.51	0.4	5.7
8/30/2017	127,784	9127	4.84	0.4	5.2
9/7/2017	51,248	3661	3.39	0.1	1.5
9/15/2017	100,957	7211	4.24	0.3	3.6
9/23/2017	244,532	17,467	4.34	0.6	8.9
10/2/2017	73,209	5229	3.53	0.2	2.2
2/17/2018	95,776	6841	4.34	0.03	0.42
2/20/2008	1,410,320	100,737	3.99	0.40	5.66
2/22/2018	705,727	50,409	3.45	0.18	2.45
2/28/2018	804,872	57,491	3.43	0.20	2.78
3/10/2018	303,261	21,662	3.57	0.08	1.09
3/29/2018	32,647	2332	4.54	0.01	0.15
4/9/2018	38,966	2783	6.43	0.02	0.25
4/16/2018	193,252	13,804	9.43	0.13	1.83
4/26/2018	112,938	8067	3.44	0.03	0.39
5/4/2018	47,046	3360	4.23	0.01	0.20
6/15/2018	142,723	10,195	5.02	0.05	0.72
6/29/2018	111,250	7946	4.81	0.04	0.54
7/6/2018	63,235	4517	5.88	0.03	0.37
7/12/2018	147,631	10,545	7.06	0.07	1.05
7/17/2018	329,575	23,541	2.97	0.07	0.99
7/21/2018	116,822	8344	4.23	0.04	0.50
8/10/2018	4511	322	6.78	0.00	0.03
8/14/2018	58,613	4187	8.73	0.04	0.51
8/19/2018	26,241	1874	4.85	0.01	0.13
9/21/2018	105,750	7554	28.90	0.22	3.08
10/9/2018	60,095	4293	15.67	0.07	0.95
10/13/2018	70,431	5031	7.33	0.04	0.52
10/31/2018	167,064	11,933	4.68	0.06	0.79
11/4/2018	29,234	2088	5.12	0.01	0.15
3/10/2018	303,261	21,662	3.57	0.08	1.09
Maus 4 – 20 acres – Runoff from corn field with cover crops					
7/16/2017	138,485	6924	5.31	0.1	2.8
8/14/2017	705,096	35,255	3.15	0.4	8.4
8/11/2017	73,196	3660	3.17	0.04	0.9
9/1/2017	152,468	7623	3.58	0.1	2.1
8/31/2017	202,398	10,120	5.06	0.2	3.9
9/7/2017	205,927	10,296	4.04	0.2	3.2
9/15/2017	285,464	14,273	4.20	0.2	4.5
10/2/2017	81,190	4059	4.27	0.1	1.3
2/17/2018	273,976	13,699	5.46	0.11	2.15
2/20/2008	2,588,568	129,428	6.33	1.18	23.56
2/22/2018	2,989,968	149,498	5.66	1.22	24.33
2/28/2018	1,065,524	53,276	5.06	0.39	7.75
3/10/2018	512,105	25,605	3.27	0.12	2.41
3/29/2018	174,841	8742	4.39	0.06	1.10
4/9/2018	85,808	4290	3.22	0.02	0.40
4/16/2018	356,902	17,845	7.46	0.19	3.83
4/26/2018	334,582	16,729	3.29	0.08	1.58
5/4/2018	126,259	6313	2.83	0.03	0.51
6/2/2018	262,083	13,104	1.74	0.03	0.66
7/17/2018	14,482	724	3.33	0.00	0.07
8/10/2018	163,549	8177	7.78	0.09	1.83
8/14/2018	862,083	43,104	4.59	0.28	5.69
8/17/2018	520,398	26,020	16.92	0.63	12.66
10/9/2018	85,188	4259	11.21	0.07	1.37
10/13/2018	387,702	19,385	7.34	0.20	4.09
10/31/2018	763,574	38,179	5.44	0.30	5.97
11/4/2018	50,083	2504	4.26	0.02	0.31

Table 6. Runoff, potassium concentrations, and loss in runoff from the Stevens Farm near Dumas, Ark.

Date sampled	Total runoff	Unit area runoff	Potassium in runoff Conc.	Loss	Load
	(gal)	(gal/acre)	(mg/L)	(lb/acre)	(lb)
Stevens 1 – 37 acres – Cotton with cereal rye cover crop					
5/20/2017	131,703	3560	10.91	0.10	3.82
5/24/2017	512,662	13,856	6.63	0.24	9.04
5/28/2017	277,607	7503	9.47	0.19	6.99
5/29/2017	315,174	8518	7.13	0.16	5.98
6/3/2017	463,465	12,526	10.10	0.34	12.45
6/22/2017	2,146,950	58,026	6.99	1.08	39.92
7/5/2017	987,782	26,697	8.07	0.57	21.20
7/18/2017	588,771	15,913	7.04	0.30	11.02
7/20/2017	480,306	12,981	5.54	0.19	7.08
8/1/2017	1,248,790	33,751	6.42	0.58	21.32
8/7/2017	1,911,490	51,662	6.59	0.91	33.50
8/13/2017	967,501	26,149	5.80	0.40	14.93
8/30/2017	4,438,640	119,963	5.89	1.88	69.54
1/15/2018	194,000	5243	5.73	0.08	2.96
1/23/2018	987,943	26,701	3.05	0.22	8.01
2/8/2018	2,339,390	63,227	2.31	0.39	14.37
2/11/2018	2,379,020	64,298	2.10	0.36	13.29
2/15/2018	1,488,670	40,234	1.84	0.20	7.29
2/20/2018	83,228	2249	3.47	0.02	0.77
2/22/2018	4,438,560	119,961	2.09	0.67	24.67
2/25/2018	1,170,300	31,630	2.78	0.23	8.65
3/1/2018	3,117,290	84,251	2.39	0.54	19.82
3/6/2018	839,467	22,688	4.73	0.29	10.56
3/12/2018	731,291	19,765	4.65	0.24	9.04
3/29/2018	693,781	18,751	2.18	0.11	4.02
4/4/2018	29,094	786	2.81	0.01	0.22
4/8/2018	558,678	15,099	1.08	0.04	1.60
4/23/2018	734,612	19,854	0.82	0.04	1.60
4/26/2018	204,679	5532	1.02	0.02	0.56
5/21/2018	29,377	794	1.25	0.00	0.10
5/22/2018	389,063	10,515	2.14	0.06	2.21
5/27/2018	29,705	803	2.07	0.00	0.16
6/21/2018	365,265	9872	3.22	0.08	3.13
6/24/2018	160,429	4336	2.04	0.02	0.87
6/28/2018	930,083	25,137	8.31	0.56	20.56
6/29/2018	200,390	5416	7.25	0.10	3.86
7/9/2018	1,078,010	29,135	6.43	0.50	18.44
7/15/2018	1,406,320	38,009	6.27	0.63	23.45
7/21/2018	1,277,830	34,536	5.94	0.55	20.19
7/29/2018	2,134,880	57,699	6.57	1.01	37.31
8/8/2018	3,389,070	91,596	6.41	1.56	57.78
8/18/2018	307,796	8319	3.11	0.07	2.55
8/21/2018	537,350	14,523	4.69	0.18	6.70
10/10/2018	375,160	10,139	4.58	0.12	4.57
10/27/2018	964,912	26,079	4.39	0.30	11.27
11/2/2018	245,650	6639	4.75	0.08	3.10
11/6/2018	456,723	12,344	3.87	0.13	4.70
Stevens 2 – 22 acres – Cotton with cereal rye cover crop					
5/20/2017	153,449	6975	35.73	0.39	8.67
5/23/2017	487,745	22,170	9.47	0.33	7.30
5/28/2017	233,102	10,596	12.87	0.22	4.74
5/29/2017	315,204	14,327	8.83	0.20	4.40
6/3/2017	302,351	13,743	8.48	0.18	4.05
6/22/2017	941,549	42,798	7.33	0.50	10.91
7/5/2017	347,434	15,792	6.00	0.15	3.30
7/7/2017	111,394	5063	6.01	0.05	1.06
7/7/2017	364,763	16,580	6.68	0.18	3.85
7/15/2017	190,037	8638	6.41	0.09	1.93
7/19/2017	92,828	4219	5.40	0.04	0.79
7/25/2017	207,037	9411	4.90	0.07	1.60
7/26/2017	65,785	2990	4.65	0.02	0.48
8/1/2017	272,931	12,406	5.50	0.11	2.37
8/4/2017	196,450	8930	4.76	0.07	1.48

