Wayne E. Sabbe
ARKANSAS
SOIL FERTILITY STUDIES
• 2004 •

Nathan A. Slaton, Editor

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WAYNE E. SABBE ARKANSAS SOIL FERTILITY STUDIES – 2004 –

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SUMMARY

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

INTRODUCTION

The 2004 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 for the 2004 growing season. This set of data includes information for counties, soil associations, physiographic areas, and selected cropping systems.

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

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

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Soil Test and Fertilizer Sales Data: Summary for the 2004 Growing Season

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

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Soil-test data from samples submitted to the University of Arkansas Soil Testing and Research Laboratory in Marianna during the period 1 September 2003 through 30 August 2004 were categorized according to geographic area, county, soil association number (SAN), and selected cropping systems. This period roughly corresponds to the 2004 crop growing season; therefore, those samples should represent the soil fertility of that cropping season. The geographic area and SAN were from the General Soil Map, State of Arkansas (Base 4-R-38034, USDA, and University of Arkansas AES, Fayetteville, Ark, December 1982). Descriptive statistics of the soil-test data were calculated for categorical ranges for soil pH, phosphorus (P), potassium (K), and zinc (Zn). Soil pH and extractable (Mehlich-3, 1:7 extraction ratio analyzed by inductively coupled atomic plasma spectroscopy) soil nutrient (i.e., P, K, Zn, etc.) concentrations indicate the relative level of soil fertility.

RESULTS AND DISCUSSION

Crop Acreage and Soil Sampling Intensity

During the interval from 1 September 2003 through 30 August 2004, 100,134 soil samples were analyzed by the University of Arkansas Soil Testing and Research Laboratory in Marianna. A total of 59,535 soil samples, representing 1,636,611 acres and 28 acres/sample, had complete data for the county, SAN, last crop produced, geographic area, total acres, soil pH, P, K, Zn, and month/day/year categories and are described in this report. Samples that did not have values in all of those categories were not included in this report. Soil samples from the Bottom Lands and Terraces and Loessial Plains, primarily row-crop areas, represented 54% of the total samples and 78% of the total acreage (Table 1). The average number of acres represented by each soil sample ranged from 2 to 96 acres/sample (Table 2). Clients from Arkansas (5161), Craighead (3449), Washington (3170), Desha (2433), and Lonoke (2253) counties submitted the most soil samples for analyses.

Soil association numbers show that most samples were taken from row-crop and pasture production areas (Table 3). The 44 and 45 SAN's represented 33% of the sampled acreage. Crop codes indicate that, in addition to row crops and pastures, turf and garden enterprises contributed largely to the number of samples submitted but represented only a small percentage of the total acreage (Table 4).

Soil Test Data

Information in Tables 5, 6, 7, and 8 pertain to the fertility status of Arkansas soils as categorized by geographic area, county, SAN, and the crop intended for production in 2004, respectively. The soil-test values relate to the potential fertility of a soil, but not necessarily to the productivity of the soil. Therefore, it is not realistic to compare soil-test values among SAN without knowledge of factors such as location, topography, and cropping system. Likewise, soil-test values among counties cannot be realistically compared without knowledge of the SAN and a profile of the local agricultural production systems. Soil-test data for cropping systems can be carefully compared; however, the specific agricultural production systems often indicate past fertilization practices or may be unique to certain soils that would influence the current soil-test values. For example, soils used for cotton production have a history of intensive fertilization, whereas intensive fertilization of soybean is normally not practiced. Similarly, rice is commonly grown on soils with low P and K concentrations, which may be more a reflection of the management practices (i.e., flooded soil conditions) used rather than routine fertilization practices. The soil pH of most soils in Arkansas ranges from 5.5 to 6.5, however the predominant soil pH range varies among counties (Table 6), SAN (Table 7), and crop (Table 8).

Table 8 contains soil-test concentration ranges and the median concentrations for each of the cropping system categories. Soil-test nutrient concentration ranges, from low to high concentrations, can be categorized into soil-test levels of 'Very Low' to 'Low', 'Medium', 'Optimum', 'High', and 'Excessive' (for P). The median is the value that has an equal number of higher and lower observations and thus is a better overall indicator of a soil's fertility status than is a mean value. Among row crops, the lowest median concentrations of P and K occur in soils used for the production of rice and irrigated soybean, whereas soils used for cotton production have the highest median concentrations of P and K among row crops. The highest median concentrations of Zn occur in soils used for non-row-crops (i.e., grasses and fruit and nut trees) excluding vegetable. Fertilizer consumption by county (Table 9) and by fertilizer nutrient and formulation (Table 10) illustrates the wide use of inorganic fertilizer predominantly in row-crop production areas, however does not account for the use of animal manures or other by-products as a source of nutrients that may be applied to the land.

PRACTICAL APPLICATIONS

The data presented, or more specific data, can be used in county- or commodity-specific educational programs on soil fertility and fertilization practices. Comparisons of annual soil-test information can also document trends in fertilization practices or areas where nutrient management issues may need to be addressed.

ACKNOWLEDGMENTS

Financial support for routine soil testing services offered to Arkansas citizens from the Arkansas Fertilizer Tonnage Fee is appreciated.

Table 1. Sample number and total acreage by geographic area for soil samples submitted to the University of Arkansas Soil Testing and Research Laboratory in Marianna from September 2003 through August 2004.

Geographic area	Acres sampled	No. of samples	Acres/sample
Ozark Highlands - Cherty Limestone and Dolomite	124,209	8,845	14
Ozark Highlands - Sandstone and Limestone	7,863	410	19
Boston Mountains	39,995	3,035	13
Arkansas Valley and Ridges	75,370	5,034	15
Ouachita Mountains	36,367	4,504	8
Bottom Lands and Terraces	727,000	19,518	37
Coastal Plain	50,085	3,849	13
Loessial Plains	542,054	12,402	44
Loessial Hills	30,348	1,685	18
Blackland Prairie	5,320	253	21

Table 2. Sample number and total acreage by county for soil samples submitted to the University of Arkansas Soil Testing and Research Laboratory in Marianna from September 2003 through August 2004.

County	Acres sampled	No. of samples	Acres/ sample	County	Acres sampled	No. of samples	Acres/ sample
Arkansas, De Witt	141,029	3,025	47	Lincoln	5,274	189	28
Arkansas, Stuttgart	88,306	2,136	41	Little River	8,957	259	35
Ashley	27,471	954	29	Logan, Booneville	2,978	163	18
Baxter	2,291	397	6	Logan, Paris	7,917	416	19
Benton	27,982	1,976	14	Lonoke	91,691	2,253	41
Boone	14,744	794	19	Madison	15,294	976	16
Bradley	1,008	122	8	Marion	7,423	299	25
Calhoun	497	63	8	Miller	5,887	466	13
Carroll	20,689	862	24	Mississippi, Blytheville	27,772	1,028	27
Chicot	53,469	597	90	Mississippi, Osceola	1,634	17	96
Clark	2,640	239	11	Monroe	59,152	951	62
Clay, Corning	18,884	1,020	19	Montgomery	4,240	307	14
Clay, Piggott	28,366	898	32	Nevada	2,073	97	21
Cleburne	4,391	332	13	Newton	3,336	210	16
Cleveland	3,791	172	22	Ouachita	427	98	4
Columbia	3,976	306	13	Perry	7,415	409	18
Conway	10,222	698	26	Phillips	28,084	617	46
Craighead	100,935	3,449	29	Pike	6,938	323	22
Crawford	5,117	353	15	Poinsett	69,732	1,381	51
Crittenden	71,128	1,718	41	Polk	5,592	327	17
Cross	83,629	1,637	51	Pope	14,590	853	17
Dallas	570	46	12	Prairie, Des Arc	4,883	154	32
Desha	26,097	2,433	11	Prairie, De Valls Bluff	18,749	435	43
Drew	2,545	169	15	Pulaski	3,810	1,836	2
Faulkner	3,808	545	7	Randolph	15,238	690	22
Franklin, Charleston	740	50	15	Saline	962	371	3
Franklin, Ozark	11,667	611	19	Scott	6,626	288	23
Fulton	3,359	125	27	Searcy	9,521	291	33
Garland	3,156	1,102	3	Sebastian, Fort Smith	6,812	594	12
Grant	1,953	151	13	Sebastian, Greenwood	66	6	11
Greene	34,071	1,666	21	Sevier	6,996	284	25
Hempstead	4,606	282	16	Sharp	3,494	259	14
Hot Spring	1,115	212	5	St. Francis	10,083	427	24
Howard	7,147	434	17	Stone	2,165	176	12
Independence	11,236	430	26	Union	1,260	231	6
Izard	3,849	265	15	Van Buren	4,228	382	11
Jackson	23,890	646	37	Washington	30,674	3,170	10
Jefferson	45,884	1,385	33	White	19,363	1,633	12
Johnson	3,850	382	10	Woodruff	13,402	426	32
Lafayette	15,165	357	43	Yell, Danville	5,969	312	19
Lawrence	33,479	983	34	Yell, Dardanelle	4,198	202	21
Lee	144,954	2,007	72				

Table 3. Sample number and total acreage by soil association number (SAN) for soil samples submitted to the University of Arkansas Soil Testing and Research Laboratory in Marianna from September 2003 through August 2004.

SAN	Soil association	Acres sampled	No. of samples	Acres/ sample
1.	Clarksville-Nixa-Noark	33,644	1,607	21
2.	Gepp-Doniphan-Gassville-Agnos	13,152	1,069	12
3.	Arkana-Moko	12,186	765	16
4.	Captina-Nixa-Tonti	60,784	5,213	12
5.	Captina-Doniphan-Gepp	3,562	124	29
6.	Eden-Newnata-Moko	881	67	13
7.	Estate-Portia-Moko	4,191	180	23
8.	Brockwell-Boden-Portia	3,672	230	16
9.	Linker-Mountainburg-Sidon	15,649	722	22
10.	Enders-Nella-Mountainburg-Steprock	24,346	2,313	11
11.	Falkner-Wrightsville	1,131	62	18
12.	Leadvale-Taft	25,910	1,985	13
13.	Enders-Mountainburg-Nella-Steprock	9,235	462	20
14.	Spadra-Guthrie-Pickwick	4,276	208	21
15.	Linker-Mountainburg	34,818	2,317	15
16.	Carnasaw-Pirum-Clebit	13,190	2,658	5
17.	Kenn-Ceda-Avilla	4,586	295	16
18.	Carnasaw-Sherwood-Bismarck	10,626	1,098	10
19.	Carnasaw-Bismarck	57	14	4
20.	Leadvale-Taft	1,083	56	19
21.	Spadra-Pickwick	6,825	383	18
22.	Foley-Jackport-Crowley	97,258	2,860	34
23.	Kobel	101,248	1,599	63
24.	Sharkey-Alligator-Tunica	136,977	2,029	68
25.	Dundee-Bosket-Dubbs	124,888	4,070	31
26.	Amagon-Dundee	43,380	1,642	26
27.	Sharkey-Steele	3,688	89	41
28.	Commerce-Sharkey-Crevasse-Robinsonville	27,704	567	49
29.	Perry-Portland	45,430	2,652	17
30.	Crevasse-Bruno-Oklared	1,416	22	64
31.	Roxana-Dardanelle-Bruno-Roellen	6,875	256	27
32.	Rilla-Hebert	118,246	3,245	36
33.	Billyhaw-Perry	10,178	226	45
34.	Severn-Oklared	7,672	142	54
35.	Adaton	65	5	13
36.	Wrightsville-Louin-Acadia	1,611	93	17
37.	Muskogee-Wrightsville-McKamie	364	21	17
38.	Amy-Smithton-Pheba	5,196	213	24
39.	Darco-Briley-Smithdale	52	6	9
40.	Pheba-Amy-Savannah	5,415	410	13
41.	Smithdale-Sacul-Savannah-Saffell	13,681	1,321	10
42.	Sacul-Smithdale-Sawyer	13,877	1,446	10
43.	Guyton-Ouachita-Sardis	11,864	453	26
44.	Calloway-Henry-Grenada-Calhoun	301,270	6,943	43
45.	Crowley-Stuttgart	240,784	5,459	44
46.	Loring	4,932	131	38
47.	Loring-Memphis	25,354	1,543	16
48.	Brandon	62	11	6
49.	Oktibbeha-Sumter	5,320	253	21

Table 4. Sample number and total acreage by crop for soil samples submitted to the University of Arkansas Soil Testing and Research Laboratory in Marianna from September 2003 through August 2004.

Crop	Acres sampled	No. of samples	Acres/ sample
Soybean - dryland	53,089	1,344	40
Soybean - irrigated	605,641	13,300	46
Cotton	304,673	8,388	36
Rice	171,150	3,508	49
Wheat	20,387	521	39
Double-crop wheat-soybean - dryland	4,004	92	44
Double-crop wheat-soybean - irrigated	18,278	411	45
Warm season grass - establish	8,056	481	17
Warm season grass - maintain	126,177	6,116	21
Cool season grass - establish	6,118	287	21
Cool season grass - maintain	55,279	2,855	19
Grain sorghum	20,495	510	40
Corn	68,756	1,588	43
All garden	7,757	3,538	2
Turf and ground cover	11,746	5,980	2
Fruit and nut	1,922	502	4
Vegetable	156	28	6
Other	154,927	10,086	15

Table 5. Soil test data by geographic area for soil samples submitted to the University of Arkansas Soil Testing and Research Laboratory in Marianna from September 2003 through August 2004.

	pH[z]			P[y] (lb/acre)					K[y] (lb/acre)				Zn[y] (lb/acre)			
Geographic area	<5.5	5.5-6.5	>6.5	<26	26-44	45-100	101-300	>300	<176	176-220	221-350	>350	<4.0	4.0-8.0	8.1-12.0	>12.0
	(Percentage of sampled acreage)															
Ozark Highlands - Cherty Limestone & Dolomite	15	57	28	5	8	20	36	31	19	11	27	43	5	19	15	61
Ozark Highlands - Sandstone & Limestone	16	57	27	8	11	27	37	17	28	14	29	29	9	35	17	39
Boston Mountains	22	62	16	7	10	20	41	22	32	14	24	30	8	24	16	52
Arkansas Valley and Ridges	31	53	16	12	13	22	33	20	31	13	27	29	11	27	17	45
Ouachita Mountains	29	52	19	6	11	22	35	26	33	14	29	24	6	23	19	52
Bottom Lands & Terraces	10	55	35	9	15	43	31	2	13	12	34	41	19	49	19	13
Coastal Plain	36	49	15	11	11	21	32	25	39	13	23	25	12	27	15	46
Loessial Plains	12	39	49	20	35	37	8	0	32	25	29	14	25	44	16	15
Loessial Hills	18	54	28	18	18	31	28	5	21	12	36	31	14	41	20	25
Blackland Prairie	32	35	33	27	17	23	20	13	27	11	22	40	17	25	22	36
Average	22	51	27	12	15	27	30	16	28	14	28	30	13	31	18	38

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

[y] Analysis by ICAP in 1:7 soil weight:Mehlich-3 volume.

Table 6. Soil test data by county for soil samples submitted to the University of Arkansas Soil Testing and Research Laboratory in Marianna from September 2003 through August 2004.

	pH[z]			P[y] (lb/acre)					K[y] (lb/acre)				Zn[y] (lb/acre)			
County	<5.5	5.5-6.5	>6.5	<26	26-44	45-100	101-300	>300	<176	176-220	221-350	>350	<4.0	4.0-8.0	8.1-12.0	>12.0
	(Percentage of sampled acreage)															
Arkansas, De Witt	6	28	66	23	42	32	2	1	34	27	27	12	22	45	21	12
Arkansas, Stuttgart	18	52	30	26	33	33	8	0	23	28	32	17	35	42	16	7
Ashley	9	48	43	11	11	36	41	1	21	14	41	24	33	39	15	13
Baxter	4	25	71	4	11	23	37	25	12	11	33	44	3	13	15	69
Benton	19	61	20	1	3	13	38	45	16	8	24	52	2	13	13	72
Boone	10	64	26	4	9	27	40	20	19	11	26	44	6	25	22	47
Bradley	24	40	36	4	8	18	39	31	31	13	31	25	12	20	21	47
Calhoun	48	38	14	11	13	11	41	24	48	21	18	13	25	30	11	34
Carroll	9	69	22	1	3	13	33	50	14	6	20	60	2	10	9	79
Chicot	6	37	57	18	34	34	12	2	8	5	17	70	16	65	11	8
Clark	45	36	19	21	21	21	18	19	48	12	18	22	18	42	14	26
Clay, Corning	8	70	22	19	28	45	8	0	36	29	32	3	13	53	25	9
Clay, Piggott	15	61	24	6	13	38	43	0	13	14	38	35	15	55	24	6
Cleburne	32	54	14	12	15	26	34	13	41	15	31	13	14	26	14	46
Cleveland	26	59	15	20	17	23	29	11	16	7	17	60	8	42	15	35
Columbia	44	44	12	12	11	18	32	27	46	11	24	19	13	21	17	49
Conway	42	43	15	12	13	32	21	22	29	16	25	30	19	30	15	36
Craighead	6	51	43	7	12	35	44	2	11	9	35	45	9	50	27	14
Crawford	24	59	17	11	14	27	34	14	30	17	28	25	6	31	24	39
Crittenden	11	60	29	4	11	47	37	1	3	6	31	60	14	49	28	9
Cross	5	34	61	16	39	39	5	1	34	21	23	22	19	50	17	14
Dallas	61	33	6	11	35	22	20	12	72	15	7	6	20	44	17	19
Desha	5	44	51	6	8	52	33	1	7	9	35	49	33	48	11	8
Drew	30	33	37	18	13	27	26	16	29	14	20	37	12	36	21	31
Faulkner	38	39	23	16	15	31	25	13	37	16	24	23	15	39	15	31
Franklin, Charleston	34	60	6	26	20	12	28	14	48	2	20	30	24	32	6	38
Franklin, Ozark	29	67	4	4	7	16	38	35	18	13	32	37	1	16	17	66
Fulton	34	50	16	10	20	38	23	9	33	22	27	18	18	43	18	21
Garland	25	56	19	7	11	25	31	26	38	12	28	22	6	26	21	47
Grant	56	33	11	15	7	27	38	13	45	11	25	19	18	35	18	29
Greene	18	58	24	14	25	39	20	2	27	17	35	21	20	55	16	9
Hempstead	39	49	12	10	12	28	29	21	29	9	34	28	10	29	21	40
Hot Spring	21	62	17	7	8	15	41	29	32	8	23	37	7	34	18	41
Howard	28	59	13	7	7	12	31	43	28	10	24	38	5	16	13	66
Independence	15	53	32	7	13	34	34	12	30	20	32	18	10	31	14	45
Izard	15	71	14	7	16	28	34	15	33	15	31	21	16	37	14	33
Jackson	16	59	25	18	27	37	16	2	32	25	33	10	22	42	12	24
Jefferson	13	47	40	11	15	47	23	4	15	12	40	33	27	44	13	16
Johnson	24	48	28	9	14	20	38	19	28	11	24	37	9	30	16	45
Lafayette	17	53	30	6	21	21	26	26	18	10	24	48	23	29	12	36
Lawrence	12	68	20	32	28	30	8	2	29	21	32	18	14	48	24	14
Lee	13	55	32	4	13	55	26	2	15	13	29	43	22	55	17	6
Lincoln	25	58	17	13	14	43	22	8	19	14	32	35	22	36	11	31
Little River	31	44	25	13	21	28	34	4	25	13	25	37	13	46	17	24

continued

Table 6. Continued.

County	pH[z]			P[y] (lb/acre)					K[y] (lb/acre)				Zn[y] (lb/acre)			
	<5.5	5.5-6.5	>6.5	<26	26-44	45-100	101-300	>300	<176	176-220	221-350	>350	<4.0	4.0-8.0	8.1-12.0	>12.0
	(Percentage of sampled acreage)															
Logan, Booneville	45	49	6	28	22	23	20	7	38	17	28	17	13	37	26	24
Logan, Paris	25	64	11	6	13	26	33	22	32	10	22	36	5	20	21	54
Lonoke	18	59	23	13	25	40	21	1	18	19	36	27	37	45	11	7
Madison	19	70	11	2	7	15	39	37	21	10	24	45	2	17	18	63
Marion	17	61	22	1	10	31	41	17	19	9	25	47	4	37	21	38
Miller	34	47	19	11	13	24	35	17	38	13	21	28	15	24	15	46
Mississippi, Blytheville	8	57	35	1	2	37	59	1	3	3	45	49	2	41	40	17
Mississippi, Osceola	0	59	41	0	24	65	11	0	12	18	53	17	0	71	29	0
Monroe	6	39	55	16	28	47	9	0	24	21	42	13	26	56	12	6
Montgomery	27	54	19	3	3	14	37	43	33	13	22	32	4	17	20	59
Nevada	38	50	12	27	11	26	22	14	49	18	13	20	13	31	19	37
Newton	10	52	38	9	9	18	45	19	13	14	31	42	12	31	17	40
Ouachita	44	41	15	17	12	29	32	10	61	16	13	10	25	31	10	34
Perry	37	56	7	16	11	20	30	23	31	11	25	33	11	31	18	40
Phillips	16	49	35	1	10	62	26	1	10	14	33	43	15	59	16	10
Pike	42	50	8	4	8	17	31	40	35	12	28	25	6	25	17	52
Poinsett	8	35	57	17	32	37	12	2	37	23	25	15	10	34	23	33
Polk	38	53	9	3	5	14	40	38	40	12	25	23	5	23	18	54
Pope	28	55	17	12	11	19	31	27	29	14	26	31	12	25	15	48
Prairie, Des Arc	18	51	31	27	38	21	8	6	34	20	33	13	27	36	21	16
Prairie, De Valls Bluff	17	43	40	27	40	26	6	1	47	26	22	5	29	41	17	13
Pulaski	27	44	29	6	13	24	39	18	28	18	34	20	5	22	20	53
Randolph	15	58	27	32	22	30	14	2	32	23	30	15	16	44	18	22
Saline	26	46	28	9	12	23	37	19	38	14	28	20	10	25	19	46
Scott	37	57	6	23	18	22	23	14	44	12	19	25	16	35	20	29
Searcy	42	47	11	9	10	30	40	11	29	18	26	27	20	34	20	26
Sebastian, Fort Smith	25	49	26	14	9	25	32	20	21	13	33	33	6	21	19	54
Sebastian, Greenwood	17	17	66	0	17	17	0	66	17	0	50	33	0	17	0	83
Sevier	43	52	5	3	11	17	34	35	36	12	21	31	3	20	18	59
Sharp	9	48	43	17	12	23	32	16	28	18	31	23	12	33	15	40
St. Francis	17	46	37	12	22	36	27	3	22	12	31	35	22	36	16	26
Stone	34	52	14	7	11	19	38	25	21	14	35	30	7	26	15	52
Union	29	52	19	11	9	17	29	34	39	13	21	27	12	23	10	55
Van Buren	30	60	10	8	12	23	41	16	34	12	29	25	18	33	19	30
Washington	13	55	32	7	9	19	35	30	17	13	30	40	4	14	16	66
White	25	57	18	9	14	25	45	7	44	16	23	17	15	29	16	40
Woodruff	11	38	51	14	28	49	6	3	15	23	46	16	11	29	17	43
Yell, Danville	35	59	6	10	12	16	36	26	37	10	20	33	8	19	21	52
Yell, Dardanelle	33	51	16	20	11	19	31	19	41	11	16	32	11	32	15	42
Average	24	51	25	12	16	28	29	15	29	14	28	29	14	34	17	35

[z] Analysis by electrode in 1:2 soil weight:deionized water volume.
[y] Analysis by ICAP in 1:7 soil weight:Mehlich-3 volume.

Table 7. Soil test data by soil association number (SAN) for soil samples submitted to the University of Arkansas Soil Testing and Research Laboratory in Marianna from September 2003 through August 2004.

SAN	Soil association	pH[z] <5.5	pH 5.5-6.5	pH >6.5	P[y] (lb/acre) <26	P 26-44	P 45-100	P 101-300	P >300	K[y] (lb/acre) <176	K 176-220	K 221-350	K >350	Zn[y] (lb/acre) <4.0	Zn 4.0-8.0	Zn 8.1-12.0	Zn >12.0
		(Percentage of sampled acreage)															
1.	Clarksville-Nixa-Noark	13	65	22	3	6	21	44	26	20	11	26	43	5	22	19	54
2.	Gepp-Doniphan-Gassville-Agnos	18	42	40	14	16	28	28	14	23	15	30	32	12	31	15	42
3.	Arkana-Moko	10	64	26	4	10	23	33	30	23	9	24	44	6	23	11	60
4.	Captina-Nixa-Tonti	16	57	27	5	6	17	36	36	17	11	28	44	3	14	15	68
5.	Captina-Doniphan-Gepp	14	66	20	7	15	25	36	17	20	6	16	58	6	41	18	35
6.	Eden-Newnata-Moko	42	40	18	8	18	28	37	9	27	24	25	24	21	33	18	28
7.	Estate-Portia-Moko	16	58	26	2	7	32	41	18	19	9	29	43	7	31	21	41
8.	Brockwell-Boden-Portia	15	57	28	13	14	24	33	16	35	18	28	19	11	38	14	37
9.	Linker- Mountainburg-Sidon	18	65	17	6	7	19	28	40	25	11	22	42	9	19	11	61
10.	Enders-Nella- Mountainburg-Steprock	24	60	16	7	11	20	46	16	34	15	25	26	8	25	18	49
11.	Falkner-Wrightsville	31	66	3	24	19	18	23	16	47	8	21	24	13	37	10	40
12.	Leadvale-Taft	30	51	19	14	13	25	31	17	30	14	27	29	9	29	18	44
13.	Enders-Mountainburg-Nella-Steprock	39	52	9	12	18	23	38	9	34	16	28	22	12	31	18	39
14.	Spadra-Guthrie-Pickwick	33	61	6	10	14	23	34	19	35	14	24	27	13	24	23	40
15.	Linker-Mountainburg	30	54	16	11	12	20	33	24	30	13	26	31	13	26	15	46
16.	Carnasaw-Pirum-Clebit	26	50	24	6	12	24	37	21	34	16	30	20	5	22	22	51
17.	Kenn-Ceda-Avilla	25	61	14	5	10	23	37	25	36	11	21	32	8	22	16	54
18.	Carnasaw-Sherwood-Bismarck	33	52	15	4	7	16	32	41	31	12	29	28	5	23	15	57
19.	Carnasaw-Bismarck	21	57	22	0	21	29	29	21	29	29	21	21	14	29	7	50
20.	Leadvale-Taft	43	46	11	25	13	23	20	19	46	9	16	29	25	18	27	30
21.	Spadra-Pickwick	36	57	7	15	11	21	30	23	30	11	26	33	11	32	18	39
22.	Foley-Jackport-Crowley	12	62	26	25	28	40	7	0	29	24	36	11	17	51	20	12
23.	Kobel	9	54	37	11	20	43	26	0	19	19	30	32	19	58	16	7
24.	Sharkey-Alligator-Tunica	12	53	35	7	23	49	21	0	5	5	21	69	16	53	23	8
25.	Dundee-Bosket-Dubbs	8	60	32	2	8	40	48	2	7	9	39	45	11	51	24	14
26.	Amagon-Dundee	9	61	30	9	9	31	49	2	13	10	39	38	7	42	30	21
27.	Sharkey-Steele	8	75	17	27	16	38	46	0	1	0	17	82	0	55	35	10
28.	Commerce-Sharkey-Crevasse-Robinsonville	4	46	50	2	7	62	28	1	4	3	23	70	5	48	37	10
29.	Perry-Portland	8	45	47	8	13	53	24	2	10	9	32	49	29	49	11	11
30.	Crevasse-Bruno-Oklared	0	73	27	0	27	68	5	0	23	9	23	45	27	36	0	37
31.	Roxana-Dardanelle-Bruno-Roellen	22	45	33	8	16	36	29	11	22	17	34	27	11	39	23	27
32.	Rilla-Hebert	10	52	38	6	12	45	37	0	10	12	42	36	36	45	11	8
33.	Billyhaw-Perry	7	50	43	10	35	33	20	2	7	8	23	62	31	51	9	9
34.	Severn-Oklared	21	42	37	6	18	39	33	4	22	9	32	37	27	37	16	20
35.	Adaton	20	80	0	20	20	20	40	0	60	0	20	20	60	0	20	20
36.	Wrightsville-Louin-Acadia	41	48	11	11	19	14	43	13	41	18	25	16	18	36	15	31
37.	Muskogee-Wrightsville-McKamie	14	81	5	5	0	0	29	66	24	10	33	33	0	0	14	86
38.	Amy-Smithton-Pheba	41	39	20	16	18	23	30	13	45	18	18	19	22	40	14	24
39.	Darco-Briley-Smithdale	17	67	16	0	0	0	17	83	17	33	50	0	0	0	17	83
40.	Pheba-Amy-Savannah	40	47	13	12	11	22	35	20	41	12	21	26	10	34	18	38
41.	Smithdale-Sacul-Savannah-Saffell	33	49	18	10	9	18	33	30	38	13	25	24	11	21	16	52
42.	Sacul-Smithdale-Sawyer	36	49	15	14	11	23	31	21	40	12	23	25	13	29	13	45

continued

Table 7. Continued.

SAN	Soil association	pH[z] <5.5	pH[z] 5.5-6.5	pH[z] >6.5	P[y] (lb/acre) <26	P[y] 26-44	P[y] 45-100	P[y] 101-300	P[y] >300	K[y] (lb/acre) <176	K[y] 176-220	K[y] 221-350	K[y] >350	Zn[y] (lb/acre) <4.0	Zn[y] 4.0-8.0	Zn[y] 8.1-12.0	Zn[y] >12.0
		(Percentage of sampled acreage)															
43.	Guyton-Ouachita-Sardis	38	52	10	5	15	19	29	32	33	13	22	32	6	27	14	53
44.	Calloway-Henry-Grenada-Calhoun	12	38	50	17	32	39	10	2	35	22	29	14	22	45	14	19
45.	Crowley-Stuttgart	11	40	49	24	38	33	5	0	28	28	31	13	28	44	18	10
46.	Loring	17	59	24	30	30	22	16	2	46	21	24	9	21	34	18	27
47.	Loring-Memphis	18	53	29	17	17	32	30	4	19	11	37	33	14	41	20	25
48.	Brandon	9	73	18	46	9	36	9	0	73	9	9	9	0	46	36	18
49.	Oktibbeha-Sumter	32	35	33	27	17	23	20	13	27	11	22	40	17	25	22	36
	Average	21	55	24	12	15	28	30	15	28	13	31	28	14	33	18	35

[z] Analysis by electrode in 1:2 soil weight:deionized water volume.
[y] Analysis by ICAP in 1:7 soil weight:Mehlich-3 volume.

Table 8. Soil-test median (Md) values and percentage distribution for selected ranges by crop for soil samples submitted to the University of Arkansas Soil Testing and Research Laboratory in Marianna from September 2003 through August 2004.

Crop	pH[z]				P[y] (lb/acre)						K[y] (lb/acre)					Zn[y] (lb/acre)				
	<5.5	5.5-6.5	>6.5	Md	<26	26-44	45-100	101-300	>300	Md	<176	176-220	221-350	>350	Md	<4.0	4.0-8.0	8.1-12.0	>12.0	Md
	(Percentage of sampled acreage)																			
Soybean - dryland	25	55	20	5.9	11	24	49	15	1	56	24	18	31	27	247	21	48	19	12	6.0
Soybean - irrigated	8	44	48	6.5	18	35	41	6	0	43	30	25	29	16	212	23	49	17	11	5.8
Cotton	5	57	38	6.4	1	3	43	53	0	104	3	6	41	50	350	20	51	21	8	6.2
Rice	10	42	48	6.5	34	34	30	2	0	33	23	17	25	35	259	22	50	16	12	5.8
Wheat	29	53	18	5.9	8	15	46	29	2	73	25	21	30	24	231	30	42	16	12	5.2
Double-crop wheat - soybean - dryland	20	51	29	6.1	2	9	58	31	0	75	20	26	26	28	231	17	41	19	23	6.6
Double-crop wheat - soybean - irrigated	6	38	56	6.6	9	28	46	17	0	54	29	27	30	14	209	18	45	18	19	6.4
Warm season grass - establish	33	47	20	5.7	10	8	24	39	19	124	35	11	28	26	240	13	27	17	43	10.5
Warm season grass - maintain	30	61	9	5.7	8	10	19	34	29	160	32	11	24	33	250	9	23	16	52	12.7
Cool season grass- establish	29	57	14	5.8	19	11	16	26	28	114	31	14	19	36	261	16	16	11	57	15.8
Cool season grass- maintain	17	69	14	5.9	4	8	22	37	29	165	22	11	26	41	301	6	23	18	53	13.4
Grain sorghum	14	60	26	6.2	6	18	52	24	0	69	11	14	41	34	281	21	49	18	12	6.0
Corn	11	55	34	6.3	4	13	53	30	0	80	13	16	41	30	283	17	49	21	13	6.4
All garden	13	40	47	6.5	3	5	14	36	42	245	13	10	27	50	353	5	16	13	66	19.9
Turf and ground cover	23	52	25	6.1	7	11	29	45	8	110	27	16	34	23	242	6	24	23	47	11.8
Fruit and nut	28	52	20	5.9	8	14	22	35	21	122	24	14	32	30	260	7	24	16	53	13.0
Vegetable	18	36	46	6.3	4	0	54	29	13	91	11	29	31	24	247	29	36	14	21	5.8
Other	28	52	20	5.9	14	15	22	28	21	96	32	14	25	29	240	13	29	14	44	10.3
Average	19	51	30		9	15	36	29	11		23	17	30	30		16	36	17	31	

[z] Analysis by electrode in 1:2 soil weight:deionized water volume.
[y] Analysis by ICAP in 1:7 soil weight:Mehlich-3 volume.

Table 9. Fertilizer consumption in Arkansas counties from 1 July 2003 through 30 June 2004[z].

County	Total	County	Total
	(tons)		(tons)
Arkansas	87,986	Lee	28,492
Ashley	22,665	Lincoln	19,085
Baxter	2,333	Little River	2,771
Benton	16,465	Logan	3,490
Boone	5,970	Lonoke	38,504
Bradley	1,550	Madison	5,517
Calhoun	342	Marion	2,850
Carroll	3,677	Miller	7,392
Chicot	17,771	Mississippi	85,760
Clark	2,931	Monroe	30,615
Clay	51,037	Montgomery	606
Cleburne	2,276	Nevada	2,010
Cleveland	300	Newton	1,514
Columbia	702	Ouachita	171
Conway	7,119	Perry	1,966
Craighead	63,246	Phillips	61,925
Crawford	6,689	Pike	5,689
Crittenden	21,983	Poinsett	81,207
Cross	44,798	Polk	1,469
Dallas	550	Pope	2,873
Desha	35,676	Prairie	34,746
Drew	13,444	Pulaski	11,687
Faulkner	4,844	Randolph	26,405
Franklin	2,792	Saline	3,030
Fulton	2,854	Scott	1,157
Garland	553	Searcy	4,623
Grant	286	Sebastian	1,110
Greene	33,671	Sevier	2,802
Hempstead	5,442	Sharp	1,318
Hot Spring	2,580	St. Francis	44,994
Howard	1,984	Stone	2,254
Independence	11,951	Union	1,174
Izard	3,324	Van Buren	7,917
Jackson	33,924	Washington	5,487
Jefferson	41,899	White	29,821
Johnson	2,359	Woodruff	36,864
Lafayette	6,286	Yell	4,912
Lawrence	34,895		

[z] Arkansas Distribution of Fertilizer Sales by Counties 1 July 2003-30 June 2004, Arkansas State Plant Board, Division of Feed and Fertilizer, Little Rock, Ark., and University of Arkansas AES, Fayetteville, Ark.

Table 10. Fertilizer nutrient and formulation consumed in Arkansas from 1 July 2003 through 30 June 2004[z].

Fertilizer	Bulk	Bagged	Fluid	Totals
	(tons)			
Mixed	384,504	42,846	14,744	442,094
Nitrogen	526,290	5,275	108,166	639,730
Phosphate	19,414	108	4	19,526
Potash	53,156	515	52	53,723
Other	41,717	4,597	1,969	48,283
Totals	1,025,080	53,342	124,935	1,203,357

[z] Arkansas Distribution of Fertilizer Sales By Counties 1 July 2003-30 June 2004, Arkansas State Plant Board, Division of Feed and Fertilizer, Little Rock, Ark., and University of Arkansas AES, Fayetteville, Ark.

