Wayne E. Sabbe
ARKANSAS
SOIL FERTILITY STUDIES
•2002•

Nathan A. Slaton, Editor

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SOIL FERTILITY STUDIES
– 2002 –

Nathan A. Slaton, Editor

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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 contained 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 2002 Soil Fertility Studies include research reports on numerous Arkansas commodities and on several research areas including topics associated with precision agriculture. 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 2002 growing season. This set of data includes data 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, the 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.

Readers are reminded that the 1996 Arkansas Soil Fertility Studies (Research Series 455) contains the index to articles in the previous Arkansas Soil Fertility Research Series.

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Soil Test and Fertilizer Sales Data: Summary for the Growing Season – 2002 –

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

BACKGROUND INFORMATION

Soil test data from samples submitted to the University of Arkansas Soil Testing and Research Laboratory in Marianna during the period 1 September 2001 through 30 August 2002 were categorized according to geographic area, county, soil association number (SAN), and selected cropping systems. This period roughly corresponds to the 2002 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, AR, December 1982). Descriptive statistics of the soil test data were calculated for categorical ranges for pH, phosphorus (P), potassium (K), nitrate-nitrogen (NO_3-N), and soluble salts (i.e., electrical conductivity, EC). Soluble salts and NO_3-N can be indicators of adverse soil conditions that result in poor plant growth or leaching potentials. Routine analysis of NO_3-N on all soil samples was discontinued in March 2001. Soil NO_3-N is routinely determined on samples for corn, cotton, and all garden categories. Otherwise, soil NO_3-N is performed only upon request. Soil pH and extractable (Mehlich 3, 1:7 extraction ratio analyzed by ICAP) soil nutrient (i.e., P, K, Ca, etc.) concentrations indicate the relative level of soil fertility.

RESULTS

Crop Acreage and Soil Sampling Intensity

During the interval from 1 September 2001 through 30 August 2002, 83,603 soil samples were analyzed in the University of Arkansas Soil Testing and Research Laboratory in Marianna. A total of 50,487 soil samples representing a total of 1,205,853 acres had complete data for the county, SAN, last crop produced, geographic area, total acres, pH, P, K, EC, 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 48% of the total samples and 71% of the total acreage (Table 1). The county average ranged from 2 to 78 acres/sample (Table 2). Clients from Arkansas (4,098 samples), Washington (3,238), Benton (2,155), and Lonoke (2,049) counties submitted the most soil samples for analyses.

Soil association numbers show that most samples were taken from row crops and pasture (Table 3). The 44 and 45 SAN represented 34% 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 represent 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 2002, respectively. The soil test values relate to the potential fertility of a soil but not necessarily to the productivity of the soil. Therefore, it may not be 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 (Table 8). 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 the routine fertilization practices. The majority of Arkansas soils have a pH >5.5, but <6.5 (Table 7).

Table 8 contains soil test levels and the median (Md) concentrations for each of the cropping system categories. The Md 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 a mean value. Among row crops, the lowest P and K median values appear for rice and irrigated soybeans. As expected, the highest median P and K concentrations for row crops were from soils used for cotton production. The median P and K concentrations for row crops have remained constant over the past 10 years, but soil P has gradually increased for soils used for warm- and cool-season grass production (data not shown).

Fertilizer consumption by county (Table 9) and by fertilizer nutrient and formulation (Table 10) illustrate the wide use of fertilizer used predominantly in row-crop production areas.

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 provided 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 2001 through August 2002.

Geographic area	Acres sampled	No. of samples	Acres/ sample
Ozark Highlands - Cherty Limestone and Dolomite	149,061	8,585	17
Ozark Highlands - Sandstone and Limestone	6,038	400	15
Boston Mountains	29,664	2,921	10
Arkansas Valley and Ridges	61,063	4,777	13
Ouachita Mountains	40,057	4,864	8
Bottom Lands and Terraces	449,148	13,421	34
Coastal Plain	43,310	3,413	13
Loessial Plains	409,557	10,685	38
Loessial Hills	14,249	1,142	13
Blackland Prairie	3,706	279	13

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 2001 through August 2002.