continued

Table 6. Continued.

Date sampled	Total runoff	Unit area runoff	Potassium in runoff		
			Conc.	Loss	Load
	(gal)	(gal/acre)	(mg/L)	(lb/acre)	(lb)
Stevens 2 – 22 acres – Cotton with cereal rye cover crop continued					
8/7/2017	808,981	36,772	6.51	0.38	8.33
8/13/2017	915,559	41,616	5.23	0.34	7.57
8/28/2017	37,941	1725	12.80	0.03	0.77
8/30/2017	1,700,490	77,295	6.31	0.77	16.97
9/18/2017	98,824	4492	11.21	0.08	1.75
1/15/2018	83,632	3801	9.05	0.05	1.20
1/23/2018	266,742	12,125	10.48	0.20	4.42
1/28/2018	1598	73	3.97	0.00	0.01
2/11/2018	733,881	33,358	3.79	0.20	4.40
2/15/2018	633,912	28,814	2.86	0.13	2.87
2/22/2018	924,164	42,007	4.64	0.31	6.78
2/25/2018	294,478	13,385	4.22	0.09	1.97
3/1/2018	393,364	17,880	4.2	0.12	2.61
3/6/2018	177,893	8086	4.21	0.05	1.18
3/11/2018	195,117	8869	2.84	0.04	0.88
4/8/2018	1,549,160	70,416	4.96	0.55	12.15
4/16/2018	1,077,630	48,983	2.99	0.23	5.10
4/23/2018	572,856	26,039	2.86	0.12	2.59
4/26/2018	110,659	5030	5.18	0.04	0.91
6/21/2018	1,308,700	59,486	5.82	0.55	12.05
7/18/2018	167,334	7606	4.53	0.05	1.20
7/26/2018	193,102	8777	5.37	0.07	1.64
8/8/2018	72,847	3311	5.89	0.03	0.68
8/9/2018	551,351	25,061	4.48	0.18	3.91
8/18/2018	220,385	10,018	4.65	0.07	1.62
8/21/2018	273,755	12,443	3.54	0.07	1.53
10/27/2018	44,494	2022	3.56	0.01	0.25
11/2/2018	162,880	7404	4.12	0.05	1.06
11/6/2018	174,563	7935	3.89	0.05	1.07
Stevens 3 – 37 acres – Cotton with cereal rye cover					
5/20/2017	62,954	1701	16.43	0.07	2.75
5/24/2017	435,640	11,774	21.91	0.69	25.39
5/28/2017	238,684	6451	19.79	0.34	12.56
5/29/2017	371,989	10,054	13.38	0.36	13.24
6/3/2017	514,504	13,906	10.2	0.38	13.96
6/22/2017	1,045,050	28,245	9.82	0.74	27.30
7/5/2017	318,961	8621	7.1	0.16	6.02
7/16/2017	403,499	10,905	6.03	0.17	6.47
7/24/2017	703,786	19,021	4.13	0.21	7.73
8/2/2017	260,249	7034	4.87	0.09	3.37
8/5/2017	185,045	5001	4.05	0.05	1.99
8/7/2017	750,254	20,277	5.55	0.30	11.07
8/13/2017	1,202,150	32,491	5.84	0.50	18.67
8/28/2017	2,241,230	60,574	5.95	0.96	35.47
7/11/2018	1,304,930	35,268	2.57	0.24	8.92
7/18/2018	338,836	9158	3.81	0.09	3.43
7/27/2018	375,320	10,144	4.57	0.12	4.56
8/9/2018	1,952,940	52,782	6.76	0.95	35.11
8/18/2018	528,580	14,286	7.34	0.28	10.32
8/21/2018	651,297	17,603	5.60	0.26	9.70
10/10/2018	54,389	1470	5.21	0.02	0.75
10/27/2018	22,715	614	4.56	0.01	0.28
11/2/2018	233,209	6303	4.21	0.07	2.61
11/6/2018	342,817	9265	4.68	0.12	4.27
Stevens 4 – 42 acres – Cotton without cover					
5/20/2017	302,386	7200	11.4	0.25	10.41
5/22/2017	737,285	17,554	7.15	0.38	15.92
5/28/2017	421,473	10,035	12.48	0.38	15.88
5/29/2017	427,878	10,188	7.59	0.23	9.81
6/3/2017	546,764	13,018	11.39	0.45	18.80
6/22/2017	892,254	21,244	5.71	0.37	15.38
7/6/2017	973,439	23,177	6.11	0.43	17.96
7/16/2017	859,488	20,464	5.46	0.34	14.17

continued

Table 6. Continued.