Response of Cotton Canopy Reflectance to Petiole Nutrients

S. Bajwa, A. Mishra, and M. Mozaffari

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Nitrogen management is a critical issue in cotton because of the dependency of cotton on the time and amount of N-fertilizer applied. A one-time application of a single rate of N on an entire field could result in significant N losses. Split applications of N require assessment of the N status of the crop to determine the need for subsequent applications. The spatial variability in soil fertility and the variability in N requirement during different growth stages of cotton are additional reasons for assessing N requirement in cotton. Additionally, a need-based site-specific application of N fertilizer may reduce total N rates as compared to a single blanket application. For implementing a need-based application, it is critical to monitor the N sufficiency in cotton. Currently, the conventional method of N monitoring in cotton includes petiole sampling and tissue analysis (Henslee et al., 2002), and chlorophyll meters. Both of these methods need extensive field data collection, which is time-consuming, laborious, and expensive. Remote sensing of crop fields works on similar principles as the chlorophyll meter, but it offers a fast and easy method for mapping crop N needs.

Canopy reflectance is closely related to the pigment content of plant canopy and biomass. Therefore, canopy reflectance is considered as a good indicator of a plant's health, especially N stress (Bronson et al., 2000; Fouche, 1999; Gopalapillai et al., 1998). While plant pigments such as chlorophyll, carotenoids, and xanthophylls absorb light energy in the visible region, the cell structures (biomass) cause light to reflect in the near-infrared region (Bajwa et al., 2003). The amount of N in a plant canopy is proportional to the amount of canopy chlorophyll, which is proportional to the amount of light absorbed by chrolophyll absorption bands (680-710 nm). Therefore, research has to be done to establish validated methods based on remote sensing to estimate crop nutrient requirements (Hergert, 1998). This study was conducted with the objective to investigate the relationship between plant canopy reflectance and petiole N concentration in cotton plants.

PROCEDURES

In 2004, a study was conducted in the 'Cutfield' or Britain Farm at the Cotton Branch Experiment Station with five total N-fertilizer rates (0, 30, 60, 90 and 120 lb N/acre) on 'FiberMax 960' (FM 960) cotton (Mozaffari et al., 2005). The experimental design was a randomized complete block design with 5 treatments and 4 replications, resulting in 20 plots. Each plot was approximately 115 ft long and 25 ft wide allowing for eight rows of cotton with 38-inch wide rows. Cotton was planted on 22 May and managed following standard cultural practices for eastern Arkansas. Seedlings emerged on 29 May and first bloom occurred on 21 July. Cotton was harvested with a combine equipped with an AgLeader PF 3000 Yield Monitor on 12 November. Nitrogen fertilizer was applied in split applications with no pre-plant application. The first N application was made on 14 July, which included rates of 0, 30, and 60 lb N/acre. Total N rates of 90 and 120 lb N/acre received only 60 lb N/acre nitrogen on 14 July. On 4 August, the 90 and 120 lb N/acre rates received a second application of 30 and 60 lb N/acre, respectively.

Canopy reflectance of cotton was measured on 17 and 27 July. Since the data were collected before the second application of N, only 3 rates of N were used for data analysis. Canopy reflectance was measured with a hand-held StellarNet EPP2000-NIR-InGaAs-25 model spectro-radiometer with a wavelength range of 250-880 nm, spectral resolution of 2.5 nm and 25° view angle. The sensor probe was held 2 ft above the canopy to get a broad canopy area. The sensor measures the amount of light reflected by the canopy with respect to the light reflected by a reference plate and calculates its ratio as the canopy reflectance. Five readings were collected from each plot and averaged. These data were analyzed with respect to petiole data collected on 16 and 30 July, respectively. Cotton petiole samples were collected from the 5th node from the top of 20 plants selected randomly in each plot (Mozaffari et al., 2005). The petioles were collected from all plots on 16 and 30 July, dried overnight at 70°C and ground to pass a 1-mm sieve. A 0.1 g sub-sample was mixed with 30 mL of 0.025 *M* aluminum sulfate solution, stirred, and allowed to stand for 15 minutes. Petiole NO_3-N concentrations were determined using an ion-specific electrode.

Canopy reflectance data measured with the spectrometer contain reflectance at wavelengths ranging from 400-1050 nm. From these reflectance readings, two vegetative indices, namely, normalized difference vegetation index (NDVI = [NIR-R]/[NIR+R]) and green NDVI (GNDVI =[NIR-G]/[NIR+G]), were calculated. Here, NIR, R, and G are the reflectance at near-infrared, red, and green, respectively. Both NDVI and GNDVI provide combined measures of biomass and pigment concentration of the canopy. The PROC GLM procedure of SAS was used to statistically analyze petiole nutrient concentrations, NDVI, and GNDVI with respect to N rates as an unbalanced design. Additionally, the relationship of NDVI and GNDVI with respect to petiole NO_3-N was also analyzed.

RESULTS AND DISCUSSION

A summary of the observed values for NDVI and GNDVI, and petiole nutrients with respect to the N treatment is shown in Table 1. Both NDVI and GNDVI increased between 17 and 27 July indicating an increase in cotton biomass and greenness. However, both NDVI and GNDVI showed very little variation with respect to petiole NO_3-N (Table 1). Analysis of variance with GLM procedure showed significant relationships between both vegetative indices and the applied N rates (Table 2). The relationship was very strong for the second week of data collection (27 July) with R^2 values of 0.88 and 0.78 for NDVI and GNDI, respectively, as compared to the first week of data collection (R^2 values of 0.58 and 0.56 for NDVI and GNDI, respectively, on 17 July). The reason for the improved correlation can be attributed to the fact that N fertilizer was applied on 14 July, which may not have affected the plant growth on 17 July significantly. The crop would have expressed the N fertilization levels in terms of greenness and vigor on 27 July much better, resulting in better correlation between vegetative indices and N rates on 27 July.

Petiole NO_3-N did not show a consistent trend with canopy reflectance (Fig. 1). The correlations between petiole NO_3-N and canopy reflectance were less than 0.38 at all wavelengths on both dates. Both vegetative indices (NDVI and GNDVI) failed to show significant correlations with petiole NO_3-N. This result was in agreement with 2003 experiment results (Bajwa et al., 2004). To further investigate the lack of correlation between remote sensing data and petiole nutrient concentration data, we performed ANOVA on petiole NO_3-N with respect to N-fertilizer rate and block. Petiole NO_3-N did not show a clear relationship with N rate on 17 July, but showed strong relationship with 27 July data at the 5% significance level. Interestingly, petiole S showed a strong correlation with canopy reflectance in the visible wavelengths of 400-700 nm.

PRACTICAL APPLICATIONS

An accurate and fast method for N monitoring can lead to need-based N applications in production agriculture. Such a need-based and site-specific application of a nutrient can reduce fertilizer use and nutrient loss into the environment. This study showed that remote sensing methods that measure canopy reflectance can be very useful in identifying N stress in cotton fields. Vegetative indices (NDVI and GNDVI) derived from canopy reflectance showed strong correlation with N rates. However, remote sensing is not a good indicator of petiole NO_3-N.

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Table 1. Summary of ground data collected from the N-rate experiment plots at the Cotton Branch Station during 2004. Both petiole data and remote sensing data were collected on two dates, 17 and 27 July.

N rate	Petiole NO_3-N	Petiole P	Petiole K	Petiole S	NDVI	GNDVI
(lb N/acre)	(mg NO_3-N/kg)	(mg P/kg)	(%)	(mg S/kg)		
		July 16, 2004			*July 17, 2004*	
0	335	2786	4.0	1365	0.84	0.68
30	1364	2425	3.6	1128	0.78	0.63
60	458	2630	4.1	1376	0.84	0.67
		July 30, 2004			*July 27, 2004*	
0	2503	4452	5.4	2275	0.93	0.77
30	13341	2420	5.3	1836	0.91	0.73
60	15355	2206	5.2	1894	0.94	0.75

Table 2. Results from GLM procedure between measured variables and N application rate. The results show the model variables, P-value and R2-value for the two dates of data collection. Model format: Y = aX + bB + c + E, where a, b, and c are model parameters, Y is dependent variable, X is independent variable, B is block, and E is model error.

	July 16-17 Data		July 27-30 data	
GLM Model	P-value	R2-value	P-value	R2-value
NDVI Vs N-rate	0.0219	0.58	<0.0001	0.88
GNDVI Vs N-rate	0.0257	0.56	0.0003	0.78
Petiole NO3-N Vs N-rate	0.0772	0.48	<0.0001	0.83
Yield Vs N-rate	0.0044	0.67	—	—

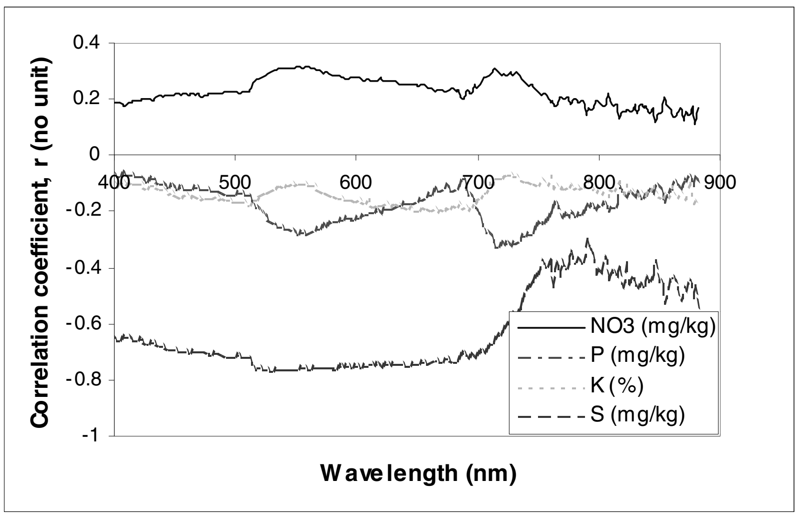

Fig. 1. Correlation between petiole nutrients (NO_3-N, P, K, and S) measured on 30 July and canopy reflectance measured on 27 July plotted against wavelengths.

Residue-Management Practice Effects on Soybean Establishment and Growth in a Young Wheat-Soybean Double-Cropped System

K.R. Brye, M.L. Cordell, and D.E. Longer

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Long-term sustainability of farmland and escalating production costs are increasing concerns of today's growers. Alternative soybean [*Glycine max* (Merr.) L.] management systems, such as double-crop production, can serve to promote sustainability and increase farm earnings.

Wheat (*Triticum aestivum* L.) is typically harvested in late spring, and soybean yield loss commonly occurs if planting is delayed beyond June 15 (UACES, 2000); thus expeditious planting of soybean after wheat harvest is imperative. Many growers burn wheat residue directly after wheat harvest to improve seedbed preparation and eliminate possible sites for insect pests and plant pathogens. Aside from these advantages, NeSmith et al. (1987) concluded that burning residue was a matter of convenience and was of no agronomic benefit.

Though residue burning is popular, some growers have adopted alternative post-wheat harvest operations such as conservation tillage or no-tillage (NT). New and improved equipment has made planting more feasible in high-residue conditions (Kelley and Sweeney, 1998). New methods produce comparable yields to conventional tillage (CT) and reduce production costs (Touchton and Johnson, 1982).

Many studies have addressed the effect of NT on soybean yield, but few have dealt with the effect of burning on soybean production in a wheat-soybean double-crop system in the mid-South. Therefore, the objective of this study was to evaluate the effects of alternative wheat residue-management practices (i.e., CT vs. NT, burn vs. no burn, and high vs. low wheat residue levels) on soybean establishment, growth, and grain yield within the first two cycles of a wheat-soybean double-crop production system.

PROCEDURES

Research was conducted on silt-loam Alfisols at the Pine Tree Branch (PTBS) and Cotton Branch (CBES) Experiment Stations. Prior to the initiation of this study, both study locations were cropped under CT; thus the results of this study represent a short-term NT history. Previous crops were sorghum (*Sorghum bicolor* L.) and soybean at PTBS and CBES, respectively. The research area was established at both locations in Spring 2002 and repeated in Spring 2003.

In Fall 2001 and 2002, 'Coker 9663' wheat was drill-seeded with a 7.5-inch row spacing at both locations. In Spring 2002, 48 10-ft by 20-ft plots were established at both locations. In 2003, the exact same plots as in 2002 were used again. All plots were fertilized with a 90 lb/acre broadcast application of N as urea (46% N) in early March 2002 and 2003. To obtain different levels of wheat residue, one half of the plots were fertilized with an additional 90 lb N/acre broadcast application as urea during the late-jointing stage in late March 2002 and 2003.

After wheat harvest in early June 2002 and 2003, the residue-burning treatment was imposed on half of the plots. Following burning each year, the CT treatment was imposed. Glyphosate-resistant soybean, 'Pioneer 95B32', maturity group 5.3, was drill-seeded with a 7-in row spacing at both locations each year. Soybeans were harvested in early November 2002 by hand due to wet soil conditions, but were harvested using a plot combine in late October 2003. Soybean yields from 2002 and 2003 were adjusted and reported on a 13% moisture basis. To capture potential effects of tillage, burning, and wheat-residue level throughout the growing season in addition to final yield, plant populations were measured early in the growing season (i.e., 8 to 10 and 30 days after planting) and at mid-season growth and development were evaluated by measuring soybean leaf-area index (LAI) at roughly the R6 stage.

Due to dissimilar cropping histories between locations and the recent establishment of the NT production system, year was not explicitly tested as a factor affecting any soybean measurement in this study. Similarly, due to dissimilar fertilization schemes prior to the initial wheat crop and dissimilar soybean seeding rates between locations and years, location was also not explicitly tested as a factor affecting soybean response to tillage, burning, or residue level. Therefore, for each year-location combination, an analysis of variance was conducted to determine the effects of burning, tillage, residue level, and their interactions on early-season plant population, mid-season LAI, and soybean yield using SAS (Version 8.1, SAS Institute, Cary, N.C.).

RESULTS AND DISCUSSION

Burning, tillage, and wheat-residue level each affected early-season soybean plant population at some point during the two-year study. By 8 days after planting (DAP) in 2002, the soybean population was higher ($P = 0.0125$) under the burn (2.2 plants/m) than no-burn treatment (1.1 plants/m) at CBES. Neither tillage nor wheat-residue level affected soybean plant populations by 8 DAP at CBES in 2002. In contrast, the soybean population was higher ($P = 0.0069$) under the low (3.5 plants/m) than high wheat-residue-level treatment (2.0 plants/m) by 8 DAP at PTBS in 2002. Neither tillage nor burning affected soybean plant populations by 8 DAP at PTBS in 2002.

By 10 DAP in 2003, only tillage affected soybean population at CBES, where the soybean population under NT (10.0 plants/m) was higher ($P = 0.0053$) than under CT (7.3 plants/m). Neither burning nor wheat-residue level affected soybean populations by 10 DAP at CBES in 2003. Similarly, neither tillage, burning, nor wheat-residue level affected soybean populations by 10 DAP at PTBS in 2003.

By 30 DAP, it is not unreasonable to expect similar effects on soybean populations as were evident earlier in the growing season (i.e., at 8 or 10 DAP). However, there were no consistent effects on soybean population by 30 DAP as existed at 8 DAP in 2002 at either location. Neither tillage, burning, nor wheat-residue level affected soybean populations at CBES by 30 DAP in 2002. In contrast to the effects on soybean populations by 30 DAP at CBES in 2002, only tillage affected soybean populations by 30 DAP at PTBS in 2002, where soybean populations were higher ($P = 0.0143$) under NT (13.3 plants/m) than under CT (3.7 plants/m).

Similar to 10 DAP, neither tillage, burning, nor wheat-residue level affected soybean populations by 30 DAP at PTBS. However, similar to the results at 10 DAP, tillage also affected soybean population by 30 DAP at CBES, such that soybean planted under NT had a higher ($P = 0.0075$) population (11.0 plants/m) than soybean planted under CT (8.1 plants/m). In addition to a significant tillage effect, wheat-residue level affected soybean population by 30 DAP at CBES in 2003, such that soybean planted into the high wheat-residue treatment resulted in a higher ($P = 0.0037$) population (10.9 plants/m) than soybean planted in the low wheat-residue treatment (8.2 plants/m).

Neither burning nor wheat-residue level affected soybean LAI approximately 90 DAP at either location in 2002 or 2003. However, tillage significantly ($P < 0.03$) affected soybean LAI at PTBS in both years. In 2002, soybean LAI was significantly higher under NT (4.7 m^2/m^2) than CT (2.1 m^2/m^2) at PTBS. Similar to 2002, soybean LAI was significantly higher under NT (3.2 m^2/m^2) than CT (2.7 m^2/m^2) at PTBS in 2003. Neither tillage, burning, nor wheat-residue level affected soybean LAI at CBES in 2003.

Early- and mid-season soybean establishment, growth, and development patterns would be expected to manifest themselves by the end of the growing season in soybean yield. Soybean plant population by 30 DAP at CBES in 2003 ($P = 0.006$ and $r = 0.39$) and mid-season LAI at both locations in 2003 ($P = 0.041$ and $r = 0.30$ at CBES; $P = 0.001$ and $r = 0.46$ at PTBS) were significantly, though weakly, correlated with soybean yield. However, despite significantly higher soybean LAI under NT than CT in both years at PTBS and a significant correlation between LAI and yield in 2003 at both locations, neither tillage, residue burning, nor wheat-residue level affected soybean yield at either location in either year. Soybean yield averaged 62.5 [standard error (SE) = 3.0] bu/acre [4.2 (SE = 0.2) Mg/ha] at CBES and 46.1 (SE = 3.0) bu/acre [3.1 (SE = 0.2) Mg/ha] at PTBS in 2002. In 2003, soybean yield decreased somewhat from that in 2002, averaging 54.6 (SE = 1.5) bu/acre [3.6 (SE = 0.1) Mg/ha] at CBES and 34.2 (SE = 1.5) bu/acre [2.3 (SE = 0.1) Mg/ha] at PTBS.

PRACTICAL APPLICATIONS

The lack of significant tillage and burning effects on soybean yield are important results indicating that soybean grown under NT performed equally as well as soybean grown under CT. Similarly, soybean grown without burning wheat residue performed equally as well as soybean grown following residue burning. In the case of tillage, fewer passes across a field under NT than CT likely results in lower on-farm expenses to prepare for soybean planting in the wheat-soybean double-crop production system. Results of this study indicate no consistent advantage of wheat-residue burning over non-burning and that the combination of NT and non-burning wheat residue can be sound management alternatives that can maintain agricultural production at a high level.

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Fertilizer Recommendation Practices for the Most Popular Crop Rotations in Arkansas Under Conventional and Reduced Tillage Systems

L. Espinoza, C. Kennedy, and P. Ballantyne

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Appropriate fertilization practices are a critical component in any conservation tillage system for each of the crop rotations found in Arkansas. However, limited information is available on best management practices for the nitrogen (N) fertilization of cotton (*Gossypium hirstum* L.) and soybean [*Glycine max* (Merr.) L.] grown under conventional, as compared with no-till and stale-seedbed, production systems. The objective of the second year of this study was to evaluate several fertility programs for crops grown under conventional, stale seedbed, and no-till production systems.

Low crop prices, increasing input costs, and accelerated sedimentation in the Delta region, commonly associated with intensive tillage operations, demand that crops be produced as efficiently as possible. The implementation of conservation tillage practices offers farmers a viable alternative to address such issues. Recent work by McConnell et al. (2001) showed a 5-fold decrease in mean sediment loss from cotton fields under conservation tillage, when compared with cotton fields under conventional tillage. Furthermore, provisions in the new farm bill offer growers higher incentives for implementing conservation practices. Current fertilizer recommendations do not distinguish between tillage practices, especially under higher yield potentials, erratic weather patterns and fast-fruiting cotton varieties. Arkansas producers will benefit greatly from information that would help them make economically and environmentally responsible decisions that will affect their sustainability.

PROCEDURES

A number of tests to study the yield response of cotton and soybean to several fertility programs, under conventional, no-till, and stale-seedbed production systems were established at the Cotton Branch Station near Marianna, Ark. Soil samples (0 to 6 inches) were collected prior to planting and extracted using the Mehlich-3 procedure (extraction ratio of 1:7), with nitrate-N measured with a selective ion electrode, and pH determined in a 1:2 soil:water mixture. The soil at the test site is classified as a Memphis silt loam. For all experiments, tillage and fertility treatments were replicated four times and arranged in a randomized complete block design.

Cotton Tests

For test 1, treatments consisted of three N rates (50, 100, and 150 lb N/acre as 32% UAN), under conventional, stale seedbed, and no-till systems. Each N-fertilizer rate was applied in a two-way split, with half applied at emergence and half at first-square.

Treatments in cotton test 2 included:

a) 'Conventional' program (CP) with 110 lb N/acre as UAN (32%), with 40% applied at emergence and 60% at first square, 1 lb B/acre in three foliar applications, and 10 lb N/acre foliar at first bloom as potassium nitrate;

b) The Nu-till® program (NT) tillage system (Ag Spectrum, Dewitt, Iowa) with 1 ton gypsum/acre, GroEnzyme® at 13 oz/acre, in-furrow fertilizer at rates equivalent to 2.5 lb N, 6.3 lb P_2O_5, and 3.1 lb K_2O/acre plus micronutrients. Sulfur was applied at planting at 26 lb S/acre as ammonium thiosulfate (12-0-0-26). Nitrogen was applied at 110 lb N/acre as UAN (32%), with 60% at planting and 40% at first square, plus 0.5 lb B/acre, and 7 lb N/acre at first bloom as a solution of N and B.

c) A 'Reduced' program (RP) that included in-furrow fertilizer at rates equivalent to 2.5 lb N, 6.3 lb P_2O_5, and 3.1 lb K_2O/acre plus micronutrients; 70 lb N/acre as UAN (32%) at first square; 1 lb B/acre in three applications; and 10 lb N/acre as potassium nitrate at first bloom.

For both tests 1 and 2, Cotton 'DP 444' was seeded on 8 May 2004 at a rate of 42,000 seeds/acre, with plots consisting of four 38-inch wide rows that were 150-ft long. A vacuum planter equipped with Martin fertilizer attachments (Martin Industries, Elkton, Ky.) was used to apply the in-furrow fertilizer. Crops were grown according to University of Arkansas Extension recommendations for pest management and irrigation. The COTMAN program was used to monitor crop development. A cotton-nutrient monitoring kit (CNM) was assigned to each treatment in test 2. All cotton plots were harvested with a plot picker equipped with a weighing system. Handpicked samples were collected for 'turn out' calculation and fiber-quality analysis. Resultant yield data were analyzed with the Duncan's procedure (α=0.05).

Soybean Test

Three, 150-ft long strips of soybean cultivar Armor 53K3 were drilled (7.5-inch wide row spacing) on top of 38-inch wide beds at a rate of 90,000 seed/acre. Soybean was grown under conventional, no-till, and stale-seedbed systems. Since no P or K fertilizer was recommended for soybean, treatments consisted of one foliar application of N at the R1 stage at a rate equivalent to 6 lb N/acre (23% liquid urea). Plant stand counts were taken 2 weeks after emergence by counting the number of plants in 10 ft of row. Counts were taken from the two middle rows of each N-treatment by tillage combination. Soybean was harvested with a 'production' combine with a weigh wagon used to determine grain yield for each harvested area. Soybean yields were standardized to 13% moisture content.

RESULTS

Selected soil properties are presented in Table 1. Low residual nitrate-N was observed in all plots, with the levels of P and K being in the "Optimum" range for cotton and soybean.

Cotton Tests

The response of cotton yield to varying N-fertilizer rates and tillage systems in test 1 is presented in Fig. 1. There was a trend for lint yields to increase with increasing N rate. Yield differences between the no-till and the conventional and stale-seedbed treatments might have been, in part, due to planter set up and not a direct result of the N rate.

The ANOVA table for cotton test 2 (data not shown) showed that the effects of tillage and fertility treatment were significantly different while the interaction between these two variables was not significant (P = 0.986). Average lint yields (Table 2) from plots under the stale-seedbed system were numerically higher than those from conventional and no-till systems, with the difference being significant when stale-seedbed yields were compared with yields from the no-till system (P = 0.044). Yields obtained from cotton receiving the Nu-till® (NT) program were significantly higher than yields from both the conventional (CF) and reduced (RF) fertility programs (P = 0.003, Table 2). Yields from the CF program were about 80 lb lint/acre higher than the RF program, but the difference was not statistically significant. Although different N rates were used for each fertility approach, the difference in N rates between the NT and the CF programs were not likely large enough to explain the approximate 200 lb lint/acre yield increase. Sulfur petiole levels remained within the established sufficiency level for all the tillage and fertility approaches. Lower N rates in the RF program, may have limited optimal plant growth, as shown in the COTMAN graph for the stale-seedbed treatment (Fig. 2). However, a similar trend was observed for plants grown on a stale seedbed under the NT system, which yielded 1567 lb lint/acre (Table 2). A very high boll-retention rate (85 to 90%) through the season probably resulted in limited allocation of carbohydrates for new fruiting structures. Timing of N-fertilizer application along with the erratic weather pattern experienced during the 2004 season could have affected the outcome of the test as well. A significant portion of the N fertilizer under the NT program is applied at planting, while the N for the rest of the fertility programs was applied at emergence or first square. The nutrient-monitoring graph

(Fig. 3) shows petiole nutrient levels in the 'Optimal' range for all fertility treatments in the stale-seedbed system. However, by the time plants started blooming, there was a larger concentration of petiole-N in plants receiving N early in the season. This situation could have affected fruiting node development.

Soybean Test

Soybean yields from plots that received foliar N were not statistically different from those that did not receive any. Figure 4 shows soybean yields by tillage treatment, averaged across foliar-N treatments. No significant difference among tillage treatments was observed. However, plant density in the no-till plots was significantly higher due to the use of two different drills (Fig. 4).

PRACTICAL APPLICATIONS

These preliminary results showed that timing of fertilizer application could be as important as the rate of fertilizer application in cotton. Comparable yields were obtained when crops were grown using no-tillage as compared to conventional tillage. Research will continue to identify the need, if any, to modify existing recommendations for soil sampling and N fertilization under various tillage systems and fertility approaches.

ACKNOWLEDGMENTS

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Table 1. Selected soil chemical properties according to intended crop. Numbers represent the average of 4 soil samples.

Intended crop	pH	NO_3-N	P	K	SO_4-S	EC
		------------ (lb/acre)	------------			(μmhos/cm)
Soybeans						
Conventional	7.0	6	171	405	26	43
Stale seed bed	6.6	5	149	352	32	49
No-till	6.3	4	150	350	26	37
Cotton (test 1&2)						
Conventional	6.3	3	122	379	51	56
Stale seed bed	6.2	4	114	350	64	45
No-till	5.3	2	109	353	54	42

Table 2. 2004 mean cotton lint yields according to tillage system and fertility program (Test 2).

Tillage system	Fertility approach	MLY[y]	Across fertility	MLY[z]	Across tillage	MLY[z]
		(lb/acre)		(lb/acre)		(lb/acre)
Conventional						
	Conventional	1307				
	Nu-till	1492	Stale seedbed	1403	Nu-till.	1469
	Reduced	1225				
Stale seedbed						
	Conventional	1387				
	Nu-till	1567	Conventional	1341	Conventional	1286
	Reduced	1257				
No-till						
	Conventional	1164				
	Nu-till	1348	No-till	1213	Reduced	1203
	Reduced	1127				
CV (%)		13.6				
LSD (0.05)		NS		150		150

[y] MLY= mean lint yield.
[z] Means followed by the same letter are not statistically different at alpha=0.05.

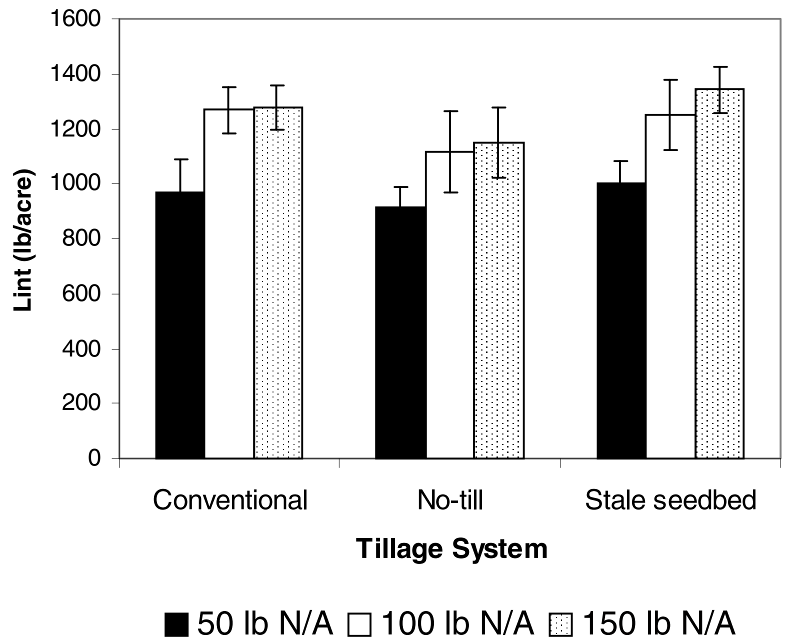

Fig. 1. Yield response of cotton to varying N rates and tillage systems during 2004 (Test 1), and associated standard deviations.

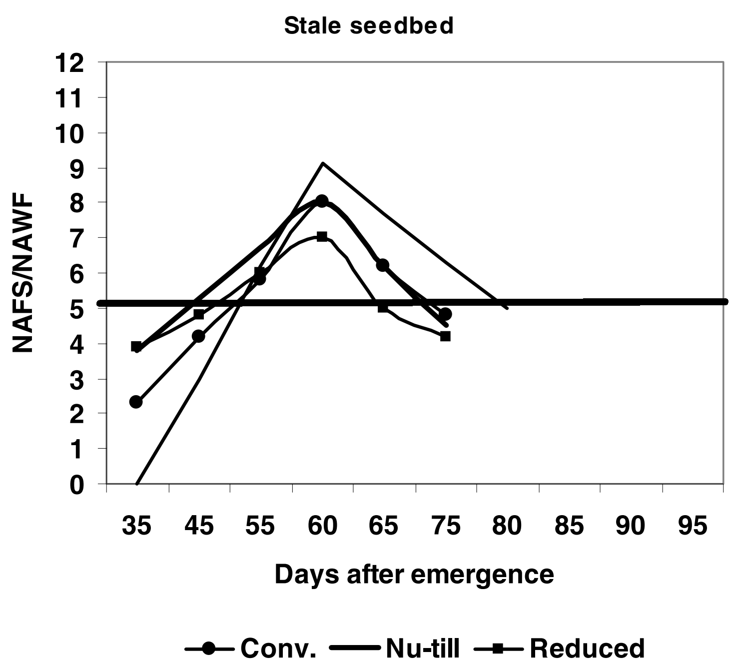

Fig. 2. Crop growth according to fertility program for cotton grown under a stale seedbed system (Test 2).

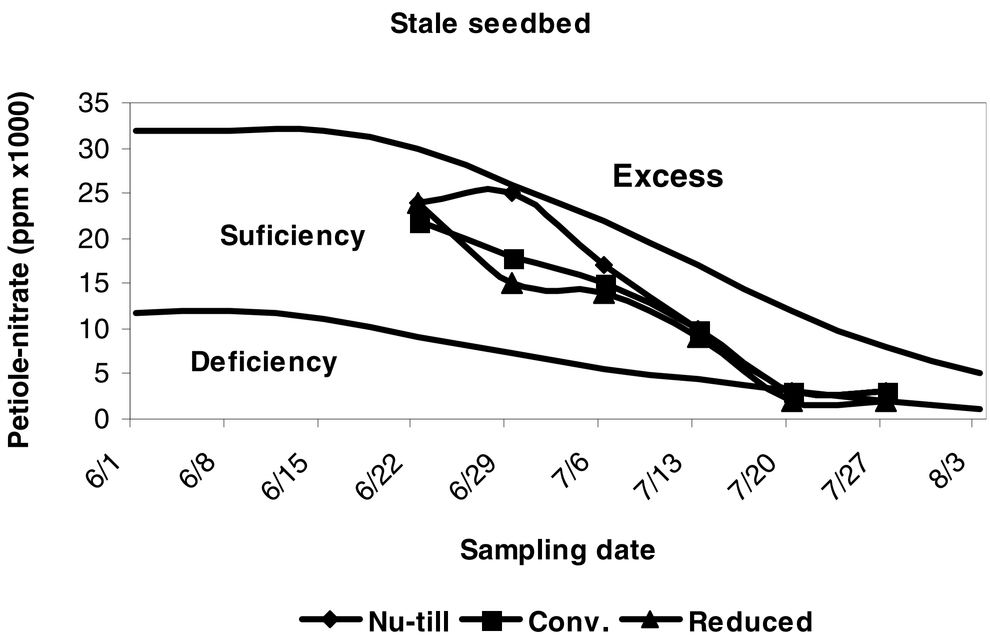

Fig. 3. Petiole-nitrate levels according to fertility program for cotton grown under a stale seedbed system (Test 2).

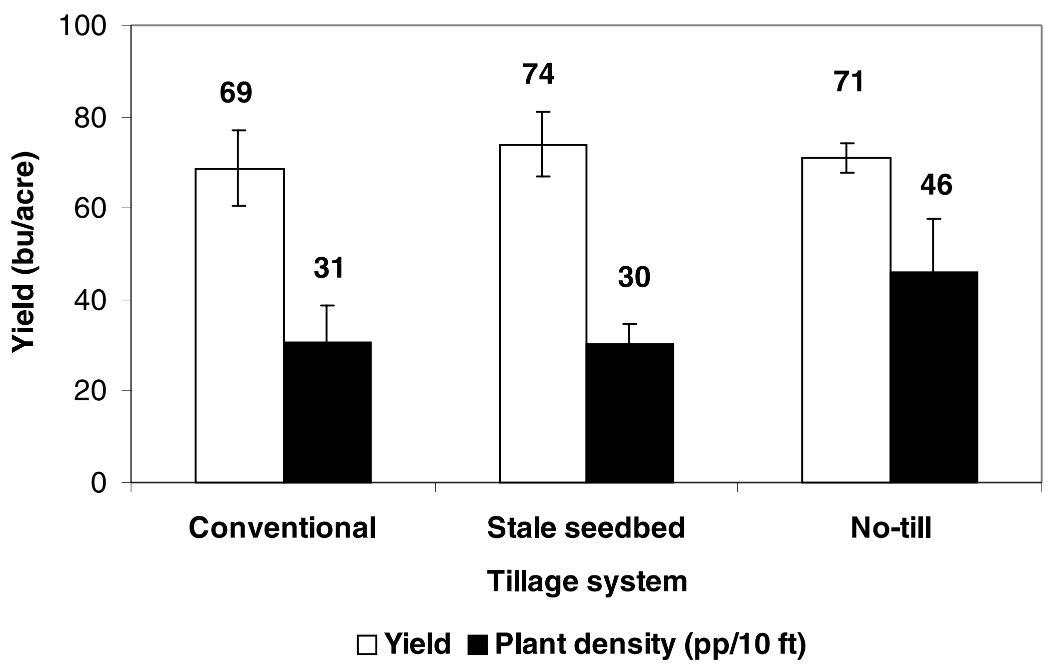

Fig. 4. Soybean yields, plant density, and associated standard deviations under no-till, stale seedbed, and conventional tillage.

Native Prairie and Agroecosystem Effects on Soil Physical Properties and Runoff Water Quality in the Arkansas Delta

T.W. Harper, T.C. Daniel, K.R. Brye, and N.A. Slaton

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Recent evaluations of surfacewater quality in eastern Arkansas have identified a number of lakes and streams that are impaired for one or more of their designated uses because of high turbidity (ADEQ, 2002). State agencies have determined the cause of the problem to be excessive soil erosion from agricultural fields. Traditional agricultural production practices leave the soil surface bare of vegetative cover most of the spring during which time the most intense rainstorms of the year occur (USGS, 2003). These conditions have proven to be a fragile combination for producing surfacewater runoff and erosion. In addition, runoff volumes from Delta soils have been shown to be extremely high, possibly due to changes in soil physical properties caused by agricultural production practices.

A number of methods, known as best management practices (BMPs), have been documented to decrease damaging runoff from agricultural lands into lakes and streams. One of these BMPs, conservation tillage (CT), has been adopted throughout the United States and has been shown to be very effective in controlling these water-quality problems. Conservation tillage provides a number of short- and long-term benefits. Short-term benefits, including increased water availability, reduced soil erosion, and improved water quality, are a direct result of residue cover present on the soil surface. Long-term benefits, including increased soil organic matter, improved soil tilth, and increased water infiltration, are a result of continuous long-term CT practices. Despite the effectiveness of CT, adoption rates in Arkansas are extremely low (CTIC, 2003) and extensive studies under Arkansas conditions are limited. The objectives of this study were to quantify differences in soil physical properties due to land use (including CT) and determine how these differences affect infiltration, runoff volume, sediment load, turbidity, and runoff concentrations of various forms of phosphorous.

PROCEDURES

A single study was conducted in March 2004 on a Grenada silt loam (Fine-silty, mixed, active, thermic, Oxyaquic Fraglossudalfs) at the Roth Prairie and Harbecke Farms located near Stuttgart, Ark. Treatments consisted of three land uses: conventional till (CN), reduced till (RT), and native prairie (PR). The CN system had been tilled one month prior to rainfall simulation while the RT system had been under continuous CT management for eight years. The CT system was currently in wheat production and had been fallow the previous season. The RT system was previously planted in soybean and a typical soybean-corn rotation had been followed. Typical management practices associated with these two systems had been followed. The native prairie system had never been disturbed. All three systems experienced several rainstorms in the month prior to rainfall simulation.