County	Acres sampled	No. of samples	Acres/ sample	County	Acres sampled	No. of samples	Acres/ sample
Arkansas, DeWitt	74,831	2,085	36	Lincoln	9,875	358	28
Arkansas, Stuttgart	74,035	2,013	37	Little River	4,812	110	44
Ashley	30,689	957	32	Logan, Booneville	2,585	176	15
Baxter	2,136	366	6	Logan, Paris	7,695	410	19
Benton	31,471	2,155	15	Lonoke	82,490	2,049	40
Boone	8,091	558	15	Madison	10,526	707	15
Bradley	583	113	5	Marion	7,721	260	30
Calhoun	278	23	12	Miller	11,736	321	37
Carroll	11,015	609	18	Mississippi, Blytheville	27,350	909	30
Chicot	18,594	240	78	Mississippi, Osceola	6,795	138	49
Clark	1,755	229	8	Monroe	29,630	562	53
Clay, Corning	15,376	764	20	Montgomery	3,628	204	18
Clay, Piggott	18,291	579	32	Nevada	1,175	82	14
Cleburne	3,011	334	9	Newton	2,988	127	24
Cleveland	376	45	8	Ouachita	1,307	302	4
Columbia	2,501	274	9	Perry	6,178	328	19
Conway	11,786	511	23	Phillips	18,387	449	41
Craighead	50,672	1,564	32	Pike	3,252	182	18
Crawford	8,600	495	17	Poinsett	34,375	936	37
Crittenden	29,765	849	35	Polk	7,095	385	18
Cross	83,144	1,522	55	Pope	15,706	894	18
Dallas	249	94	3	Prairie, Des Arc	15,066	336	45
Desha	21,364	1,701	13	Prairie, DeValls Bluff	11,725	236	50
Drew	1,746	199	9	Pulaski	8,754	1,880	5
Faulkner	4,629	440	11	Randolph	10,081	510	20
Franklin, Charleston	578	55	11	Saline	1,211	312	4
Franklin, Ozark	7,357	372	20	Scott	1,847	129	14
Fulton	2,325	172	14	Searcy	6,462	328	20
Garland	3,291	1,619	2	Sebastian (Fort Smith)	1,381	306	5
Grant	580	129	5	Sebastian (Greenwood)	1,266	183	7
Greene	28,302	1,376	21	Sevier	5,585	200	28
Hempstead	4,876	263	19	Sharp	3,027	270	11
Hot Spring	2,418	178	14	St. Francis	20,293	667	30
Howard	5,955	408	15	Stone	2,015	162	12
Independence	10,254	374	27	Union	3,260	516	6
Izard	4,407	241	18	Van Buren	6,032	436	14
Jackson	21,189	642	33	Washington	63,132	3,238	20
Jefferson	47,967	1,305	37	White	9,930	1,680	6
Johnson	6,513	476	14	Woodruff	13,033	302	43
Lafayette	3,075	139	22	Yell, Danville	5,359	290	19
Lawrence	33,922	1,142	30	Yell, Dardanelle	3,094	146	21
Lee	29,997	861	35				

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 2001 through August 2002.

SAN	Soil Association	Acres sampled	No. of samples	Acres/ sample
1.	Clarksville-Nixa-Noark	19,144	1,093	18
2.	Gepp-Doniphan-Gassville-Agnos	14,104	1,166	12
3.	Arkana-Moko	13,680	719	19
4.	Captina-Nixa-Tonti	94,236	5,353	18
5.	Captina-Doniphan-Gepp	5,514	127	43
6.	Eden-Newnata-Moko	2,383	127	19
7.	Estate-Portia-Moko	2,057	131	16
8.	Brockwell-Boden-Portia	3,981	269	15
9.	Linker-Mountainburg-Sidon	10,133	689	15
10.	Enders-Nella-Mountainburg-Steprock	19,531	2,232	9
11.	Falkner-Wrightsville	1,423	75	19
12.	Leadvale-Taft	22,658	1,927	12
13.	Enders-Mountainburg-Nella-Steprock	5,793	372	16
14.	Spadra-Guthrie-Pickwick	2,354	178	13
15.	Linker-Mountainburg	28,835	2,225	13
16.	Carnasaw-Pirum-Clebit	19,031	2,807	7
17.	Kenn-Ceda-Avilla	3,324	206	16
18.	Carnasaw-Sherwood-Bismarck	11,440	1,499	8
19.	Carnasaw-Bismarck	590	50	12
20.	Leadvale-Taft	1,224	68	18
21.	Spadra-Pickwick	4,448	234	19
22.	Foley-Jackport-Crowley	82,645	2,818	29
23.	Kobel	14,011	375	37
24.	Sharkey-Alligator-Tunica	30,101	676	45
25.	Dundee-Bosket-Dubbs	88,316	2,306	38
26.	Amagon-Dundee	35,859	1,136	32
27.	Sharkey-Steele	5,956	172	35
28.	Commerce-Sharkey-Crevasse-Robinsonville	23,169	441	53
29.	Perry-Portland	34,766	1,881	19
30.	Crevasse-Bruno-Oklared	357	15	24
31.	Roxana-Dardanelle-Bruno-Roellen	7,816	317	25
32.	Rilla-Hebert	112,037	2,930	38
33.	Billyhaw-Perry	6,258	143	44
34.	Severn-Oklared	6,897	148	47
35.	Adaton	95	4	24
36.	Wrightsville-Louin-Acadia	612	28	22
37.	Muskogee-Wrightsville-McKamie	253	31	8
38.	Amy-Smithton-Pheba	4,047	159	26
39.	Darco-Briley-Smithdale	613	42	15
40.	Pheba-Amy-Savannah	2,380	331	7
41.	Smithdale-Sacul-Savannah-Saffell	11,298	1,224	9
42.	Sacul-Smithdale-Sawyer	19,200	1,347	14
43.	Guyton-Ouachita-Sardis	5,772	310	19
44.	Calloway-Henry-Grenada-Calhoun	232,471	6,060	38
45.	Crowley-Stuttgart	177,086	4,625	38
46.	Loring	1,897	92	21
47.	Loring-Memphis	12,196	1,037	12
48.	Brandon	156	13	12
49.	Oktibbeha-Sumter	3,706	279	3

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 2001 through August 2002.