Date sampled	Total runoff	Unit area runoff	Potassium in runoff		
			Conc.	Loss	Load
	(gal)	(gal/acre)	(mg/L)	(lb/acre)	(lb)
		Stevens 4 – 42 acres – Cotton without cover continued			
7/27/2017	222,190	5290	5.21	0.08	3.50
8/7/2017	925,246	22,030	7.37	0.49	20.59
8/13/2017	2,185,260	52,030	7.41	1.16	48.89
8/28/2017	88,662	2111	8.45	0.05	2.26
8/30/2017	2,482,460	59,106	8.01	1.43	60.04
9/18/2017	116,786	2781	21.63	0.18	7.63
1/15/2018	668,860	15,925	6.86	0.33	13.85
1/23/2018	911,999	21,714	7.11	0.47	19.58
1/28/2018	198,958	4737	6.87	0.10	4.13
2/8/2018	1,610,680	38,350	4.68	0.54	22.76
2/11/2018	2,447,330	58,270	4.04	0.71	29.85
2/15/2018	1,583,090	37,693	3.65	0.42	17.45
2/20/2018	103,340	2460	6.51	0.05	2.03
2/22/2018	3,056,680	72,778	8.07	1.77	74.48
2/25/2018	1,135,560	27,037	6.80	0.56	23.31
3/1/2018	2,443,200	58,171	7.67	1.35	56.58
3/6/2018	876,220	20,862	9.60	0.60	25.40
3/11/2018	1,031,520	24,560	7.56	0.56	23.54
3/29/2018	1,476,730	35,160	5.34	0.57	23.81
4/4/2018	182,043	4334	6.48	0.08	3.56
4/8/2018	1,643,380	39,128	2.80	0.33	13.89
4/16/2018	860,359	20,485	4.27	0.26	11.09
4/23/2018	912,902	21,736	2.10	0.14	5.79
5/22/2018	1,577,400	37,557	2.25	0.26	10.72
5/27/2018	180,250	4292	3.45	0.04	1.88
6/21/2018	281,778	6709	4.64	0.09	3.95
6/28/2018	518,974	12,357	7.45	0.28	11.67
6/29/2018	52,305	1245	10.57	0.04	1.67
7/7/2018	772,518	18,393	5.21	0.29	12.15
7/14/2018	774,413	18,438	5.76	0.32	13.47
7/21/2018	454,978	10,833	5.85	0.19	8.04
7/28/2018	371,327	8841	6.68	0.18	7.49
7/29/2018	132,123	3146	9.56	0.09	3.81
8/9/2018	1,691,070	40,264	6.82	0.83	34.82

Table 7. Runoff, potassium concentrations, and loss in runoff at each site for events measured in 2017 and 2018.

Farm	Field size	Treatment	Total runoff	Total unit area runoff	Potassium in runoff		
					Conc.	Loss	Load
	(acres)		(total acre-inches)	(acre-inches/acre)	(mg/L)	(lb/acre)	(lb)
Marley 1	17.4	Four poultry houses	250.4	14.4	6.67	20.4	349
Marley 2	3.6	Four poultry houses	82.6	23.0	10.34	41.0	147
Marley 3	7.9	Poultry houses after grassy waterway	128.1	16.2	8.62	29.6	234
Morrow 1	24.0	Grazed pasture	27.5	1.1	8.79	1.87	45
Morrow 2	35.2	Ephemeral stream flow entering farm	577.1	16.4	7.37	9.91	862
Morrow 3	158.0	Ephemeral stream flow leaving farm	766.1	4.8	11.02	7.61	1201
Moore 1	30.7	Corn field	279.6	9.1	16.35	31.37	962
Moore 2	2.4	Rear of original poultry houses	47.7	19.9	9.71	37.33	90
Moore 3	2.5	Front of original poultry houses	43.8	17.5	16.22	58.15	145
Moore 4	3.3	Front of new poultry houses	25.1	7.6	9.97	10.19	34
Maus 1	18.0	Corn with cover crop	192.8	10.7	5.35	4.00	72
Maus 2	19.0	Corn with cover crop	519.3	27.3	6.88	14.16	269
Maus 3	14.0	Corn with cover crop	265.6	19.0	5.86	6.56	92
Maus 4	20.0	Corn with cover crop	495.9	24.8	5.27	6.36	127
Stevens 1	37.0	Cotton w/cereal rye cover crop	1794.9	48.5	4.75	16.36	605
Stevens 2	22.0	Cotton w/cereal rye cover crop	663.92	30.2	6.53	7.47	164
Stevens 3	37.0	Cotton w/cereal rye cover crop	535.42	14.5	7.17	7.19	266
Stevens 4	42.0	Cotton without cover crop	1441.08	34.3	7.02	17.67	742

Cover Crop and Phosphorus and Potassium Effects on Soil-Test Values and Cotton Yield

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Abstract

The addition of cover crops into crop rotations may influence soil-test P and K and crop yield to fertilization. This report summarizes year 2 results focused on examining cotton yield response to cover crop and fertilizer-P and -K rates and the influence of cover crop on changes in selected soil chemical properties due to cover crop growth. Research was conducted at two locations with soil samples collected near the times of cover crop establishment and termination. Cotton was grown following cover crop termination with the first annual P and K applications made to subplot fertilizer treatments. The mean aboveground nutrient content of cereal rye at termination contained the equivalent of 33 lb P_2O_5 and 153 lb K_2O/acre at one site not damaged by foraging geese indicating substantial nutrient uptake can occur from fall and winter cover crop growth. At this site, soil-test K decreased 33 ppm following cereal rye and 16 ppm following winter fallow indicating soil-test results were affected by temporal and cover crop effects. Cotton yield was increased from 5% to 35% from K fertilization at both sites.