Plots (2- by 1.5-m) were established and used for rainfall simulation. The experimental design was completely randomized with four replications for a total of 12 plots. Prior to rainfall simulation, residue cover was measured on all 12 plots using the string method (Hartwig and Laflen, 1978). Volumetric water content was also determined on the plots using dielectric voltage readings converted to volumetric water content using a soil-specific calibration. Soil samples were taken and analyzed for aggregate stability, bulk density, total organic carbon, and Mehlich-3-extractable nutrient concentrations. Soil samples were taken from the area immediately surrounding the plots using a 2-inch diameter core sampler.

Soil samples were taken to a depth of 2 inches to characterize the zone of soil that interacts with runoff water. Mehlich-3-extractable P concentrations were obtained using an Inductively Coupled Argon Plasma Spectrometer (ICAP) and, along with pH and several other nutrients, are shown in Table 1. Post-simulation measurements included soil resistance.

Rainfall simulations were conducted on 26 and 27 March according to National Phosphorous Project Protocol (Sharpley and Daniel, 2004) for simulated rainfall-surface runoff studies (http://www.soil.ncsu.edu/sera17/). One rainfall simulator (Humphry et al., 2002) was used to simulate a 7.0 cm/hour (2.8 inches/hour) rainfall, which is equivalent to a storm with a 5- to 10-yr return period in eastern Arkansas (USDC, 1963). Water used for rainfall simulations came from uncontaminated sources and, prior to application, was sent through a series of exchange-resin filters to simulate the chemistry of natural rainfall. The duration of the simulations varied from plot to plot depending on time until runoff, but were conducted to provide 30-minute runoff events. Runoff volume was collected, recorded, and a 1 L composite sample was taken for analyses. Runoff water samples were analyzed for sediment load (concentration × runoff volume), turbidity, soluble-reactive phosphorus (SRP), and total phosphorus (TP).

The effect of land use was determined by analysis of variance procedures conducted with the PROC ANOVA procedure in SAS. A significance level of 0.05 was chosen and, when appropriate, means were separated using the Fisher's protected least significant difference (LSD) method.

RESULTS AND DISCUSSION

Significant differences in residue cover existed among the three land uses with CN having the least (27.5%) and PR having the highest cover (98.5%, Table 2). The RT system also had a high amount of residue cover (80.8%), but was still significantly lower than that of the PR. Runoff volume was numerically the highest from the RT (91.9%) plots and statistically greater than runoff from the PR (65.7%). Runoff volume from the CN (79.8%) was not significantly different from the RT or PR plots. Soluble-phosphorus load was significantly higher from the RT (10.7 mg/plot) than from the CN (1.5 mg/plot) and PR (0.2 mg/plot) (Table 2). High phosphorus loads from RT systems are typically attributed to broadcast application of fertilizer and decomposition of residue on the surface of the soil. Phosphorus load is also influenced by the high volume of runoff from the RT system.

Total phosphorus load from CN (114.6 mg/plot) plots was twice that of RT (54.7 mg/plot) plots and nearly 10 times that of the PR (13.7 mg/plot) system (Table 2). This significant difference in TP load is most likely due to the increased amount of solids in the CN runoff. Total-solid load from the CN (89.2 g/plot) was more than 30 times greater than loads from the PR and RT systems which were nearly identical at 2.6 and 2.8 g/plot, respectively (Table 2). This difference in solid load is also reflected in the turbidity values of the three systems. Turbidity (measured in Nephelometric Turbidity Units, NTUs) of the CN (550 NTUs) runoff was significantly higher than that of the PR (22 NTUs) and RT (109 NTUs) systems (Table 2).

Bulk density of the PR (0.91 g/cm^3) system was significantly lower than that of the RT (1.19 g/cm^3) and CN (1.21 g/cm^3) systems (Table 3). Aggregate stability was significantly higher in the PR (49.6%) than in the RT (25.3%) and CN (19.8%) systems. Reduced tillage, although not statistically different, exhibited a trend of increased aggregate stability when compared with the CN plots. Total soil carbon of the PR (3.08%) plots was nearly twice as high as that of the RT (1.46%) and CN (1.59%) plots (Table 3). Significant soil resistance differences were apparent at the 10- to 30-cm depths of the soil profile (data not shown). Reduced tillage and CN also showed significantly higher soil resistance than the PR system at the 10- to 30-cm depth. The increased soil resistance is indicative of the presence of a plow pan.

PRACTICAL APPLICATIONS

The short-term benefits of CT were evident. Reduced tillage practices were shown to be extremely effective at improving water quality, especially in terms of TP load, solid load, and turbidity, when compared to CN systems. In fact, when considering these parameters, RT exhibited very similar numbers to that of the undisturbed system, the native prairie.

The high soluble-phosphorus loads from the RT plots are of some concern. Even though SRP concentrations are typically higher from RT systems than from CN systems, loads are usually more similar because of the decreased runoff from RT plots. That was not the case in this experiment with the highest runoff volume coming from the RT plots. A typically accepted solution to controlling SRP loads is to make sure fertilizer is applied to RT systems several days prior to an expected rainfall, giving the fertilizer time to adsorb to the soil. In this case, fertilizer had not been applied to the RT system in several months, but the plots still showed very high SRP loads.

The long-term benefits of CT, even after eight years of continuous CT management, were not yet evident. Reduced tillage did not result in increased water infiltration compared to the CN systems. Nor did RT practices show significant differences in soil physical properties although the RT system was beginning to show signs of improved soil physical properties, especially in terms of aggregate stability. So, while RT is an effective BMP for improving overall water quality, it may not necessarily be the answer to other problems, including increased water infiltration and reduced SRP loads, especially in the Arkansas Delta.

ACKNOWLEDGMENTS

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Table 1. Soil pH and mean Mechlich-3-extractable nutrient concentrations for selected nutrients for conventional till (CN), native prairie (PR), and reduced till (RT) systems at the Roth Prairie and Harbecke Farms near Stuttgart, Ark.

	Soil	Mehlich-3-extractable nutrient concentrations						
System	pH	P	K	Ca	Mg	S	Na	Zn
		(mg/kg)						
CN	5.7	56	225	419	45	18	17	3.8
PR	5.0	23	142	207	46	27	17	1.3
RT	6.7	33	115	935	106	13	23	5.6

Table 2. The influence of land-management system on residue cover, runoff volume, soluble reactive phosphorous, total phosphorous, sediment load, and turbidity for conventional till (CN), native prairie (PR), and reduced till (RT) systems at the Roth Prairie and Harbecke Farms near Stuttgart, Ark.

	System			
Measurement	CN	PR	RT	LSD0.05
Residue cover (%)	27.5	98.5	80.8	7.8
Runoff volume (%)	79.8	65.7	91.9	14.4
Soluble reactive phosphorous (mg/plot)	1.5	0.2	10.7	5.5
Total phosphorous (mg/plot)	114.6	13.7	54.7	20.5
Sediment load (g/plot)	89.2	2.6	2.8	17.5
Turbidity (NTUs)	550.0	22.2	109.5	68.1

Table 3. The influence of land-management system on soil bulk density (BD), aggregate stability (AS), and total carbon (TC) of conventional till (CN), native prairie (PR), and reduced till (RT) systems at the Roth Prairie and Harbecke Farms near Stuttgart, Ark.

	Soil physical properties		
System	BD	AS	TC
	(g/cm^3)	(%)	
CN	1.21 a[z]	19.8 a	1.59 a
PR	0.91 b	49.6 b	3.08 b
RT	1.19 a	25.3 a	1.46 a

[z]Means in a column followed by the same letter are not significantly different at the 0.05 level.

Comparisons of Foliar Nitrogen Fertilization Strategies and Methods for Cotton

J.S. McConnell, R.C. Doherty, J.A. Rauls, and M. Mozaffari

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Foliar-nitrogen (N) fertilization of cotton is a widely used production practice to augment soil-applied N fertilization programs. Producers have used various methods to determine the timing of foliar-N applications but still raise questions about the validity of foliar fertilization. Reported responses of cotton to foliar fertilization range from no yield and minimal yield responses to significant and economically viable yield increases. The objective of this research was to compare three foliar-N fertilization methods and determine which of these methods is most likely to produce an increase in yields.

Producers fertilize cotton with N to avoid yield loss due to N deficiency. Typically, large amounts of N fertilizer are split-applied, with about half the total amount applied around planting time and the remainder applied before first bloom (Maples et al., 1990). Soil testing for N and the subsequent fertilizer N recommendations may be inappropriate for cotton grown under all production conditions during all years. During years of high-yield potential, recommended rates of early-season fertilizer N may be insufficient for maximal yield and during years of low-yield potential, fertilizer N may be over-supplied (Miley, 1982).

Previous research has indicated that pre-plant and early sidedress N applications might not meet full-season crop demands. These studies indicated that either soil- or foliar-applied N after first flower may help meet crop N needs and increase yields (Maples and Baker, 1993). These studies and others were also used to develop critical deficiency and sufficiency values of petiole nitrate-N (NO_3-N) and incorporate them into the Cotton Nutrient Monitoring Program (CNMP, Maples et al., 1992). Foliar fertilization of cotton with 23% N (urea) solutions based on CNMP-generated recommendations has been widely practiced by Arkansas cotton producers to meet late-season N requirements (Snyder, 1991).

Recent research indicates that the yield response of cotton to foliar-N applications under current production conditions may not be as dramatic as observed in earlier work (Keisling et al., 1995; McConnell and Baker, 1998). Furthermore, the use of petiole NO_3^--N concentration as an indicator of crop N status has been questioned (Heitholt, 1994).

PROCEDURES

Studies of the responses of cotton to three methods of foliar N fertilization were begun at the Southeast Branch Experiment Station, near Rohwer, Ark., in 2003. Five N-fertilization strategies were compared to an unfertilized control. All plots, except for the unfertilized control, received a recommended early-season split application of soil-applied N of 100 lb N/acre as urea (46% N); half of the N was applied shortly after emergence and half at first square. Four additional foliar, fertilizer-N treatments included: i) Soil-Applied, 30 lb urea-N/acre soil applied at first flower; ii) Foliar-Timed, four weekly scheduled foliar applications of 10 lb N/acre as 23% N solution; iii) Foliar-Cardy, foliar applications of 10 lb N/acre as 23% N solution according to Cardy Meter thresholds (Kenty et al., 2003); and iv) Foliar-CNMP, foliar applications of 10 lb N/acre as 23% N solution according to the University of Arkansas CNMP recommendations (Maples et al., 1992). Thus, only two treatments, the unfertilized control and the standard early-season application of 100 lb N/acre, did not receive supplemental late-season N applications. Phosphorus and potassium fertilizers were applied annually as a preplant, blanket treatment to all plots at rates of 46 lb P_2O_5/acre and 60 lb K_2O/acre.

Tests were conducted under furrow-irrigated and dryland conditions. The cotton variety used was Stoneville 4892 BR in 2003 and PayMaster 1218 BR in 2004. The tests were planted on 12 May 2003 and 11 May 2004. The soil at the test site was a Hebert silt loam. Selected soil chemical properties were analyzed in spring 2003 (Table 1). Measurements taken on the foliar-N fertilization test included seedcotton yield, plant height, plant population, petiole analysis, and node development information. All data were analyzed using the Statistical Analysis System (SAS). The experimental design was a split block with furrow irrigation or dryland production as the main blocks. F-tests and least significant differences (LSD) were calculated at the α=0.05 level of probability. Only yield responses of cotton to the N-treatments are presented in this report.

RESULTS AND DISCUSSION

The 2003 growing season was marred by abnormally wet and cool growing conditions in May and most of June. These inclement conditions were probably responsible for substantial delays in seedling growth and reduced yields. Ponding of water in the irrigated block of this test further exacerbated the weakened condition of the seedlings resulting in lower yields with furrow irrigation than dryland cotton. The 2004 growing season was more moderate and favorable to high yields than in 2003.

Foliar and soil applications of 23% urea solutions were made periodically during the growing seasons (Table 2 and 3), and ended as the crop approached maturity. Foliar N treatments varied between the first two years of the study. The greatest rate of foliar N (six applications totaling 60 lb N/acre) was applied in conjunction with the Cardy Meter analyses (Foliar-Cardy) in 2003 (Table 2). The least foliar N (three applications totaling 30 lb N/acre) was applied when the CNMP (Foliar-CNMP) was used to trigger foliar fertilization in 2003. In 2004, the greatest rate of foliar N was applied using Cardy meter thresholds (five applications totaling 50 lb N/acre) under irrigated conditions (Table 3). The least foliar N was applied according to CNMP protocols (one application of 10 lb N/acre) in 2004.

Yields were found to significantly differ with the interactive effects of irrigation with N-fertilization in 2003 (Table 4). Dryland managed cotton generally produced greater yields than furrow-irrigated cotton. Furrow irrigated cotton that received N fertilizer produced significantly greater yields than the unfertilized control. Cotton receiving 100 lb N/acre with no foliar N produced the numerically greatest yield, which was not different than cotton receiving additional late-season N.

For dryland management, cotton receiving 100 lb N/acre with no foliar N, soil-applied 30 lb N/acre, and Foliar-Cardy N management strategies produced similar yields that were significantly greater than the control (Table 4). Cotton that received N, regardless of N management strategy, produced similar yields indicating that supplemental foliar N is not always needed to maximize cotton yields.

In 2004, cotton yields were not significantly influenced by irrigation method or the interaction of irrigation with the N-management strategy in 2004 (Table 5). The lack of significant irrigation effects allows combining or pooling of the data from the irrigation blocks. The untreated control produced significantly lower cotton yields than all other treatments. The standard, recommended rate of 100 lb of soil-applied N/acre produced cotton yields that were not significantly different than cotton receiving an additional 30 lb of soil-applied N/acre at first flower or the scheduled foliar N treatment. Foliar fertilization triggered by CNMP and Cardy meter thresholds resulted in the greatest yields in 2004.

PRACTICAL APPLICATION

The apparent discontinuity in yield results between the 2003 and 2004 growing seasons indicates there is substantial variability in cotton response to foliar-N applications. The second year results indicate there is potential to increase yields with foliar-N fertilizer applications to developing cotton. More testing is needed before final conclusions are reached.

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Table 1. Residual nitrate-nitrogen (NO_3^--N), phosphorus (P), potassium (K), soil pH, and electrical conductivity (EC) to a depth of two feet in six-inch increments from the foliar N-fertilization methods test site at the University of Arkansas - Southeast Branch Experiment Station near Rohwer, Ark., in 2003 prior to fertilization.

Depth	NO_3^--N	P[z]	K[z]	pH[y]	EC[y]
(in.)	(lb/acre)				(µS/m)
Irrigated					
0 - 6	9	123	256	6.9	23
6 - 12	4	21	240	6.5	17
12 - 18	4	14	327	5.3	24
18 - 24	4	14	338	5.2	25
Dryland					
0 - 6	17	132	342	5.5	23
6 - 12	6	34	185	5.6	12
12 - 18	6	29	207	5.0	19
18 - 24	9	23	294	4.9	23

[z] Mehlich-3 extractable (1:7 extraction ratio)
[y] Soil pH and EC measured in a 1:2 soil-water mixture.

Table 2. Application dates of supplemental N treatments as triggered by N-fertilization strategies on the foliar-N methods test at the Southeast Branch Experiment Station near Rohwer, Ark., during 2003.

N-fertilization		Date of foliar or late-season soil fertilization							
Early season	Late season	7/9	7/17	7/23	7/30	8/6	8/13	8/19	8/26
(lb N/acre)	(method)								
Irrigated									
100	Foliar-CNMP				X		X	X	
100	Foliar-Cardy		X	X	X	X	X	X	
100	Foliar-Timed		X	X	X				
100	Soil Applied	X							
100	0								
0	0								
Dryland									
100	Foliar-CNMP				X		X	X	
100	Foliar-Cardy		X	X	X	X	X		
100	Foliar-Timed		X	X	X				
100	Soil Applied	X							
100	0								
0	0								

Table 3. Application dates of supplemental N treatments as triggered by N-fertilization strategies on the foliar-N methods test at the Southeast Branch Experiment Station near Rohwer, Ark., during 2004.

N-fertilization		Date of foliar or late-season soil fertilization				
Early season	Late season	7/8	7/14	7/21	7/28	8/4
(lb N/acre)	(method)					
Irrigated						
100	Foliar-CNMP			X	X	X
100	Foliar-Cardy	X	X	X	X	X
100	Foliar-Timed	X	X	X		
100	Soil Applied		X[z]			
100	0					
0	0					
Dryland						
100	Foliar-CNMP					X
100	Foliar-Cardy			X	X	X
100	Foliar-Timed	X	X	X		
100	Soil Applied		X[z]			
100	0					
0	0					

[z] The soil applied, first flower N treatment was delayed one week due to wet soil conditions.

Table 4. Seedcotton yields as affected by N-management strategy of the foliar nitrogen methods test at the Southeast Branch Experiment Station near Rohwer, Ark., during 2003.

		Seedcotton yield[z]		
N-fertilization		Irrigation method		
Early season	Late season	Dryland	Irrigated	Mean
(lb N/acre)	(method)	--------- (lb seedcotton/acre) -----		
100	Foliar-CNMP	3265	2769	3017
100	Foliar-Cardy	3753	2590	3127
100	Foliar-Timed	3261	2852	3041
100	Soil Applied	3357	2469	2947
100	0	3511	2941	3248
0	0	2844	1699	2272
To compare means within the same irrigation block, LSD(0.05) = 489				
To compare means in different irrigation blocks LSD(0.05) = 720				
Irrigation Method Mean		3325	2540	

[z] Lint yield may be estimated by dividing seedcotton yield by 3.

Table 5. Seedcotton yields as affected by N-management strategy of the foliar nitrogen methods test at the Southeast Branch Experiment Station near Rohwer, Ark., during 2004.

		Seedcotton yield[z]		
N-fertilization		Irrigation method		
Early season	Late season	Dryland	Irrigated	Mean
(lb N/acre)	(method)	--------- (lb seedcotton/acre) -----		
100	Foliar-CNMP	4804	5092	4935
100	Foliar-Cardy	4688	4802	4745
100	Foliar-Timed	4727	4318	4507
100	Soil Applied	4121	4506	4282
100	0	4259	4147	4207
0	0	2856	2415	2672
LSD (0.05)				417
Irrigation Method Means		4217	4251	

[z] Lint yield may be estimated by dividing seedcotton yield by 3.

Varietal Responses of Cotton to Nitrogen Fertilization

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Optimizing yield and earliness of cotton (*Gossypium hirsutum* L.) varieties with nitrogen fertilization is an ongoing concern of cotton producers in Arkansas (Maples and Frizzell, 1985; McConnell et al., 1993). Genetically engineered cotton varieties are currently being used in increasingly larger portions of the cotton-producing acreage of Arkansas and the Cotton Belt. Producers have been quick to utilize 'Bollgard' and Roundup®-Ready varieties, as well as 'stacked gene' varieties that combine these two technologies into one cotton variety. Advantages of these new varieties include higher yield potential, enhanced pest resistance, resistance to herbicides, superior lint quality, faster maturity, and other new characteristics. With the increase in new cotton varieties into Delta production systems, the N requirements of the new varieties are often questioned by producers. The objective of this study was to determine the responses of new, genetically engineered cotton varieties to N-fertilization rate.

New cotton cultivars have increased the genetic diversity of cotton grown in the Delta. The genetic variability of currently available varieties indicates that crop management practices, such as fertilization, required to achieve optimal yields and earliness might differ from older varieties. Optimizing N fertilization for individual cotton varieties is one possible way of tailoring production practices to achieve optimal economic returns.

PROCEDURES

Studies of the responses of cotton varieties to N fertilization were begun at the Southeast Branch Experiment Station in 1989 (McConnell et al., 1993). Tested varieties have changed as new varieties have been introduced into the Delta region. Varieties currently under evaluation include Stoneville 4892 BR (ST 4892BR), FiberMax 960 BR (FM 960BR), Pay Master (PM 1281BR) and Deltapine 555 BR (DP 555BR). All varieties tested are genetically engineered to tolerate early-season applications of Roundup® herbicide and to resist damage from heliothis species insect pests. This is the first year of results from tests including these new varieties.

Nitrogen fertilizer rates were 0, 50, 100, and 150 lb N/acre. The source of the N was urea. The N fertilizer rates were split-applied with one-half the total N rate applied after emergence and one-half when the crop reached the first-square stage. The urea-N was incorporated with shallow plowing after each application. The same N rates have been applied to the same plots since the inception of testing (1989). Phosphorus and potassium fertilizer were annually applied as a preplant, blanket treatment to all plots at rates of 46 lb-P_2O_5/acre and 60 lb-K_2O/acre. The test was furrow-irrigated using tensiometers to trigger irrigation. The varieties were planted on 12 May 2003 and 11 May 2004. The soil (Hebert silt loam) at the test site was sampled and analyzed for nutrient content in 1999 (Table 1).

The measurements taken on the cotton varieties included seedcotton yield, plant height, plant population, and node development information. All data were analyzed using the Statistical Analysis System (SAS). The experimental design was a randomized complete block design with a factorial arrangement of cultivars and N rates. F-tests and least significant differences (LSD) were calculated at the α=0.05 level of probability. Only yield responses of cotton to N-fertilization and variety selection are presented in this report.

The 2003 growing season was marred by abnormally wet and cool growing conditions in May and most of June. These inclement conditions were responsible for a substantial delay in maturity for the 2003 crop. In 2003, cotton yields were lower than expected and lower than other years of similar testing (McConnell et al., 2003). Growing conditions were more moderate in 2004 resulting in more rapid crop maturity and greater overall yields.

RESULTS AND DISCUSSION

No significant differences in the yield of cotton occurred as a function of the interaction between cotton variety and N-fertilizer rate in 2003 or 2004 (Tables 2 and 3). The lack of significant interactions between varieties and N-rates indicates that these cotton varieties respond similarly, if not equally, to N fertilizer rate.

Seedcotton yields among varieties, averaged across N rates, were not statistically different in 2003 (Table 2). The mean yield of PM 1281BR, the numerically greatest yielding variety, was only 233 lb seedcotton/acre greater than the yield of ST 4892BR, the numerically lowest yielding variety. Although yields were lower in 2003 than in preceding years, significant cotton-yield differences were observed among N rates, averaged across varieties (Table 2). The 50 lb N/acre rate produced a 73% increase in yield from the untreated control. The 100 lb N/acre rate produced a 24% increase in yield above 50 lb N/acre. The 150 lb N/acre rate produced the maximum yields and was 12% greater than the mean cotton yield from 100 lb N/acre. All differences among the N-treatment means were statistically significant.

Both variety and N rate (main treatment effects) significantly influenced cotton yields in 2004 (Table 3). DP 555BR was significantly lower yielding than the other three varieties tested. PM 1218BR, ST 4892BR, and FM 960BR did not significantly differ in yield and differed numerically by only 159 lb seedcotton/acre. The effect of N rate on yields in 2004 was similar to 2003. Seedcotton yield significantly increased with each 50 lb N/acre addition. The average yield produced by the untreated check was less than half of the 150 lb N/acre rate.

PRACTICAL APPLICATION

These initial results suggest that genetically engineered cotton varieties have similar N fertilizer requirements and do not likely require different N-fertilizer management strategies than conventional cotton varieties. Significant yield loss may occur if these varieties are not adequately fertilized. Additionally, the varieties may respond differently as growing conditions vary.

ACKNOWLEDGMENTS

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Table 1. Residual nitrate-nitrogen (NO_3^--N), phosphorus (P), potassium (K), soil pH, and electrical conductivity (EC) to a depth of two feet in six-inch increments from the variety by N-fertilization rate in test site in 1999.

Depth	NO_3-N	P[z]	K[z]	pH[y]	EC[y]
(in.)	---------	(lb/acre)	----------		(µS/m)
0 - 6	1.8	70	260	6.3	26
6 - 12	1.7	30	125	6.4	20
12 - 18	1.7	29	149	6.1	21
18 -24	2.4	22	243	6.0	44
LSD(0.05)	0.4	6	18	0.1	3

[z] Mehlich-3 extractable (1:7 extraction ratio).
[y] Soil pH and EC measured in a 1:2 soil-water mixture.

Table 2. Seedcotton yields of four genetically engineered cotton varieties as affected by N-fertilizer rate at the Southeast Branch Experiment Station near Rohwer, Ark., during 2003.

	Cotton variety				N-rate
N rate	ST 4892BR	FM 960BR	PM 1281BR	DP 555BR	mean
(lb/acre)	------------------ (lb seedcotton yield/acre[z]) --------------------				
150	3590	4219	3903	3805	3869
100	3514	3570	3476	3246	3467
50	2616	2788	3095	2648	2787
0	1820	1721	1428	1479	1612
LSD(0.05) to compare N-rate means = 67 lb/acre					
Cultivar mean[y]	2807	2980	3040	2869	--

[z] Lint yield may be estimated by dividing seedcotton yield by 3.
[y] Mean yields of varieties, averaged across N rates, were not different.

Table 3. Seedcotton yields of four genetically engineered cotton varieties as affected by N-fertilizer rate at the Southeast Branch Experiment Station near Rohwer, Ark., during 2004.

	Cotton variety				N-rate
N rate	ST 4892BR	FM 960BR	PM 1281BR	DP 555BR	mean
(lb/acre)	------------------ (lb seedcotton yield/acre[z]) --------------------				
150	5140	5058	5044	4318	4890
100	4448	4390	4670	3872	4353
50	3630	3509	4084	3255	3615
0 2541	2444	2221	1651	2214	
LSD(0.05) to compare N-rate means = 330					
Cultivar means[y]	3925	3850	4009	3275	--
LSD (0.05) to compare cultivar means = 299					

[z] Lint yield may be estimated by dividing seedcotton yield by 3.
[y] Mean yields of varieties, averaged across N rates, were not different.

Long-Term Irrigation Methods and Nitrogen Fertilization Rates in Cotton Production: The Last Three Years of the McConnell - Mitchell Plots

J.S. McConnell, J. A. Rauls, R.C. Doherty, and M. Mozaffari

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Nitrogen (N) and water management are two very important aspects of successful cotton (*Gossypium hirsutum* L.) production. If cotton becomes N deficient, the plants may become chlorotic and not photosynthesize sufficiently to meet the demands of crop growth. Nitrogen deficiency of cotton typically results in reduced yields, pre-mature cut out, and reduced fiber quality. Few studies of the interactions of N fertilizer and irrigation have been conducted for cotton. This is especially true under the humid production conditions of southeast Arkansas (McConnell et al., 1988). The objectives of these studies were to evaluate the growth, development, and yield of intensively managed cotton as a function of N fertilization and soil N dynamics under different irrigation methods.

Both over- and under-fertilization of cotton with N may result in reduced yields. Over fertilization may also induce delayed maturity in cotton (Maples and Keogh, 1971). Reductions in yield and quality due to N deficiency may severely reduce the value of the crop and have adverse economic consequences for producers (Bondada et al., 1996; Radin and Mauney, 1984).

Generally, cotton yields have increased with increasing N fertilization throughout the previous years of this test (McConnell et al., 1988; McConnell and Baker, 1998). The N treatments that usually resulted in the greatest yields were applications of 60- to 150-lb N/acre, depending upon the irrigation treatment and year. The yields of the high-frequency center-pivot irrigation block during some years were significantly influenced by verticillium wilt. The disease was more virulent in the plots receiving higher N rates, thereby reducing yields with increasing N.

Adequate soil moisture is also necessary for cotton to achieve optimal yields. Early and mid-season water requirements of cotton should be met to avoid yield loss that may occur if the crop undergoes drought stress (Jordan, 1986; Wanjura, et al., 1996). If the soil becomes either too wet or too dry, cotton plants will undergo stress and begin to shed fruit (Guinn et al., 1981).

In the previous years of this study, irrigation generally increased cotton yields except during seasons when early-season rainfall resulted in standing water that delayed maturity of the irrigated plants; or when verticillium wilt was prevalent. The method of irrigation that maximized yield varied among years, and therefore, appeared to be less important than irrigation usage.

PROCEDURES

An experiment to examine the interactions of N-fertilization strategy (N-rate and application times) and irrigation method was initiated at the Southeast Branch Experiment Station on a Hebert silt loam soil in 1982. This test, the McConnell-Mitchell Plots, is the oldest continuous field experiment in Arkansas. The experimental design was a split block with irrigation methods as the main blocks. Four irrigation methods were used from 1982 until 1987. Five irrigation methods were employed from 1988 to 1993. Only three irrigation methods have been used since 1993 (Table 1).

Ten total N treatments were tested within each irrigation method. Six different N rates (0, 30, 60, 90, 120, and 150 lb urea-N/acre) were tested with different application rates and timings (Table 2). Phosphorus and potassium fertilizer were annually applied as a preplant, blanket treatment to all plots at rates of 46 lb-P_2O_5/acre and 60 lb-K_2O/acre. Nitrogen fertilization was discontinued for the 2000 through 2003 growing seasons to examine the effects of residual soil nitrate-nitrogen (NO_3-N) on cotton development. Treatments were resumed in 2004 after 2003 yield results indicated minimal yield response from residual N. Soil samples were taken from the plots and analyzed for residual NO_3-N to a depth of five feet in 2000 and 2004 (Tables 3 and 4).

The McConnell-Mitchell Plots were planted on 23 April 2002, 12 May 2003, and 11 May 2004. Both the 2002 and 2003 crops were influenced by cool, wet conditions early in the growing season. The 2004 growing season was more moderate than in 2003.

All data were analyzed using the Statistical Analysis System (SAS). The experimental design was a randomized complete block with seedcotton yield data analyzed by year. F-tests and least significant differences (LSD) were calculated at the α=0.05 level of probability. Only yield responses of cotton to N-fertilization are presented in this report.

RESULTS AND DISCUSSION

Residual soil-N was largely depleted under furrow and center-pivot irrigation after four years of cotton production without N fertilization (Tables 3 and 4). Residual N under dryland production conditions was also substantially less in 2004 than in 2000. Additionally, the zone of accumulation of residual N appears to be deeper in the soil profile in 2004 than in 2000 under dryland production conditions.

The interaction between irrigation method and residual soil N from previous N-fertilization significantly affected yields during the 2002 and 2003 growing seasons (Tables 5 and 6). The interaction of N fertilization treatments with irrigation methods also significantly affected yields during 2004 (Table 7).

During the 2002 growing season, high-frequency irrigation usually increased cotton yields compared to furrow irrigation or dryland production (Table 5). Additionally, furrow-irrigated cotton tended to produce greater yields than dryland cotton. The cool, wet, early season of 2003 substantially delayed cotton development. The supplemental water applied in the irrigated blocks increased plant height (data not shown) and probably total plant weight, but delayed maturity of the crop. During 2003, delayed maturity and increased cotton growth resulted in reduced yields for cotton grown in both the high-frequency and the furrow-irrigated blocks (Table 6). The 2004 growing season was more moderate than the previous two years, thereby producing generally greater yields than in 2003 (Table 7). Greatest yields in 2004 were associated with furrow irrigation. Center-pivot irrigation tended to delay maturity of the crop resulting in the lowest yields.

Cool, wet conditions in the 2002 growing season resulted in severe seedling disease, but not stand loss. Near optimal growing conditions through the rest of the season resulted in acceptable yields, however, response to residual soil NO_3-N was limited in 2002 (Table 5). Cotton yields under dryland and high-frequency irrigation usually did not significantly respond to the residual soil NO_3-N. Cotton produced with furrow irrigation had only minimal yield response to residual soil NO_3-N when previous total N rates were greater than 60 lb N/acre. As the residual NO_3-N was consumed by the cotton crops, it had less influence on plant development and yield in subsequent years.

Compared with 2002 even worse early-season growing conditions occurred in 2003. Cool, wet weather persisted from early May through June and delayed growth, development, and squaring of the seedlings. The impaired plants of 2003 produced the lowest mean yields for the last three years of this study (Table 6). Response to residual soil NO_3-N was not significant in either the high-frequency irrigated or the furrow-irrigated blocks. The lack of yield response in these two blocks indicates that the residual soil NO_3-N was depleted. Cotton yields significantly increased due to residual NO_3-N from previous N fertilization in the dryland block. The greatest yielding treatments were those testing highest in residual NO_3-N in 2000 which had previously received 120- to 150-lb N/acre (Table 3). These results indicate that substantial residual soil NO_3-N still influenced plant development of cotton under dryland production conditions.

Resumption of N-fertilization treatments in 2004 produced immediate and significant yield responses (Table 7). Yield increased under all irrigation methods with increasing N up to the maximum 150 lb N/acre, though not all differences were significant. Additionally, plant height and plant maturity were also significantly affected by N-fertilization treatments (data not shown).

PRACTICAL APPLICATIONS

Irrigated cotton generally produced higher yields than cotton grown under dryland conditions, but the highest yielding irrigation method depended on the yearly climate effects. Cotton yield response to residual soil N from previous N-fertilization treatments tended to decline with time. Residual soil N was sufficient the first year (2002) to produce relatively high yields when previous N-fertilization rates were high and cotton was irrigated. After three growing seasons (2000, 2002, and 2003) and one fallow season (2001), cotton yield response in 2003 to residual soil NO_3-N was negligible for irrigated cotton with only the dryland block producing seedcotton yields that increased as previous N rate increased. Resumption of N fertilization treatments in 2004 immediately resulted in significant yield increases.

ACKNOWLEDGMENTS

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Table 1. Duration, tensiometer thresholds and depths, and water application rates for three irrigation methods used in the McConnell-Mitchell Plots at the Southeast Branch Experiment Station near Rohwer, Ark., since 1993.

Irrigation methods	Duration	Tensiometer Threshold	Tensiometer Depth	Water applied[z]
		-(cbar)-	-(in.)-	-(in.)-
High frequency	Planting to P.B.[y]	35	6	0.75
center-pivot	P.B. to Aug. 15	35	6	1.00
Furrow flow	Until Aug. 15	55	12	Not precise
Dryland	Not irrigated	--	--	--

[z] Water application rate per irrigation.
[y] P.B.=Peak bloom

Table 2. Nitrogen (N) fertilization treatments and application timings for the McConnell-Mitchell Plots at the Southeast Branch Experiment Station near Rohwer, Ark.

Total N-Rate	Pre-plant	First square	First flower
- (lb N/acre) -	-------------	(lb N/acre)	-------------
150	75	75	0
150	50	50	50
150	30	60	60
120	60	60	0
120	40	40	40
90	45	45	0
90	30	30	30
60	30	30	0
30	15	15	0
0	0	0	0

Table 3. Residual nitrate-nitrogen (NO_3-N) to a depth of five feet in six-inch increments from five N-fertilization rates (Table 1, split applied, half pre-plant and half at first square) under three irrigation methods in the McConnell-Mitchell study in Spring, 2000.

Soil	Irrigation method and total N-fertilizer rate																	
	Furrow irrigated						Dryland						High-frequency center-pivot					
depth	0	30	60	90	120	150	0	30	60	90	120	150	0	30	60	90	120	150
(in.)	(lb residual NO_3-N/acre)																	
0- 6	2	2	2	2	3	3	6	6	6	29	87	65	1	1	3	3	2	2
0 - 6	2	2	2	2	3	3	6	6	6	29	87	65	1	1	3	3	2	2
6 - 12	2	2	1	2	2	2	5	9	6	33	108	102	1	1	2	3	3	5
12 - 18	2	3	3	2	3	4	4	6	5	35	138	135	2	1	3	3	3	11
18 - 24	3	3	3	2	4	7	4	5	6	36	125	111	2	1	2	1	2	20
24 - 30	3	3	3	3	4	7	4	4	6	31	91	104	2	3	2	2	3	18
30 - 36	2	3	3	3	5	6	3	3	5	22	58	68	2	3	1	3	4	10
36 - 42	3	3	3	3	4	7	3	3	4	12	54	37	2	2	2	3	4	7
42 - 48	3	2	3	2	4	9	2	3	3	7	37	21	2	2	3	3	6	6
48 - 54	3	3	3	3	4	8	3	3	4	6	21	15	2	3	2	3	6	4
54 - 60	2	2	3	2	7	6	13	6	30	2	33	57	6	4	2	2	5	7
Mean	2	3	3	2	4	6	5	5	8	21	75	71	2	2	2	3	4	9

Table 4. Residual nitrate-nitrogen (NO_3-N) to a depth of five feet in six-inch increments from five N-fertilization rates (Table 1, split-applied, half pre-plant and half at first square) under three irrigation methods in the McConnell-Mitchell study in Spring, 2004.