Crop	Acres sampled	No. of samples	Acres/ sample
Soybean - dryland	42,236	1,237	34
Soybean - irrigated	421,331	10,236	41
Cotton	191,247	5,812	33
Rice	86,428	2,057	42
Wheat	19,089	589	32
Double-crop wheat-soybean - dryland	5,792	200	29
Double-crop wheat-soybean - irrigated	15,913	318	50
Warm season grass - establish	12,208	613	20
Warm season grass - maintain	96,384	4,632	21
Cool season grass - establish	31,496	1,244	25
Cool season grass - maintain	56,150	2,607	22
Grain sorghum	12,102	302	40
Corn	23,424	594	39
All garden	8,665	3,266	3
Turf and ground cover	11,122	6,788	2
Fruit and nut	1,159	481	2
Vegetable	57	11	5
Other	171,050	9,500	18

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 2001 through August 2002.

Geographic area	pH			P[z] (lb/acre)					K[z] (lb/acre)				EC[y] (µmhos/cm)		
	<5.5	5.5-6.5	>6.5	<26	26-44	45-100	101-300	>300	<176	176-220	221-350	>350	<100	100-500	>500
	(Percentage of sampled acreage)														
Ozark Highlands - Cherty Limestone and Dolomite	12	59	29	4	8	21	38	29	22	12	29	37	82	17	1
Ozark Highlands - Sandstone and Limestone	7	61	32	11	19	29	25	16	36	13	27	24	91	9	0
Boston Mountains	15	59	26	5	11	27	41	16	35	14	27	24	85	15	0
Arkansas Valley and Ridges	22	58	20	13	13	23	30	21	36	14	26	24	89	11	0
Ouachita Mountains	26	56	18	7	11	26	35	21	42	16	25	17	87	13	0
Bottom Lands and Terraces	6	47	47	9	16	47	27	1	19	15	37	29	96	4	0
Coastal Plain	24	52	24	11	12	21	33	23	46	15	23	16	91	8	1
Loessial Plains	6	34	60	21	33	36	9	1	38	25	28	9	95	5	0
Loessial Hills	15	52	33	22	17	31	23	7	26	14	37	23	87	12	1
Blackland Prairie	36	39	25	17	16	24	31	12	39	13	17	31	83	16	1
Average	17	52	31	12	16	29	29	14	34	15	28	23	89	11	0

[z] Analysis by 1:7 soil weight:Mehlich-3 volume.
[y] EC = electrical conductivity; which is a measure of soluble salts in 1:2 soil weight:water 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 2001 through August 2002.