Introduction

Cover crop inclusion in crop rotations has the potential benefits of reducing soil erosion, recycling mobile soil nutrients, reducing weed pressure, and increasing soil organic matter (Shipley et al., 1992). Research investigating the effects of cover crops on soil nutrient availability has focused on nitrogen (N) availability to the subsequent summer-grown, cash crop. Less time and effort have been devoted to examining the effect of cover crop on soil-test properties and crop response to P and K fertilization. Carver et al. (2017) reported no effect of cover crop on soil-test P and K in Kansas when soil samples were collected after summer crop harvest. In Arkansas, soil samples for crops to be grown the following year may be collected soon after summer crop harvest in the fall months or during the winter months. Slaton et al. (2018) showed that soil-test P and K changed minimally across fall and winter months when soil samples were collected following soybean (*Glycine max*), but soil-test K increased from rice (*Oryza sativa*) harvest until December at which time it plateaued. In general, soil-test P was relatively constant across time probably because harvested grain removes a large proportion of P taken up by crops and P in crop residue is slowly released as residue decomposes. These results suggest that soil-test K might change significantly across time following the harvest of high residue crops like corn (*Zea mays*) and rice as the K in crop residue leaches into the soil with rainfall. The presence of an actively growing cover crop, especially crops that accumulate substantial biomass, could change soil-test K dynamics across time and influence soil-test-based fertilizer recommendations.

The goal of this research is to establish long-term plots cropped to corn, cotton (*Gossypium hirsutum*), and soybean that receive different annual P and K rates and are grown with or without a cereal rye (*Secale cereal*) cover crop to monitor short- and long-term changes in soil chemical properties and soil health. Slaton et al. (2018) summarized year 1 results from this project, which focused on examining the uniformity of initial soil chemical properties, soil health parameters, and crop yield. This report summarizes year 2 results focused on examining cotton yield response to cover crop and P and K fertilizer rates and the influence of cover crop on changes in selected soil chemical properties between soil samples collected in the fall at cover crop establishment and spring at cover crop termination.

Procedures

Trials were established in 2017 at the University of Arkansas System Division of Agriculture's Rohwer Research Station (RRS) in a 5.7 acre field having soils classified as Herbert silt loam (59%), McGehee silt loam (19%) and Sharkey and Desha clay (22%) and a 10-acre field at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station (LMCRS) having Calloway (54%), Loring (28%), and Memphis (1%) and Marvell (16%) soil series (Slaton et al., 2018). At each site, the plots were 4-rows (38-in spacing) wide and extended the length of the field, approximately 260 ft at LMCRS and 220 ft at RRS. Each experiment was a randomized complete block with a split-plot treatment structure where cover crop (with or without) was the main plot and fertilizer rate was the subplot. Corn was the first crop grown in 2017. Following corn harvest in fall 2017, the cover crop treatments were established by planting cereal rye on 20 October (65 lb/acre) at the RRS and 11 October (98 lb/acre) at LMCRS. Two composite soil samples (0–6 in. depth) were collected from each plot (30 November or 6 December) representing the east and west sides of the field area about 80 ft from the field middle where crop yield is measured, which leaves 30 to 50 ft on the ends of each plot. A second set of soil samples was collected from the same areas on 20 March at RRS

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and 22 March at LMCRS to examine the effect of cover crop growth and sample time on selected soil chemical properties. The soil samples were analyzed for soil pH and Mehlich-3 extractable nutrients.

In the P trial at each location, samples of cereal rye were also collected to measure aboveground nutrient content of the cereal rye immediately before cover crop termination with glyphosate. Two samples, one from the east side and one from the west side of each plot, having visual growth representative of each plot were composited by cutting a 3.3-ft section from one drill row in the top center of the bed of each plot (4.1 ft^2 sample area/plot). Samples were dried to a constant moisture, ground to pass a 2-mm sieve, digested with concentrated nitric acid, and digests were analyzed for nutrient concentrations.

The P and K fertilizer treatments were applied to the soil surface for the first time at each site on 22 March at RRS and 20 April at LMCRS. The P and K fertilizer treatments were applied using a 12-ft wide drop spreader (Gandy Company, Owatonna, Minn.) following calibration to apply the lowest rate. The intermediate and high rates were applied by a second or third pass, respectively, across the plot. Blanket applications of P (46 or 92 lb P_2O_5/acre at RRS and LMCRS, respectively) were applied to the K trial and K fertilizer was applied to the P trials (120 lb K_2O/acre). Cotton was planted on 3 May at RRS (Stoneville 5122 GLT emerged 9 May) and 7 May at LMCRS (Stoneville 4949 GLT).

The cotton at each site received recommended pest control and N fertilization but received no other fertilizer nutrients. At the LMCRS, 92 lb N/acre as urea was applied to the soil surface on 6 June. No rainfall occurred for the next 8 days suggesting that some ammonia loss may have occurred. Cotton was harvested on 30 September. At the RRS, corn received applications of 75 lb N/acre as 32% urea-ammonium nitrate knifed into the edge of the bed on 29 May and again on 7 June. Cotton was harvested on 1 October. Seedcotton yield was measured by harvesting the two middle rows in three, 45-ft long sections located in the middle of each plot. Following cotton harvest, cereal rye was planted 4 December 2018 at LMCRS and due to wet field conditions, was not planted (as of 4 January 2019) at RRS.

The effect of cereal rye growth and nutrient uptake on soil-test P and K was evaluated by calculating the difference between spring and fall sample means from each plot (fall 2017–spring 2018). The soil-test difference in fall and spring soil-test properties, cereal rye dry matter, aboveground nutrient uptake and seedcotton yield were analyzed using the MIXED procedure of SAS v. 9.4 (SAS Institute, Cary, N.C.), using cover crop as the main plot, fertilizer treatment as the subplot and replicate as a random effect. The analysis of variance (ANOVA) was performed by nutrient and site. Differences were interpreted as significant when the 2-way ANOVA P-value was ≤ 0.10.

Results and Discussion

Cereal rye dry matter, nutrient concentrations and aboveground nutrient content was similar among the planned fertilizer-P treatments within each of the two sites (Table 1). No differences were expected since no fertilizer treatments were applied in 2017. The mean aboveground nutrient content of cereal rye was the equivalent of about 33 lb P_2O_5 and 153 lb K_2O/acre at RRS and 4 lb P_2O_5/acre and 33 lb K_2O/acre at LMCRS indicating substantial nutrient uptake can occur from fall and winter cover crop growth. Nutrient uptake might have been greater had geese not grazed on the forage. The K trials were not sampled because these plots were further away from the farm shop and geese had grazed these plots nearly to the ground.

At the LMCRS, soil-test P of fall 2017 samples was not affected by the main effects or their interaction (Table 2). In Spring 2018, the cover crop main effect significantly affected soil-test P. Soil-test P declined by 4 ppm following cereal rye but declined by <1 ppm following winter fallow. Despite soil-test K variability within the trial area between cover-crop treatments for soil samples collected in the fall 2017 and spring 2018, the differences for K and S were not significant at LMCRS. No or only small differences in soil-test properties were expected at LMCRS due to the low biomass produced by the cereal rye cover crop.