Soil	Irrigation method and total N-fertilizer rate																	
	Furrow irrigated						Dryland						High-frequency center-pivot					
depth	0	30	60	90	120	150	0	30	60	90	120	150	0	30	60	90	120	150
(in.)	(lb residual NO_3-N/acre)																	
0- 6	2	2	2	2	3	3	6	6	6	29	87	65	1	1	3	3	2	2
0 - 6	3	2	1	2	4	2	4	4	4	3	6	4	2	3	3	4	2	3
6 - 12	1	1	2	2	2	2	4	4	4	3	4	6	2	1	3	2	2	3
12 - 18	2	2	2	5	2	2	5	5	5	5	6	8	2	2	3	2	2	2
18 - 24	4	3	3	3	3	3	5	5	5	5	12	9	2	2	3	2	2	2
24 - 30	3	2	3	4	3	3	5	5	6	6	13	41	2	2	3	2	3	2
30 - 36	3	3	3	3	3	3	5	4	6	9	19	52	2	2	3	2	3	2
36 - 42	3	2	3	3	3	3	5	4	6	12	37	80	3	2	3	2	3	2
42 - 48	2	2	3	3	2	3	5	5	7	17	54	89	3	2	3	3	3	3
48 - 54	2	2	3	3	3	3	5	5	7	17	64	89	3	2	3	3	3	3
54 - 60	2	2	2	3	3	3	5	6	7	10	41	79	2	3	3	3	3	3
Mean	3	2	2	3	3	3	5	5	6	9	26	45	3	2	3	2	3	3

Table 5. Seedcotton yield response to residual N from ten nitrogen (N)-fertilization treatments under three irrigation methods during 2002 in the McConnell-Mitchell plots at the Southeast Branch Experiment Station near Rohwer, Ark.

	N-rate and timing[z]			Irrigation method			
Total N rate	PP	FS	FF	High frequency	Furrow irrigated	Dryland	N-rate mean
	(lb N/acre)			(lb seedcotton yield/acre[y])			
150	75	75	0	3847	3413	2901	3379
150	50	50	50	3900	3464	3114	3485
150	30	60	60	3864	3369	3202	3470
120	60	60	0	3692	3466	2998	3378
120	40	40	40	3886	3214	3391	3489
90	45	45	0	3733	3342	3204	3419
90	30	30	30	3616	3330	3245	3395
60	30	30	0	4041	3146	3056	3407
30	15	15	0	3602	3037	3297	3304
0	0	0	0	3481	2867	2886	3071
To compare N-treatment means within irrigation method LSD(0.05) = 340							
To compare N-treatment means between irrigation methods LSD(0.05) = 493							
Irrigation method mean yield				3766	3265	3128	

[z] N application times; PP, preplant; FS, first square; and FF, first flower.
[y] Lint yield may be estimated by dividing the seedcotton yield by 3.

Table 6. Seedcotton yield response to residual N from ten nitrogen (N)-fertilization treatments under three irrigation methods during 2003 in the McConnell-Mitchell plots at the Southeast Branch Experiment Station near Rohwer, Ark.

	N-rate and timing[z]			Irrigation method			
Total N rate	PP	FS	FF	High frequency	Furrow irrigated	Dryland	N-rate mean
	(lb N/acre)			(lb seedcotton yield/acre[y])			
150	75	75	0	1833	1406	2568	1936
150	50	50	50	1873	1463	2659	1998
150	30	60	60	2244	1412	2246	1967
120	60	60	0	2045	1646	2671	2120
120	40	40	40	2003	1271	2678	1983
90	45	45	0	1882	1353	1815	1677
90	30	30	30	1780	1426	2344	1852
60	30	30	0	1770	1493	1507	1593
30	15	15	0	1805	1381	1905	1697
0	0	0	0	1796	1284	1237	1439
To compare N-treatment means within irrigation method LSD(0.05) = 397							
To compare N-treatment means between irrigation methods LSD(0.05) = 472							
Irrigation method mean yield				1904	1413	2169	

[z] N application times; PP, pre-plant; FS, first square; and FF, first flower.
[y] Lint yield may be estimated by dividing the seedcotton yield by 3.

Table 7. Seedcotton yield response to N from ten nitrogen (N)-fertilization treatments under three irrigation methods during 2004 in the McConnell-Mitchell plots at the Southeast Branch Experiment Station near Rohwer, Ark.

	N-rate and timing[z]			Irrigation method			
Total N rate	PP	FS	FF	High frequency	Furrow irrigated	Dryland	N-rate mean
	(lb N/acre)			(lb seedcotton yield/acre[y])			
150	75	75	0	3320	3870	3277	3476
150	50	50	50	3134	4042	3930	3690
150	30	60	60	3049	4467	3691	3710
120	60	60	0	2948	3829	3413	3396
120	40	40	40	3008	3888	3821	3562
90	45	45	0	2756	3761	3098	3205
90	30	30	30	2749	3697	3323	3241
60	30	30	0	2730	3037	2563	2777
30	15	15	0	2077	2974	2425	2475
0	0	0	0	1757	2224	1048	1676
To compare N-treatment means within irrigation method LSD(0.05) = 412							
To compare N-treatment means between irrigation methods LSD(0.05) = 663							
Irrigation method mean yield				2753	3563	3058	

[z] N application times; AE, after emergence; FS, first square; and FF, first flower.
[y] Lint yield may be estimated by dividing the seedcotton yield by 3.

Effect of Nitrogen Fertilization on Cotton Yield and Petiole Nitrogen Content and Soil Properties at Two Sites

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Managing nitrogen (N) fertility remains a major nutritional concern in cotton (*Gossypium hirsutum* L.) production. The increasing price of N fertilizers and environmental concerns have added to the complexity of N management. Agronomically sound management of N fertilizer allows cotton growers to get a sound return on their fertilizer investment and protect the environment from potential water-quality problems. Technological innovations, market forces (i.e., demand for high fiber quality), and the introduction of modern cotton cultivars in the past two decades have changed crop production practices and the nutritional requirements of cotton produced in the Mississippi Delta Region of Arkansas (MDRA). Consequently, most of our current soil-test calibration and petiole-monitoring data supporting our current recommendations are becoming outdated. Nitrogen fertilization trials were conducted to update N-fertilizer recommendations for cotton production in the MDRA. The specific objectives of these studies were to evaluate the effect of N fertilizer and cotton cultivar on seedcotton yield and petiole NO_3-N concentrations.

PROCEDURES

Two replicated N fertilization trials were conducted in 2004 at two locations on the University of Arkansas Cotton Branch Experiment Station (CBES) in Marianna, Ark. Experiments were located on the Britain farm on a Calloway-Loring complex and on the Graves farm on a Zachary-Memphis complex.

Graves Farm Experiment

The effect of N fertilizer rate (0, 40, 60, 80, 120, and 200 lb N/acre) on seedcotton yield and petiole NO_3-N concentrations of 'Stoneville 4892' (ST 4892) and 'PayMaster 1218' (PM 1218) cotton cultivars was evaluated at the Graves farm. The first 40 lb N/acre were broadcast as ammonium sulfate and incorporated with a do-all. The balance of each N rate was knifed in as urea ammonium nitrate solution during the second week before bloom and third week of bloom. Details on N application rates and scheduling are listed in Table 1. The experimental design was a randomized complete block with a split-plot treatment structure where cultivar was the main plot factor and N rate was the subplot factor. Individual plots were 43-ft long and 12.6-ft wide allowing for four rows of cotton with 38-inch row spacings. Prior to planting, on 5 May all plots received broadcast applications of 60 lb K_2O/acre as potassium chloride and 46 lb P_2O_5/acre as triple superphosphate, which were mechanically incorporated. Irrigation, stand establishment, and pest management practices recommended by the University of Arkansas Cooperative Extension Service were followed. Cotton was planted on 12 May, seedlings emerged on 25 May, first bloom occurred on 21 July, and cotton was harvested with a mechanical picker on 16 October.

Prior to application of any fertilizer two composite soil samples were collected from the 0- to 6-inch soil depth of each replication. Soil samples were extracted with Mehlich-3 solution (1:10 ratio) and the concentration of elements in the soil extracts was measured by inductively coupled plasma atomic-emission spectroscopy. Soil pH was measured by a 1:2 (weight:volume) soil-water mixture extraction. Selected mean soil-test values are reported in Table 2.

Cotton petiole samples were collected from the 5th node from the top of 20 plants selected randomly in each plot from the week before bloom until the fourth week of bloom. Cotton petioles were dried overnight at 70°C and ground to pass a 1-mm sieve. A 0.1 g subsample was mixed with 30 mL of 0.025 *M* aluminum sulfate solution, stirred, and allowed to stand for 15 minutes. Petiole NO_3-N concentrations were determined using an ion-specific electrode.

Analysis of variance was performed to evaluate the effect of cotton cultivar, N application rate, and their interaction on seedcotton yield and petiole NO_3-N using the PROC GLM procedure in SAS. Significant treatment means were separated by Waller-Duncan test when appropriate.

Britain Farm Experiment

At the Britain Farm the effect of N application rate (0, 30, 60, 90, and 120 lb N/acre) on seedcotton yield and petiole NO_3-N concentrations of 'FiberMax 960' (FM960) cultivar was evaluated. The experimental design was a randomized complete block design with four replications of each treatment. Detailed information on N fertilizer application schedules is provided in Table 3. Nitrogen was knifed in using urea ammonium nitrate solution. Individual plots were 115-ft long and 25.2-ft wide allowing for eight rows of cotton with 38-inch row spacings. Prior to planting, on 5 May, all plots received 60 lb K_2O/acre as potassium chloride and 46 lb P_2O_5/acre as triple superphosphate, which were broadcast to the soil surface and mechanically incorporated. Irrigation, stand establishment, and pest management practices recommended by the University of Arkansas Cooperative Extension Service were followed. Cotton was planted on 22 May, seedlings emerged on 29 May, first bloom occurred on 21 July, and cotton was harvested with a mechanical picker equipped with an AgLeader PF 3000 Yield Monitor on 12 November.

Prior to application of any fertilizer, composite soil samples (four subsamples per plot) were collected from the 0- to 6-, 6- to 12-, and 12- to 24-inch depth increments of all plots with a tractor-mounted hydraulic probe. Petiole samples were collected and processed as described previously from all plots for three weeks beginning with the week before bloom.

Analysis of variance was performed to evaluate the effect of N rate on seedcotton yield and petiole NO_3-N concentration. Significant (*P*=0.05) treatment means were separated by Waller-Duncan test when appropriate.

RESULTS AND DISCUSSION

Graves Farm Experiment

Pre-application soil-test NO_3-N in the top 6 inches averaged 4.4 lb/acre and soil pH averaged 6.0 (Table 2). According to our current recommendations, a response to N fertilizer is expected when soil-test NO_3-N <25 lb/acre. Since there was no significant cultivar or cultivar × N-rate interaction, seedcotton yields were averaged across cultivars for each N rate. Nitrogen application had a significant effect on the seedcotton yield (Table 4). Seedcotton yields increased as N rate increased from 0 to 160 lb N/acre. The greatest yield was produced by 160 lb N/acre, although it was not different statistically from yields produced with 120 and 200 lb N/acre. Petiole NO_3-N concentrations were greatest the week before bloom and decreased numerically until 3 weeks after bloom for all N rates (Table 4). Within sampling times, petiole NO_3-N concentrations differed among N rates only the week before bloom and during the 4th week of bloom. Although near maximal seedcotton yields were produced by 120 to 160 lb N/acre, petiole NO_3-N concentrations were below the established sufficiency level for all N rates and sample times suggesting that yields may have benefitted from foliar N or that the established petiole sufficiency levels are inaccurate.

Britain Farm Experiment

Pre-application soil-test NO_3-N was 10 and 7 lb/acre in the 0-to 6- and 6-to 12-inch depth increments, respectively (Table 3). Soil pH at these two depths averaged 6.0 and 5.4. Nitrogen application rate significantly influenced seedcotton yield (Table 5). Maximal cotton yields were produced by application of 90 to 120 lb N/acre. There was no significant difference in petiole NO_3-N concentration for samples collected before the first application of N fertilizer (14 July) and petiole N was below the critical levels for all treatments. However, increasing the N application rate significantly increased petiole NO_3-N concentrations for the 20 and

29 July sample dates. Petiole-N data for all treatments except the unfertilized control were above the sufficiency levels on 20 July.

PRACTICAL APPLICATION

Near maximum seedcotton yields were produced by application of 90 to 160 lb N/acre in two N-rate trials conducted on silt loam soils in 2004. Soil NO_3-N concentrations were <25 lb/acre at both sites. Although supplemental foliar N was not evaluated in these studies, petiole NO_3-N concentration data continue to suggest that the current sufficiency levels used to recommend foliar N on cotton are too high.

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Table 1. Nitrogen application rates and schedule for soil-applied N for a N-fertilization trial with PayMaster 1218 and Stoneville 4892 cotton cultivars at Graves Farm in 2004.

	Application time[z]		
Total N rate	May 7	July 2	Aug 2
(lb N/acre)			
0	0	0	0
40	40	0	0
80	40	0	40
120	80	40	0
160	80	40	40
200	80	40	80

[z] N source for the 1st 40-lb increment was ammonium sulfate and the rest was applied as urea.

Table 2. Selected chemical property means of soil samples collected from the 0- to 6-inch depth of the Graves Farm experimental site and the 0- to 6- and 6- to 12-inch soil depths from the Britain Farm in 2004.

Site	Soil depth	Soil pH[z]	Soil OM[y]	NO_3-N[x]	P[w]	K[w]	Ca[w]	Mg[w]	Cu[w]	Zn[w]
	(in.)		(%)	(lb/acre)						
Graves Farm	0-6	6.0	1.5	4.4	64	203	2368	433	2.4	4.3
Britain Farm	0-6	6.0	1.1	10.0	82	215	2648	382	2.6	3.9
Britain Farm	6-12	5.4	0.9	7.0	72	176	2082	344	2.4	3.4

[z] Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.
[y] OM, soil organic matter determined by Weight Loss on Ignition.
[x] NO_3-N measured by ion-specific electrode.
[w] Mehlich-3-extractable soil nutrients (1:10 extraction ratio).

Table 3. Nitrogen application rates and dates for the N fertilization trial with FiberMax 960 (FM960) cotton cultivar at the Britain Farm in 2004.

Total N rate	1st application (14 July)	2nd application (4 August)
(lb N/acre)		
0	0	0
30	30	0
60	60	0
90	60	30
120	60	60

Table 4. Effect of soil-applied N-fertilizer rate, averaged across cultivars, on seedcotton yield and cotton petiole NO_3-N concentration at the Graves Farm in 2004.

		Petiole NO_3-N concentration by sample date				
N rate	Seedcotton yield	14 July wk before bloom	21 July 1st wk of bloom	27 July 2nd wk of bloom	9 August 3rd wk of bloom	16 August 4th wk of bloom
(lb N/acre)	(lb/acre)	(mg NO_3-N/kg)				
0	1085	2239	1583	561	455	390
40	1713	2132	1445	1075	222	284
80	2222	3601	1272	222	292	286
120	2552	7308	3132	1232	257	319
160	2866	4793	1983	879	292	419
200	2788	3789	1482	809	527	319
Minimum Sufficiency Level[z]		5000	10000	9000	7000	5000
MSD at 0.05[y]	567	1797	NS	NS	NS	100

[z] Published by Snyder et al. (1995).
[y] Minimum Significant Difference as determined by Waller-Duncan Test (NS, not significant at *P*=0.05).

Table 5. Effect of N fertilization on seedcotton yield and petiole NO_3-N concentration of FiberMax 960 cultivar at Britain Farm in 2004.

		Petiole NO_3-N concentrations by sample date		
N rate	Seedcotton yield	16 July wk before bloom	30 July 2nd wk of bloom	18 August 4th wk of bloom
(b N/acre)	(lb/acre)	(mg NO_3-N/kg)		
0	2482	335	2503	221
30	2709	613	13341	944
60	3475	486	15055	2299
90	3751	520	14306	4454
120	3653	369	16705	4434
Minimum Sufficiency Level[z]		5000	10000	9000
MSD at 0.05[y]	923	NS	4177	2051

[z] Published by Snyder et al. (1995).
[y] Minimum Significant Difference as determined by Waller-Duncan Test (NS, not significant at *P*=0.05).

Yield and Petiole Potassium Levels of Cotton as Affected by Potassium Fertilization

M. Mozaffari, D.M. Oosterhuis, J.S. McConnell, N.A. Slaton, E. Evans, K. Hattenhauer, A. Bibi, E. Gonias, F.M. Bourland, and C. Kennedy

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Well-balanced potassium (K) nutrition is an important requirement for producing a high-quality, high-yielding cotton (*Gossypium hirsutum* L.) crop. Potassium plays an important role in translocation of sugars and activation of many of the enzymes required for various plant metabolic processes (Coker et al., 2003). Plant demand for K is particularly high during fruit development (Oosterhuis et al., 2003). Therefore, K deficiency will negatively influence cotton yield and lint quality. During the past two decades cotton production systems have changed by advancements in technology and introduction of new fast-fruiting cultivars. Information on cotton response to K fertilization under current production practices will enable us to provide cotton growers with economically sound K-fertilizer recommendations.

In recent years researchers have evaluated the potential for using spectral radiometry to assess the nutritional status of crops. Spectral radiometry is a rapid non-destructive technique, which if proven suitable can significantly improve our ability to monitor crop nutritional status in-season. One such method is the use of a chlorophyl meter. One of the commonly used instruments is a Minolta SPAD (soil plant analysis development) meter. The SPAD meter measures the difference in light absorption at 430 and 750 nm (Wood et al., 1992). The former is the transmittance peak for chlorophyl 'a' and 'b', and the latter is in the near-infrared region. The instrument converts the difference in light absorption at these two wavelengths into a numerical SPAD value ranging from 0 to 80 as an index of plant chlorophyl content. As a part of ongoing efforts to improve K-fertilizer recommendations for cotton production in Arkansas, a field experiment was conducted to evaluate the effect of K-fertilizer rate on yield and petiole-K concentration of two modern cotton cultivars. A second objective of the study was to evaluate the potential for using spectral radiance measurements for predicting K status of cotton leaves.

PROCEDURES

A replicated field experiment was conducted at the University of Arkansas Cotton Branch Experiment Station (CBES) in Marianna, Ark., during the 2004 growing season on a Calloway silt loam. The experimental design was a randomized complete block with a split-plot treatment structure where cotton cultivar ('Stoneville 4892' and 'Paymaster 1218') was the main-plot factor and K rate (0, 30, 60, 90, 120, and 150 lb K_2O/acre) was the subplot factor. All K treatments were applied on 16 July except the highest K rate plots which received 120 lb K_2O/acre on 16 July and the remaining 30 lb K_2O/acre on 3 Aug. Each experimental treatment was replicated four times. Individual plots were 43-ft long and 12.5-ft wide allowing for four rows of cotton with 38-inch row spacings. Prior to planting, all plots were fertilized on 5 May with ammonium sulfate and triple superphosphate to supply 30 lb N and 46 lb of P_2O_5/acre, respectively. A solution of urea ammonium nitrate (32% N) was knifed in to supply an additional 60 lb N/acre on 16 July. On 6 August, 30 lb N/acre was broadcast on all plots. All plots were established with conventional tillage and recommended pest-management practices were followed. Cotton was planted on 12 May, seedlings emerged on 25 May, first bloom occurred on 21 July, and cotton was harvested with a mechanical picker on 16 October. Prior to application of any soil amendments, two composite soil samples were collected from the 0- to 6-inch soil depth of each replication in the experimental area. Soil samples were extracted with Mehlich-3 solution (1:10 ratio) and the elemental concentrations were measured by inductively coupled plasma atomic-emission spectroscopy (ICP-AES). Soil pH was measured by a 1:2 (weight:volume) soil-water mixture extraction.

Leaf fluorescence and chlorophyll content were measured three weeks after first flower on 11 August on 10 uppermost, fully expanded main-stem leaves (4th node from the top) in each plot on 'Paymaster 1218' cotton cultivar. Flourescence was measured using a modulated fluorometer (Osi-FL) and chlorophyll content was measured using a Minolta SPAD 502 chlorophyl meter. Cotton petiole samples were collected from the 5th node from the top of 20 plants selected randomly at five dates including the week before the first bloom and the first four weeks of bloom. Cotton petioles were dried overnight at 70°C and ground to pass a 1-mm seive. A 0.075 g sub-sample was mixed with 21 mL of 2% acetic acid, shaken for 10 minutes, and then filtered. Petiole concentrations of K, P, and S were determined by ICP-AES. Analysis of variance was performed to evaluate the effect of cotton cultivar, K application rate, and their interaction on seedcotton yields and petiole-K concentration using SAS PROC GLM procedure. Significant treatment means were separated by the Waller-Duncan test when appropriate.

RESULTS AND DISCUSSION

Statistical analysis of seedcotton yields and petiole-K concentration data indicated that there was no significant cultivar or cultivar × K rate (interaction) effects. Pre-application soil-test data indicated that the soil was slightly acidic (pH 6.0) and soil-test K was 209 lb K/acre, which is considered 'Medium' for cotton and thus the benefits of K fertilization would be possible, but nominal (<15% yield increase, Table 1). Seedcotton yields ranged from 2170 to 2518 lb/acre and were not significantly (P=0.05) affected by K-fertilizer rate, although we observed a trend for seedcotton yield to increase as K fertilizer rate increased (Table 2). Data suggest that additional research is needed to correlate Mehlich-3-extractable K with cotton-yield response to K fertilization.

Petiole-K concentrations increased as K-fertilizer rate increased and decreased with time (i.e., cotton development, Table 2). Potassium fertilization significantly increased petiole-K concentrations during the week before bloom and the 3rd and 4th week of bloom. Early in the season, petiole-K concentrations were above the critical concentrations currently in use by the University of Arkansas Cotton Nutrient Monitoring Program for all plots. However, petiole-K concentrations in the check plots dropped below the critical levels during the 3rd and 4th week of the bloom.

Leaf fluorescence of Paymaster 1218 cotton ranged from 0.52 to 0.62 [(Fms-Fs)/Fms], but there were no consistent differences among K-fertilizer rates (data not shown). Likewise, there was no consistent effect of K-fertilizer rate on leaf chlorophyll (data not shown). Low K may decrease the activity of some enzymes, such as rubisco, but this was not observed. Additional research will be conducted in the future to investigate the potential utility of these measurements for monitoring the K nutritional status of cotton.

PRACTICAL APPLICATION

The two modern cotton cultivars tested in this experiment had similar K requirements. Potassium fertilization failed to increase cotton yields, regardless of cotton cultivar, despite below optimal soil-test K levels. Petiole-K concentrations were a reflection of K fertilization rates and generally decreased during the growing season. Petiole-K concentrations in cotton that received K fertilizer were consistently above the critical levels set forth by the University of Arkansas Petiole Nutrient Monitoring Program.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fees. The authors wish to thank staff of the University of Arkansas Soil Testing and Research Laboratory and the CBES for their assistance with field work and laboratory analysis.

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Table 1. Selected chemical properties of soil samples collected from the 0- to 6-inch depth of experimental sites.

pH[z]	OM[y]	NO_3-N[x]	P[w]	K[w]	Ca[w]	Mg[w]	Cu[w]	Zn[w]
	(%)	(lb/acre)						
6.0	1.6	4	66	209	2350	460	2.3	4.4

[z] Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.
[y] OM, soil organic matter determined by Weight Loss on Ignition.
[x] NO_3-N measured by ion-specific electrode.
[w] Mehlich-3-extractable soil nutrients (1:10 extraction ratio).

Table 2. Effect of soil-applied K fertilizer, averaged across cultivars, on seedcotton yield and petiole-K concentration on a Calloway silt loam at CBES in 2004.

		Petiole-K concentration by sample time				
K_2O rate	Seedcotton yield	14 July wk before bloom	21 July 1st wk of bloom	27 July 2nd wk of bloom	9 August 3rd wk of bloom	16 August 4th wk of bloom
(lb/acre)	(lb/acre)	(% K)				
0	2170	4.68	4.21	3.20	2.76	1.97
30	2195	5.10	4.77	3.78	3.35	2.40
60	2345	5.42	4.55	3.57	2.98	2.62
90	2518	5.46	4.76	3.93	4.06	2.85
120	2335	5.41	4.82	3.43	3.98	3.32
150	2422	5.41	4.78	4.20	4.47	3.42
Minimum sufficiency level[z]		4.0	4.0	3.5	3.0	2.5
MSD at 0.05[y]	NS	0.57	NS	NS	0.74	0.62

[z] Published by Snyder et al. (1995)
[y] Minimum Significant Difference as determined by Waller-Duncan Test (NS, not significant at *P*=0.05).

Effect of Phosphorus Fertilizer Rate on Seedcotton Yield and Petiole Phosphorus Concentrations

M. Mozaffari, D.M. Oosterhuis, J.S. McConnell, N.A. Slaton, E. Evans, E. Gonias, A. Bibi, and C. Kennedy

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Phosphorus (P) is a major component of molecules involved in energy transfer in cotton (*Gossypium hirsutum* L.) and P deficiency will limit plant growth and lint production. While P toxicity is very rare in most agricultural soils, excessive accumulation of P in agricultural soils and its potential transport into surfacewaters is an environmental concern. To maintain healthy plants and protect the environment accurate P-fertilizer recommendations are required. In Arkansas, P-fertilizer recommendations are currently based on soil-P extracted with a modified Mehlich-3 (M3) solution (1:7 soil:solution). Additionally, most of the correlation and calibration research supporting our cotton P-fertilizer recommendations was conducted with cultivars that are no longer in use. This database is currently the best available scientific information for P fertilization of cotton in Arkansas. Improving the monitoring techniques for evaluating the P-nutritional status of cotton will provide cotton growers with an additional tool for managing their crop nutrition. The University of Arkansas Soil Testing and Research Laboratory will change the extraction procedure from the modified Mehlich-3 to the standard Mehlich-3 (1:10 soil:solution) procedure, which extracts more P from soil.

Research on improving techniques for monitoring plant-nutrient status is another area that can lead into improved P management. In recent years researchers have evaluated the potential for using spectral radiometry to assess the nutritional status of crops. Spectral radiometry is a rapid non-destructive technique, which if proven suitable can significantly improve our ability to monitor crop nutritional status in-season. One such method is the use of a chlorophyl meter. One of the commonly used instruments is a Minolta SPAD (soil plant analysis development) meter. The SPAD meter measures the difference in light absorption at 430 and 750 nm (Wood et al., 1992). The former is the transmittance peak for chlorophyl 'a' and 'b', and the latter is in the near-infrared region. The instrument converts the difference in light absorption at these two wavelengths into a numerical SPAD value ranging from 0 to 80 as an index of plant chlorophyl content. The objectives of this replicated field experiment were to evaluate the effect of P fertilization and cotton cultivar on seedcotton yield and evaluate the effect of P fertilization on plant stress as indicated by leaf fluorescence and chlorophyl content. The outcomes of the research will be used to improve the accuracy of our P-fertilizer recommendations for cotton grown in Arkansas.

EXPERIMENTAL PROCEDURES

A replicated field experiment was conducted at the University of Arkansas Cotton Branch Experiment Station (CBES) in Marianna, Ark., during the 2004 growing season on a Zachary silt loam. This soil is representative of typical soils used for cotton production in the Mississippi Delta Region of Arkansas. The experimental design was a randomized complete block with a split-plot treatment structure where cotton cultivar ('Stoneville 4892' and 'Paymaster1218') was the main plot factor and P rate (0, 30, 60, and 90 lb P_2O_5 /acre) was the subplot factor. Each experimental treatment was replicated four times. Individual plots were 43-ft long and 12.5-ft wide allowing for four rows of cotton with 38-inch row spacings. Prior to application of any soil amendments two composite soil samples were collected from the 0- to 6-inch soil depth of each replication. Soil samples were extracted with Mehlich-3 solution (1:10

ratio) and the concentration of elements in the soil extracts were measured by inductively coupled plasma atomic-emission spectroscopy (ICP-AES). Soil pH was measured by a 1:2 (weight:volume) soil-water mixture extraction. Prior to planting, on 5 May, all plots were fertilized with 30 lb N/acre as ammonium sulfate and 40 lb K_2O/acre as potassium chloride. A solution of urea ammonium nitrate (32% N) was knifed in at a rate of 60 lb N/acre on 16 July. On 6 August another 30 lb N/acre and 40 lb K_2O/acre were broadcast onto all plots. Seedbeds were prepared using conventional tillage and cotton management practices closely followed University of Arkansas Cooperative Extension Service production guidelines. Cotton was planted on 12 May, emerged on 25 May; first bloom occurred on 21 July, and the crop was harvested with a mechanical picker on 16 October.

Cotton petiole samples were collected from the 5th node from the top of 20 randomly selected plants at the week before first bloom and the first two weeks of bloom. Cotton petioles were dried overnight at 70°C and ground to pass a 1-mm seive. A 0.075 g sub-sample was mixed with 21 mL of 2% acetic acid, shaken for 10 minutes, and filtered. Petiole concentrations of K, P, and S were determined by ICP-AES. Leaf fluorescence and chlorophyll content were measured three weeks after first flower on 11 August on 10 uppermost, fully expanded main-stem leaves (4th node from the top) in each plot on 'Paymaster 1218' cotton cultivar. Fluorescence was measured using a modulated fluorometer (Osi-FL) and chlorophyll content was measured using a Minolta SPAD meter.

Analysis of variance was performed to evaluate the effect of cotton cultivar, P application rate, and their interaction on seedcotton yield and petiole-P concentration using the PROC GLM procedure of SAS. Significant treatment means were separated by the Waller-Duncan test when appropriate.

RESULTS AND DISCUSSION

Prior to application of P fertilizer, Mehlich-3-extractable P in the top 6 inches averaged 52 lb P/acre (Table 1). Current University of Arkansas fertilizer guidelines recommend application of 30 lb P_2O_5/acre at this level of soil-test P. Seedcotton yield was not significantly affected (P >0.05) by the main effects of cultivar or P rate or by the cultivar × P-rate interaction. Although not statistically significant, the lowest yield was produced by the unfertilized control and the greatest yield was produced by the highest P fertilizer rate (Table 2). The data suggest that P was not a cotton yield-limiting factor and both cultivars have similar P requirements. Updated University of Arkansas P fertilizer recommendations for cotton and the standard Mehlich-3 extractant will interpret the soil-test P for this soil as 'Medium', which means that a small, positive yield response may occur from P fertilization. We observed similar results in 2003, which suggests that additional research with a wider range of soils is needed to develop new P-fertilizer recommendations for cotton.

Petiole-P concentrations were affected by P-fertilizer rate only on 15 July and generally decreased as cotton development progressed (Table 2). Leaf fluorescence of the 'Paymaster 1218' cultivar ranged from 0.53 to 0.59 [(Fms-Fs)/Fms] with a trend for leaf fluorescence to increase as P rate increased, which may indicate less physiological stress (Fig. 1). Additional work will be conducted in future years to investigate the potential utility of this technique for monitoring the P-nutritional status of cotton. No consistent trend was observed for the effect of P fertilizer rates on cotton leaf chlorophyll, however chlorophyl content of plants fertilized with 60 lb P_2O_5/acre were significantly higher than those fertilized with 90 lb P_2O_5/acre (Fig. 2). As P plays an important role in membranes and energy transfer it was hypothesized that increasing P would be reflected in higher chlorophyll levels for improved photosynthesis.

PRACTICAL APPLICATIONS

Cotton planted in a silt loam with initial Mehlich-3-extractable (1:10 soil:solution) P of 52 lb P/acre did not respond to P fertilization, suggesting that P was not a cotton yield-limiting factor on this soil. Cotton cultivar and the cultivar × P-rate interaction did not have a significant effect on seedcotton yields. Data will be used to build a database of cotton yield response to P fertilization so that soil-test P can be interpreted accurately and used to develop agronomically and environmentally sound P fertilizer recommendations for cotton production in Arkansas.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fees. The authors wish to thank staff of the University of Arkansas Soil Testing and Research Laboratory and the CBES for their assistance with field work and laboratory analysis.

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Table 1. Selected chemical property means of soil samples collected from the 0- to 6-inch depth of a Zachary silt loam at the experimental site.

pH[z]	OM[y]	ECEC[x]	NO_3-N[w]	P[v]	K[v]	Ca[v]	Mg[v]	Cu[v]	Zn[v]
	(%)	($cmol_c$/kg)	----------	----------	----------	(lb/acre)	----------	----------	----------
6.2	1.6	13	3.7	52	168	2279	423	2.2	3.9

[z] Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.
[y] OM, soil organic matter determined by Weight Loss on Ignition.
[x] ECEC, estimated cation-exchange capacity.
[w] NO_3-N measured by ion-specific electrode.
[v] Mehlich-3-extractable soil nutrients (1:10 extraction ratio).

Table 2. Effect of soil-applied P-fertilizer rate, averaged across cultivars, on seedcotton yield and petiole-P concentration of cotton grown on a Zachary silt loam at the Cotton Branch Experiment Station in 2004.

		Petiole-P concentration by sample time		
P_2O_5 rate	Seedcotton yield	15 July wk before bloom	10 August 3rd wk of bloom	20 August 4th wk of bloom
(lb/acre)	(lb/acre)	----------	(mg P/kg)	----------
0	2007	3638	2070	1174
30	2071	3478	2129	1157
60	2167	4530	2255	1250
90	2171	4207	2356	1160
MSD at 0.05[z]	NS	822	NS	NS

[z] Minimum Significant Difference as determined by Waller-Duncan Test (NS, not significant at P=0.05).

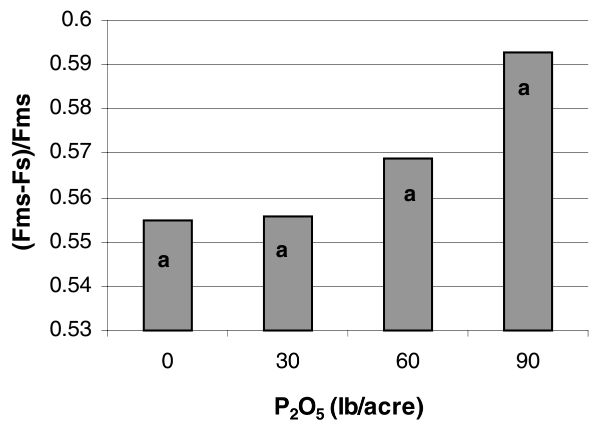

Fig. 1. Effect of P-fertilizer rate on leaf fluorescence [(Fms-Fs)/Fms] measured three weeks after first flower on cotton cultivar Paymaster 1218. Columns with the same letter are not significantly different (P=0.05).

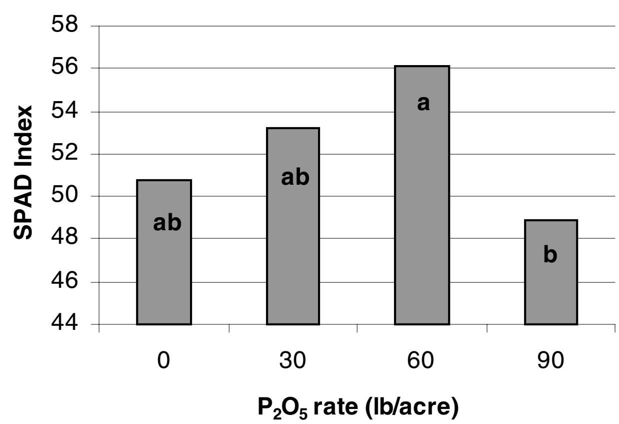

Fig. 2. Effect of P-fertilizer rate (lb P_2O_5/acre) on leaf chlorophyll content (SPAD units) measured three weeks after first flower on cultivar Paymaster 1218. Columns with the same letter are not significantly different (P=0.05).

Pelleted Poultry Litter and Inorganic-N Fertilizer Increase Cotton Yield

M. Mozaffari, N.A. Slaton, E. Evans, J.S. McConnell, and C. Kennedy

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Nitrogen (N) is the most important plant nutrient in cotton (*Gossypium hirsutum* L.) production. Improved N-fertility practices enable cotton growers to maximize the return on their fertilizer investments and protect the environment from potential environmental consequences of excessive N loss to ground and surface waters. Innovations in crop production such as introduction of new fertilizers and new short-season cultivars necessitate continuous research for refinement of fertility recommendations and methods of predicting in-season N requirements. In recent years poultry producers have turned to pelletization to increase the economic feasibility of transporting poultry litter from nutrient-rich poultry production areas to areas of high demand for nutrients such as the Mississippi Delta Region of Arkansas (MDRA). Field studies on evaluation of cotton response to pelleted poultry litter (PPL) in the MDRA are needed to provide information for growers who might be interested in utilizing poultry manure as a source of N. The specific objectives of studies reported here were to evaluate the effect of inorganic N fertilizer and PPL application rate on a) seedcotton yield and b) petiole NO_3-N concentration on a soil commonly used for cotton production in the MDRA.