	pH			P^z (lb/acre)					K^z (lb/acre)				EC^y (µmhos/cm)		
Geographic area	<5.5	5.5-6.5	>6.5	<26	26-44	45-100	101-300	>300	<176	176-220	221-350	>350	<100	100-500	>500
	(Percentage of sampled acreage)														
Arkansas, DeWitt	3	23	74	21	42	33	3	1	37	30	27	6	97	3	0
Arkansas, Stuttgart	8	43	49	31	32	31	6	0	33	25	28	14	93	7	0
Ashley	5	28	67	12	12	33	41	2	23	16	45	16	95	5	0
Baxter	5	30	65	4	14	22	31	29	18	13	28	41	71	28	1
Benton	11	64	25	1	4	17	40	38	19	10	29	42	77	23	0
Boone	8	57	35	4	14	32	36	14	28	12	28	32	88	11	1
Bradley	8	25	67	5	7	18	43	27	34	23	34	9	98	2	0
Calhoun	9	52	39	0	0	30	52	18	48	26	17	9	91	9	0
Carroll	4	53	43	1	3	21	43	32	16	8	27	49	71	27	2
Chicot	5	33	62	12	36	27	20	5	8	6	30	56	88	11	1
Clark	43	38	19	16	11	26	31	16	59	11	16	14	94	5	1
Clay, Corning	3	55	42	13	33	43	10	1	48	25	23	4	98	2	0
Clay, Piggott	6	49	45	9	16	44	29	2	24	15	40	21	97	3	0
Cleburne	18	62	20	7	14	27	33	19	36	13	31	20	90	9	1
Cleveland	16	73	11	18	11	29	27	15	58	9	20	13	98	2	0
Columbia	34	45	21	11	10	18	39	22	50	14	26	10	91	8	1
Conway	29	58	13	17	12	19	24	28	34	13	22	31	95	5	0
Craighead	5	38	57	10	18	43	27	2	21	13	39	27	92	8	0
Crawford	17	62	21	11	15	29	31	14	37	18	29	16	94	6	0
Crittenden	6	48	46	1	7	59	31	2	1	3	36	60	97	3	0
Cross	3	19	78	19	34	40	6	1	43	23	21	13	97	3	0
Dallas	21	55	24	18	17	19	27	19	61	22	11	6	96	4	0
Desha	3	35	62	5	11	55	29	0	12	13	35	40	97	3	0
Drew	30	43	27	19	11	24	32	14	31	11	33	25	86	13	1
Faulkner	28	41	31	14	18	22	29	17	30	17	28	25	81	17	2
Franklin, Charleston	22	40	38	16	16	20	44	4	26	22	35	17	98	2	0
Franklin, Ozark	22	66	12	8	9	20	32	31	29	11	27	33	85	15	0
Fulton	6	56	38	7	13	24	44	12	19	15	30	36	84	16	0
Garland	26	58	16	4	11	31	39	15	50	16	24	10	81	19	0
Grant	29	50	11	17	17	15	33	18	44	12	23	21	86	12	2
Greene	12	57	31	22	26	36	15	1	31	18	34	17	96	4	0
Hempstead	26	46	28	15	11	30	28	16	41	13	20	26	90	10	0
Hot Spring	29	47	24	11	11	16	32	30	53	11	22	14	93	6	1
Howard	20	64	16	4	4	11	23	58	24	9	30	37	85	14	1
Independence	14	52	34	10	16	30	34	10	39	20	28	13	90	9	1
Izard	9	58	33	14	17	25	30	14	47	17	19	17	88	12	0
Jackson	8	55	37	12	21	44	20	3	34	24	30	12	92	8	0
Jefferson	8	46	46	4	8	50	33	5	18	16	42	24	95	4	1
Johnson	19	62	19	11	15	21	31	22	36	12	26	26	90	10	0
Lafayette	15	53	32	7	6	27	33	27	27	20	30	23	91	9	0
Lawrence	3	61	36	27	34	33	6	0	37	26	29	8	97	3	0
Lee	7	47	46	3	11	63	23	0	17	23	43	17	98	2	0
Lincoln	8	44	48	5	8	39	42	6	17	14	40	29	98	2	0
Little River	11	49	40	11	22	38	20	9	45	13	17	25	89	9	2

continued

Table 6. Continued.

Geographic area	pH <5.5	pH 5.5-6.5	pH >6.5	P[z] (lb/acre) <26	P 26-44	P 45-100	P 101-300	P >300	K[z] (lb/acre) <176	K 176-220	K 221-350	K >350	EC[y] (µmhos/cm) <100	EC 100-500	EC >500
	(Percentage of sampled acreage)														
Logan, Booneville	30	59	11	40	13	21	18	8	56	16	17	11	92	8	0
Logan, Paris	18	61	21	11	16	28	32	13	41	14	19	26	95	5	0
Lonoke	10	53	37	16	25	42	16	1	26	20	35	19	94	6	0
Madison	14	74	12	5	10	15	43	27	25	11	30	34	91	9	0
Marion	11	52	37	3	12	25	40	20	19	13	30	38	85	15	0
Miller	22	48	30	10	19	26	35	10	37	16	22	25	89	11	0
Mississippi, Blytheville	10	66	24	1	2	44	51	2	6	7	49	38	97	3	0
Mississippi, Osceola	2	60	38	4	17	55	23	1	2	11	30	57	93	7	0
Monroe	3	34	63	22	26	43	8	1	32	24	32	12	97	3	0
Montgomery	27	60	13	4	7	16	35	38	40	10	22	28	91	8	1
Nevada	21	67	12	26	13	17	29	15	39	13	28	20	89	11	0
Newton	12	56	32	13	18	32	21	16	33	13	25	29	89	11	0
Ouachita	25	59	16	10	5	15	49	21	53	15	23	9	90	9	1
Perry	30	64	6	22	15	20	25	18	39	12	24	25	88	12	0
Phillips	10	44	46	3	10	50	36	1	15	15	46	24	94	6	0
Pike	23	62	15	4	9	9	27	51	42	14	22	22	85	14	1
Poinsett	3	22	75	27	28	31	13	1	44	20	22	14	95	5	0
Polk	39	53	92	6	10	19	37	28	47	14	21	18	91	9	0
Pope	22	57	21	11	13	24	29	23	36	12	25	27	91	9	0
Prairie, Des Arc	3	38	59	21	36	35	7	1	41	32	22	5	94	6	0
Prairie, DeValls Bluff	9	35	56	23	48	23	4	2	45	28	19	8	92	8	0
Pulaski	23	50	27	8	12	26	35	19	34	20	30	16	87	13	0
Randolph	11	44	44	15	19	46	17	3	33	21	27	19	94	6	0
Saline	28	51	21	9	14	23	31	23	51	9	21	19	86	13	1
Scott	19	66	15	9	15	24	37	15	40	9	21	30	92	6	2
Searcy	24	63	13	9	9	29	40	13	30	10	28	32	87	13	0
Sebastian, Fort Smith	23	43	34	12	6	22	32	28	26	12	30	32	75	24	1
Sebastian, Greenwood	9	69	22	16	19	14	27	24	44	15	22	19	92	8	0
Sevier	30	63	7	10	12	15	34	29	43	8	23	26	94	5	1
Sharp	10	58	32	12	20	34	23	11	35	13	33	19	88	11	1
St. Francis	6	36	58	9	27	46	15	3	26	21	34	19	95	5	0
Stone	19	63	18	4	4	22	36	34	28	11	28	33	82	17	1
Union	16	48	36	10	14	30	35	11	55	20	19	6	95	5	0
Van Buren	20	68	12	8	12	30	32	18	37	13	29	21	90	10	0
Washington	13	62	25	4	7	19	40	30	23	11	29	37	84	16	0
White	15	52	33	8	13	29	41	9	39	16	28	17	82	18	0
Woodruff	7	66	27	11	22	53	14	0	23	24	46	7	97	3	0
Yell, Danville	26	69	5	21	9	24	33	13	40	15	21	24	95	5	0
Yell, Dardanelle	12	56	32	5	12	27	36	20	21	14	34	31	95	5	0
Average	15	53	32	11	15	29	29	16	34	16	28	22	91	9	0