At the RRS, soil-test P in fall 2017 samples and spring 2018 was not affected by the main effects or their interaction, but the cover crop main effect was significant for the difference in soil-test P (Table 3). Soil-test P following the cereal rye cover crop actually increased by 2 ppm but decreased by 2 ppm following winter fallow. Like the LMCRS, soil-test K and S for fall 2017 and spring 2018 samplings showed some variability among main effects within the trial area. The calculated differences for K and S would account for variability across time and both showed significant effects due to cover crop (K and S), the planned P rate treatment (K and S, results not shown) and their interaction (S only, not shown). Soil-test K decreased by 33 ppm following cereal rye growth and 16 ppm following winter fallow indicating a temporal effect and cover crop effect. Soil-test S was essentially unchanged following winter fallow but increased by 2 ppm following cereal rye.

Overall, the fall 2017 and spring 2018 soil-test P values at LMCRS suggested that cotton would not respond to P since soil-test P was considered Medium (26–35 ppm, Table 2). Fertilizer-P rate and the interaction between P rate and cover crop had no significant effect on seedcotton yield at LMCRS (Table 4). Averaged across the fertilizer rates, cotton planted following cereal rye (1930 lb/acre) produced lower yields than cotton following winter fallow (2381 lb/acre). In the K rate trial, a cotton yield increase to K fertilization was expected as soil-test K was considered Low (61–90 ppm) in the fall 2017 and Very Low (<61 ppm) in spring 2018 (Table 2). Seedcotton yield was affected by fertilizer-K rate and the cover crop by K rate interaction (Table 5). In general, seedcotton yield was greater following winter fallow than following cover crop when moderate to high fertilizer-K rates were applied and seedcotton yield tended to be lower following winter fallow than following cereal rye when no fertilizer-K was applied.

The fall 2017 and spring 2018 soil-test P values at RRS suggested that cotton would not respond to P since soil-test P was considered Optimum (36–50 ppm, Table 3). Cotton yield was affected by the interaction between fertilizer-P rate and cover crop treatments (Table 4). The interaction showed a trend for yields to be numerically higher following cereal rye at most of the applied fertilizer-P rates (Table 4). In the K trial, a cotton yield increase to K fertilization was not likely since soil-test K was considered Optimum (131–175 ppm) in the fall 2017 and Medium (91–130 ppm) in spring 2018 (Table 2). The ANOVA showed that seedcotton yield was not affected by cover crop or the interaction, but averaged across cover crop treatments, was affected by fertilizer-K rate (Table 5). Application of K fertilizer, regardless of rate resulted in a yield increase of 192 to 229 lb/acre or 5% to 6% above the yield of cotton receiving no K.

Practical Applications

When cotton was treated uniformly in all management aspects except winter cover crop, seedcotton yield was generally not affected by P fertilization rate on two soils having Medium to Optimum soil-test P values. Seedcotton yields were increased by K fertilization at both sites with the magnitude of yield response to K fertilizer being greatest at LMCRS where the soil had the lowest initial soil-test K. The presence of the cereal rye cover crop did cause a significant change between soil samples collected in the fall at cover crop establishment and the spring at cover crop termination. The dynamics of crop N nutrition and N loss mechanisms may have been affected by the cover crop and caused some of the potential differences among treatments. The results of this one trial are not sufficient to make recommendations from, but growers should probably collect soil samples during late fall or early winter (e.g., November–early December) before cover crops accumulate substantial biomass and nutrient uptake. This sample time may provide the most accurate assessment of soil-K availability.

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Table 1. Analysis of variance *P*-values and means for cereal rye dry matter, concentration of selected nutrients, and aboveground content of P, S, and K at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station (LMCRS) and Rohwer Research Station (RRS) in March 2018 before cover crop termination.

	LMCRS		RRS	
Measurement	Fertilizer rate	Mean	Fertilizer rate	Mean
	(*P*-value)		(*P*-value)	
Dry matter (lb/acre)	0.7889	1534	0.9862	5536
P, %	0.7430	0.258	0.6882	0.266
K, %	0.3172	1.774	0.2577	2.24
Ca, %	0.5620	0.157	0.3606	0.218
Mg, %	0.5754	0.117	0.4678	0.155
S, %	0.4168	0.0993	0.5148	0.119
Fe, ppm	0.1575	66	0.9939	58
Mn, ppm	0.5560	79	0.7743	75
Zn, ppm	0.4469	10.0	0.9896	15.8
Cu, ppm	0.9110	3.6	0.8165	4.8
B, ppm	0.7693	1.1	0.8850	2.5
P Content (lb/acre)	0.8385	4.0	0.9997	14.6
S Content (lb/acre)	0.8767	1.5	0.9307	6.6
K Content (lb/acre)	0.8665	27	0.8065	125

Table 2. Analysis of variance *P*-values and overall mean values of elected soil properties in fall 2017 and spring 2018 as the difference between soil sample dates in the North Research Area of Field B-1-N (Phosphorus Trial) at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station.

Soil property	Fall 2017 soil samples					Spring 2018 soil samples				
	Block	CC†	FR‡	CCxFR	Mean	Block	CC	FR	CCxFR	Mean
Soil pH	0.0001	0.0001	0.0875	0.6616	7.1	0.1119	0.3618	0.8277	0.8932	7.1
P (ppm)	0.0001	0.8624	0.2146	0.9592	30	0.0001	0.0013	0.4422	0.9102	28
K (ppm)	0.0261	0.0045	0.8875	0.4846	67	0.3127	0.0214	0.3823	0.5975	58
Ca (ppm)	0.0004	0.2413	0.4265	0.7120	1062	0.0001	0.0579	0.5330	0.8927	916
Mg (ppm)	0.0001	0.1944	0.9877	0.6763	314	0.0008	0.0711	0.9954	0.8224	275
S (ppm)	0.3934	0.2070	0.3202	0.5928	6.5	0.2622	0.0930	0.4670	0.5825	5.9
Fe (ppm)	0.0003	0.9926	0.4344	0.6858	161	0.00010	0.2301	0.4447	0.8063	169
Mn (ppm)	0.0001	0.1801	0.9408	0.7020	91	0.0001	0.3257	0.9450	0.8231	112
Cu (ppm)	0.0001	0.2947	0.1759	0.0653	0.9	0.0001	0.1204	0.5026	0.8202	0.8
Zn (ppm)	0.0001	0.0531	0.7488	0.8307	0.9	0.0001	0.0262	0.3901	0.92100	1.0
B (ppm)	0.0001	0.0142	0.7127	0.5110	2.0	0.0101	0.0231	0.6971	0.4990	0.1
P Diff	--	--	--	--	--	0.9546	0.0648	0.85111	0.9409	2.5
K Diff	--	--	--	--	--	0.2364	0.7958	0.7320	0.9886	9.0
S Diff	--	--	--	--	--	0.9741	0.7362	0.7841	0.8343	0.6

† CC, cover crop, main-plot effect.
‡ FR, Fertilizer rate, subplot effect.