PROCEDURES

During the 2004 growing season two replicated field experiments were conducted at the University of Arkansas Cotton Branch Experiment Station (CBES) in Marianna, Ark., on a Zachary silt loam. The two studies were implemented as one study arranged in a split-plot randomized complete block structure with four replications of each treatment. Each subplot was 43-ft long and 12.6-ft wide allowing for four rows of cotton with 38-inch row spacings. Nitrogen source was the main plot factor and N rate was the subplot factor. Cotton ('PayMaster 1218') was planted on 25 May, seedlings emerged on 30 May, first bloom occurred on 22 July, and cotton was harvested with a mechanical picker on 8 November.

Treatments for the inorganic-N fertilizer experiment were 0, 40, 80, 120, 160, and 200 lb N/acre. The first 40 or 80 lb N/acre were broadcast as ammonium sulfate and incorporated with a do-all. The balance of each inorganic-N fertilizer rate was knifed in as urea ammonium nitrate solution (32% N) according to the schedule in Table 1. Pelleted litter was applied at rates of 0, 1500, 3000, 4500, 6000, and 7500 lb/acre supplying 0, 60, 120, 180, 240 and 300 lb total-N/acre. Pelleted litter was broadcast by hand and incorporated with a do-all on 24 May. On 5 May, 80 lb K_2O/acre as potassium chloride and 46 lb P_2O_5/acre as triple superphosphate were surface-applied and incorporated in all plots. Conventional tillage and pest management practices were followed and irrigation was managed according to the University of Arkansas Cooperative Extension Service Irrigation Scheduler Program. Cotton petiole samples were collected from the 5th node from the top of 20 plants selected randomly in each plot from the week before first bloom until the end of the 5th week of bloom. Cotton petioles were dried overnight at 70°C and ground to pass a 1-mm sieve. A 0.1 g sub-sample was mixed with 30 mL of 0.025 *M* aluminum sulfate solution, stirred, and allowed to stand for 15 minutes. Petiole NO_3-N concentration was determined using an ion-specific electrode.

The effect of N rate for each N source on seedcotton yield and petiole NO_3-N was analyzed separately using a randomized complete block design because the total-N rates between sources differed. Analysis of variance was performed using the SAS GLM procedure. Significant treatment means were separated by the Waller-Duncan test.

RESULTS AND DISCUSSION

Inorganic-N Fertilizer

Application of 120 lb N/acre produced the greatest seedcotton yield (Table 2) and was significantly greater than N rates ≤40 lb N/acre. Although not significantly lower than the maximum yield produced with 120 lb N/acre, seedcotton yields declined numerically when N rates exceeded 120 lb N/acre due in part to excessive vegetative growth. Petiole NO_3-N concentrations reflected N application rate and time (Table 2). Numerical petiole NO_3-N concentrations varied among N rates between 14 July and 28 July, but were not statistically different. Significant differences among N rates occurred only during the 4th and 5th week of bloom. Petiole NO_3-N concentrations were not statistically compared across time, but showed that petiole NO_3-N concentration in cotton fertilized with 0, 40, and 80 lb N/acre had decreased by the 2nd week of bloom (28 July, Table 2). For N rates >80 lb N/acre, petiole NO_3-N decreased between the first (20 July) and 4th (11 August) weeks of bloom. Nitrogen application on 4 August caused an increase in petiole NO_3-N between the 4th (11 August) and 5th (17 August) weeks of bloom indicating that cotton utilized late-season applied N. At the end of the 5th week of the bloom (17 Aug) the NO_3-N concentrations in cotton petioles receiving 40 and 80 lb N/acre on 4 Aug for 160 and 200 lb N/acre treatments were at least three times higher than the other treatments (Table 2).

Pelleted Poultry Litter

Application of PPL significantly increased seedcotton yield (Table 3). However, unlike the inorganic-N fertilizer, application of >120 lb N/acre (>3000 lb PPL/acre) did not numerically reduce the seedcotton yield. Presumably, slow release of N from PPL did not promote excessive vegetative growth, as was the case with inorganic N rates >120 lb N/acre. Seedcotton yield increased as PPL-N rate increased from 0 to 120 lb N/acre and reached a plateau from 120 to 300 lb N/acre. Although the numerically greatest yields were produced by application of 300 lb PPL-N/acre, the yield was not statistically different from 120 and 240 lb PPL-N/acre. Except for the 300 lb PPL-N/acre rate, yields between each increasing-rate increment of inorganic- and PPL-N were comparable numerically, suggesting that pelleted poultry litter rates of 120 lb N/acre supplied adequate plant-available N for the production of maximal cotton yields. Petiole NO_3-N concentrations i) were not different among PPL-N rates within each sample time; ii) generally decreased during the season; and iii) were numerically greater on 14 July and 11 August than values obtained for cotton receiving inorganic-N. However, no discernable trend was observed between the PPL-N rate and petiole NO_3-N (Table 3). By the 1st week of bloom (20 July) petiole NO_3-N concentrations were below the minimum sufficiency levels regardless of N rate and source (Table 2 and 3). Analysis of cotton seed, lint, whole plant, and soil samples collected at or after harvest may provide valuable insight into the causes of yield enhancement due to PPL application.

PRACTICAL APPLICATION

Yield of cotton grown on a typical MDRA agricultural soil was significantly increased by application of N fertilizer or PPL. The optimal N rate for inorganic-N fertilizer was 120 lb N/acre and for PPL was 240 lb PPL-N/acre. The seedcotton yields increased linearly with increasing PPL-N rate. This might be due to slow but continuous release of N from PPL. Research should be continued to investigate the fertilizer-N value of various poultry litter sources for use as an alternative and/or a complement to inorganic-N, as well as P and K fertilizers for cotton grown in Arkansas.

ACKNOWLEDGMENTS

We wish to thank the staff of the CBES and the University of Arkansas Soil Testing and Research Laboratory for their assistance. Without their contributions, this study would not have been possible.

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Table 1. Nitrogen source, rate, and application times for evaluating the effect of inorganic-N fertilizer and pelleted poultry litter (PPL) on seedcotton yield and petiole NO_3-N at the Cotton Branch Experiment Station in 2004.

N source	PPL rate	Total N rate	Preplant (May 24)	Sidedress N (July 21)	Sidedress N (August 4)
	(lb/acre)	(lb N/acre)			
Control	0	0	0	0	0
AS[z]	0	40	40	0	0
AS, Urea	0	80	40	0	40
AS, Urea	0	120	80	40	0
AS, Urea	0	160	80	40	40
AS, Urea	0	200	80	40	80
PPL-control	0	0	0	0	0
PPL	1,500	60	60	0	0
PPL	3,000	120	120	0	0
PPL	4,500	180	180	0	0
PPL	6,000	240	240	0	0
PPL	7,500	300	300	0	0

[z] AS, ammonium sulfate

Table 2. Effect of inorganic-N fertilizer rate on seedcotton yield and petiole NO_3-N concentration at the Cotton Branch Experiment Station in 2004.

N rate	Seedcotton yield	14 July wk before 1st bloom	20 July 1st wk of bloom	28 July 2nd wk of bloom	11 August 4th wk of bloom	17 August 5th wk of bloom
(lb N/acre)	(lb/acre)	(mg NO_3-N/kg)				
0	1723	5740	4673	2330	504	534
40	2648	6135	4942	2333	380	384
80	2937	6350	6137	1050	347	531
120	3264	4799	5827	2330	1787	461
160	2919	8576	4775	3278	499	1540
200	2953	6651	4209	2555	842	1855
Minimum sufficiency level[z]		5000	10000	9000	5000	2000
P-value	0.002	0.956	0.40	0.513	0.020	0.0002
MSD at 0.05[y]	503	NS	NS	NS	918	593

[z] Published by Snyder et al. (1995)
[y] Minimum Significant Difference as determined by Waller-Duncan Test (NS, not significant at P=0.05).

Table 3. Effect of N-rate from preplant-incorporated pelleted poultry litter (PPL) on seedcotton yield and cotton petiole NO_3-N concentration at the Cotton Branch Experiment Station in 2004.

N rate	Seedcotton yield	14 July wk before 1st bloom	20 July 1st wk of bloom	28 July 2nd wk of bloom	11 August 4th wk of bloom	17 August 5th wk of bloom
(lb N/acre)	(lb/acre)	(mg NO_3-N/kg)				
0	1743	8916	5298	2690	836	461
60	2677	11607	5537	3757	3165	390
120	3291	5880	5309	1324	1283	245
180	3090	11708	5554	3049	2028	350
240	3376	6765	5703	832	2320	386
300	4118	9993	7016	2921	933	461
Minimum sufficiency level[z]		5000	10000	9000	5000	2000
P-value	0.006	0.705	0.827	0.711	0.2152	0.7071
MSD at 0.05[y]	858	NS	NS	NS	NS	NS

[z] Published by Snyder et al. (1995).
[y] Minimum Significant Difference as determined by Waller-Duncan Test (NS, not significant at P=0.05).

Inorganic Nitrogen Fertilizer and Pelleted Poultry Litter Increase Wheat Yield in Arkansas

M. Mozaffari, N.A. Slaton, and E. Evans

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Balanced nitrogen (N) nutrition is essential for the production of high-yielding and quality wheat (*Trticum aestivum* L.). Many growers produce winter wheat following grain sorghum (*Sorghum bicolor* L) in rotation. Grain sorghum is a high-residue crop and information on wheat response to N fertilization in a wheat-sorghum rotation is useful for developing and refining our current wheat N-fertilization recommendations. The use of poultry litter as a fertilizer in the Mississippi Delta Region of Arkansas (MDRA) should be addressed to develop use guidelines for growers. To facilitate the transfer of nutrients from nutrient-rich poultry production areas, poultry litter is being pelletized as a means of reducing transportation cost. Pelleted poultry litter (PPL) contains N, P, K, and small quantities of micronutrients. Pelleted litter is currently marketed by some fertilizer distributors in the MDRA as a fertilizer. However, there is little information on crop and soil response to PPL in crop production systems of the MDRA. The objectives of the experiment were to evaluate the effect of N source and application rate on wheat grain yield and to evaluate the effect of poultry litter on soil chemical properties.

PROCEDURES

A replicated field experiment was conducted at the University of Arkansas Cotton Branch Experiment Station (CBES) in Marianna, Ark., on a Calloway silt loam during the 2003 growing season. 'Sabbe' wheat was drill seeded (6-inch row spacing) at 120 lb/acre on 25 October 2003. Nitrogen fertilizer was applied as urea (Urea) in late winter or as pelleted litter either preplant-incorporated in the fall (PPLF) before seeding or surface-applied in late winter (PLLW) at five N rates. Urea was applied at rates of 40, 80, 120, 160, and 240 lb N/acre on 2 March 2004. Pelleted litter (4.05% total N) was applied at rates of 1000, 2000, 3000, 4000, and 6000 lb/acre, which corresponds to total-N rates of 40, 81, 122, 162, and 243 lb N/acre. Nitrogen rates for all sources will be referred to as 40, 80, 120, 160, and 240 lb N/acre. An unfertilized control (0 lb N/acre) was also included. Each plot was 30-ft long and 5-ft wide and contained 10 rows of wheat. All plots were fertilized with triple superphosphate and muriate of potash to supply 40 and 30 lb/acre of K_2O and P_2O_5, respectively, to ensure that yield was not limited by K or P deficiency. All preplant fertilizers were broadcast and then mechanically incorporated. Standard cultural practices recommended by the University of Arkansas Cooperative Extension Service were followed.

The experiment was a randomized complete block with a 3 (N source/time) × 5 (N rate) factorial treatment structure with five replications. The entire plot was harvested with a small plot combine. Grain moisture values were adjusted to a uniform moisture content of 13% for statistical analysis.

Composite soil samples were collected from the 0- to 6-inch depth of the control and the low and high N rate treatments of each source in the fall before treatments were applied and from all treatments in the first four replications after wheat harvest (6 June 2004). Soil samples were oven dried, crushed, extracted with Mehlich-3 solution (1:10 ratio), and the concentration of elements in the extract was measured by Inductively Coupled Plasma Atomic Emission Spectroscopy. Soil nitrate was extracted with aluminum sulfate and measured with a specific-ion electrode. Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.

Analysis of variance procedures were conducted for wheat yield and post-harvest soils data using the PROC GLM procedure in SAS (SAS Institute, Inc., Cary, N.C.). When appropriate, mean separations were performed using the Fisher's Protected Least Significant Difference method at a significance level of 0.1.

RESULTS AND DISCUSSION

Wheat grain yields were significantly affected by the source of N, averaged across N rates, and N rate, averaged across N sources (Table 1). Application of urea significantly increased wheat yields compared with pelleted litter, regardless of application time. Wheat yields receiving either fall- or late-winter-applied pelleted litter produced significantly greater wheat yields compared with the unfertilized control. Application of urea at 120 lb N/acre produced the maximum yield of 4621 lb/acre (77 bu/acre), but urea at rates >120 lb N/acre caused lodging and tended to decrease wheat yields. Data suggest that pelleted poultry litter applied at intermediate to high rates can provide some N to winter wheat when applied either in the fall or late winter, but will likely require supplemental inorganic N fertilizer to produce maximal yields.

Preplant soil samples showed that the mean pH was 6.1, estimated cation exchange capacity (ECEC) averaged 13 $cmol_c$/kg soil, soil organic matter (SOM) averaged 1.6%, and base saturation (BS) averaged 73%. Mehlich-3-extractable P and K were > 80 and 220 lb/acre, respectively, and considered sufficient for wheat production. Chemical analysis of soil samples collected after wheat harvest indicated that the N source, averaged across all N rates, significantly affected soil P, K, Cu, and Zn (Table 2). For all of these nutrients the pelleted poultry litter-treated soils had similar levels of P, K, and Zn as the unfertilized control, but were greater when compared to the inorganic N fertilizer. Because the unfertilized control Zn and P were similar to soil receiving litter, there may have been significant variability among plots before fertilizers were applied or soil-test nutrient concentrations may have been affected by whet yield. Soil Cu was the only extracted nutrient that poultry litter may have actually increased. Averaged across the N sources, the application of poultry litter significantly (P=0.1) increased Mehlich-3-extractable Cu presumably due to the effect of poultry litter applied at N rates > 120 lb/acre.

PRACTICAL APPLICATIONS

Pelleted poultry litter applied either in the fall or late winter significantly increased wheat grain yields compared with the unfertilized control. However, when compared with yields of wheat receiving 120 lb N/acre as urea (applied in late winter), pelleted poultry litter at rates up to 6000 lb/acre failed to produce maximal wheat yields. Therefore, yield data from this one study suggest that pelleted litter can supply only a portion of the N required by wheat to produce maximal grain yields. Supplemental N applied in late winter is needed to produce maximal wheat yields. Further studies are required to more accurately delineate the amount of plant-available nutrients provided by fall- or late-winter-applied pelleted litter to winter wheat in Arkansas and to monitor its influence on soil fertility as determined by soil-testing.

ACKNOWLEDGMENTS

We wish to thank the staff of the CBES for their assistance; without their contributions this study would not have been possible.

Table 1. Influence of N source, averaged across N rates, and N rate, averaged across N sources, on wheat grain yields at the Cotton Branch Experiment Station in 2003-2004.

N source	Wheat yield	N rate	Wheat yield
	(lb grain/acre)	(lb N/acre)	(lb grain/acre)
None	2767	0	2767
Pelleted litter (Fall)	3525	40	3417
Pelleted litter (Late Winter)	3528	80	3634
Urea	4246	120	3646
		160	3973
		240	4195
P-value	0.0041		0.0716
LSD (0.10)	651		650

Table 2. The effect of inorganic-N (INF), pelleted poultry litter applied in the fall (PPLF), and pelleted poultry litter applied in the winter (PPLW), averaged across N rates, on selected soil chemical properties from soil samples (0- to 6-in depth) collected after wheat harvest at the Cotton Branch Station.

N source	Soil pH[z]	Soil OM[y]	Soil NO_3-N[x]	P[w]	K[w]	Ca[w]	Mg[w]	Cu[w]	Zn[w]
(lb/acre)		(%)	(lb/acre)						
None	6.3	1.8	4	144	363	2579	712	2.9	5.7
INF	6.3	1.8	5	126	334	2414	675	2.8	4.8
PPLF	6.3	1.8	4	146	384	2478	698	3.2	5.4
PPLW	6.3	1.9	4	148	423	2506	705	3.3	5.9
P-Value[v]	0.50	0.20	0.13	< 0.001	< 0.001	0.38	0.50	< 0.001	0.0002
LSD (0.10[v])	NS	NS	NS	12	40	NS	NS	0.2	0.6

[z] Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.
[y] OM, soil organic matter determined by Weight Loss on Ignition.
[x] NO_3-N measured by ion-specific electrode.
[w] Mehlich-3-extractable soil nutrients (1:10 extraction ratio).
[v] Minimum Significant Difference as determined by LSD Test (NS, not significant at *P*=0.1).

Table 3. The effect of N rate, averaged across the N sources, on chemical properties of the soil samples collected after wheat harvest from the 0- to 6-in depth at the Cotton Branch Station.

N rate	Soil pH[z]	Soil OM[y]	Soil NO_3-N[x]	P[w]	K[w]	Ca[w]	Mg[w]	Mn[w]	Cu[w]	Zn[w]
(lb/acre)		(%)	(lb/acre)							
0	6.3	1.8	4	144	363	2579	712	223	2.9	5.7
40	6.4	1.8	4	132	394	2443	693	218	2.9	5.3
80	6.2	1.9	5	138	391	2500	715	223	3.1	5.3
120	6.3	1.8	5	136	368	2492	687	224	3.0	5.3
160	6.4	1.8	5	147	379	2407	673	231	3.1	5.7
240	6.2	1.9	5	146	369	2487	695	236	3.3	5.4
P-Value[v]	0.08	0.60	0.56	0.11	0.65	0.8	0.8	0.69	0.02	0.49
LSD0.10[v]	0.1	NS	NS	NS	NS	NS	NS	NS	0.3	NS

[z] Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.
[y] OM, soil organic matter determined by Weight Loss on Ignition.
[x] NO_3-N measured by ion-specific electrode.
[w] Mehlich-3-extractable soil nutrients (1:10 extraction ratio).
[v] Minimum Significant Difference as determined by LSD Test (NS, not significant at *P*=0.1).

INORGANIC NITROGEN FERTILIZER AND PELLETED POULTRY LITTER INCREASE CORN YIELD

M. Mozaffari, N.A. Slaton, and E. Evans

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Nitrogen is the most limiting nutrient in corn (*Zea mays* L.) production. Corn acreage in Arkansas has almost doubled in recent years, making it an important source of income for farmers. Improved nitrogen (N) fertilization practices can increase net profits to corn growers and prevent unnecessary input of the nutrients into the environment. Introduction of pelleted poultry litter (PPL) to corn production systems in the Mississippi Delta Region of Arkansas (MDRA) is an area of corn fertilization that needs to be addressed. Pelleted poultry litter contains N, phosphorus (P), potassium (K), and small quantities of micronutrients. However, there is virtually no information on corn and soil response to PPL in the MDRA. A field experiment was conducted to compare corn N response to a range of N rates applied as inorganic-N fertilizer (INF) and PPL. The objectives of this study were to evaluate the effect of PPL and inorganic N-fertilizer rate on corn grain yield and soil properties in a typical MDRA soil.

PROCEDURES

A replicated field experiment was conducted at the University of Arkansas Cotton Branch Experiment Station (CBES) in Marianna, Ark., on a Loring silt loam during the 2004 growing season. Standard tillage and other cultural practices recommended by the University of Arkansas Cooperative Extension Service for corn production were followed. Experimental variables were N source and N rate. Inorganic-N fertilizer (INF) and PPL (4.05% N) were each applied at a range of N rates. Inorganic-N fertilizer was applied at 50, 100, 150, 200, and 250 lb N/acre and PPL was applied at bulk rates of 1500, 3000, 4500, and 6000 lb/acre, which correspond to about 60, 120, 180, and 240 lb total-N /acre. An unfertilized control (0 lb N/acre) was also included. All INF treatments received a preplant application of 20 lb N/acre as ammonium sulfate prior to planting and the balance of the INF was sidedressed as urea when plants were 6 weeks old. All of the PPL treatments were applied before planting and mechanically incorporated. All plots were also fertilized with 80 lb P_2O_5/acre as triple superphosphate and 60 lb K_2O/acre as muriate of potash to ensure that yield was not limited by K or P deficiency. All preplant amendments were broadcast and mechanically incorporated. Experimental plots were 40-ft long and 12.6-ft wide allowing for four rows of corn planted in 38-inch wide rows. The corn cultivar Pioneer 32p76BT was planted on 9 April 2004 and harvested with a plot combine on 1 September 2004. Grain yield was adjusted to a uniform moisture content of 15% for statistical analysis.

After harvest, composite soil samples were collected from the 0- to 6-inch depth of all plots. Soil samples were extracted with Mehlich-3 solution (1:10 ratio) and the concentration of elements in the extract was measured by inductively coupled plasma atomic emission spectroscopy. Soil-nitrate N was extracted with 0.025 *M* aluminum sulfate and measured with a specific-ion electrode. Soil pH was measured by electrode in a 1:2 (weight:volume) soil-water mixture extraction. Treatments were arranged in a ranodmized complete block design with four replications of each treatment. Analysis of variance (ANOVA) was performed to evaluate the effect of inorganic-N fertilizer and PPL N rate on corn grain yield and soil chemical properties.

RESULTS AND DISCUSSION

Pelletized litter rates of 120 to 240 lb N/acre produced greater yields than the unfertilized control that were similar to INF rates of 50 lb N/acre (Table 1). Inorganic-N fertilizer rates ≥150 lb N/acre all produced significantly greater yields than the highest PPL-N rate, suggesting that PPL alone would not be capable of supplying the N requirement for corn. Soil NO_3-N at the highest rates of PPL and INF-N was significantly higher than the untreated check (Table 2). At the highest rates of PPL, Mehlich-3-extractable P, K, and Cu were significantly greater than the unfertilized control and most INF rates.

PRACTICAL APPLICATIONS

Application of inorganic-N fertilizer or PPL increased corn yields, but maximal yields were produced only by inorganic-N fertilizer. Data suggest that PPL may serve as a starter N when P-based rates (1500 to 3000 lb/acre) are applied, but will require the application of supplemental inorganic-N for maximal yields to be achieved. This single site-year of data suggests that corn growers who use PPL will also benefit from the addition of other nutrients. However, additional research is needed to delineate agronomically and environmentally sound PPL application rates to avoid over-application and accumulation of some nutrients in the soil.

ACKNOWLEDGMENTS

We wish to thank the staff of CBES for their assistance. Without their contribution this study would not have been possible.

Table 1. Effect of application of inorganic-N fertilizer (INF) and pelleted poultry litter (PPL) on corn grain yields at the Cotton Branch Experiment Station (CBES) in 2004.

N source	PPL rate	Total-N rate	Corn yield
	(lb PPL/acre)	(lb N/acre)	(bu/acre)
Control	0	0	68
INF[z]	0	50	120
INF	0	100	134
INF	0	150	153
INF	0	200	161
INF	0	250	151
PPL[y]	1500	60	79
PPL	3000	120	124
PPL	4500	180	120
PPL	6000	240	113
MSD[x] at 0.05	--	--	20

[z] For inorganic-N fertilizer, the first 20 lb N/acre was applied as ammonium sulfate and the rest was applied as urea.
[y] PPL = Pelleted poultry litter.
[x] Minimum significant difference as determined by Waller-Duncan Test (*P*=0.05).

Table 2. Effect of inorganic-N fertilizer (INF) and pelleted poultry litter (PPL) on soil chemical properties of soil collected post-harvest from the 0- to 6-inch depth of the corn experiment at the Cotton Branch Experiment Station in 2004.

N source	Total N rate	Soil pH[z]	Soil OM[y]	Soil NO_3-N[x]	Mehlich-3-extractable nutrients					
					P	K	Ca	Mg	Cu	Zn
	(lb/acre)		(%)		(lb/acre)					
None	0	6.8	1.8	11	108	301	2750	451	2.9	9.4
INF	50	6.4	1.6	10	93	265	2484	462	2.6	7.5
INF	100	6.6	1.6	9	104	268	2545	431	3.0	10.6
INF	150	6.6	1.7	11	103	248	2542	469	3.0	9.4
INF	200	6.7	1.5	14	104	271	2908	413	3.2	7.1
INF	250	6.4	1.5	15	89	231	2501	448	2.8	6.8
PPL	60	6.8	1.6	13	122	320	2712	464	3.2	10.9
PPL	120	6.7	1.5	14	138	370	2510	444	3.4	9.5
PPL	180	6.8	1.7	12	130	354	2871	438	3.8	11.8
PPL	240	6.9	1.7	16	172	412	3501	439	4.0	11.8
MSD at 0.05[w]		NS	NS	4	40	64	NS	NS	0.6	4.3

[z] Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.
[y] OM, soil organic matter determined by Weight Loss on Ignition.
[x] NO_3-N measured by ion-specific electrode.
[w] Minimum significant difference as determined by Waller-Duncan Test (NS, not significant at $P = 0.05$).

Sidedress Application of Nitrogen for Improving Corn Production in Arkansas

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Arkansas corn acreage has steadily increased from 180,000 acres in 2000 to nearly 360,000 acres in 2003. Due to corn's high nitrogen (N) requirement, supplemental N fertilizer is needed to obtain high yields. Nitrogen (N) fertilization is one of the largest variable input costs for corn production. During the 2003 cropping season, the University of Arkansas recommended an average of 207 lb N/acre for corn production (median was 210 lb N/acre, data from UA soil-test results). Assuming approximately 360,000 acres of corn were planted and N fertilizer cost of $0.28/lb N, Arkansas corn farmers spent approximately $20 million on N fertilizer in 2003.

Currently, corn N fertilization in Arkansas and several other states is based on the potential crop yield goal due to the lack of a better alternative. Unfortunately, this approach does not take into consideration the amount and potential availability of native soil N and may result in over-application of N. Over-application of N is an economic loss to the growers and also poses a potential environmental problem.

In recent years, the pre-sidedress soil nitrate test (PSNT) and amino sugar N test (ASNT) have shown the potential for i) identifying soils that will not respond to additional N application and/or ii) predicting optimal N application rates. Applying N fertilizer only when it is actually needed will increase the growers' profit margin and address the potential environmental concerns. The PSNT is based on the premise that the amount of soil NO_3-N at four to five weeks after plant emergence is the integrated result of many soil and climate factors that influence N availability. Therefore, soil nitrate concentration at this time is directly related to the soil's N-supplying capacity for the entire growing season. Adaptation of the PSNT or ASNT tests to corn production in Arkansas requires data from N response studies and PSNT and ASNT levels in soil from multiple representative sites and years under crop production systems of Arkansas. The objective of these studies was to evaluate the response of corn grain yield to varying rates of sidedressed N fertilizer. Data from 2004 and subsequent years will serve as a scientific database for correlating and calibrating the PSNT and ASNT for corn N management.

PROCEDURES

Six replicated field experiments were conducted at multiple locations on soils representing major corn-producing counties of Arkansas. Four of the sites were on commercial farms and two were on University of Arkansas Agricultural Experiment Station (UAAES) research farms. Information on previous crops, soil series, corn cultivar, planting, sidedress, and harvest date, and row spacing is listed in Table 1. Nitrogen application rates were 0, 50, 100, 150, 200, and 250 lb N/acre. Other nutrients were managed according to the University of Arkansas Cooperative Extension Service (UACES) soil-test-based recommendations. Experimental plots were 40-ft long and 4- to 5-rows wide depending on the location. The experimental design was a randomized complete block with four replications of each treatment. At all sites, 20 lb N/acre as ammonium sulfate was applied prior to or at planting and the remaining N balance was sidedressed as urea by hand about 5 to 8 weeks after corn emergence when soil conditions were suitable for field work. The check plots did not receive any starter fertilizer. Prior to the application of sidedressed N, composite soil samples were collected from the 0- to 8- and 0- to 12- inch soil depths from all plots. At the Independence County site, the presence of a hardpan prevented sampling beyond the 6-inch depth.

At the UAAES sites, the two center rows of each plot were harvested with a plot combine. On commercial farm sites, two 15-ft-long sections were harvested from the two center rows of each plot by hand. Corn yields were adjusted to a uniform moisture content of 15% for statistical analysis. Irrigation was either managed by the UACES Irrigation Scheduler program or by the grower. In general, corn management at all sites closely followed practices recommended by the UACES.

At selected locations, soil samples were collected from the 0- to 6-inch depth after corn harvest. Post-harvest soil samples were extracted with Mehlich-3 solution (1:10 ratio) and the concentration of elements in the extract was measured by Inductively Coupled Plasma Atomic Emission Spectroscopy. Soil nitrate was extracted with aluminum sulfate and measured with a specific-ion electrode (Donahue, 1992). Soil pH was measured in a 1:2 (weight:volume) soil-water mixture extraction. Nitrate in pre-sidedress soil samples was measured as described above. Analysis of variance (ANOVA) was performed to evaluate the effect of sidedress-N application on corn yield for each site separately.

RESULTS AND DISCUSSION

Soils at experimental sites were representative of agricultural soils under corn production in Arkansas (Table 2). Yield results from the Independence and Jefferson county sites were flawed and discarded due to flooding or misapplication of N. Corn grain yield over the four locations ranged from 55 to 94 bu/acre for the unfertilized control and 126 to 251 bu/acre for the highest N rate of 250 N/acre (Table 3). At all N rates, the highest yields were produced at Desha County and the lowest yields were obtained at Jackson County. The low soil Ca/Mg ratio (Table 2) may have been responsible for low yield potential at the Jackson County site. The results of this one-year study at Desha County appear to support the current UACES recommendation of 250 lb N/acre for attaining a yield of 225 bu/acre of corn. At the Mississippi County site, where the soil is mapped as a silty clay loam, corn yields significantly increased with increasing N rate and we did not observe a yield plateau. The actual yield potential at this site may have been higher than the 161 bu/acre achieved at the 250 lb N / acre rate. We will include N rates higher than 250 lb N/acre next year, since such information will be useful for delineating optimal N rates on fine-textured soils. At the Jackson and Lee county sites, corn grain yield no longer increased when more than 150 lb N/acre was applied. These data indicate that the optimal N rate varied among the sites (150-250 lb N/acre) as corn yield potential varied. Thus, since all soils do not have the same yield potential, they should not have the same recommended N rate. A realistic yield potential goal should be set for each soil and no more N should be applied than what is required to reach the optimal corn yield potential. This one year of data indicates that on silt loams, about 1 lb N/acre should be applied for every 1 bu/acre of potential corn grain yield.

PRACTICAL APPLICATIONS

Mid-season sidedress application of N fertilizer up to 250 lb N/acre increased corn grain yield from 55 to 251 bu/acre at the Desha County site and 94 to 126 bu/acre at the Jackson County site. The optimal N application rate in this one-year study varied from 150 to 250 N/acre as yield potential varied across the sites. In the absence of a better science-based guideline, corn growers need to set a realistic yield goal and fertilize accordingly for an optimal return on their N-fertilizer investment. Corn growers can increase the efficiency of N uptake by corn by applying only a small amount of starter N fertilizer at planting. The bulk of the N fertilizer should be applied as a sidedress when the corn plant is large enough to take up the N more quickly. This sidedress application of N to established, fast-growing corn enables the corn plant to better compete against the N-loss mechanisms of denitrification and leaching.

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UACES and the staff of the UA Southeast Research and Extension Center and Cotton Branch Experiment Station for their contributions.

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Table 1. Selected agronomic information for six corn fertility experiments conducted in 2004.

Site (county)	Previous crop	Soil series	Cultivar	Planting date	N sidedress dates	Harvest date	Row spacing
							(in.)
Desha	Sorghum	Desha silt loam	Pioneer 32P76YG	5 April	3 June	29 August	38
Independence	Soybean	Hontas silt loam	Garst 8350	4 April	20 May	27 August	30
Jackson	Soybean	Dundee silt loam	Pioneer 33M54	23 March	20 May	24 August	30
Jefferson	Cotton	Herber silt loam	Pioneer 32P76BT	17 March	4 May	26 August	38
Lee	Soybean	Loring silt loam	Pioneer 32P76BT	9 April	26 May	1 September	38
Mississippi	Soybean	Tunica silty clay loam	Dekalb 6324	10 April	4 June	20 August	30

Table 2. Selected chemical properties of the (0- to 6-inch) depth of soils before first N application for N fertilization trial sites conducted in 2004. Data not available for the Lee county test site.

County	Soil pH[z]	Soil OM[y]	NO_3-N[x]	P[w]	K[w]	Ca[w]	Mg[w]	S[w]	Mn[w]	Cu[w]	Zn[w]	B[w]
		(%)	(mg/kg)									
Desha	7.3	1.5	5	72	144	2279	454	15	125	2.0	4.1	0.8
Independence	5.6	3.2	11	27	141	2090	340	24	270	3.7	9.4	0.7
Jackson	6.8	1.3	6	122	228	807	940	15	350	2.3	2.0	0.6
Jefferson	7.5	1.0	4	68	196	2404	128	12	46	1.0	11.1	1.6
Mississippi	5.6	3.1	21	52	280	4188	665	48	540	7.3	18.6	1.5

[z] Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.
[y] OM, soil organic matter determined by Weight Loss on Ignition.
[x] NO_3-N measured by ion-specific electrode.
[w] Mehlich-3-extractable soil nutrients (1:10 extraction ratio).

Table 3. Corn grain yields as affected by N application rate for four N-rate trials conducted in Arkansas during 2004.

County/site	N application rate (lb N/acre) 0	50	100	150	200	250	LSD (0.05)
	(bu/acre)						
Desha	55	115	172	192	206	251	18
Jackson	94	106	118	125	129	126	16
Lee	68	120	135	154	161	152	23
Mississippi	57	80	89	107	126	161	14

Nitrogen Fertilizer Management for Corn

J.H. Muir and J.A. Hedge

RESEARCH PROBLEM

Nitrogen (N) fertilizer programs for corn (*Zea mays* L.) generally include a preplant application followed by the remainder of the crop's N requirement supplied in a sidedress application to the young crop. A small quantity of N is sometimes applied with or near the seed as a starter fertilizer at planting. The early-spring planting dates required for production of optimal corn yields in Arkansas often expose corn seedlings to lower than optimum soil temperatures. The low soil temperatures may result in slow root growth and phosphorus (P) deficiency even though soil-test P levels are considered adequate. A starter fertilizer may benefit corn growth and yield in these situations. An application of N at tasseling has been used by some producers for many years. Little research data is available on N management for corn in recent years in Arkansas.

BACKGROUND INFORMATION

Placing small amounts of starter fertilizer (usually N, P, or N and P) with or near the seed has increased early-season corn plant height and grain yield and decreased the number of days to silking in northeast Louisiana (Mascagni and Boquet, 1996). The majority of the corn crop's N requirement is generally split between a preplant and a sidedress application to reduce the risk of N loss via denitrification or leaching under excess moisture conditions early in the growing season. No studies have been reported that have examined all aspects (i.e., starter, preplant and sidedress, and tasseling N-fertilizer applications) of N fertilizer management together.

RESEARCH DESCRIPTION

A study was conducted on a Calhoun silt loam at the Pine Tree Branch Station (PTBS) located near Colt, Ark.; on a Sharkey silty clay at the Northeast Research and Extension Center (NEREC) at Keiser, Ark.; on a Collins silt loam at the Arkansas State University farm (ASU) located in Jonesboro, Ark.; and on a Loring silt loam at the Cotton Branch Experiment Station (CBES) in 2004 to evaluate N as a starter fertilizer, several preplant/sidedress applied N combinations, and N applied at tasseling in a single experiment. Treatments included a) starter N at 0 and 15 lb N/acre, applied 2 inches below and 2 inches to the side of the seed at planting, b) four preplant/sidedress ratios (25/75, 33/67, 50/50, 75/25), and c) 0 and 50 lb N/acre at tasseling. The corn hybrid DKC64-11 (RR2/YG CB) was used at all four locations. Initial soil-test values are given in Table 1. Details of the experiment are given in Table 2. Each study was a randomized complete block design with a 2 × 4 × 2 factorial arrangement of treatments and four replications. The N source for starter N treatments was urea ammonium nitrate (UAN, 32-0-0) at all four locations. Urea was the N source for preplant/sidedress and N at tasseling applications. The sidedressed N was applied between the rows by hand and mechanically incorporated. Plots were hand harvested at ASU. Plot combines were used for harvest at the NEREC, PTBS, and CBES. Yields were adjusted to 15.5% moisture for statistical analysis.

RESULTS

When compared with the yields of the unfertilized control, corn receiving N fertilizer produced greater yields at all sites. However, N-fertilizer treatments had no significant influence on corn yields at the ASU, NEREC, and PTBS sites in 2004 (Table 3). The lack of significant differences among corn yields receiving N suggests that N fertilizer can be managed with a wide variety of methods for production of near maximum yields. At the CBES location, corn yields were significantly affected by starter N and the starter N × preplant/sidedress interaction (Table 4), although data show no consistent trend for better or worse corn yields among treatments. Nearly optimal growing conditions during the 2004 growing season resulted in high yields at all locations when the recommended rate of N was applied.