[z] Analysis by 1:7 soil weight:Mehlich-3 volume.
[y] EC = electrical conductivity; which is a measure of soluble salts in 1:2 soil weight:water 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 2001 through August 2002.

SAN	Soil Association	pH			P^z (lb/acre)					K^z (lb/acre)				EC^y (µmhos/cm)		
		<5.5	5.5-6.5	>6.5	<26	26-44	45-100	101-300	>300	<176	176-220	221-350	>350	<100	100-500	>500
		(Percentage of sampled acreage)														
1.	Clarksville- Nixa- Noark	12	63	25	5	10	22	43	20	23	13	31	33	86	13	1
2.	Gepp-Doniphan-Gassville-Agnos	8	46	46	11	16	28	29	16	23	15	29	33	84	15	1
3.	Arkana-Moko	8	51	41	6	10	26	37	21	30	12	23	35	79	20	1
4.	Captina-Nixa-Tonti	13	63	24	3	5	18	40	34	21	11	29	39	81	19	0
5.	Captina-Doniphan-Gepp	5	57	38	6	15	37	32	10	11	16	32	41	90	10	0
6.	Eden-Newnata-Moko	28	62	10	7	8	29	46	10	30	11	32	27	92	8	0
7.	Estate-Portia-Moko	4	51	45	11	10	18	31	30	22	12	25	41	83	17	0
8.	Brockwell-Boden-Portia	9	65	26	12	23	34	22	9	43	13	28	16	94	6	0
9.	Linker-Mountainburg-Sidon	11	61	28	5	13	26	35	21	31	14	27	28	83	16	1
10.	Enders-Nella-Mountainburg-Steprock	16	58	26	6	10	27	42	15	37	14	27	22	85	15	0
11.	Falkner-Wrightsville	32	65	3	16	13	25	36	10	37	8	39	16	88	12	0
12.	Leadvale-Taft	20	54	26	15	13	21	31	20	34	15	26	25	87	13	0
13.	Enders-Mountainburg-Nella-Steprock	30	61	9	22	18	27	23	10	52	12	22	14	96	4	0
14.	Spadra-Guthrie-Pickwick	20	67	13	17	10	25	29	19	41	12	24	23	93	6	1
15.	Linker-Mountainburg	22	59	19	10	13	24	31	22	34	14	27	25	89	11	0
16.	Carnasaw-Pirum-Clebit	23	54	23	7	12	27	35	19	41	17	26	16	85	14	1
17.	Kenn-Ceda-Avilla	33	57	10	17	12	20	29	22	50	13	22	15	96	4	0
18.	Carnasaw-Sherwood-Bismarck	30	58	12	3	9	26	38	24	44	16	24	16	87	13	0
19.	Carnasaw-Bismarck	28	44	30	4	10	26	34	26	46	12	14	28	80	20	0
20.	Leadvale-Taft	32	54	14	34	7	27	19	13	34	15	16	35	94	6	0
21.	Spadra-Pickwick	29	64	7	25	11	23	26	15	42	10	27	21	91	8	1
22.	Foley-Jackport-Crowley	6	56	38	20	31	39	9	1	34	25	30	11	96	4	0
23.	Kobel	9	55	36	15	24	41	19	1	26	22	40	12	98	2	0
24.	Sharkey-Alligator-Tunica	4	45	51	6	21	57	16	0	6	5	16	73	96	3	1
25.	Dundee-Bosket-Dubbs	6	47	47	7	13	48	31	1	20	13	39	28	97	3	0
26.	Amagon-Dundee	10	65	25	1	4	43	49	3	10	9	47	34	96	3	1
27.	Sharkey-Steele	0	41	59	0	15	62	23	0	4	4	25	67	95	5	0
28.	Commerce-Sharkey-Crevasse-Robinsonville	3	39	58	5	11	58	25	1	3	3	29	65	90	10	0
29.	Perry-Portland	4	34	62	6	15	51	26	2	14	14	36	36	96	4	0
30.	Crevasse-Bruno-Oklared	27	27	46	7	20	27	7	39	7	20	20	53	80	20	0
31.	Roxana-Dardanelle-Bruno-Roellen	22	49	29	14	16	30	28	12	37	13	27	23	93	7	0
32.	Rilla-Hebert	4	42	54	3	8	51	37	1	12	15	48	25	97	3	0
33.	Billyhaw-Perry	8	40	52	8	13	43	36	0	20	10	41	29	93	5	2
34.	Severn-Oklared	12	41	47	10	17	43	25	5	20	19	22	39	94	6	0
35.	Adaton	50	25	25	50	25	25	0	0	100	0	0	0	100	0	0
36.	Wrightsville-Louin-Acadia	14	79	7	7	4	18	29	42	39	21	32	8	100	0	0
37.	Muskogee-Wrightsville-McKamie	42	42	16	32	19	19	19	11	36	23	36	5	87	10	3
38.	Amy-Smithton-Pheba	19	51	30	21	11	24	31	13	55	15	15	15	93	6	1
39.	Darco-Briley-Smithdale	12	60	28	0	17	38	31	14	52	12	12	24	86	14	0
40.	Pheba-Amy-Savannah	24	55	21	16	13	18	31	22	50	13	22	15	93	6	1
41.	Smithdale-Sacul-Savannah-Saffell	25	52	23	9	7	15	35	34	43	14	26	17	89	10	1
42.	Sacul-Smithdale-Sawyer	23	52	25	11	15	27	31	16	47	17	22	14	91	8	1
43.	Guyton-Ouachita-Sardis	31	52	17	8	11	24	35	22	47	14	21	18	95	4	1
44.	Calloway-Henry-Grenada-Calhoun	6	33	61	18	30	39	12	1	40	23	28	9	95	5	0