Table 3. Analysis of variance *P*-values and overall mean values of selected soil properties in fall 2017 and spring 2018 as the difference between soil sample dates in the North Research Area of Field 1-D (Phosphorus Trial) at the University of Arkansas System Division of Agriculture's Rohwer Research Station.

Soil property	Fall 2017 soil samples					Spring 2018 soil samples				
	Block	CC†	FR‡	CCxFR	Mean	Block	CC	FR	CCxFR	Mean
Soil pH	0.1687	0.0047	0.1232	0.9984	6.7	0.6117	0.0013	0.8786	0.5223	6.7
P (ppm)	0.0001	0.2399	0.7485	0.9160	43	0.0001	0.1340	0.8119	0.8933	44
K (ppm)	0.0001	0.6674	0.0068	0.0597	141	0.0016	0.0010	0.2957	0.0746	116
Ca (ppm)	0.3551	0.2082	0.0224	0.9986	936	0.2920	0.9318	0.7617	0.2295	856
Mg (ppm)	0.0001	0.8823	0.0588	0.9958	137	0.0006	0.6635	0.8276	0.5676	131
S (ppm)	0.0004	0.0021	0.5698	0.0150	6.2	0.0996	0.0023	0.2085	0.1802	7.4
Fe (ppm)	0.0001	0.6725	0.7389	0.9652	233	0.0001	0.0001	0.8289	0.9505	318
Mn (ppm)	0.0001	0.0044	0.7186	0.2335	76	0.159	0.0001	0.6929	0.8584	131
Cu (ppm)	0.0003	0.7539	0.4103	0.9930	2.4	0.0130	0.2430	0.2163	0.7716	2.2
Zn (ppm)	0.0002	0.2712	0.1543	0.2671	0.5	0.2733	0.8669	0.8218	0.7554	0.7
B (ppm)	0.0001	0.0001	0.9097	0.5230	0.9	0.3794	0.0488	0.7805	0.5693	0.3
P Diff	--	--	--	--	--	0.0002	0.0002	0.6354	0.2908	-0.5
K Diff	--	--	--	--	--	0.1089	0.0003	0.0069	0.1328	25
S Diff	--	--	--	--	--	0.2030	0.0001	0.0209	0.0280	-1.0

† CC, cover crop, main-plot effect.
‡ FR, Fertilizer rate, subplot effect.

Table 4. Seedcotton yield as affected by assigned annual P rate, cereal rye cover crop, and their interaction during the second year of long-term trials at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station (LMCRS) and Rohwer Research Station (RRS) in 2018.

	LMCRS			RRS		
Annual P rate[†]	**Fallow**	**Cereal rye**	**Rate mean**	**Fallow**	**Cereal rye**	**Rate mean**
(lb P_2O_5/acre)	---(lb seedcotton/acre)---					
0	2379	1900	2139	3361 b[‡]	3881 a	3621
40	2379	1939	2159	3445 b	3795 a	3620
80	2358	1776	2067	3656 ab	3704 a	3680
120	2403	1985	2194	3725 a	3674 a	3699
CC Mean	2382 a	1905 b	NS	3547	3763	--
P rate	0.2603			0.8684		
Cover crop	0.0159			0.2100		
Interaction	0.5779			0.0670		
C.V., %	5.8			6.2		

[†] Fertilizer rates were applied for the first time in 2018.
[‡] Different lowercase letters next to means within a site indicate significant differences ($P \leq 0.10$).

Table 5. Seedcotton yield as affected by assigned annual K rate, cereal rye cover crop, and their interaction during the second year of long-term trials at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station (LMCRS) and Rohwer Research Station (RRS) in 2018.

	LMCRS			RRS		
Annual K rate[†]	**Fallow**	**Cereal rye**	**Rate mean**	**Fallow**	**Cereal rye**	**Rate mean**
(lb K_2O/acre)	---(lb seedcotton/acre)---					
0	1906 g[‡]	2282 def	2094 c	3720	3945	3832 b
60	2419 cdef	2622 bc	2521 b	3974	4133	4054 a
120	3001 ab	2421 cde	2711 ab	3921	4127	4024 a
180	3176 a	2488 cd	2832 a	4080	4043	4062 a
Mean	2626	2453	--	3824	4062	--
K rate	<0.0001			0.0510		
Cover crop	0.4228			0.5473		
Interaction	0.0002			0.5705		
C.V., %	6.1			4.8		

[†] Fertilizer rates were applied for the first time in 2018.
[‡] Different lowercase letters next to means within a site indicate significant differences ($P \leq 0.10$).

Corn Yield and Soil-Test Responses to Annual Fertilization with Different Phosphorus- and Potassium-Containing Fertilizers

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Abstract

Multi-nutrient fertilizers make for convenient blending and application of multiple macronutrients, secondary nutrients, and micronutrients in a single application. This research investigated corn (*Zea mays* L.) yield and soil-test response to annual fertilization with different phosphorus (P) and potassium (K) sources involving traditional fertilizers or multi-nutrient fertilizers and represented the sixth year of this trial. The trial was a 3 (P and K source) by 4 (P rate) factorial compared to a N fertilizer only control. The fertilizer sources were monoammonium phosphate (MAP), MAP + muriate of potash (MOP), or MicroEssentials (MESZ, 10-40-0-10-S-1Zn) plus Aspire (0-0-58-0.5B) and MOP. When K was included in the treatment, 120 lb K_2O/acre was applied as MOP or a 50:50 blend of MOP + Aspire. The annual P rates for each source ranged from 30 to 120 lb P_2O_5/acre/year. Corn yield was greatest when fertilized with MESZ + Aspire/MOP (230 bu/acre) and least when fertilized with only MAP (163 bu/acre). Regardless of fertilizer source, the greatest yield was produced from the application of 30 lb P_2O_5/acre/year (206 bu/acre), and application of no P (188 bu/acre) or 120 lb P_2O_5/acre/year (184 bu/acre) produced the lowest overall yield. Annual application of MESZ and Aspire have increased soil-test S, Zn, and B compared to treatments that have received fertilizers lacking these nutrients.