PRACTICAL APPLICATION

Starter fertilizer has shown promise in corn production in four of the last six years. Further data are needed to fully evaluate ratios of preplant/sidedress N applications and N applications made at tasseling. Prior results have consistently shown significant yield responses to starter fertilizer on the order of 10 bu/acre or more (Muir and Hedge, 2003). Producers may wish to consider whether the cost of applying a starter fertilizer is worth the possible yield increase. In 2004, corn yields were high at all locations; however, neither starter N nor N at tasseling was required to produce maximal yields when the recommended rate of applied N was applied in any preplant/sidedress ratio at three of the four locations.

ACKNOWLEDGMENTS

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Table 1. Selected soil-test values at four experimental sites used for corn N fertilization trials during 2004.

Parameter	NEREC	CBES	PTBS	ASU
pH	6.2	6.8	6.1	6.2
NO_3-N	7	7	13	24
P (lb/acre)	127	84	58	72
K (lb/acre)	568	337	341	269
Ca (lb/acre)	5847	3363	3132	2516
Mg (lb/acre)	1160	894	353	474
Na (lb/acre)	77	48	97	44
S (lb/acre)	28	15	56	34
Fe (lb/acre)	380	300	202	188
Mn (lb/acre)	29	130	321	331
Cu (lb/acre)	4.9	3.4	2.4	4.3
Zn (lb/acre)	7.4	3.4	5.1	7.6
B (lb/acre)	0.8	0.6	0.2	0.5

Table 2. Selected details on N fertilizer and cultural management for four corn fertilization trials conducted in Arkansas during 2004.

Management event	ASU	NEREC	PTBS	CBES
Date preplant N applied	1 April	2 April	3 April	5 April
Additional preplant fertilizer	None	None	None	None
Date of planting	15 April	16 April	6 April	8 April
Date of sidedress N application	22 May	25 May	24 May	21 May
Date of N at tasseling application	22 June	26 June	17 June	24 June
Quantity of N applied (preplant + sidedress)	160 lb/acre	300 lb/acre	180 lb/acre	180 lb/acre
Plot size	10 ft × 25 ft	12.7 ft × 40 ft	10 ft × 40 ft	10 ft × 25 ft
Row spacing	30 in.	38 in.	30 in.	30 in.
Harvest area (two center rows)	16 ft	33 ft	30 ft	18 ft

Table 3. Influence of nitrogen fertilizer treatment management on corn grain yield at four locations in 2004.

Nitrogen treatments			Corn grain yield by site			
Starter	Preplant/sidedress	Tassel	ASU	NEREC	PTBS	CBES
---- (lb N/acre) ----			---- (bu/acre) ----			
15	0.25/0.75[z]	50	184.7	162.1	140.4	140.7
15	0.25/0.75	0	189.2	156.2	135.5	121.0
15	0.33/0.67	50	183.4	151.6	151.2	162.8
15	0.33/0.67	0	192.6	155.0	148.1	136.2
15	0.50/0.50	50	187.4	163.7	148.2	136.8
15	0.50/0.50	0	189.2	158.5	132.3	129.1
15	0.75/0.25	50	184.7	136.8	140.1	137.1
15	0.75/0.25	0	187.3	147.2	150.1	153.6
0	0.25/0.75	50	178.8	164.6	144.3	125.7
0	0.25/0.75	0	187.3	154.5	134.3	130.0
0	0.33/0.67	50	186.6	147.8	147.4	149.5
0	0.33/0.67	0	181.6	154.0	134.0	150.4
0	0.50/0.50	50	197.1	157.6	150.4	145.1
0	0.50/0.50	0	179.6	142.4	150.9	147.1
0	0.75/0.25	50	196.4	151.8	133.1	120.6
0	0.75/0.25	0	193.2	156.4	142.4	114.6
0	0	0	159.8	34.7	95.3	29.8
P-values for main effects and treatment interactions						
Starter N			0.9432	0.9134	0.7807	0.3532
Preplant N			0.7530	0.1508	0.5748	<u>0.0120</u>
Tassel N			0.9758	0.5127	0.3949	0.3248
Starter × preplant			0.6060	0.0898	0.3044	0.0225
Starter × tassel			0.2483	0.6375	0.9938	0.2974
Preplant × tassel			0.6074	0.0975	0.3222	0.5530
Starter × preplant × tassel			0.7169	0.8880	0.6656	0.2135

[z] Total N rates were 160 lb N/acre for ASU, 300 lb N/acre for NEREC, and 180 lb N/acre for PTBS and CBES.

Table 4. Influence of starter N and preplant/sidedress N ratio on corn grain yield at the Cotton Branch Experiment Station during 2004.

	Starter N rate (lb N/acre)	
Preplant/sidedress N ratio[z]	0	15
	---- (bu/acre) ----	
25/75	128	131
33/67	150	149
50/50	146	133
75/25	118	145
To compare corn grain yields within starter fertilizer rates $LSD_{(0.05)}$ = 9		
To compare corn grain yields within preplant/sidedress N ratio $LSD_{(0.05)}$ = 13		

[z] 180 lb N/acre total preplant/sidedress N application rate

Poultry Litter Ash and Raw Litter Residual Effects on Wheat and Soybeans in an Eastern Arkansas Rice, Wheat, and Soybean Rotation

M.S. Reiter, T.C. Daniel, N.A. Slaton, C.E. Wilson, Jr., C.H. Tingle, and B.R. Bock

RESEARCH PROBLEM

Land applications of abundant amounts of poultry litter in Northwest Arkansas (NWA) have contributed to excessive soil-test phosphorous (P) in sensitive watersheds. Meanwhile, rice (*Oryza sativa* L.), soybean [*Glycine max* (Merr.) L.], and wheat (*Triticum aestivum* L.) producers in eastern Arkansas are adding inorganic-P fertilizers to raise soil-test P. Our objective was to evaluate how P in raw poultry litter with (PLWA) and without alum (PLWOA) and poultry litter ash (PLAsh) compare to triple superphosphate (TSP) as a P source for crops grown in eastern Arkansas.

BACKGROUND

Poultry in Arkansas produces approximately 1.2 million tons of litter annually. The settlement for the City of Tulsa and Tulsa Metropolitan Utility Authority vs. Tyson Foods, Cobb-Vantress, Peterson Farms, Simmons Foods, Cargill, George's, and the City of Decatur required that poultry producers 1) have a nutrient management plan to help curb over-application of litter and 2) ship 30% of the litter out of the Eucha-Spavinaw watershed (Tulsa Agreement, 2004). An alternative to land application of poultry litter is its use to generate power. A possible power generation facility in NWA, Fibrowatt[1], would produce consolidated ash that may be a beneficial fertilizer and reduce shipping cost of raw litter (Fibrowatt, 2004).

PROCEDURES

Research plots were established in Spring 2003 at the Pine Tree Branch Station (PTBS) in Colt, Ark., on a Calhoun silt loam (pH = 6.7, Fine-silty, mixed, active, thermic, Typic Glassaqualfs) and at the Rice Research and Extension Center (RREC) in Stuttgart, Ark., on a Dewitt silt loam (pH = 5.0, Fine, smectitic, thermic Typic Albaqualfs) with the planting of 'Wells' rice. Results of the rice experiments conducted in 2003 were reported by Reiter et al. (2004). This report describes the residual effect of the P sources and rates applied to rice in 2003 on the subsequent wheat and soybean crops.

Composite soil samples were taken from the 0- to 4-in depth after the rice, wheat, and soybean crops were harvested to test for available P, potassium, calcium, magnesium, copper, zinc, manganese, iron, sodium, boron, and aluminum using the Mehlich-3 extractant (data not yet available for soils following the 2004 soybean crop). Each experiment was conventionally tilled prior to drill seeding 'Sabbe' wheat in October 2003 at a rate of 125 lb seed/acre. Following wheat harvest, wheat straw was burned and the soybean cultivar Morsoy RT5620N was drilled in June 2004 at a population of 165,000 seeds/acre into a conventionally tilled seedbed at the RREC and an undisturbed seedbed (no-till) at the PTBS. Each plot was 10-ft wide and 25-ft long with a 24-inch border separating adjacent plots. In general, University of Arkansas wheat and soybean production recommendations for fertility, irrigation, and pest control were followed. Urea and ammonium sulfate were used to apply 75 lb N/acre and 24 lb S/acre to wheat at Feekes growth stage 3 (early tillering) in late February, with a second split of 75 lb N/acre (as urea) broadcast at Feekes growth stage 6 (first node visible) in mid-March. No additional fertilizer was added to the soybean crop.

[1] Reference to trade or company name is for specific information only and does not imply approval or recommendation of the company by the University of Arkansas to the exclusion of others that may be suitable.

Each experiment was a randomized complete block design with a 4 × 5 factorial treatment arrangement and four replications. Phosphorus sources applied to rice in 2003 were PLWA (1.0% P), PLWOA (1.2% P), PLAsh (6.9% P), and TSP (20.1% P) with application rates of 0, 30, 60, 90, and 120 lb P_2O_5/acre. Total dry-matter accumulation was determined at Feekes growth stage 10.1 (early heading) and at maturity for wheat and R1 (beginning bloom) and R6 (full seed) for soybean by harvesting the aboveground plant tissues from a 3-ft section in the second row of each plot. Plant samples were dried at 140°F to a constant weight. Wheat and soybean yield were determined at maturity by harvesting the middle 5-ft of each plot with a plot combine. Wheat and soybean yields were adjusted to 13.5 and 13.0% moisture, respectively, for statistical analysis.

The General Linear Model (GLM) procedure was used to test for significance (SAS Inst., Cary, N.C.). Significance levels of $p<0.10$ were chosen *a priori*. Means were separated using Fisher's protected least significant differences (LSD).

RESULTS AND DISCUSSION

Wheat

Prior to wheat planting, soil-test P concentrations as affected by P application to the previous rice crop were determined (Table 1, 2, and 3). At the RREC, the P rate × source interaction indicated that soil-test P increased as P_2O_5 application rate increased, but the rate of increase depended on P source (Table 2). When P rates ≥90 lb P_2O_5/acre were applied, soil-test P concentrations were greatest when PLAsh was the P source. Results from the PTBS concluded that soil receiving PLAsh had greater soil-test P concentrations than the other P sources and soil-test P increased linearly as P_2O_5 rate increased (Table 3).

Significance levels for wheat-production dependent variables are shown in Table 4. At the PTBS, wheat dry-matter at maturity was significantly affected by the P source × rate interaction (Table 5). At low P application rates, wheat dry-matter accumulation was generally greatest for wheat receiving PLWA. The P in alum-treated litter may be unavailable to plants immediately after its application to soil, but for alkaline soils the P in alum-treated litter may eventually become plant available.

Wheat yield was affected by the P source × rate interaction at the PTBS (Table 6). Within P application rates, wheat yields differed among P sources for the 0, 90, and 120 lb P_2O_5/acre rates. Among rates within each P source, wheat yields differed for PLWOA, PLAsh, and TSP, but showed no consistent yield trend. However, at the RREC, PLAsh had one of the highest wheat yields (Table 7) among P sources, and also increased soil-test P concentration prior to wheat planting when applied at high rates (Table 2). Generally, when averaged across P sources, application of 60 lb P_2O_5/acre significantly increased wheat yields at the RREC (Table 7).

Following wheat harvest, Mehlich-3-extractable soil P had a significant P source × rate interaction at the PTBS (Table 8). Compared with the unfertilized control, Mehlich-3 P was significantly increased by application of 90 and 120 lb P_2O_5/acre as PLAsh or PLWOA and 120 lb P_2O_5/acre as TSP. Soil-test P did not change significantly when PLWA was applied, regardless of application rate, suggesting that alum-bound P may not be available for crop uptake in high-pH soils by one year after application and that the growth response mentioned previously (Table 5) at low P rates may not have been due to the P in PLWA. When averaged across P rates, soil from the RREC showed that PLAsh had higher Mehlich-3 P concentrations than PLWOA, PLWA, and TSP (Table 9). Mehlich-3 P increased linearly as P application rate, averaged across P sources, increased (Table 9). Mehlich-3-extractable soil Cu concentrations at the RREC were greater for soil receiving PLAsh, PLWOA, and PLWA compared with TSP (Table 9). A similar trend was observed at the PTBS where PLWOA and PLWA had higher soil Cu concentrations than PLAsh and TSP, which increased with P_2O_5 rate.

Soybean

Soybean yield at maturity or dry matter at the R1 and R6 growth stages were not significantly affected by the main effects or their interaction (data not shown). The mean soybean yields were 65 bu/acre at the PTBS and 49 bu/acre at the RREC.

PRACTICAL APPLICATIONS

Poultry litter ash may be an adequate P fertilizer source for wheat and soybean production. In contrast, PLWA failed to increase soil-test P suggesting that it may not be plant available within one year following application. Application of all poultry litter-derived P sources did not harm rice, wheat, or soybean growth and yield indicating that these materials can be applied to soils in eastern Arkansas without adversely influencing short-term crop growth. Application of these materials may also increase soil metal concentrations, such as Cu.

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Table 1. Statistical p-values for Mehlich-3-extractable soil nutrients for the P source and rate main effects and P source × rate interaction in factorial experiments utilizing poultry litter ash (PLAsh), poultry litter with alum (PLWA), poultry litter without alum (PLWOA), and triple super phosphate (TSP) at the Pine Tree Branch Station (PTBS) in Colt, Ark., and the Rice Research and Extension Center (RREC) in Stuttgart, Ark.

	Source of variation and location					
	Source		Rate		Source × rate	
Dependent variable	RREC	PTBS	RREC	PTBS	RREC	PTBS
Prior to wheat planting						
pH	0.0179[z]	0.3546	0.8006	0.7402	0.0352[z]	0.0574[z]
Electrical conductivity	0.0005[z]	0.2304[y]	0.6900	0.0317[z]	0.1089[y]	0.1321[y]
Phosphorus	<0.0001[z]	0.0234[z]	<0.0001[z]	0.0042[z]	0.0041[z]	0.3109
Potassium	0.1479[y]	0.0829[z]	0.6395	0.0078[z]	0.2713	0.2425[y]
Calcium	0.0013[z]	0.6578	0.2768	0.2906	0.1978[y]	0.0993[z]
Magnesium	0.0386[z]	0.3684	0.4748	0.1779[y]	0.8040	0.1985[y]
Sulfur	<0.0001[z]	0.0045[z]	<0.0001[z]	0.0006[z]	<0.0001[z]	0.2689
Sodium	0.3428	0.1218[y]	0.3032	0.7308	0.1747[y]	0.4269
Iron	0.1607[y]	0.2712	0.0778[z]	0.5433	0.1074[y]	0.6866
Manganese	0.0731[z]	0.1624[y]	0.3100	0.1494[y]	0.8347	0.6348
Zinc	<0.0001[z]	0.1930[y]	<0.0001[z]	0.0289[z]	0.0037[z]	0.6889
Copper	<0.0001[z]	<0.0001[z]	<0.0001[z]	<0.0001[z]	0.0018[z]	0.0229[z]
Boron	0.0533[z]	0.0599[z]	0.4539	0.5412	0.1802[y]	0.8491
Prior to soybean planting						
Phosphorus	0.0284[z]	0.0038[z]	<0.0001[z]	<0.0001[z]	0.2924	0.0137[z]
Potassium	0.5318	0.7191	0.6229	0.2571	0.9642	0.5405
Calcium	0.0782[z]	0.2682	0.2169[y]	0.5283	0.0409[z]	0.4581
Magnesium	0.8080	0.2252[y]	0.4535	0.5775	0.1987[y]	0.3804
Sulfur	<0.0001[z]	0.4485	0.0002[z]	0.5030	0.0144[z]	0.5411
Sodium	0.8124	0.0611[z]	0.2757	0.9202	0.3010	0.5053
Iron	0.1731[y]	0.1684[y]	0.0382[z]	0.6488	0.5715	0.0279[z]
Manganese	0.0122[z]	0.2945	0.1576[y]	0.3058	0.4389	0.4089
Zinc	<0.0001[z]	0.8657	0.0009[z]	0.9708	0.6083	0.2334[y]
Copper	<0.0001[z]	0.0469[z]	0.0102[z]	0.0065[z]	0.2500[y]	0.7681
Boron	0.2953	0.8426	0.3707	0.3436	0.7296	0.6713
Aluminum	0.0013[z]	0.8928	0.2592	0.3458	0.3295	0.1169[y]

[z] Significant main effect or interaction ($p < 0.1000$).
[y] Trend ($0.1000 < p \geq 0.2500$).

Table 2. Mehlich-3 soil-test phosphorus (P) levels in 2003, prior to wheat planting, as affected by the P source × rate interaction in factorial experiments utilizing poultry litter ash (PLAsh), poultry litter with alum (PLWA), poultry litter without alum (PLWOA), and triple superphosphate (TSP) at the Rice Research and Extension Center (RREC) in Stuttgart, Ark.

	P_2O_5 rate (lb P_2O_5/acre)[z]				
Source	0	30	60	90	120
	(mg Mehlich-3 P/kg soil)				
PLAsh	8.9	11.5	12.2	18.2	26.7
PLWA	8.9	8.5	10.9	10.7	12.4
PLWOA	8.3	8.8	13.5	12.4	12.9
TSP	7.4	9.2	10.8	9.9	12.8
LSD (0.10)	4.1				

[z] Extracted with the standard Mehlich-3 method (1:10 v:v extraction).

Table 3. Mehlich-3 soil test levels for phosphorus (P) and potassium (K) in 2003, prior to wheat planting, for source and rate main effects in factorial experiments utilizing poultry litter ash (PLAsh), poultry litter with alum (PLWA), poultry litter without alum (PLWOA), and triple super phosphate (TSP) at the Pine Tree Branch Experiment Station (PTBS) in Colt, Ark.

	Mehlich-3 extractable element[z]				
Source[y]	P	K	Rate[x]	P	K
	-- (mg element/kg soil) -		(lb P_2O_5/acre)	-- (mg element/kg soil) --	
PLAsh	31.0	122.2	0	19.4	107.6
PLWOA	23.2	122.1	30	21.7	113.2
PLWA	22.3	121.8	60	25.4	124.2
TSP	23.4	110.5	90	25.5	124.5
			120	32.8	126.1
LSD (0.10)	5.2	8.9		5.8	10.0

[z] Extracted with the standard Mehlich-3 method (1:10 v:v extraction).
[y] Averaged across all rates.
[x] Averaged across all sources.

Table 4. Statistical p-values for crop growth parameters as affected by the P source and rate main effects and P source × rate interaction in factorial experiments utilizing poultry litter ash (PLAsh), poultry litter with alum (PLWA), poultry litter without alum (PLWOA), and triple super phosphate (TSP) at the Pine Tree Branch Station (PTBS) in Colt, Ark., and the Rice Research and Extension Center (RREC) in Stuttgart, Ark.

	Source of variation and location					
	Source		Rate		Source × rate	
Dependent variable	RREC	PTBS	RREC	PTBS	RREC	PTBS
Wheat						
Early heading drymatter (Feekes 10.1)	0.5961	0.7466	0.1307[z]	0.1033[z]	0.4977	0.2973
Maturity drymatter	0.5033	0.1153[z]	0.4228	0.3013	0.6345	0.0083[y]
Yield	0.0647	0.3039	0.0462[y]	0.4319	0.9311	0.0386[y]
Test weight	0.7871	0.0767[y]	0.1816[z]	0.6730	0.4528	0.2504
Grain moisture	0.7256	0.8228	0.0340[y]	0.1849[z]	0.4246	0.6424
Soybean						
Beginning bloom drymatter (R1)	0.8759	0.4620	0.6708	0.6297	0.2779	0.4956
Full seed drymatter (R6)	0.2473[z]	0.1574[z]	0.2344[z]	0.5930	0.1378[z]	0.1911[z]
Yield	0.3018	0.4817	0.7347	0.5306	0.5231	0.9581
Test weight	---[x]	0.0627[y]	---[x]	0.0720[y]	---[x]	0.2998
Grain moisture	0.3323	0.4696	0.2409[z]	0.2882	0.1658[z]	0.2748

[z] Trend ($0.1000 < p \geq 0.2500$).
[y] Significant main effect or interaction ($p < 0.1000$).
[x] Data not available.

Table 5. Wheat dry matter at maturity in 2004 for the P source × rate interaction in factorial experiments utilizing poultry litter ash (PLAsh), poultry litter with alum (PLWA), poultry litter without alum (PLWOA), and triple super phosphate (TSP) at the Pine Tree Branch Station (PTBS) in Colt, Ark.

	P_2O_5 rate (lb P/acre)				
Source	0	30	60	90	120
	(lb dry matter/acre)				
PLAsh	10553	9272	12316	10640	11863
PLWA	12454	11150	14237	10453	10663
PLWOA	10146	9504	8823	13226	11278
TSP	9576	10916	9826	11696	10413
LSD (0.10)	2178				

Table 6. Wheat yield in 2004 for the source × rate interaction in factorial experiments utilizing poultry litter ash (PLAsh), poultry litter with alum (PLWA), poultry litter without alum (PLWOA), and triple super phosphate (TSP) at the Pine Tree Branch Station (PTBS) in Colt, Ark.

	P_2O_5 rate (lb P_2O_5/acre)				
Source	0	30	60	90	120
	(bu/acre)				
PLAsh	8.9	11.5	12.2	18.2	26.7
PLAsh	91.7	90.0	91.2	84.6	93.3
PLWA	96.1	92.3	93.0	90.6	93.8
PLWOA	78.3	89.4	89.9	100.8	95.4
TSP	87.0	86.7	94.7	89.2	86.1
LSD (0.10)	8.0				

Table 7. Wheat yield and test weight in 2004 for P source and rate main effects in factorial experiments utilizing poultry litter ash (PLAsh), poultry litter with alum (PLWA), poultry litter without alum (PLWOA), and triple super phosphate (TSP) at the Rice Research and Extension Center (RREC) in Stuttgart, Ark., and the Pine Tree Branch Station (PTBS) in Colt, Ark.

	Location and dependent variable			
	Yield	Test weight		Yield
Source[z]	RREC	PTBS	Rate[y]	RREC
	(bu/acre)	(lb/bu)	(lb P_2O_5/acre)	(bu/acre)
PLAsh	51.0	54.2	0	44.5
PLWOA	49.0	54.3	30	45.8
PLWA	47.1	55.7	60	50.1
TSP	45.4	55.1	90	48.9
			120	51.0
LSD (0.10)	3.5	1.0		3.5

[z] Averaged across all rates.
[y] Averaged across all sources.

Table 8. Mehlich-3[z] soil-test phosphorus (P) levels, following wheat harvest, in 2004 for the source × rate interaction in factorial experiments utilizing poultry litter ash (PLAsh), poultry litter with alum (PLWA), poultry litter without alum (PLWOA), and triple super phosphate (TSP) at the Pine Tree Branch Station (PTBS) in Colt, Ark.

	P_2O_5 rate (lb P_2O_5/acre)				
Source	0	30	60	90	120
	(mg Mehlich-3 P/kg soil[z])				
PLAsh	20.2	23.4	23.0	27.0	35.8
PLWA	22.3	21.1	23.0	20.1	23.3
PLWOA	19.6	22.8	20.0	25.3	26.8
TSP	20.2	20.6	23.1	23.4	26.2
LSD (0.10)	4.1				

[z] Extracted with the standard Mehlich-3 method (1:10 v:v extraction).

Table 9. Mehlich-3 soil-test concentrations for phosphorus (P), copper (Cu), and aluminum (Al) in 2004, following wheat harvest, for the P source and rate main effects in factorial experiments utilizing poultry litter ash (PLAsh), poultry litter with alum (PLWA), poultry litter without alum (PLWOA), and triple super phosphate (TSP) at the Rice Research and Extension Center (RREC) in Stuttgart, Ark., and the Pine Tree Branch Station (PTBS) in Colt, Ark.

	Location and Mehlich-3-extractable element[z]							
	RREC			PTBS		RREC		PTBS
Source[y]	P	Cu	Al	Cu	Rate[x]	P	Cu	Cu
	(mg element/kg soil)				(lb P_2O_5/acre)	(mg element/kg soil)		
PLAsh	16.7	1.2	545.1	0.9	0	9.6	1.2	0.8
PLWOA	14.0	1.4	544.3	1.0	30	11.6	1.2	0.9
PLWA	12.0	1.4	572.2	1.0	60	13.1	1.2	0.9
TSP	13.5	1.0	555.2	0.9	90	15.1	1.3	0.9
					120	16.4	1.4	1.0
LSD (0.10)	2.6	0.1	15.0	0.1		2.4	0.1	0.1

[z] Extracted with the standard Mehlich-3 method (1:10 v:v extraction).
[y] Averaged across all rates.
[x] Averaged across all sources.

Effect of Nitrogen on the Growth of Field-Grown Shade Trees in Eastern Arkansas

J.A. Robbins

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Limited data is available on the effect of nitrogen (N) rate on the growth of field-grown shade trees (Struve, 2002). Specific results are dependent on the N rate, time of application, and species involved (Rose, 1999; Smith and Treaster,1990). The objective of this research was to evaluate the effect of N rate on the growth of field-nursery-grown shade trees in Arkansas.

PROCEDURES

Research was conducted at a commercial field shade-tree nursery in Harrisburg, Ark. The cultivar and tree species used in this study include: 'Franksred' red maple (*Acer rubrum)*, 'Prairie Fire' crabapple (*Malus* species), and swamp white oak (*Quercus bicolor)*. Trees were planted as bareroot (BR) plants on 25 March 2002 by the nursery owner. Plants were watered as needed by drip irrigation. Tree spacing within a row is 6 ft on center. The pattern of tree row spacing is two rows of trees separated by an 8-ft wide aisle, a 12-ft wide aisle, and then another set of two tree rows each separated by an 8-ft wide aisle. Tree density is approximately 560 trees/acre.

A maintenance level (36 lb N/A) of N fertilizer was broadcast by hand on 11 April 2002 with some of the BR trees just beginning to break bud. In subsequent years the first N-fertilizer treatments were applied in mid-March, which is 3 to 4 weeks before bud break for northeast Arkansas. Nitrogen fertilizer treatments were applied in mid-March (spring), late May (summer), and mid-October (fall) of 2003 and 2004. Urea was broadcast by hand to the soil surface in a 1-sq. ft. area around the tree trunk. Treatments were assigned in a completely randomized design. Treatments were applied to single plants, which represented one replicate. The total number of replications varied among species with single plant replicates of 17 'Franksred' red maple, 15 for 'Prairie Fire' crapapple, and 18 for swamp white oak. In June of every year the soil was sampled (4 or 6 inches) and tested to determine P and K levels. A slight deficiency was noted based on the soil-test results for both nutrients in 2003 and appropriate fertilizer treatments were made (110 lb P_2O_5/acre as triple superphosphate, 0-46-0; and 110 lb K_2O/acre as muriate of potash, 0-0-60). No additional P or K was applied in 2004.

Fully mature leaves were collected in June of each year for tissue analyses. Leaf samples were dried in an oven at 65°C for 48 hours and ground to a powder using a coffee mill. Leaf tissue was digested in concentrated HNO_3 and 30% H_2O_2 and digests were analyzed by inductively coupled atomic spectroscopy to determine leaf P and K concentrations. Leaf N concentration was determined by combustion.

Tree growth was evaluated by measuring the trunk caliber 1 m above the soil surface and tree height on 20 November 2003 and 1 December 2004. Analysis of variance was performed and, when appropriate, mean separation was performed using the Tukey method (p =0.05).

RESULTS AND DISCUSSION

Regardless of the tree species, N rate did not have a significant effect on tree height or trunk caliper during the second (2003) and third growing season (2004, Tables 1- 3). Nitrogen fertilizer rate also failed to significantly influence leaf-N and -K concentrations during the third growing season (2004) for all three species (Tables 1-3). Significant differences in tissue-P concentrations occurred among N treatments only for the swamp white oak species (Table 1). Although some of the leaf-P concentrations differed among N treatments, the concentrations were all considered sufficient for normal tree growth.

PRACTICAL APPLICATIONS

Regardless of N treatments, no differences in tree growth or leaf-N concentrations have been observed after three growing seasons. This finding is supported by results at other field nurseries in Arkansas by this researcher. As the trees mature additional research will help clarify what, if any, additional N is required to maximize the growth of field-grown shade trees in Arkansas. Preliminary data suggest the need for N fertilization is minimal for field-grown nursery tree production and thus hold potential for reducing nutrient input costs.

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Table 1. Trunk caliper, shoot height, and leaf-N, -P, and -K concentrations for swamp white oak fertilized with different N-fertilizer rates and application times at a field-shade-tree nursery in Harrisburg, Ark. Mean separation by Tukey's HSD (p=0.05).

N fertilizer treatment[z]		Mean trunk caliper		Mean tree height		2004 leaf nutrient concentrations		
2003	2004	2003	2004	2003	2004	N	P	K
		(cm)				(%)		
36-0-0[y]	36-0-0	2.6 a	4.1 a	171 a	230 a	2.3 a	0.14 b	0.85 a
72-0-0	72-0-0	2.6 a	3.9 a	168 a	234 a	2.3 a	0.14 b	0.89 a
50-50-0	50-50-0	2.4 a	3.7 a	157 a	208 a	2.3 a	0.14 b	0.91 a
50-50-50	50-50-50	2.4 a	3.8 a	165 a	219 a	2.4 a	0.16 ab	0.89 a
44-0-0[x]	0-0-0	2.6 a	4.3 a	168 a	242 a	2.4 a	0.16 ab	0.90 a
Unfertilized control		2.4 a	3.5 a	168 a	224 a	2.4 a	0.19 a	0.94 a

[z] Unless otherwise noted the N-fertilizer source was granular urea (46% N); N was applied mid-March (spring), late May (summer), and/or mid-October (fall).

[y] Values represent N application times (Spring-Summer-Fall): mid-March, late May, and mid-October of 2003 and 2004.

[x] PolyOn (Pursell Technologies, Sylacauga, Ala.) 17-5-11 (N-P_2O_5-K_2O analysis), 12-14 month controlled-release fertilizer; 'punch and fill' method.

Table 2. Trunk caliper, shoot height, and leaf-N, -P, and -K concentrations for 'Franksred' red maple fertilized with different N-fertilizer rates and application times at a field-shade-tree nursery in Harrisburg, Ark. Mean separation by Tukey's HSD (p=0.05).

N fertilizer treatment[z]		Mean trunk caliper		Mean tree height		2004 leaf nutrient concentrations		
2003	2004	2003	2004	2003	2004	N	P	K
		(cm)				(%)		
50-0-0[y]	50-0-0	2.7 a	4.7 a	276 a	379 a	2.1 a	0.19 a	0.90 a
50-50-0	50-50-0	2.6 a	4.6 a	263 a	388 a	2.1 a	0.20 a	0.89 a
50-50-50	50-50-50	2.7 a	4.7 a	289 a	378 a	2.2 a	0.20 a	0.87 a
50-50-100	50-50-100	2.9 a	4.7 a	285 a	396 a	2.1 a	0.20 a	0.86 a
94-0-0[x]	0-0-0	2.6 a	4.7 a	256 a	366 a	2.1 a	0.21 a	0.92 a
Unfertilized control		2.9 a	4.9 a	263 a	402 a	2.1 a	0.21 a	0.93 a

[z] Unless otherwise noted the N-fertilizer source was granular urea (46% N); N was applied mid-March (spring), late May (summer), and/or mid-October (fall).

[y] Values represent N application times (Spring-Summer-Fall): mid-March, late May, and mid-October of 2003 and 2004.

[x] PolyOn (Pursell Technologies, Sylacauga, Ala.) 17-5-11 (N-P_2O_5-K_2O analysis), 12-14 month controlled-release fertilizer; 'punch and fill' method.

Table 3. Trunk caliper, shoot height, and leaf -N, -P, and -K concentrations for 'Prairie Fire' crabapple fertilized with different N-fertilizer rates and application times at a field-shade-tree nursery in Harrisburg, Ark. Mean separation by Tukey's HSD (p=0.05).

N fertilizer treatment[z]		Mean trunk caliper		Mean tree height		2004 leaf nutrient concentrations		
2003	2004	2003	2004	2003	2004	N	P	K
		(cm)				(%)		
50-0-0[y]	50-0-0	2.6 a	3.3 a	189 a	230 a	2.1 a	0.18 a	1.40 a
50-50-0	50-50-0	2.5 a	3.3 a	184 a	220 a	2.1 a	0.17 a	1.32 a
50-50-50	50-50-50	2.4 a	3.3 a	194 a	234 a	2.1 a	0.17 a	1.31 a
50-50-100	50-50-100	2.4 a	3.3 a	191 a	228 a	2.1 a	0.19 a	1.27 a
94-0-0[x]	0-0-0	2.6 a	3.4 a	191 a	234 a	2.1 a	0.19 a	1.31 a
Unfertilized control		2.5 a	3.3 a	185 a	236 a	2.0 a	0.19 a	1.27 a

[z] Unless otherwise noted the N-fertilizer source was granular urea (46% N); N was applied mid-March (spring), late May (summer), and/or mid-October (fall).

[y] Values represent N application times (Spring-Summer-Fall): mid-March, late May, and mid-October of 2003 and 2004.

[x] PolyOn (Pursell Technologies, Sylacauga, Ala.) 17-5-11 (N-P_2O_5-K_2O analysis), 12-14 month controlled-release fertilizer; 'punch and fill' method

Winter Wheat Response to Phosphorus Fertilization

N.A. Slaton, R.E. DeLong, M. Mozaffari, S.D. Clark, and D.L. Boothe

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Phosphorus fertilizer is applied to about 28% of the soft red winter wheat (*Triticum aestivum* L.) acreage in Arkansas with an average application rate of 38 lb P_2O_5/acre (USDA-NASS, 2001). Research investigating wheat yield response to P fertilization was recently summarized to correlate soil-test P (modified Mehlich-3 P) with relative wheat yield and calibrate the appropriate P fertilizer rates by soil-test level (Slaton et al., 2005). Data were specific for wheat grown immediately following rice (*Oryza sativa* L.) on silt loam soils.

The process of correlation and calibration of crop response to fertilization and soil-test nutrient levels must be continuous to ensure that fertilization guidelines are accurate. We have continued to conduct research on wheat response to P fertilization for two reasons. First, the University of Arkansas Soil Test Laboratory will change soil testing procedures from the modified Mehlich-3 to the published Mehlich-3 method (Mehlich, 1984) with extracted P determined by inductively coupled plasma spectroscopy (ICPS), which requires that the critical soil-test P for the published Mehlich-3 method be determined. Secondly, the critical soil-test P published by Slaton et al. (2005) was specific for wheat following rice, which may not be representative for wheat following other crops in the rotation. Therefore our primary objectives were to 1) develop a database to correlate Mehlich-3 extractable P with wheat yield response, and 2) calibrate P fertilizer rate recommendations with several soil-test P levels.

PROCEDURES

Six field studies were established at four locations including two experiments at the Cotton Branch Experiment Station (CBES) in Marianna, Ark., and the Pine Tree Branch Station (PTBS) near Colt, Ark., and single experiments at Cullum Seeds site in Hickory Ridge, Ark. (HR), and the Rice Research Extension Center (RREC) near Stuttgart, Ark., in 2003. The soils were mapped as Calloway silt loams for both experiments at the CBES, a Henry silt loam at HR, Calhoun silt loams for both experiments at the PTBS, and a Dewitt silt loam at the RREC. The crop grown immediately before seeding winter wheat was field corn (*Zea mayes* L.) at the HR; cow pea [*Vigna unguiculata* (L.) Walp.] and grain sorghum (*Sorghum bicolor* L.) at the CBES; rice at the RREC; and rice and soybean [*Glycine max* (Merr) L.] at the PTBS. Rice straw was partially burned before tillage at the PTBS.

Two composite soil samples (0- to 4-inch depth) were taken from each replicate at each site-year. Soil was oven-dried, crushed, and passed through a 2-mm sieve for measurement of Mehlich-3-extractable nutrients, soil-water pH, and total soil carbon and nitrogen. Mehlich-3 extracts were analyzed using ICPS. Mean values of selected soil chemical properties are listed in Table 1.

'Sabbe' and 'Armor 3035' soft red winter wheat were drill-seeded at 115 lb seed/acre at all sites into conventionally-tilled seedbeds, except HR where only Armor 3035 was drill-seeded. Individual plots consisted of 9 or 10 rows of wheat that were 20-ft long and separated from adjacent plots by an 18- to 24-inch wide alley. Urea (40 lb N/acre) was broadcast in the fall to experiments following corn, grain sorghum, or rice.

Phosphorus fertilizer was applied to the soil surface immediately before or after seeding, at rates of 0, 25, 50, 75, 100, and 200 lb P_2O_5/acre as triple superphosphate. Late-winter N (150 lb N/acre) was applied in two split applications with 20 lb N/acre as ammonium sulfate and 75 lb N/acre as urea applied in mid-February and followed by another 55 lb N/acre as urea in mid-March. Selected dates of agronomic importance are listed in Table 2.