continued

Table 7. Continued.

SAN	Soil Association	pH <5.5	pH 5.5-6.5	pH >6.5	P[z] (lb/acre) <26	P[z] 26-44	P[z] 45-100	P[z] 101-300	P[z] >300	K[z] (lb/acre) <176	K[z] 176-220	K[z] 221-350	K[z] >350	EC[y] (µmhos/cm) <100	EC[y] 100-500	EC[y] >500
		(Percentage of sampled acreage)														
45.	Crowley-Stuttgart	6	35	59	26	37	32	5	0	34	27	28	11	94	6	0
46.	Loring	28	46	26	16	22	28	25	9	40	19	22	19	75	22	3
47.	Loring-Memphis	14	52	34	22	17	32	23	6	24	14	39	23	88	12	0
48.	Brandon	23	54	23	54	0	31	8	7	69	0	8	23	100	0	0
49.	Oktibbeha-Sumter	36	39	25	17	16	24	31	12	39	13	17	31	83	16	1
	Average	18	52	30	13	14	31	28	14	34	14	27	25	91	9	0

[z] Analysis by 1:7 soil weight:Mehlich-3 volume.
[y] EC = electrical conductivity; which is a measure of soluble salts in 1:2 soil weight:water volume.

Table 8. Soil test data by crop for soil samples submitted to the University of Arkansas Soil Testing and Research Laboratory in Marianna from September 2001 through August 2002.