Introduction

Farmers now have more fertilizer options for crop fertilization than at any time in modern farming history. Chemical companies have developed numerous liquid fertilizer sources, multi-nutrient granular sources, and enhanced efficiency fertilizers in effort to increase crop yields, increase fertilizer nutrient uptake efficiency, increase market share, satisfy customer demands, or combinations of these reasons. Many of these fertilizers are marketed with limited field research or using logic that is based on sound agronomic concepts that lack research to validate the effectiveness of the new fertilizers or fertilization strategies compared to existing fertilization approaches. For example, secondary nutrients and micronutrient deficiencies are believed by many to be increasing and required for high yield production. Research-based recommendations using secondary and micronutrient soil-test results may not exist or, when they do exist, may or may not support claims that their use consistently results in crop yield benefits.

Many of the long-term fertilization plots in the U.S. focus on lime, nitrogen, phosphorus, and potassium fertilization and provide invaluable information regarding the long-term implications of management of these soil chemical properties and crop yield. Unfortunately, many of these long-term fertilization plots lack secondary and micronutrient treatments. Sulfur (S), zinc (Zn), and boron (B) can limit crop yields in Arkansas and their deficiency has been noted in other crop-producing states within the U.S. In other cases, unbiased research has failed to find a crop yield benefit from application of fertilizers containing these secondary nutrients and micronutrients. Research presented in this report addresses whether annual use of multi-nutrient fertilizers that supply P, K, S, Zn, and B are beneficial compared to fertilization strategies that include only P and K or P only. A second component of this research addresses whether application of low, moderate, or high annual rates of P fertilizer influence crop yield and interact with the applied micronutrients.

Procedures

The experiment was established in spring 2013 on a soil mapped as a Calloway silt loam at the University of Arkansas System Division of Agriculture's Pine Tree Research Station with details of the first five years reported by Slaton et al. (2018). Only the details for the 2018 trial are provided in this report. The individual plots are 30-ft long by 12.5-ft wide plots (five, 30-in. wide beds) and the treatments were applied to the same plots as originally assigned. Following harvest of the 2017 soybean crop, the top of the beds were knocked down with a rototiller and in the spring of 2018, fertilizer treatments were applied and the beds were reformed before planting. Polymer-coated urea (ESN, Nutrien, Saskatoon, SK Canada) was broadcast-applied preplant before beds were repulled. Another 60 lb N/acre as urea was broadcast-applied on 24 May 2018. Selected soil properties of soil receiving only N fertilizer are listed in Table 1.

The 14 fertilizer treatments are listed in Table 2. The only change in treatments from prior years was that 120 lb K_2O/acre was applied (increased from 90 lb K_2O/acre) to the treatments (treatments 3–14) receiving either muriate of potash (MOP) or Aspire and, for treatments 11–14, the Aspire rate was limited to 100 lb fertilizer/acre with the balance of the K_2O rate supplied as MOP. The overall design of the trial is a randomized complete block, 3 (P and K source) by 4 (P rate) factorial with two fertilizer-N only controls. Armor 1414 corn hybrid was planted 11 April 2018 with a target seed population of 35,000/acre.

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Soil samples were collected 13 Feb. 2018 from the 0- to 4-in. depth from selected treatments to assess the effect of fertilizer treatments on soil chemical properties (Table 1). To be consistent with plots sampled in previous years, soil samples were collected from treatments 2, 4, 8, 11, 12, 13, and 14. Treatments 4, 8, and 12 allow comparison of soil properties among treatments that have always received 60 lb P_2O_5 as monoammonium phosphate (MAP; 4 and 8) or MicroEssentials (MESZ; 12), but different amounts of Zn, S, B, and K. Comparison of treatments 11 through 14 allow examination of the effect of annual applications of increasing rates of P, S, Zn, and B. A composite soil sample was also collected from the 0- to 6-in. depth from the N only treatment to examine soil property differences between two common soil sample depths.

Analysis of variance (ANOVA) was performed on selected soil test properties and corn yield data using the 3 by 4 factorial treatment structure compared to the N fertilizer only treatment (Table 2, treatment 4). Soil chemical properties from the 0- to 4- and 0- to 6-in. depths from treatment 4 were compared to examine how soil depth influences selected soil properties. Differences among treatments were identified as significant when the treatment *P*-value was <0.10. The ANOVA was performed with the GLM procedure of SAS v. 9.4 (SAS Institute, Cary, N.C.) with block as a random effect and fertilizer source and rate treatments as fixed effects.

Results and Discussion

Corn yield was affected only by the main effects of fertilizer source and rate, but not their interaction (Table 3). Corn yields were greatest when fertilized with MESZ + Aspire and MOP. Surprisingly, the application of MAP+MOP produced a similar yield as corn receiving only N for the past six years, which were both greater than the yield of corn fertilized with only MAP. The results indicate a major response to K fertilization and a negative effect of increasing P rate when it was not accompanied with other nutrients (K, S, Zn, and B). Corn yield, averaged across all sources, was maximized by application of 30 to 90 lb P_2O_5/acre. Corn fertilized with 30 lb P_2O_5/acre produced higher yields than corn fertilized with 0 and 120 lb P_2O_5/acre.

Application of increasing annual rates of MESZ and a constant annual rate of Aspire resulted in a significant increase in soil-test P (Table 4). Application of the same rate of MAP and MESZ resulted in similar increases in soil-test P. The primary reason for the annual soil sampling was to see if the secondary nutrients and micronutrients included in the MESZ and Aspire fertilizer sources influenced the soil-test values. Results showed that inclusion of these micronutrients in an annual fertilization program with MESZ and Aspire does result in increased soil-test S, Zn, and B with S and Zn values increasing numerically and sometimes statistically as MESZ rate increased.

Soil samples collected from the 0- to 6-in. depth of each replicate of treatment 4, showed that soil pH was not affected by sample depth as both sample depths had a mean pH of 6.4. As expected, the 0- to 6-in. sample depth had numerically, but not significantly, lower soil-test values for the immobile elements of P (30 ppm for 0- to 4-in. vs. 23 ppm for 0- to 6-in.), K (65 vs. 72 ppm), and Zn (0.9 vs. 1.0 ppm). Only soil-test S was different between the sample depths with S being higher (10 ppm) in the 0- to 4-in. depth than the 0- to 6-in. depth.