Whole, aboveground plant samples were taken at Feekes stages 6 (jointing) and 10.1 (early heading, Table 2) at each site-year to determine dry-matter accumulation, tissue-P concentration, and total aboveground P uptake. For each sample date, a 3-ft row section of the first inside row was cut at the soil surface, placed in a paper bag, oven-dried at 60°C to a constant weight, and ground to pass a 1-mm sieve. A 0.25 g sub-sample was digested in concentrated HNO_3 and H_2O_2 and analyzed for nutrient concentration by ICPS. At maturity, grain yields were measured by harvesting each plot with a small-plot combine. Grain yields were adjusted to a uniform moisture content of 13% moisture.

For each experiment, except HR and PTBS-Rice, P rates were arranged as randomized complete block design with a split-plot treatment structure where cultivar was the main-plot factor and P rate was the split-plot factor. Treatments were replicated four times. Poor drainage resulted in excessive water damage to the Sabbe wheat at the PTBS-Rice, therefore only the Armor 3035 data were analyzed. For the HR and PTBS-Rice, P rates were arranged as randomized complete block design and replicated six and four times, respectively. Because Mehlich-3-extractable soil P varied among sites, each experiment was analyzed separately. Analysis of variance procedures were conducted with the PROC GLM procedure in SAS (SAS Institute, Inc., Cary, N.C.). Mean separations were performed by Fisher's Protected Least Significant Difference method at a significance level of 0.05.

RESULTS

The cultivar × P rate interaction was not significant (P >0.05) for any site, indicating that both cultivars respond to P fertilization similarly. When averaged across P rates, Armor 3035 produced numerically or statistically greater wheat yields than Sabbe at three of the four sites (Table 3).

Soil-test P was similar at four sites with mean values ranging from 20 to 24 mg P/kg (Table 1). Soil-test P for both experiments at the CBES were similar and >38 mg P/kg, which is high enough that positive responses to P fertilization were not expected. Significant yield increases to P fertilization occurred only at the RREC and HR sites (Table 4), which followed rice and field corn, respectively. Application of 25 lb P_2O_5/acre at HR and 50 lb P_2O_5/acre at the RREC significantly increased yields compared with the unfertilized control, but near maximal grain yields were produced at both sites only when ≥75 lb P_2O_5/acre were applied.

The relative yields of the unfertilized control were 79% for the RREC and 83% for HR, whereas the relative yields of the unfertilized control at the other four sites were >93%. Based on the correlation of P extracted using the modified Mehlich-3 method with the relative yield of winter wheat following rice in rotation, soil-test P of 20 to 24 mg P/kg would fall into the 'Low' to 'Medium' soil-test levels (Slaton et al., 2005). The fact that two other sites with similar soil-test P failed to respond positively to P fertilization suggests that i) P was not the most yield-limiting factor present, ii) the soil-test P concentration range of 20 to 24 mg P/kg is near the soil-test P threshold for near maximal yield, and/or iii) that other soil factors (e.g., pH) not accounted for with the current correlation are influencing P availability to wheat.

Whole-plant P concentrations at Feekes stages 6 were affected by cultivar only at the CBES site when wheat followed cow pea and grain sorghum (data not shown). Armor 3035 had greater tissue-P concentrations than Sabbe for both experiments. By Feekes stage 10.1 whole-plant P concentrations were not significantly different between cultivars for any site.

At Feekes stage 6, P-fertilizer application rate significantly affected tissue-P concentration for all sites except when wheat followed rice at the RREC and grain sorghum at the CBES (Table 5). At Feekes stage 10.1, P-fertilizer application rate was significant for all sites except when wheat followed soybean at the PTBS and grain sorghum at the CBES. For both growth stages, wheat P concentration generally increased as P fertilizer rate increased. Tissue-P concentrations declined from Feekes stage 6 to 10.1 at all sites. The two sites (HR and RREC) that had the lowest P concentrations at Feekes stage 10.1 also were grown on soils with pH <6.5 (Table 1) and showed significant grain yield increases from P fertilization, suggesting that tissue analysis near heading may be the more appropriate growth stage to assess the P nutritional status of wheat. Tissue-P concentrations at this late growth stage would likely be too late for corrective fertilization, but may be of value for correlation of soil properties to develop P fertilization guidelines.

PRACTICAL APPLICATION

Winter wheat grown on silt loam soils with Mehlich-3 P <25 mg P/kg (~50 lb P/acre) often requires P fertilization to produce near maximal yields. Although the database is not yet large enough to make definitive conclusions, soil pH, previous crop, or both may play important roles in determining the critical soil-test P for winter wheat. When P is required for maximal yield production, P fertilizer rates are usually 75 to 100 lb P_2O_5/acre. In general, Mehlich-3 P values >30 mg P/kg (~60 lb P/acre) appear sufficient for winter wheat. Once a sufficiently large database has been accumulated, new soil-test P recommendations will be developed and the economics of P fertilization will be evaluated.

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Table 1. Mean soil-test data from the 0-to 4-inch depth for phosphorus rate trials with winter wheat in the 2003-2004 growing season.

Site[z]	Previous crop	$pH_{w1:2}$	Soil carbon	Total inorganic N	Mehlich-$3_{1:10}$ P	K	Ca	Mg	Mn	Zn	Cu
			(%)		(mg/kg)						
HR	Corn	7.0	1.20	43	21	115	1234	179	177	14.5	1.9
RREC	Rice	5.2	0.97	11	24	119	909	106	85	1.1	1.3
PTBS	Rice	6.4	1.43	9	21	205	1378	288	135	1.5	1.5
PTBS	Soybean	7.5	1.58	18	20	130	2153	347	291	1.1	1.8
CBES	Grain sorghum	6.5	0.88	40	38	150	934	239	86	1.5	1.7
CBES	Cow pea	6.7	0.82	22	44	168	1240	190	128	2.8	1.9

[z] HR, Hickory Ridge; RREC, Rice Research Extension Center; PTBS, Pine Tree Branch Station; CBES, Cotton Branch Experiment Station.

Table 2. Selected agronomic information from six P rate trials conducted in 2003-2004.

Site[z]	Previous crop	Seeded	Fall N applied	Late-winter N application Split #1	Late-winter N application Split #2	Plant sample dates 6.0	Plant sample dates 10.1	Harvest
		(day / month)						
HR	Corn	31 Oct.	11 Nov.	19 Feb.	10 March	10 March	13 April	4 June
CBES	Grain sorghum	23 Oct.	22 Oct.	18 Feb.	12 March	12 March	14 April	4 June
CBES	Cow pea	23 Oct.	22 Oct.	18 Feb.	12 March	12 March	14 April	3 June
PTBS	Rice	31 Oct.	30 Oct.	18 Feb.	10 March	10 March	14 April	9 June
PTBS	Soybean	31 Oct	30 Oct.	18 Feb.	10 March	10 March	14 April	9 June
RREC	Rice	21 Oct.	21 Oct.	19 Feb.	10 March	10 March	13 April	3 June

[z] HR, Hickory Ridge; RREC, Rice Research Extension Center; PTBS, Pine Tree Branch Station; CBES, Cotton Branch Experiment Station.

Table 3. Effect of cultivar, averaged across P fertilizer rates, on wheat grain yields at six locations with various previous crops in 2003-2004.

	Site - previous crop			
	RREC	PTBS	CBES	
Cultivar	Rice	Soybean	Grain sorghum	Cow pea
	[grain yield (bu/acre)]			
Armor 3035	47	86	82	83
Sabbe	55	81	68	67
LSD(0.05)	NS	NS	8	4
P-value	0.0682	0.1820	0.011	0.0010
C.V., %	9.9	4.8	4.9	5.9

Table 4. Effect of phosphorus fertilizer rate, averaged across cultivars, on wheat yield at six sites in 2004.

	Site - previous crop					
P fertilizer	HR	PTBS	RREC	PTBS	CBES	
rate	Corn[z]	Rice[z]	Rice	Soybean	Grain sorghum	Cow pea
(lb P_2O_5/acre)	[grain yield (bu/acre)]					
0	80	53	45	82	73	75
25	86	56	48	83	73	75
50	88	56	51	83	76	73
75	93	56	56	86	76	75
100	96	53	53	84	75	74
200	93	57	57	85	76	77
LSD(0.05)	5	NS	5	NS	NS	NS
P-value	<0.0001	0.8676	0.0004	0.2951	0.3978	0.6827
C.V., %	4.2	11.6	9.9	4.8	4.9	5.9

[z] Armor 3035 was the only cultivar seeded or harvested.

Table 5. Effect of phosphorus fertilizer rate, averaged across cultivars, on whole-plant P concentrations of wheat for Feekes stages 6 and 10.1 at six sites in 2004.

P-fertilizer rate/stage	HR Corn[z]	PTBS Rice[z]	RREC Rice	PTBS Soybean	CBES Grain sorghum	CBES Cow pea
($lb\ P_2O_5$/acre)	(% tissue-P concentration)					
Feekes 6						
0	0.13	0.24	0.26	0.32	0.41	0.41
25	0.14	0.31	0.26	0.35	0.41	0.43
50	0.15	0.31	0.26	0.36	0.40	0.45
75	0.19	0.33	0.26	0.36	0.42	0.45
100	0.20	0.39	0.26	0.39	0.44	0.48
200	0.30	0.48	0.28	0.41	0.45	0.49
LSD(0.05)	0.06	0.06	NS	0.05	NS	0.03
P-value	<0.0001	<0.0001	0.3616	0.0118	0.3101	<0.0001
C.V., %	23.0	12.0	9.1	12.7	11.0	6.1
Feekes 10.1						
0	0.14	0.17	0.14	0.26	0.27	0.28
25	0.16	0.18	0.14	0.27	0.26	0.31
50	0.16	0.18	0.15	0.26	0.28	0.32
75	0.20	0.20	0.15	0.28	0.29	0.32
100	0.21	0.20	0.15	0.28	0.30	0.35
200	0.21	0.24	0.19	0.29	0.32	0.36
LSD(0.05)	0.04	0.04	0.02	NS	0.03	0.03
P-value	0.0019	0.0111	<0.0001	0.0690	0.0087	<0.0001
C.V., %	16.9	11.9	11.2	8.0	11.7	7.8

[z] Armor 3035 was the only cultivar seeded or harvested.

Full-Season, Irrigated Soybean Yield Response to Phosphorus and Potassium Fertilization

N.A. Slaton, R.E. DeLong, and R. Thompson

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Phosphorus (P) and potassium (K) fertilizers are applied to about 35% of the soybean [*Glycine max* (Merr.) L.] acreage in Arkansas with average application rates of 55 lb P_2O_5/acre and 63 lb K_2O/acre (USDA-NASS, 2003). The average soybean yield in Arkansas for 2.88 million harvested acres in 2003 was a record high of 36 bu/acre which removes about 29 lb P_2O_5/acre and 50 lb K_2O/acre (AASS, 2004). Many counties average better than 40 bu/acre with numerous fields producing yields >50 to 60 bu/acre. Studies to correlate soil-test P and K availability indices and calibrate P and K fertilizer rates for soybean in Arkansas have not been conducted for at least 10 years. The yield potential of cultivars and management practices in current use is superior to that used in previous correlation and calibration studies, making these studies essential to ensure that P and K fertilizer recommendations are sufficient to sustain high-yield potential and soil fertility. The objectives of these field studies were to determine soybean yield response to P and K fertilization rates on silt loam soils used for irrigated-soybean production and to begin developing a database for correlation and calibration of fertilizer recommendations for soybean.

PROCEDURES

Grower Field Trials

Phosphorus and K rate trials were established in three and two grower fields, respectively, in Poinsett County, Ark., during 2004. Each plot was 10-ft wide and 20-ft long. Specifically, identical P and K trials were established on Hillemann silt loam on the Block Farm and a Henry silt loam on the Covington Farm. The third P trial was established at the Johns Farm on a Hillemann silt loam soil. The cooperating growers omitted preplant P and K fertilizers from an area in each field. A soybean cultivar, selected by the grower ('DK5366RR' for Block, 'Progeny 5822RR' for Covington, and 'DPL5915RR' for Johns), was drill-seeded on the entire field and P and K trials were established. The previous crop at all sites was rice (*Oryza sativa* L.). Soybean was seeded by 1 June on the Block and Johns farms and on 15 July at the Covington site (replant). For each site-year trial, at least three composite soil samples were collected from the 0- to 4-inch depth with one composite sample collected per two replicates. Soil samples were oven-dried at 55°C, crushed, and passed through a 2-mm sieve. Soil-water pH was determined in a 1:2 soil weight:water volume mixture, plant-available nutrients were extracted using the published Mehlich-3 method (Mehlich, 1984), and elemental concentrations determined by inductively coupled plasma spectroscopy (ICPS). Selected soil chemical properties means are listed in Table 1.

Potassium trials included five rates (0, 40, 80, 120, and 160 lb K_2O/acre) of muriate of potash which were broadcast to the soil surface shortly after planting. Triple superphosphate (~50 lb P_2O_5/acre) and granular boron (0.5 to 1.0 lb B/acre) were broadcast to the soil surface of each K test to ensure that these nutrients were not yield-limiting. Each trial was a randomized complete block design with 6 replications.

Phosphorus fertilization trials were established adjacent to the two K-rate trials. Triple superphosphate was broadcast to the soil surface shortly after planting at 0, 60, and 120 lb P_2O_5/acre. Muriate of potash (~60 lb K_2O/acre) and granular boron (1.0 lb B/acre) were broadcast to the soil surface of each P test to ensure that these nutrients were not yield limiting. Each trial was a randomized complete block design with 6 replications.

The third P fertilization trial evaluated monoammonium phosphate (MAP, 11-52-0) and MAP plus 'Avail' at rates of 50, 100, and 150 lb P_2O_5/acre plus two control plots that received either 0 or 32 lb N/acre as urea. Each P treatment receiving <150 lb P_2O_5/acre was supplemented with urea so the total N rate applied to each was 32 lb N/acre to compensate for possible soybean growth and yield responses that could be attributed to the different N rates supplied by different rates of MAP. All treatments were applied to the dry soil surface shortly after planting. The experiment was a randomized complete block with a 2 (P source) × 3 (P rate) factorial treatment arrangement plus a no-P control. Each treatment was replicated six times. There were no differences between yields of the two controls receiving 0 lb P_2O_5/acre, so the unfertilized control yields were averaged into a single value.

Trifoliate leaves (20) or whole-plant samples (~6 to 8 plants) were collected from each plot at the R2 growth stage, dried to a constant moisture, ground to pass a 1-mm sieve, digested, and analyzed for elemental concentrations by ICPS. The middle 5 ft of each plot was harvested with a plot combine at maturity. Soybean moisture was adjusted to 13% for final yield calculations.

For all studies, analysis of variance procedures were conducted by site-year with the PROC GLM procedure in SAS (SAS Institute, Inc., Cary, N.C.). When appropriate, mean separations were performed using Fisher's Protected Least Significant Difference method at a significance level of 0.10.

Pine Tree Branch Station Trials

In 2001, two K fertilization trials were established in adjacent areas (referred to as study areas 39 and 40) at the Pine Tree Branch Station (PTBS) and seeded to rice from 2001 through 2003. The soil series for both sites is mapped as a Calhoun silt loam. During 2001 and 2002, 0, 30, 60, 90, and 120 lb K_2O/acre were applied to 16-ft long by 24-ft wide plots in both research areas. In 2003, the K-rate plots of study area 39 were divided in half (16 ft by 12 ft plots) with one half receiving no K and the other half receiving the K rate previously applied. For study area 40, K was applied to the 16 ft by 24 ft plot at the same rates applied in previous years. In March 2004, a composite soil sample (0- to 4-inch depth) was collected from each plot. Soil samples were processed as described for the grower field studies. For each experiment, selected soil chemical property means from all plots are listed by K rate in Table 1.

In 2004, soybean ('Armor 53K3' *cv.*) was drilled into an undisturbed seedbed (no-till) on 11 May 2004. Potassium fertilizer treatments as described previously were applied on 10 May 2004. Triple superphosphate (46 lb P_2O_5/acre) was broadcast-applied to all plots. Soybean were irrigated as needed during the growing season. Twenty mature trifoliate leaves were collected from each plot at the R2 growth stage and processed as described previously. At maturity, two (study 40) or four (study 39) 5-ft wide strips were harvested from each K rate. Soybean yields were adjusted to 13% moisture for statistical analysis.

Experiment 39 was a randomized complete block design with a split-plot treatment structure where the K rate (0, 30, 60, 90, and 120 lb K_2O/acre) from previous years (2001 and 2002) was the main plot and the K rate applied in 2003 and 2004 was the subplot.The subplot was assigned a designation of 'with K' or 'without K', which simply indicates whether K was applied in 2003 or 2004. Each treatment was replicated five times. For experiment 40, the study was arranged as a randomized complete block design with four replicates. Analysis of variance procedures were conducted with the PROC GLM procedure in SAS (SAS Institute, Inc., Cary, N.C.). Mean separations were performed by Fisher's Protected Least Significant Difference method at a significance level of 0.10.

RESULTS

Grower Fields P and K Rate Studies

Soybean yields were not significantly affected by P application rate at the Block and Covington farms (Table 2). Phosphorus fertilization was not expected to increase soybean yields at the Covington site since soil-test P was relatively high in comparison with soil at the Block site. At the Johns Farm, soybean yields were increased by 9 to 17% due to P fertilization (Table 3). Soybean yields increased incrementally as P rate increased with the greatest yields produced by the highest P rate. The Johns site also had the lowest soil-test P (7 mg P/kg). The P concentration of mature trifoliate leaves at the R2 stage ranged from 0.38 to 0.40% P at the Block Farm and whole-plant P concentrations at the R2 stage for soybean at the Johns Farm ranged from 0.17 to 0.22%P. Tissue analysis from the Covington Farm is not yet complete.

Soybean yields at the Block and Covington farms were not significantly increased by application of K (Table 3). Both sites had soil-test K >98 mg K/kg (>196 lb K/acre) suggesting that K fertilization may not always be needed to produce high soybean yields when soil-test K approaches 100 mg K/kg. For the Block Farm, trifoliate leaf-K concentrations at the R2 stage were significantly affected by K rate and ranged from 1.53 to 1.88% K with leaf-K concentration increasing as K rate increased (data not shown). Leaf analysis is not yet complete for the Covington site.

PTBS Potassium Rate Studies

Analysis of soil-test K for the two studies at the PTBS site showed that two (test 40) or three (test 39) years of K fertilization had not significantly changed soil-test K (data not shown). The mean soil-test K for experiment 39 was 79 mg K/kg and ranged from 73 to 85 mg K/kg among K rates. The mean soil-test K for experiment 40 was 88 mg K/kg and ranged from 85 to 95 mg K/kg among K rates. In general, soil that had received no K fertilizer for two or three years had the lowest soil-test K and soil that received annual applications of 120 lb K_2O/acre had the greatest numerical soil-test K.

During reproductive growth, symptoms of K deficiency were observed on soybean that had received no K fertilizer during the previous three years. Soybean yields were increased significantly by K fertilization in both experiments at the PTBS (Table 4). For test 40, soybean yields increased as annual K application rate increased from 0 to 60 lb K_2O/acre. When K rate was >60 lb K_2O/acre, soybean yields continued to increase numerically but were not statistically different. Trifoliate leaf-K concentrations were significantly affected by K rate (P <0.0001) and ranged from 1.27 to 2.11%K with K concentration increasing as annual K rate increased (data not shown). Trifoliate leaf-P and -B concentrations were not affected by K application and averaged 0.50%P and 22.4 mg B/kg.

For test 39, the interaction between annual K-rate applied during 2001 and 2002 and the subplot K rates applied in 2003 and 2004 did not significantly (P = 0.2519) influence soybean yields. However, both the main and subplot K rates significantly influenced soybean yields. When the K rate applied in 2002 was ≥60 lb K_2O/acre, soybean yields were significantly greater than from application of 0 and 30 lb K_2O/acre, even though the mean soil-test K concentrations were statistically similar. Regardless of the K rate applied in 2001 and 2002, application of K in 2003 and 2004 significantly increased soybean yields. When averaged across the annual K rates applied in 2001 and 2002, soil receiving K in 2003 and 2004 produced soybean yields of 56 bu/acre compared with 50 bu/acre when no K was applied only during 2003 and 2004. The data suggest that previous K fertilization has residual benefits when applied at sufficient rates, but for this soil, annual application of K was required to produce maximal yields. Based on numerical yields, annual application of 60 to120 lb K_2O/acre were required to maintain the high-yield potential of soybean. These data suggest that the Mehlich-3 extractant may not accurately predict the availability of soil K since soil-test K was not different among K rates, but soybean yields were higher where K had previously been applied on an annual basis at adequate rates.

PRACTICAL APPLICATION

Soybean yields were increased significantly by P fertilization at one of three trials and by K fertilization at 2 of 4 trials with both K-responsive trials at the PTBS. When soybean yield potential is high and soil-test P is very low, <10 mg P/kg (<20 lb P/acre) as at the Johns Farm, P applied at relatively high rates (> 100 lb P_2O_5/acre) may be needed to produce maximal soybean yields. Annual applications of K fertilizer failed to significantly increase soil-test K on the alkaline Calhoun silt loam at the PTBS, but were required to produce near maximal yields. Data suggest that application of K rates greater than that required to produce maximal soybean yields may be inefficient or that the Mehlich-3 extractant does not extract K from some soil-K pool that is contributing plant-available K during the growing season. Growers should continue to apply P and K as suggested by the results of soil-testing until additional data are collected to correlate and calibrate fertilizer recommendations for soybean.

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Table 1. Selected soil chemical properties list by site and nutrient for soybean fertilization trials with soybean conducted in 2004.

Site	Soil	Mehlich-3-extractable soil nutrients										
	pH	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
		(mg/kg)										
Phosphorus trials												
Block	6.4	12	96	1670	274	15	58	509	163	2.9	1.0	0.2
Covington	7.5	62	95	1582	257	68	44	270	33	7.2	1.3	0.1
Johns	6.5	7	118	1076	288	53	44	354	73	2.4	0.9	0.2
Potassium trials												
Block	6.2	19	101	1649	269	14	54	554	164	3.1	1.0	0.1
Covington	7.6	65	98	1634	269	77	55	176	30	5.5	1.0	0.1
PTBS-39	7.9	17	88	2370	361	18	62	272	138	4.7	1.5	0.3
PTBS-40	7.8	16	79	1725	356	16	53	266	148	6.5	1.4	0.1

Table 2. Influence of P fertilizer rate on soybean yield at three sites in Poinsett County during 2004.

	Site			
P fertilizer rate	Block Farm	Covington Farm	P application rate	Johns Farm[z]
(lb P_2O_5/acre)	--------------- (bu/acre)	-------------------	(lb P_2O_5/acre)	(bu/acre)
0	74	44	0	59
60	73	40	50	64
120	73	39	100	65
--	--	--	150	69
LSD (0.10)	NS[y]	NS	--	3.7

[z] Yields are averaged across two P fertilizer sources.
[y] NS, not significant at the 0.10 level.

Table 3. Influence of K fertilizer rate on soybean yield at two sites in Poinsett County during 2004.

K fertilizer rate	Block Farm	Covington Farm
(lb K_2O/acre)	------------------------- (bu/acre)	--------------------------
0	73	37
40	75	37
80	73	38
120	81	36
160	79	35
LSD(0.10)	NS[z]	NS
P-value	0.4139	0.5558
C.V., %	12.0	9.8

[z] NS, not significant at the 0.10 level.

Table 4. Influence of K fertilizer rate on soybean yield at two sites in Poinsett County during 2004.

Annual K fertilizer rate	Trial 40	Trial 39[z]
(lb K_2O/acre)	------------------------- (bu/acre)	--------------------------
0	46	45
30	55	49
60	57	57
90	60	56
120	66	54
LSD(0.10)	9	4
P-value	0.0197	0.0045
C.V., %	12.3	8.3

[z] Main effect of annual K application rates, averaged across K rates applied in 2003 and 2004.

Irrigated Soybean Yield Response to Boron Application Time and Rate

N.A. Slaton, R.E. DeLong, and R. Thompson

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Boron (B) deficiency of soybean [*Glycine max* (Merr) L.] continues to be a common yield- and growth-limiting factor in several counties in northeast Arkansas. Although B-fertilization guidelines have been developed and presented at Extension grower meetings, many soybean growers in northeast Arkansas have not incorporated B into their soybean fertilization programs. Other than field location (county), field history, soil pH, and soil texture, more specific B-fertilization guidelines regarding the soil characteristics that are likely to identify B-deficient soils have yet to be developed. A survey of Arkansas soybean fields, when finished, may identify more specific soil characteristics that can be used to distinguish soils that are prone to B deficiency (Mozaffari et al., 2003). In the meantime, we have continued to establish B-fertilization trials in northeast Arkansas to build a database of soil chemical traits, trifoliate leaf-B concentrations, and yield response of soybean to B fertilization. The primary objectives of field trials conducted in 2004 were to identify the times and rates of B fertilization that produce maximal soybean yields and to identify the range of B concentrations in trifoliate leaves of soybean that are considered deficient and sufficient during vegetative (about V6 stage) and reproductive (R2 stage) growth.

PROCEDURES

Boron-fertilization trials were established in four commercial soybean fields located west of Crowley's Ridge on silt loam soils in Poinsett County during 2004. Selected information for each site is listed in Table 1. The cultivar was selected by each grower and soybean was drill-seeded into conventionally tilled seedbeds at all sites except Covington where soybeans were drilled (replant) into an untilled seedbed. The Covington and Morgan field tests were established in replanted fields where the first soybean stand failed due to excessive rainfall. The previous soybean stand was destroyed by tillage at the Morgan site, but at the Covington site soybean was seeded into the existing stand, which was thin and non-uniform. Boron fertilizer was applied preplant as Granubor (1 lb B/acre) at the fields surrounding tests at the Covington and Block sites and to soybean foliage (mid-August) at the Morgan site. In all cases, direct B application to the flagged research areas was avoided. No B fertilizer was applied to the field surrounding the Johns research site. Before B was applied, a composite soil sample was collected from the 0- to 4-inch depth from each unfertilized control plot at each site to determine soil chemical properties. Soil samples were dried at 55°C in a forced-draft oven and crushed, pH was determined in a 1:2 soil weight-water volume mixture by electrode, and subsamples of soil were extracted using the Mehlich-3 method (Mehlich, 1984). Elemental concentrations of Mehlich-3 extracts were determined by inductively coupled plasma spectroscopy (ICPS). Selected soil chemical properties for each site are listed in Table 2.

Boron was applied at rates of 0, 0.5, 1.0, and 2.0 lb B/acre from shortly after seeding to the V2 stage (V1 stage) or at the R1-R2 stage (R2 stage) of soybean. At the Block and Morgan sites, the V1-stage B was applied as a B solution (Solubor DF, 17.5%B) using a CO_2 backpack sprayer calibrated to deliver 10 gal solution/acre. At the Covington and Johns sites, granular B (Granubor, 15% B) was carefully broadcast by hand to each plot due to windy conditions. At the R2 stage, B at all sites was applied as a solution (Solubor DF) to soybean foliage with a CO_2 backpack sprayer calibrated to deliver 10 gal solution/acre. Each plot was 12-ft wide, 20-ft long, and plots were separated by an 18-inch wide alley. Phosphorus (50 lb P_2O_5/acre as triple superphosphate) and K (80 lb K_2O/acre as muriate of potash) fertilizers were broadcast to all plots. Soybean was irrigated as needed and managed by each cooperating grower and rice was the previous crop (2003) grown at all sites.

Mature trifoliate-leaf samples (20/plot) were collected from the unfertilized controls and each plot received B fertilizer at the V1 stage at one or two times (V6 and/or R2 stages) during the season at each site (Table 1). Samples were placed in paper bags, dried to a constant moisture at 60°C, and ground to pass a 1-mm sieve. A subsample of tissue was digested in concentrated HNO_3 and 30% H_2O_2 and elemental concentrations of the digests were determined by ICPS. At maturity, a 5-ft wide section from the center of each plot was harvested with a plot combine for grain-yield determination. Harvest-moisture content and weight of the harvested soybean grain were determined immediately and yields were adjusted to 13% moisture for statistical analysis.

Each experiment was a randomized complete block with a split-plot treatment structure, where B application rate (0.5, 1.0, 2.0 lb B/acre) was the whole-plot factor and B application time (V1, R2, and none) was the split-plot factor. The 0 lb B/acre rate was treated as an application time (None) in the statistical design. Each treatment was replicated six times. Since tissue was collected from selected treatments, trifoliate leaf-B concentration was analyzed as a randomized complete block design. Data from each site were analyzed separately. At the Johns site, excessive rainfall and poor drainage resulted in early-season stand loss in some plots within the first three replications. Yield from these plots was entered as missing data. Yield data were analyzed using the PROC GLM procedure in SAS version 8.2. (SAS Institute, Inc., Cary, N.C.). Mean separations were performed by Fisher's Protected Least Significant Difference method at a significance level of $\alpha = 0.10$.

RESULTS

Boron deficiency symptoms were observed only in areas of the Morgan field, but not in the research area during early August. The most severe B-deficiency symptoms were observed near the well-water inlet. The growers subsequently applied B to the field area surrounding the research test. Delayed maturity, a symptom of B deficiency, of soybean receiving no B, was noticed only at the Covington site. Soil water pH was >7.0 in only the Covington and Morgan fields, but all fields had low Mehlich-3-extractable B (Table 2).

The interaction between B application rate and time was not significant for seed yield at any site. Significant soybean yield increases, attributed to B fertilization, occurred only at the Covington site (Table 3). Boron applied at the R2 stage, averaged across B rates, produced a significantly greater yield than the unfertilized control, but was not different than the mean yield of soybean receiving B at the V1 stage. No positive yield response at the Block and Johns sites was expected since soil pH was <7.0. Boron rate, averaged across application times, had no significant influence on soybean yields (Table 4). Yield means for B application rate (0.5, 1.0 and 2.0 lb B/acre) were averaged across B application times (V1, R2, and None) and included an untreated control in calculation of the mean yield.

The B concentration of mature trifoliate soybean leaves at all samples times and sites was significantly affected by B application rate at the V1 stage (Table 5). Boron concentrations increased as B rate increased, but the range of B concentrations varied considerably among sites and growth stages. For example, the V6-stage B concentrations at the Johns Farm were quite high shortly after B application when soil was very moist due to continuous rainfall, but declined considerably by the R2 stage. Tissue-B concentrations at the R2 stage of soybean receiving no B were <20 mg B/kg at all sites except the Block Farm suggesting that soybean could have benefitted from B fertilization. Based on trifoliate-B concentration, soybean was B-deficient only at the Covington site which showed positive yield increases to B fertilization (Table 3). At sites where tissues were collected twice, B concentrations declined as plant development progressed suggesting that the critical B concentration for soybean during vegetative stage is different from that at the R2 stage (Table 5). Additional data are needed to determine if B-deficiency can be predicted by sampling soybean tissues during vegetative growth.

PRACTICAL SIGNIFICANCE

Positive soybean yield increases to B fertilization are most likely to occur on alkaline silt loam soils with no history of B fertilization. No particular B-application time or rate showed consistent, significant benefits over another across all 2004 trial sites. However, there appears to be little or no need to apply more than 1 lb B/acre. Data from 2004 suggest that soils with pH <7.0 may also convey low tissue-B concentrations. Until more specific criteria can be delineated, growers should consider applying 0.5 to 1.0 lb B/acre to soybean grown on neutral to alkaline silt loam soils west of Crowley's Ridge so that B deficiency does not limit soybean growth or yield.

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Table 1. Selected soil and agronomic information from four B fertilization studies in 2003.

Site	Soil series[z]	Cultivar	Plant date	B application dates V1	B application dates R2	Plant sample dates V6	Plant sample dates R2	Harvest date
			(day - month)					
Covington	Henry	Prog5822RR	15 July	15 July	12 Aug	--	12 Aug	10 Nov
Block	Hillemann	DK5366RR	9 May	4 June	7 July	16 June	7 July	6 Oct
Johns	Hillemann	DPL5915RR	19 May	16 June	12 Aug	14 July	12 Aug	10 Nov
Morgan	Hillemann	Armor 58V8	July 2	15 July	12 Aug	--	12 Aug	10 Nov

[z] Soil series as identified in County Soil Survey Maps for Poinsett County, Ark.
[y] Approximate seeding dates.

Table 2. Selected soil chemical properties from four B fertilization trials with soybean conducted in Poinsett County grower fields during 2004.

Farm-site	Soil pH	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
		Mehlich-3-extractable soil nutrients (mg/kg)										
Block	6.4	15	86	1614	255	13	50	527	176	2.9	0.9	0.1
Covington	7.4	60	93	1652	269	76	52	286	35	7.4	1.1	0.1
Johns	6.0	19	157	1031	276	80	45	362	58	6.1	1.2	0.1
Morgan	8.5	17	122	3968	353	9	65	248	196	18.9	1.7	0.3

Table 3. Influence of B-fertilizer application time, averaged across B rates, on soybean yield at four sites in Poinsett County during 2004.

B application time	Block Farm	Covington Farm	Johns Farm	Morgan Farm
	---------- (bu/acre) ----------			
None	66	31	58	54
V1 stage	65	34	56	54
R2 stage	65	33	59	54
LSD (0.10)	NS[z]	2	2	NS
P-value	0.9821	0.0105	0.0521	0.8861
C.V., %	8.8	8.5	5.6	7.9

[z] NS, not significant at the 0.10 level.

Table 4. Influence of B-fertilizer application rate, averaged across two B application times, on soybean yield at four sites in Poinsett County during 2004.

B fertilizer rate	Block Farm	Covington Farm	Johns Farm	Morgan Farm
	---------- (bu/acre) ----------			
0.5	67	32	57	54
1.0	66	34	58	55
2.0	64	34	56	53
LSD(0.10)	NS[z]	NS	NS	NS
P-value	0.6884	0.2579	0.5296	0.4679
C.V., %	8.8	8.5	5.6	7.9

[z] NS, not significant at the 0.10 level.

Table 5. Influence of B-fertilizer application rate (V1 application time) on the B concentration of mature trifoliate soybean leaves at the V6 and/or R2 stage at four sites in Poinsett County during 2004.

	Block Farm		Covington Farm	Johns Farm		Morgan farm
B fertilizer rate	V6	R2	R2	V6	R2	R2
(lb B/acre)	---------- (mg B/kg) ----------					
0	40.1	29.2	10.3	40.5	19.8	19.4
0.5	45.1	34.4	31.2	63.2	30.3	25.8
1.0	44.7	36.3	48.7	83.1	35.8	36.1
2.0	52.0	40.2	62.3	132.0	38.0	45.1
LSD(0.10)	3.5	3.0	7.9	18.6	8.5	3.2
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
C.V., %	7.4	8.5	22.5	21.8	27.1	10.6

Influence of Nitrogen Fertilizer Application Rate and Time on Winter Wheat Yields

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Nitrogen (N) fertilizer is required on most soils in Arkansas to produce high-yielding soft red winter wheat (*Triticum aestivum* L.). The time and rate of N application are critical management decisions because they can influence the N-fertilizer uptake efficiency (Alcoz et al., 1993) and tillering (Weisz et al., 2001), which are highly correlated with wheat yields. In Arkansas, N fertilizer is usually applied in February when wheat plants are at Feekes stage 4 or 5, which coincides with the end of tillering. A small amount (~40 lbs N/acre) of N fertilizer is also recommended at planting for winter wheat following corn (*Zea mayes* L.), grain sorghum (*Sorghum bicolor* L.), and rice (*Oryza sativa* L.) to stimulate tillering. These crop residues have wide carbon to N ratios that may immobilize inorganic soil and fertilizer N.

Kelly (1995) reported that winter wheat following grain sorghum required higher N rates to produce near maximal yields than wheat following soybean in Kansas. Regardless of the previous crop, yields were similar for wheat receiving all N preplant in the fall, all N applied at Feekes stage 4, or N split between preplant and Feekes stage 4, suggesting that N can be applied either preplant or in late winter. Previous research in Arkansas has failed to provide conclusive evidence to support the need for a small proportion of fall-applied N to produce maximal yields (Fig. 1).

Both fall and late-winter N have advantages and disadvantages. Fall N must be applied, incorporated, and paid for before wheat is successfully established, which is undesirable since crop failure due to inadequate stand, pests, winter injury, or excessive moisture may occur. The primary disadvantage of late-winter N applications is that N fertilizer must often be applied by airplane, which increases application costs, because soil is too moist and soft for application with ground equipment. The topography, soil physical properties, and risk factors of individual fields may dictate the best N application time if there is little or no agronomic difference between N application times. The primary objectives of this research were to determine whether i) winter wheat following various summer crops requires fall N for producing maximum yields and ii) fall N alone produced similar yields as N applied in late-winter. If fall N is required to produce maximal grain yields, a secondary objective was to calibrate the appropriate fall and late-winter N-rate combinations required to produce maximal grain yields.