Crop	pH				P[z] (lb/acre)						K[z] (lb/acre)					NO_3-N[y] (lb/acre)				EC[x] (µmhos/cm)			
	<5.5	5.5-6.5	>6.5	Md[y]	26-<26	45-44	101-100	176-300	221->300	Md	<176	100-220	350	>350	Md	<26	100	>100	Md	<100	500	>500	Md
	(Percentage of sampled acreage)																						
Soybean - dryland	12	56	32	6.3	11	22	51	16	0	58	25	23	30	22	227	98	2	0	9	91	9	0	29
Soybean - irrigated	2	34	64	6.8	20	36	40	4	0	41	38	25	26	11	195	98	2	0	8	96	3	1	35
Cotton	3	44	53	6.6	1	3	51	45	0	97	5	11	50	34	305	99	1	0	8	96	4	0	32
Rice	6	41	53	6.6	29	33	35	3	0	37	36	19	28	17	207	88	12	0	7	79	20	1	43
Wheat	22	58	20	6.0	13	17	48	22	0	63	28	18	33	21	233	92	8	0	14	79	18	3	36
Double-crop wheat-soybean - dryland	9	57	34	6.3	2	14	63	21	0	70	7	17	53	23	273	89	11	0	8	73	27	0	29
Double-crop wheat - soybean - irrigated	5	35	60	6.7	10	23	56	11	0	53	29	25	33	13	210	98	2	0	8	89	11	0	35
Warm season grass - establish	19	60	21	6.1	8	7	21	30	34	161	32	13	26	29	243	87	12	1	17	65	32	13	48
Warm season grass - maintain	20	67	13	5.9	9	10	22	31	28	132	35	13	27	25	229	93	7	0	13	77	21	2	39
Cool season grass - establish	16	72	12	6.0	2	6	18	43	31	203	24	13	27	36	281	86	13	1	18	65	32	3	52
Cool season grass - maintain	13	70	17	6.0	5	10	23	38	24	151	27	13	29	31	265	88	12	0	15	71	26	3	45
Grain sorghum	7	52	41	6.4	8	20	49	23	0	68	24	24	31	21	228	98	2	0	9	93	6	1	31
Corn	9	51	40	6.4	6	15	55	23	1	67	21	21	44	14	240	98	2	0	11	78	21	1	38
All garden	10	36	54	6.6	3	5	14	34	44	259	17	11	26	46	326	74	25	1	17	63	28	9	61
Turf and ground cover	19	52	29	6.2	5	11	29	45	10	111	37	17	30	16	209	84	16	0	17	64	32	4	51
Fruit and nut	29	48	23	6.0	15	15	26	30	14	78	43	10	24	23	204	86	14	0	12	80	15	5	44
Vegetable	27	18	55	6.6	18	9	9	18	46	295	46	0	9	45	232	82	18	0	10	75	13	12	49
Other	22	54	24	6.0	16	16	25	27	16	79	38	14	25	23	212	87	12	1	12	77	20	3	42
Average	14	50	36		10	15	35	26	14		28	16	31	25		90	10	0		78	19	3	

[z] Analysis by 1:7 soil weight:Mehlich-3 volume.

[y] Number of plant samples from first to last categories are 463, 1050, 5689, 286, 101, 114, 87, 379, 2267, 1200, 1644, 116, 447, 1277, 951, 118, 8, and 3656.

[x] EC = electrical conductivity; which is a measure of soluble salts in 1:2 soil weight:water volume.

Table 9. Fertilizer consumption in Arkansas counties from 1 July 2001 through 30 June 2002[z].

County	Total	County	Total
	(tons)		(tons)
Arkansas	87,809	Lee	27,705
Ashley	19,564	Lincoln	13,632
Baxter	4,285	Little River	769
Benton	14,886	Logan	3,880
Boone	7,553	Lonoke	44,048
Bradley	3,065	Madison	6,508
Calhoun	352	Marion	1,380
Carroll	4,133	Miller	9,386
Chicot	20,242	Mississippi	70,490
Clark	5,061	Monroe	33,709
Clay	44,468	Montgomery	557
Cleburne	3,490	Nevada	2,484
Cleveland	155	Newton	1,196
Columbia	776	Ouachita	126
Conway	8,990	Perry	2,316
Craighead	49,097	Phillips	68,431
Crawford	12,251	Pike	13,445
Crittenden	22,878	Poinsett	75,810
Cross	47,782	Polk	1,949
Dallas	13	Pope	3,107
Desha	40,254	Prairie	36,159
Drew	6,520	Pulaski	12,638
Faulkner	5,895	Randolph	21,455
Franklin	4,425	Saline	4,135
Fulton	2,880	Scott	1,534
Garland	186	Searcy	1,423
Grant	279	Sebastian	173
Greene	28,437	Sevier	5,404
Hempstead	5,555	Sharp	1,434
Hot Spring	1,779	St. Francis	52,344
Howard	2,073	Stone	3,452
Independence	11,940	Union	1,645
Izard	4,615	Van Buren	10,212
Jackson	37,238	Washington	6,040
Jefferson	37,234	White	47,870
Johnson	2,305	Woodruff	30,841
Lafayette	6,857	Yell	2,090
Lawrence	28,457		

[z] Arkansas Distribution of Fertilizer Sales by Counties July 1, 2001-June 30, 2002, Arkansas State Plant Board, Division of Feed and Fertilizer, Little Rock, Arkansas and University of Arkansas AES, Fayetteville, Arkansas.

Table 10. Fertilizer nutrient and formulation consumed in Arkansas from 1 July 2001 through 30 June 2002[z].