Practical Applications

Corn yields were significantly affected by fertilizer source and rate but not by the rate by source interaction. Corn yields were greater when S, a secondary nutrient, and the micronutrients Zn and B were included with P and K as compared to the application of P and K alone. The omission of annual K fertilization was detrimental to yield. Although the interaction was not significant, it showed that application of high P rates in the absence of Zn fertilization had a negative effect on corn yield with numerical yield tending to decrease as P rate increased suggesting that the addition of higher amounts of P may have induced Zn deficiency. The numerical yield means of the treatments clearly indicate that balanced nutrition is important, especially when certain nutrients are applied at relatively high rates. Although the P rate component had no significant effect on corn yield, it is important to note that for MESZ, corn yields were uniform and high across all applied P rates, but when only MAP and potash were applied, application of increasing P rates caused yields to decline. The soil-test results indicate that annual use of MESZ and Aspire slowly increase soil-test S, Zn, and B and may be beneficial for avoiding nutrient deficiencies, avoiding the negative effects of certain nutrient interactions, and sustaining high crop yields. This study addressed only a couple of the agronomic questions regarding the use of multi-nutrient fertilizers and the results raise a number of other agronomic and economic questions about fertilization that need further investigation.

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Slaton, N.A., R. DeLong, J. Hedge, Y. Liyew, and T. Jones. 2018. Crop and soil test responses to annual fertilization with different fertilizers. *In:* N.A. Slaton (ed.). Wayne E. Sabbe Arkansas Soil Fertility Studies 2017. University of Arkansas Agricultural Experiment Station Research Series 649:48-51. Access date: 24 Nov 2018. Available at: https://arkansas-ag-news.uark.edu/pdf/649.pdf

Table 1. Selected soil chemical properties in soil that received no phosphorus or potassium fertilizers for five cropping years.

		Mehlich-3 extractable nutrients								
Year	Soil pH	P	K	Ca	Mg	S	Fe	Mn	Zn	B
		[ppm (± standard deviation)]								
2018	6.4	11 (1.4)	64 (4.2)	1640	272	9 (0)	180	342	0.7	0.2

Table 2. Fertilizer treatments for the first 5 years of research from 2013–2017.

	P rates and source†		2013–2014‡		2015–2017§	
Treatment	P rate	P source	Zn rate	K rate	K source	K rate
(no.)	(lb P_2O_5/acre)		(lb Zn/acre)	(lb K_2O/acre)		(lb K_2O/acre)
1	0	Control	0	0	None	0
2	0	N only	0	0	None	0
3	30	MAP	0	90	MOP	0
4	60	MAP	0	90	MOP	0
5	90	MAP	0	90	MOP	0
6	120	MAP	0	90	MOP	0
7	30	MAP	0.75	90	MOP	90
8	60	MAP	1.50	90	MOP	90
9	90	MAP	2.25	90	MOP	90
10	120	MAP	3.00	90	MOP	90
11	30	MESZ	0.75	90	ASP¶	90
12	60	MESZ	1.50	90	ASP	90
13	90	MESZ	2.25	90	ASP	90
14	120	MESZ	3.00	90	ASP	90

† The same P sources and rates have been used for the duration of the experiment. MAP, monoammonium phosphate (11-52-0); and MESZ, Microessentials (12-40-0-10S-1Zn).

‡ During 2013–2014, treatments 7–10 received Zn as granular $ZnSO_4$ with an analysis of 36% Zn and 17.5% and matched the Zn rate supplied as MESZ in treatments 11–14. Application of $ZnSO_4$ to treatments 7–10 were discontinued after 2014. Muriate of potash (MOP) was applied to treatments 3–14 at a uniform rate. Ammonium sulfate was applied to treatments 7-10 to balance the S added to with each MESZ rate in treatments 11–14.

§ During 2015-2017, K fertilization was discontinued in treatments 3–6, and the K source was changed to Aspire (ASP) for treatments 11–14.

¶ The K rate for treatments 7–14 was increased to 120 lb K_2O/acre in 2018. The ASP rate was limited to 100 lb/acre and the balance of the K rate was supplied with muriate of potash.

Table 3. Mean corn yield in 2018 as affected by fertilizer (P, K, S, and Zn) source, annual P rate, and their interaction in the sixth year of fertilization.

	Annual P_2O_5 rate					
Fertilizer source†	0	30	60	90	120	Average‡
	(bu/acre)					
N only	189	--	--	--	--	188 b
MAP	--	172	179	156	147	163 c
MAP + MOP	--	216	194	184	178	193 b
MESZ + Aspire	--	230	227	237	227	230 a
Average	188 bc	206 a	200 ab	192 abc	184 c	--
Source (FS)			<0.0001			
P rate (PR)			0.0451			
PR × PS			0.2848			

† Fertilizer Abbreviations: MAP, monoammonium phosphate (11-52-0); MESZ, MicroEssentials (12-40-0-10S-1Zn); MOP, muriate of potash (0-0-60); Aspire, 0-0-58-0.5B).

‡ Within the 'Average' column or the 'Average' row, mean yields followed by different lowercase letters indicate significant yield differences among treatments (*P*-value ≤ 0.10).

Table 4. The effect of fertilizer treatment on selected Mehlich-3 extractable nutrients after five years of cropping and fertilization from soil samples collected in spring 2018 (See Table 2 for annual treatment list).

Treatment	5 year sum total nutrient rate					Mehlich-3 extractable nutrients				
no.	P_2O_5	K_2O	S	Zn	B	P	K	S	Zn	B
	(lb fertilizer-nutrient/acre applied)					(ppm)				
2	0	180	0	0	0	11	64	9	0.7	0.2
4	300	180	0	0	0	30	72	10	1.0	0.2
8	300	450	1.5	3.0	0	25	106	9	1.4	0.2
11	150	450	38	3.8	2.75	18	108	10	1.8	0.5
12	300	450	75	7.5	2.75	27	101	11	2.9	0.5
13	450	450	113	11.3	2.75	39	100	12	3.9	0.5
14	600	450	150	15.0	2.75	65	109	14	5.7	0.5
					$LSD_{0.10}$	8	18	1	0.5	<0.1
					P-value	0.0001	0.0011	0.0001	0.0001	0.0001
					C.V., %	19.8	15.9	7.8	16.9	11.2

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