PROCEDURES

Field studies were established at five locations including two experiments at the Cotton Branch Experiment Station (CBES) in Marianna, Ark., and single experiments at Hickory Ridge, Ark. (HR), the Pine Tree Branch Station (PTBS) near Colt, Ark., and the Rice Research Extension Center (RREC) near Stuttgart, Ark., in 2003. The soils were mapped as a Calloway silt loam for both experiments at the CBES, a precision-graded Henry silt loam at HR, a Calhoun silt loam at the PTBS, and a Dewitt silt loam at the RREC. The crop grown immediately before seeding winter wheat was field corn at the HR, cowpea [*Vigna unguiculata* (L.) Walp.] and grain sorghum at the CBES, and rice at the PTBS and RREC. Rice straw was partially burned before seedbed preparation at the PTBS. Two composite soil samples (0- to 4-inch depth) were taken from each replicate at each site-year. The samples were mixed thoroughly, oven dried, crushed, and passed through a 2-mm sieve for measurement of Mehlich-3-extractable nutrients, soil-water pH, and total soil carbon and N. Mehlich-3 extracts were analyzed using inductively coupled atomic plasma spectroscopy (ICPS). Soil nitrate (NO_3-N) and ammonium (NH_4-N) were extracted with 1 *N* KCl from oven-dried soil. Mean values of selected soil chemical properties are listed in Table 1.

'Sabbe' soft red winter wheat was drill-seeded at 115 lb seed/acre at all sites, except HR where 'Armor 3035' was drill-seeded into conventionally tilled seedbeds. Individual plots consisted of 9 or 10 rows of wheat that were 20-ft long and separated from adjacent plots by an 18- to 24- inch wide alley.

Nitrogen treatments consisted of all combinations of five fall- and late-winter-applied N rates, including 0, 40, 80, 120, and 160 lb N/acre, with the total N applied ranging from 0 to 320 lb N/acre. Fall N was broadcast as urea and mechanically incorporated before seeding at all locations except HR. At the HR, Agrotain-treated urea was applied to a dry soil surface after wheat emergence and incorporated by rain within 5 days. Late-winter N was applied as 100 lb ammonium sulfate/acre (20 lb N/acre) and the balance of the late-winter N rate was urea. Late winter N rates >80 lb N/acre were made in two split applications. A maximum of 80 lb N/acre was made for the first application with the balance of the rate >80 lb N/acre applied in the second split. Selected dates of agronomic importance are listed in Table 2.

The total number of tillers in a 3-ft section of the first inside row was counted before plant samples were taken at early heading from all fall N rates and the 0 and 160 lb N/acre rates applied in the late winter. Whole, aboveground plant samples were taken at the late-boot to early heading stage in each study to determine dry-matter accumulation, tissue-N concentration, and total aboveground N uptake (data not shown). A 3-ft row section of the first inside row was cut at the soil surface, placed in a paper bag, oven dried at 60°C to a constant weight, and ground to pass a 1-mm sieve. At maturity, grain yields were measured by harvesting each plot with a small-plot combine. Grain yields were adjusted to a uniform moisture content of 13% moisture.

For each experiment, N treatments were arranged as a randomized complete block design with a 5 (fall N rates) × 5 (spring N rates) factorial treatment structure. Each treatment was replicated four times. Because the previous crop differed among locations, each experiment was analyzed separately. Analysis of variance procedures were conducted with the PROC GLM procedure in SAS (SAS Institute, Inc., Cary, N.C.). Mean separations were performed by Fisher's Protected Least Significant Difference method at a significance level of 0.05.

RESULTS

Grain Yield

The fall × late-winter N-rate interaction was significant for all sites except the PTBS (Table 3), suggesting that application of fall only, late-winter only, and/or various combinations of fall and late-winter N applications may produce maximal wheat yields. Depending on the treatment, previous crop, and growing conditions at each site-year with a significant fall × late-winter N-rate interaction, total N rates required to produce maximal wheat yields ranged from 80 to 120 lb N/acre following corn, 80 to 160 lb N/acre following grain sorghum, 80 to 160 lb N/acre following cowpea, and from 160 to 240 lb N/acre following rice (RREC). In general, wheat receiving N only at late-winter achieved maximal grain yields with less N (40 to 80 lb N/acre) than when N was applied only at seeding, but only when wheat followed a crop other than rice. Good, but not excessive (i.e., sandy soils) soil drainage should likely be a requirement when N is to be applied in the fall. Wheat following rice at the RREC was the only site that showed preplant-N rates of 40 to 80 lb N/acre were required to achieve maximal yields. Yield data from the RREC suggest that the late-winter N rates may not have been high enough since wheat yields increased linearly and never reached a plateau (Table 3). A dense infestation of annual bluegrass (*Poa annua* L.) competed quite effectively with winter wheat for fertilizer N and poor drainage may have further limited the retention of inorganic N in the soil.

For wheat following rice at the PTBS, the main effects of fall and late-winter N rates were both significant (Table 4). Application of 80 to 160 lb N/acre applied in the fall, averaged across late-winter N rates, produced yields from 38 to 42 bu/acre that were significantly greater than mean yields of wheat receiving no fall N. Wheat yields showed a similar yield response pattern to late-winter N fertilizer rate, but wheat yields, averaged across fall N rates, had a wider range (22 to 50 bu/acre), indicating greater benefits from late-winter applied N. Maximal yields of 45 to 50 bu/acre were produced with 120 to 160 lb N/acre. Extremely poor drainage likely limited wheat growth and response to N, and also may have caused some N, especially fall-applied N, to be lost via denitrification.

PRACTICAL APPLICATIONS

Fall-applied N is not needed to maximize the yields of winter wheat, even when it is grown following crops like corn, grain sorghum, and cowpea. Tillering data suggested that preplant-N increased tillering (Table 5), but adequate rates of late-winter N were capable of producing sufficient tillering to achieve maximal grain yields (Table 6). Data also suggest that fall-applied N can produce maximal wheat yields without supplemental N applied in the late-winter, when fields have good internal and surface drainage to prevent waterlogged soil conditions. However, the optimal N-rate required to maximize wheat yields was higher for fall-applied N compared with late-winter applied N, presumably because of lower fertilizer recovery attributed to immobilization, leaching, runoff, and/or denitrification. Residual soil N from fertilization of corn and grain sorghum that preceded wheat may have provided adequate N to minimize immobilization of fertilizer N. Wheat following rice appears to be the lone situation where fall N may be of benefit, due at least in part to low soil inorganic-N concentrations, high amounts of rice straw that immobilize fertilizer N, or both.

ACKNOWLEDGMENTS

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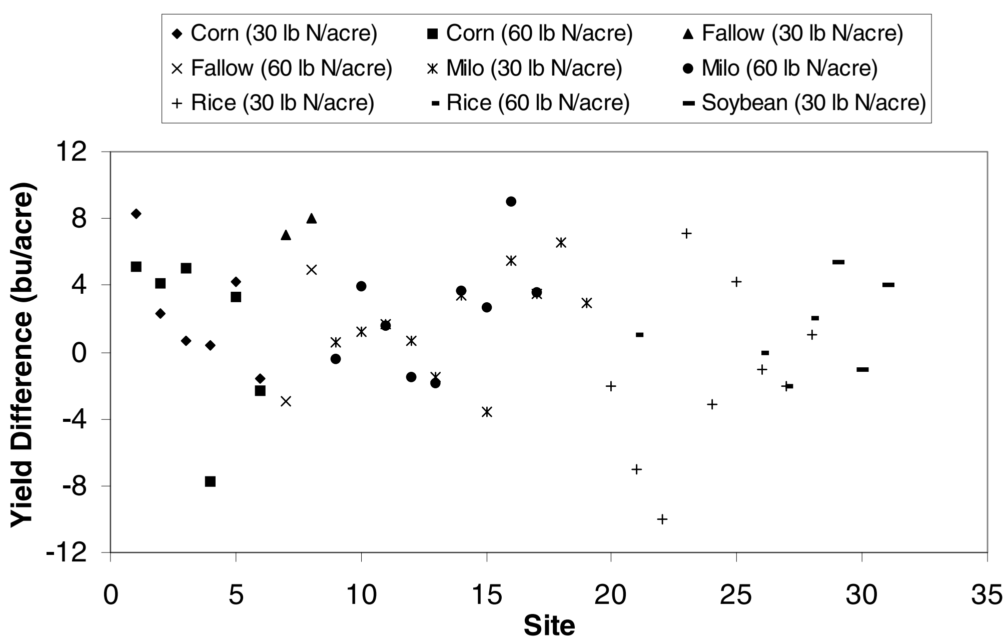

Fig. 1. Summary of 31 previously conducted research trials investigating the influence of preplant-incorporated N on winter wheat yield in Arkansas (results summarized from various issues of the Arkansas Soil Fertility Studies). Yield difference values <0 bu/acre indicate no benefit from fall N application.

Table 1. Mean soil-test information by site for N-rate trials with winter wheat in 2004.

Site[z]	Previous crop	Soil pH	Total soil C	Total soil N	Soil NO_3-N	Soil NH_4-N	Mehlich-3-extractable nutrients P	K	Ca	Mg	Mn	Zn	Cu
			(%)		(ppm)								
HR	Corn	6.8	1.200	0.118	32.5	10.3	28	159	1225	196	106	20.0	2.1
RREC	Rice	5.1	0.974	0.084	3.4	7.7	24	189	768	99	102	0.8	1.2
PTBS	Rice	6.6	1.432	0.136	2.5	6.7	38	184	1460	263	93	2.2	1.2
CBES	Milo	6.8	0.882	0.109	27.8	12.5	38	178	1362	227	114	1.5	1.9
CBES	Cow pea	6.4	0.818	0.085	8.1	14.0	39	162	989	272	83	1.5	1.7

[z] HR, Hickory Ridge; RREC, Rice Research Extension Center; PTBS, Pine Tree Branch Station; CBES, Cotton Branch Experiment Station.

Table 2. Selected agronomic dates of importance for five N-rate field trials conducted in 2003-2004.

Site[z]	Previous crop	Seeded	Fall N applied	Spring N application Split #1	Split #2	Heading sample	Harvest
		(day - month)					
HR	Corn	31 Oct.	11 Nov.	19 Feb.	10 March	13 April	4 June
CBES	Grain sorghum	23 Oct.	22 Oct.	18 Feb.	12 March	14 April	4 June
CBES	Cow pea	23 Oct.	22 Oct.	18 Feb.	12 March	14 April	3 June
PTBS	Rice	31 Oct.	30 Oct.	18 Feb.	10 March	14 April	9 June
RREC	Rice	21 Oct.	21 Oct.	19 Feb.	10 March	13 April	3 June

[z] HR, Hickory Ridge; RREC, Rice Research Extension Center; PTBS, Pine Tree Branch Station; CBES, Cotton Branch Experiment Station.

Table 3. The interaction between fall and late-winter N rates on wheat grain yield following corn, grain sorghum, cow pea, and rice at four sites during 2003-2004.

Late-winter N rate	Fall N rate (lb N/acre) 0	40	80	120	160
(lb N/acre)	[Grain yield (bu/acre)]				
Corn at HR [LSD(0.05) = 10 bu/acre]					
0	51	67	76	85	72
40	64	77	83	80	79
80	85	89	83	86	82
120	85	80	81	85	80
160	88	82	85	83	79
Grain sorghum at CBES [LSD(0.05) = 8 bu/acre]					
0	34	49	50	61	63
40	53	64	68	63	65
80	57	72	67	68	58
120	66	69	67	56	53
160	63	64	60	51	49
Cow pea at CBES [LSD(0.05) = 8 bu/acre]					
0	54	59	57	61	64
40	56	69	71	64	63
80	71	64	62	58	54
120	59	59	60	55	54
160	60	55	56	52	47
Rice at RREC [LSD(0.05) = 6 bu/acre]					
0	15	24	32	45	46
40	27	37	47	49	50
80	41	45	57	59	56
120	50	63	58	63	60
160	59	66	66	63	61

Table 4. Effect of fall N rate averaged across late-winter N rates, and late-winter N rate averaged across fall N rate, on grain yield of Sabbe wheat following rice at the Pine Tree Branch Station in 2003-2004.

N rate	Fall N rate	Spring N rate
(lb N/acre)	------------ [Grain yield (bu/acre)] ------------	
0	27	22
40	33	28
80	38	36
120	42	45
160	42	50
LSD(0.05)	7	7

Table 5. Effect of fall N rate, averaged across late-winter N rates, on the number of winter wheat tillers per 3 row-ft at multiple sites following various crops in 2003-2004.

	Site - previous crop[z]				
	HR[y]	RREC	PTBS	CBES	
Fall N rate	Corn	Rice	Rice	Grain sorghum	Cow pea
(lb N/acre)	---------- (tillers/3 linear-row ft) ----------				
0	150	56	76	74	78
40	160	70	84	98	93
80	175	69	92	92	94
120	177	75	89	104	95
160	164	81	92	108	98
LSD(0.05)	20	12	NS[x]	15	NS
P-value	0.0464	0.0038	0.1797	0.0005	0.0953
C.V., %	11.5	16.3	17.5	14.9	16.7

[z] Sabbe wheat at all sites except Hickory Ridge, which was seeded in Armor 3035.
[y] HR, Hickory Ridge; RREC, Rice Research Extension Center; PTBS, Pine Tree Branch Station; CBES, Cotton Branch Experiment Station.
[x] NS, not significant at the 0.05 level.

Table 6. Effect of late-winter N rate, averaged across fall N rates, on wheat tiller number at multiple locations and previous crops in 2004.

	Site - previous crop[z]				
	HR[y]	RREC	PTBS	CBES	
Spring N rate	Corn	Rice	Rice	Grain sorghum	Cow pea
(lb N/acre)	---------- (tillers/3 linear-row ft) ----------				
0	156	61	66	80	75
160	176	80	107	111	108
LSD(0.05)	12	12	10	9	10
P-value	0.0039	<0.0001	<0.0001	<0.0001	<0.0001

[z] 'Sabbe' wheat at all sites except Hickory Ridge, which was seeded in Armor 3035.
[y] HR, Hickory Ridge; RREC, Rice Research Extension Center; PTBS, Pine Tree Branch Station; CBES, Cotton Branch Experiment Station.

Evaluation of the Residual Benefits of Boron Fertilization on Soybean and Rice

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Boron deficiency of soybean [*Glycine max* (Merr.) L.] has become a common problem in northeast Arkansas. Research has demonstrated that 0.25 to 1.0 lb B/acre can significantly increase soybean seed yields on alkaline silt loam soils. In contrast, rice (*Oryza sativa* L.) grown in northeast Arkansas has not shown consistent positive or negative yield responses to direct applications of B fertilizer. Some growers have questioned whether B toxicity, especially of rice, could become a problem after years of B fertilization to the soils that are now considered B-deficient for soybean production. Because the soybean-rice rotation is common only in the mid-South rice-producing region of the USA, previous research has not addressed whether a single application of B fertilizer provides residual benefits or increases the risk of B toxicity in subsequent crops such as rice. The objectives of this study were to evaluate i) the immediate and residual influence of a single B application on soybean tissue-B concentration and yield; ii) how B rate applied the previous year influences rice growth, tissue-B concentration, and yield; and iii) the influence of B rate on Mehlich-3-extractable B in the surface and subsoil during a two or three-year period.

PROCEDURES

Experiments were established on a Dewitt silt loam at the Rice Research Extension Center (RREC) near Stuttgart, Ark., and on a Calhoun silt loam at the Pine Tree Branch Station (PTBS) near Colt, Ark., in 2002. Boron deficiency of soybean had not been documented at either site. Research sites were flagged and six B rates (0, 1, 2, 4, 6, and 8 lb B/acre) were randomly assigned to each plot (13-ft wide by 20-ft long). At each site, plot boundaries were maintained from 2002 through 2004. In 2002 (May), a composite soil sample (0- to 6-inch depth) was taken from each plot to determine the initial soil chemical and physical properties. Soil samples were also collected to a depth of 24 inches and divided into 6-inch depth increments to evaluate subsoil chemical properties from each plot designated as an unfertilized control. Composite soil samples were also collected from each plot in 2003 (0- to 6-inch depth samples collected in April) and 2004 (0- to 4-inch depth samples collected in March). Subsoil samples were also taken a second time in 2003 (April) from plots that received 0, 2, 4, and 6 lb B/acre as described previously. Each year, soil was dried in a forced-draft oven at 55°C, crushed, and stored in the sample boxes until processing. Soil-water pH, and Mehlich-3-extractable (1:10 extraction ratio) nutrients, including B, were determined on each sample. Mean values of selected soil chemical properties are listed for each site, year, and depth in Table 1.

Boron fertilizer (0, 1, 2, 4, 6, and 8 lb/acre) was applied to the tilled soil surface in May 2002 as a dry granular fertilizer (Granubor, 15% B) at the RREC and sprayed as a solution (Solubor, 17.5% B) at the PTBS. No additional B was applied to these plots for the duration of the study. Triple superphosphate (100 lb/acre) and muriate of potash (150 lb/acre) fertilizers were broadcast to each site each year. Nitrogen fertilizer (120 lb N/acre as urea) was applied preflood to rice grown at each site in 2003. The RREC site received about 3 tons $CaCO_3$ lime/acre in early March 2002 to increase surface soil pH.

In 2002, soybean (‘Caviness’ *cv.*) was drill-seeded (15-inch row spacing) on 30 May for the PTBS and 22 May for the RREC. Soybean was managed according to University of Arkansas Cooperative Extension Service recommendations for stand establishment, fertilization, management of pests, and irrigation. Soybean were flood-irrigated with well water at the PTBS and reservoir water at the RREC as needed throughout the growing season. Twenty recently matured trifoliate soybean leaves were sampled at the R2 growth stage, dried to constant weight at 60°C, ground to pass through a 1-mm sieve, and digested for elemental analysis. Soybean yield was determined by harvesting a 5-ft wide section from the middle of each plot and adjusted to 13% moisture for statistical analysis.

In 2003, 'Wells' rice was drill seeded (100 lb seed/acre) in mid-to-late April at the PTBS and RREC. Soil was tilled before seeding at the RREC, but was planted no-till into the previous year's soybean stubble at the PTBS. Rice was managed according to University of Arkansas Cooperative Extension Service recommendations for stand establishment, N fertilization, management of pests, and irrigation. Whole-plant samples were collected at the panicle-differentiation stage by removing all aboveground plant tissues from a 3-ft long section from the first interior row of rice. Twenty flag leaves (removed from leaf sheath at the collar) were collected at the late-boot to early heading stage. All tissue samples were processed as described previously for soybean. Rice yield was determined at maturity by harvesting the middle 4 or 5 rows from the middle of each plot. Grain yields were adjusted to a uniform moisture content of 12% for statistical analysis.

In 2004, 'Armor 53K3' soybean were drill-seeded on 11 May at the PTBS and 16 June at the RREC. Soil was tilled before seeding at the RREC, but was planted no-till into the previous year's rice stubble at the PTBS. Twenty recently matured trifoliate leaves were collected from each plot at the V6 and R2 growth stages at each site and processed as described previously. Grain yield was determined as described previously.

Each experiment was a randomized complete block design with six replications. Analysis of variance procedures were conducted with the PROC GLM procedure in SAS (SAS Institute, Inc., Cary, N.C.). Locations were analyzed separately. Mean separations were performed using Fisher's Protected Least Significant Difference method at a significance level of 0.10.

RESULTS

Soil Analysis

Surface soil samples collected from each plot in 2002 contained similar concentrations of Mehlich-3-extractable B indicating that each test site was relatively uniform with regard to soil-test B. In 2003, one year after B was applied, B-application rate significantly affected Mehlich-3-extractable B in the surface soil samples at each site (Table 2). For each site, Mehlich-3-extractable B increased linearly as B-application rate increased. Linear regression for both sites indicated that Mehlich-3-extractable B increased by about 0.10 mg B/kg/1 lb elemental B ($r^2 = 0.4730$) applied the previous year (2002). Mehlich-3-extractable B in the 6- to 12-inch soil depth was also affected by B application rate (only four rates evaluated) at the PTBS. Compared with the unfertilized control (0.22 mg B/kg), Mehlich-3 B in the 6- to 12-inch depth was significantly increased only by application of 6 lb B/acre (0.31 mg B/kg). At the RREC, subsoil-B concentrations were not affected by B application rate and averaged 0.16 mg B/kg.

By 2004, two years after B was applied, B-rate significantly affected Mehlich-3-extractable B only at the PTBS (Table 2). Mehlich-3-extractable B increased by about 0.05 mg B/kg soil/1 lb B ($r^2 = 0.6203$) two years after B application suggesting that Mehlich-3-extractable B decreases as time after application increases. The lack of significant differences among B rates at the RREC in 2003 and 2004 were at least partially due to the large coefficient of variation values (Table 2), which may been caused by i) application of granular B rather than a B solution and/or ii) movement of B and soil within and among plots from tillage. At the RREC, B was applied as a granular fertilizer, rather than a solution, due to windy conditions at the time of application.

Soybean and Rice Response to B Fertilization

Soybean seed yields in 2002 and 2004 and rice grain yields in 2003 were not influenced by B-application rate (Table 3). Soybean trifoliate leaf-B concentrations at the R2 growth stage were significantly affected by B-application rate at both sites in 2002 (Table 4). In general, trifoliate leaf-B concentration increased as B application rate increased. Soybean B concentrations exceeded 60 mg B/kg, the proposed toxic concentration, when 1 lb B/acre was applied at the PTBS and when 4 lb B/acre was applied at the RREC. Although significant yield decreases from B fertilization were not measured, soybean yields at both sites tended to decline numerically when >4 lb B/acre was applied (Table 3).

Boron concentrations of rice flag leaves in 2003 significantly increased as B-application rate increased at both sites (Table 4). Whole-plant rice B concentrations at panicle differentiation showed similar results as flag leaves (data not shown). In 2004, mature trifoliate soybean leaves collected at the V6 stage at both sites were also significantly increased by B-application rate, two years after B fertilizer was applied (Table 4). At the PTBS, trifoliate leaf-B concentrations were also affected by B rate at the R2 stage. The B concentration of the untreated control at the R2 stage was similar to that at the V6 stage, but B concentrations were numerically greater for B rates > 0 lb B/acre between samples times. Rice (2003) and soybean (2004) tissue-B concentration data suggest that a single application of B increases B uptake by future crops. The residual effect of B fertilization increases as B-application rate increases and lasts for at least two years. Compared with the unfertilized control, application of 1 lb B/acre, the maximal rate recommended for soybean, significantly increased soybean trifoliate leaf-B concentration in 2004 only at the PTBS. Tissue analysis for the R2 samples collected at the RREC are not yet complete.

PRACTICAL APPLICATIONS

Increasing the B-fertilizer rate applied in 2002 significantly increased Mehlich-3-extractable B in the 0- to 4- or 6-inch soil depths at both locations in 2003 and only at the PTBS in 2004, but generally had little influence on subsoil-B concentrations. Application of high B rates (>1 lb B/acre) in 2002 had no residual, negative influence on rice (2003) or soybean (2004) growth and yield. Application of recommended rates of B to soybean once every two years in a rice-soybean rotation may slightly increase soil-test B and provide sufficient residual B for future crops so that B fertilization frequency or rate of application may be reduced or possibly omitted after several years of application. Recommended rates of B would likely have to be applied for many years before sufficient soil-B accumulated to cause B toxicity in flood-irrigated rice and/or irrigated-soybean grown on alkaline soils in northeast Arkansas. Additional research is needed to interpret Mehlich-3-extractable B and determine how long a single application of B influences subsequent crop B nutrition.

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Table 1. Selected soil chemical property means for two experiments initiated at the Pine Tree Branch Station (PTBS) and Rice Research Extension Center (RREC) in 2002.

Year	Site	Soil depth	pH	Mehlich-3-extractable soil nutrients								
				P	K	Ca	Mg	Na	S	Mn	Zn	B
		(in.)		(mg/kg soil)								
2002	PTBS	0 to 6	7.9	20	96	1629	289	94	20	121	2.0	0.83
2002	PTBS	6 to 12	6.6	7	63	1009	247	115	19	166	0.8	0.12
2002	PTBS	12 to 18	4.9	5	64	497	177	107	27	79	0.8	0.09
2002	PTBS	18 to 24	5.0	6	77	480	220	161	19	82	1.4	0.13
2003	PTBS	0 to 6	7.6	22	102	1973	322	59	11	126	1.5	--[z]
2003	PTBS	6 to 12	4.8	5	53	1125	267	92	16	191	0.7	--
2003	PTBS	12 to 18	4.7	4	52	473	169	101	31	72	0.8	0.18
2003	PTBS	18 to 24	4.7	4	68	423	224	167	22	84	1.4	0.22
2004	PTBS	0 to 4	7.9	23	121	1949	295	43	11	96	2.0	--
2002	RREC	0 to 6	6.3	10	109	938	179	92	21	141	0.7	0.32
2002	RREC	6 to 12	7.6	2	66	1098	216	234	7	139	0.3	0.09
2002	RREC	12 to 18	6.3	2	91	905	215	336	18	27	0.3	0.09
2002	RREC	18 to 24	5.3	2	160	780	193	530	43	28	0.4	0.09
2003	RREC	0 to 6	6.9	14	110	1167	241	82	14	192	5.3	--
2003	RREC	6 to 12	7.0	3	55	1292	234	174	10	190	0.5	0.16
2003	RREC	12 to 18	6.4	3	62	1060	240	247	13	41	0.4	0.07
2003	RREC	18 to 24	5.2	2	110	855	214	424	33	26	0.5	0.05
2004	RREC	0 to 4	6.2	11	135	858	178	49	12	111	4.4	--

[z] '--' indicates that Mehlich-3-extractable B was affected by previous B applications and values are listed in the text or in Table 2.

Table 2. The influence of B-application rate (applied in May 2002) on surface soil Mehlich-3-extractable B concentration in 2003 and 2004 at the Pine Tree Branch Station (PTBS) and Rice Research Extension Center (RREC).

B fertilizer rate	Site-year			
	PTBS-2003	PTBS-2004	RREC-2003	RREC-2004
(lb B/acre)	(mg Mehlich-3-extractable B/kg soil)			
0	0.48	0.19	0.40	0.10
1	0.58	0.28	0.43	0.09
2	0.75	0.39	0.57	0.11
4	0.95	0.43	0.69	0.14
6	1.01	0.56	0.73	0.14
8	1.28	0.57	1.40	0.26
LSD(0.10)	0.21	0.11	0.46	NS[z]
P-value	<0.0001	<0.0001	0.0184	0.1570
C.V., %	24.7	26.2	53.0	85.6

[z] NS, not significant at the 0.10 level.

Table 3. The influence of B-application rate (applied in May 2002) on soybean yields in 2002 and 2004 and rice yields in 2003 at the Pine Tree Branch Station (PTBS) and Rice Research Extension Center (RREC).

B fertilizer	Soybean 2002		Rice 2003		Soybean 2004	
rate	PTBS	RREC	PTBS	RREC	PTBS	RREC
	(bu/acre)					
0	71	51	156	176	57	50
1	71	52	152	175	52	49
2	69	50	154	180	55	49
4	76	48	152	172	56	47
6	67	44	160	171	59	42
8	66	44	155	173	55	49
LSD(0.10)	6	NS[z]	NS	NS	NS	NS
P-value	0.0892	0.643	0.7382	0.9616	0.7058	0.3293
C.V., %	8.5	18.4	6.5	10.3	13.5	11.5

[z] NS, not significant at the 0.10 level.

Table 4. The influence of B-application rate (applied in May 2002) on mature trifoliate leaf-B concentrations of soybean in 2002 (R2 stage) and 2004 (V6 and R2 stages) and flag leaf-B concentrations of rice at heading in 2003 at the Pine Tree Branch Station (PTBS) and Rice Research Extension Center (RREC).

	Soybean 2002		Rice 2003		Soybean 2004 (stage/site)		
B fertilizer	Trifoliate leaves		Flag leaves		Trifoliate leaves		
rate	R2PTBS	R2RREC	PTBS	RREC	V6PTBS	R2PTBS	V6RREC
(lb B/acre)	[Tissue-B concentration (mg B/kg)]						
0	56.0	39.6	6.1	6.1	29.0	30.7	49.6
1	66.2	45.8	6.0	6.3	32.6	43.9	49.9
2	83.1	51.8	7.3	6.4	36.3	45.7	50.5
4	74.3	61.1	7.5	6.2	37.3	48.9	53.4
6	84.7	61.6	8.8	7.2	36.7	51.5	52.3
8	122.4	72.6	9.3	7.2	39.1	50.8	54.9
LSD (0.10)	23.4	10.3	0.9	0.8	2.5	2.5	2.9
P-value	0.0014	0.0001	<0.0001	0.0132	<0.0001	<0.0001	0.0274
C.V., %	29.2	17.5	9.9	9.7	7.1	5.5	5.8

Adaptation of Soybean Cultivars to Restrictive Soil Environments

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RESEARCH PROBLEM

Seed yields of numerous entries in the Arkansas Soybean Performance Tests in 2003 ranged from 60 to 70 bu/acre when grown in high-yielding environments (Dombek et al., 2004). Some growers continue to produce lower soybean yields than in the past in specific fields, although they use sound cultural practices and grow cultivars that have proven to have high-yield potential in yield performance tests on experiment stations located throughout Arkansas. Rice is frequently grown in rotation with soybean on many of the fields and lower yields have been noted for both crops by some growers. A research program with the objectives of producing higher-yielding soybean cultivars for use in restrictive environments and to identify factors that reduce soybean yields in these environments is being continued.

BACKGROUND INFORMATION

Restrictive environments being used in this program are ones in which no factors known to limit soybean yields have been identified. Most yield tests used in conventional soybean breeding programs are conducted in environments that maximize yield potential. Screening for cultivar tolerance or resistance to specific diseases in greenhouses or in field environments where the specific diseases are the only limiting factors present is appropriate and needed. For restrictive environments, selection and testing in that environment are necessary to identify experimental strains that have the genetic ability to produce high yields in the presence of the factors responsible for reducing yields of conventional cultivars.

RESEARCH DESCRIPTION

A wide array of soybean genotypes has been grown in restrictive environments on producer fields in order to select those genotypes that grew well and produced the highest seed yields. These genotypes have been intercrossed to develop populations that have been subjected to re-selection and yield testing in restrictive environments. Crosses among those selected genotypes have been made as well. Increases of experimental strains were grown at the Northeast Research Extension Center (NEREC) at Keiser, Ark., and at the Pine Tree Branch Station (PTBS) near Colt, Ark., in 2001. Elite and advanced strains were evaluated for yield and agronomic characters in productive environments at NEREC and PTBS in 2002 and 2003. Elite and advanced strains were evaluated in Poinsett County on two sites which had been shown to be restrictive environments in 2003. The soil series for both sites was a Hillemann silt loam. The Hillemann series has frequently been associated with restrictive environments. Soil samples were taken from the upper 6 inches of both sites and analyzed for soil pH, electrical conductivity, and Mehlich-3 (1:10 ratio)-extractable nutrients at the University of Arkansas Agricultural Diagnostic Laboratory in Fayetteville.

Tests of elite and advanced strains were planted in randomized complete block tests on a Hillemann silt loam located northeast of Weiner, Ark., in Poinsett County in 2004. The farmer reported that this site has produced lower soybean yields than the 2003 sites. Soil samples were taken from the upper 6 inches of soil in the field and analyzed at the University of Arkansas Diagnostic Laboratory in Fayetteville as described previously. A deep soil core was taken from this site to a depth of 80 inches. Elite and advanced strains were evaluated in randomized complete block tests at the NEREC and PTBS to determine yielding ability in productive environments. Two strains, RJ97-500 and RJ97-555, were entered in the 2004 Arkansas Soybean Performance Tests to determine their performance in a wide array of environments across the state.

RESULTS

Soil electrical conductivity, pH, and nutrient concentration of the upper 6 inches of the Hilleman silt loam at the Poinsett County test site are shown in Table 1. A deep sample of the test-site soil was also analyzed and results are presented in Table 2. Comparison of soil pH and nutrient concentrations taken from varying depths in the field indicates the need for rooting depth to be considered in future studies on restrictive environments. Differences in rooting depth among different genotypes may relate to differences in their growth and seed production. Rainfall on this field began just before complete maturity of all test entries and continued through October and November. Water stood on the test site for most of that time period and has prevented harvest of seed.

Seed yield of elite experimental strains at NEREC and PTBS in 2004 are presented in Table 3. Yields of advanced strains at the same locations are shown in Table 4. The yields at these locations indicate that the process of selecting parents for crossing and progeny in restrictive environments is an effective means of developing strains that yield as well as, or better than, existing cultivars when grown in productive environments. Yields of many of these experimental strains grown in restrictive environments in 2003 were higher than check cultivars to which they were compared (Widick and Dunn, 2003).

PRACTICAL APPLICATIONS

Experimental strains developed by selecting among diverse genotypes grown in restrictive environments have been shown to have potential for higher yields than conventional cultivars in both restrictive (2003) and productive environments (2003 and 2004). Cultivars developed in this manner should allow soybean growers, who have soil conditions similar to the ones in which these strains were developed and tested, to increase their seed yield and profitability.

ACKNOWLEDGMENTS

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Table 1. Electrical conductivity, pH, and nutrient concentration of Hillemann silt loam soils at three sites in Poinsett County in 2004.

Site	Soil pH[z]	Soil EC[z]	Mehlich-3-extractable nutrients										Soil Cl[y]
			P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	
			(lb/acre)										
1	7.1	176	88	351	3796	617	35	146	401	70	15.2	2.5	83
2	7.6	140	35	185	2956	506	22	159	291	62	4.4	2.0	45
3	6.7	394	67	288	3830	613	101	266	359	50	11.4	2.4	217

[z] Soil pH and electrical conductivity (EC, μmhos/cm) determined in a 1:2 (weight:volume) soil-water mixture.
[y] Water-extractable Cl.

Table 2. Soil electrical conductivity, pH, and nutrient concentration of a Hillemann silt loam soil at six depths at site 3 (Table 1) in Poinsett County in 2004

Soil	Soil	Soil	Mehlich-3-extractable soil nutrients											Soil
depth	pH[z]	EC[z]	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B	Cl[y]
(in.)			(lb/acre)											
0-10	7.8	297	56	204	7008	699	36	177	189	710	11.9	3.4	0.6	133
10-20	7.8	195	20	120	2878	534	33	172	154	285	0.6	1.8	0.2	99
20-32	5.5	134	17	122	1976	361	119	160	198	36	0.7	1.8	0.2	93
32-45	4.4	120	5	75	525	181	109	134	185	15	0.6	2.1	0.2	86
45-67	4.0	137	3	180	495	518	62	315	339	34	2.6	3.7	0.2	89
67-80	3.9	116	6	200	503	702	20	445	231	12	3.5	3.9	0.2	121

[z] Soil pH and electrical conductivity (EC, µmhos/cm) determined in a 1:2 (weight:volume) soil-water mixture.
[y] Water extractable Cl.

Table 3. Seed yield of elite experimental strains and check cultivars grown at the Northeast Research and Extension Center (NEREC) and at the Pine Tree Branch Experiment Station (PTBS) in 2004.

NEREC		PTBS	
Strain	Yield	Strain	Yield
	(bu/acre)		(bu/acre)
RJ97-497	62.7	RJ97-500	65.5
RJ97-419	62.6	RJ97-045	61.4
RJ97-500	61.8	RJ97-535	60.6
RJ97-535	60.0	Accomac	59.4
DK4661	59.5	Hutcheson	58.1
RJ97-045	57.3	RJ97-536	57.1
Caviness	57.3	DK4661	57.0
Accomac	56.1	Manokin	56.9
RJ97-497	56.1	RJ97-497	56.5
RJ97-419	55.2	RJ97-555	53.0
RJ97-536	54.9	Caviness	52.3
Hutcheson	53.6	RJ97-419	51.7
Manokin	52.0	Dixie 478	50.6
LSD (0.05)	5.83	LSD (0.05)	3.95

Table 4. Seed yield of advanced experimental strains and check cultivars grown at the Northeast Research and Extension Center (NEREC) and at the Pine Tree Branch Experiment Station (PTBS) in 2004.

NEREC		PTBS	
Strain	Yield	Strain	Yield
	(bu/acre)		(bu/acre)
RJ00-277	61.9	RJ00-168	59.0
DK4661	61.6	RJ00-277	58.3
RJ00-090	61.3	RJ00-058	54.3
RJ00-046	60.7	RJ00-097	54.2
RJ00-168	59.5	RJ00-334	53.5
RJ00-078	58.6	Hutcheson	52.5
RJ00-261	58.4	Accomac	51.5
RJ00-058	57.5	RJ00-090	51.5
Accomac	57.1	RJ00-046	50.2
RJ00-156	56.7	RJ00-078	50.1
Hutcheson	56.2	Manokin	50.0
RJ00-097	56.2	DK4661	47.4
Dixie 478	54.3	Dixie 478	44.2
Manokin	50.2		
K1606	43.8		
LSD (0.05)	3.76	LSD (0.05)	8.05

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