Fertilizer	Bulk	Bagged	Fluid	Totals
	(tons)			
Mixed	397,421	42,571	14,299	454,291
Nitrogen	525,157	5,201	113,340	643,698
Phosphate	21,129	157	0	21,286
Potash	44,887	560	49	45,496
Other	35,479	2,689	613	38,781
Totals	1,024,073	51,178	128,300	1,203,551

[z] Arkansas Distribution of Fertilizer Sales By Counties July 1, 2001-June 30, 2002, Arkansas State Plant Board, Division of Feed and Fertilizer, Little Rock, Arkansas and University of Arkansas AES, Fayetteville, Arkansas.

The Influence of Nitrogen Fertilizer and Wheat-Straw Management on Double-Cropped Soybean Germination and Development

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

RESEARCH PROBLEM

Many eastern Arkansas producers who typically grow soybean (*Glycine max* L.) in a wheat (*Triticum aestivum* L.)-soybean double-crop system choose to burn wheat residue immediately after harvest as a means of seedbed preparation. Burning residue adds a considerable amount of carbon dioxide (CO_2) to the atmosphere and prevents the return of much needed carbon (C) to the soil. Alternative wheat-residue management practices have the potential to be as, if not more, environmentally sound, economical, time-efficient, and productive as the traditional practice of burning wheat residue prior to growing a soybean crop. Alternative wheat-residue management practices may also improve the quality of the soil resource in the delta region of eastern Arkansas.

BACKGROUND

The Arkansas Agricultural Statistics Service estimated that approximately 3.0 million acres of soybean were planted in 2001 in Arkansas. The bulk of this area is in eastern Arkansas, and one-third of the soybean acreage are produced in a soybean-wheat double-crop production system. Benefits of this particular production system include: increased profits due to more efficiently used resources, reduced soil-water losses, and enhanced utilization of tillage methods that conserve soil, water, and energy (Sanford, 1982).

Though many farmers choose to burn wheat residue immediately after harvest as a simple means of seedbed preparation and to facilitate planting and pest control, burning residue is of little agronomic benefit (NeSmith et al., 1987). Burning adds CO_2 to the atmosphere and prevents the return of much needed C to the soil, and soil C and organic matter are at quite low levels in eastern-Arkansas soils. Returning organic materials to the soil would not only enhance soil quality but also would have positive environmental benefits. The positive results may include decreased erosion, prevention of agricultural runoff, and decreased amounts of CO_2 released to the atmosphere.

Despite the popularity of burning in eastern Arkansas, some farmers have adopted alternative post-wheat harvest operations. New and improved equipment has made planting more feasible in high-residue conditions; therefore, some farmers opt to plant into wheat stubble after conservation tillage (CT) or no-tillage (NT) field preparation methods. These methods are environmentally sound and have been proven to produce comparable yields while reducing production costs. As compared to CT, NT requires less labor and energy and decreases the need for certain machinery.

We hypothesized that reduced or no-tillage methods paired with non-burning of residue would result in similar soybean growth and development compared to conventional production system practices. The objective of this study was to evaluate the effect of various wheat residue-management practices on soybean growth and development.

PROCEDURES

Research was conducted on similar silt-loam Fragiudalfs in eastern Arkansas at the Pine Tree (PTBS) Branch and Cotton Branch (CBES) Experiment Stations. The previous crops grown were grain sorghum (*Sorghum bicolor* L.) and soybean at the PTBS and CBES, respectively. Prior to wheat planting, the plot area was disced twice followed by landplaning and field cultivation at the PTBS and disced twice followed by field cultivating at the CBES.

A split-strip plot was designed with six replications. The treatments evaluated were NT and CT, burning and non-burning wheat residue, and high and low wheat residue levels. All eight treatment combinations were included in the experimental design.

FIELD MANAGEMENT

Before wheat planting at the CBES, a 200 lb/acre broadcast application of 9-23-30 blended fertilizer was applied. In Fall 2001, the Coker 9663 wheat variety was drill seeded with a 6-inch row spacing at a rate of 98 lb/acre at the PTBS and 100 lb/acre at the CBES. In Spring 2002, 10- by 20-ft plots were established. In early March, all plots were fertilized with a 90 lb N/acre broadcast application of urea (46% N). To obtain different levels of aboveground wheat-residue production, twenty-four of the forty-eight plots were fertilized with an additional 90 lb N/acre as urea during the late-jointing stage.

Wheat was harvested in early June at both locations. A plot combine was used to collect the entire length of the middle 5 ft of each plot. After the wheat harvest, the burning treatment was imposed. After burning, the conventional tillage treatment was imposed, which included discing twice and seedbed smoothing.

Soybeans were planted on 17 and 18 June at the PTBS and CBES, respectively. The glyphosate-resistant Pioneer 35B82 soybean variety of maturity group 5.3 was planted at a seeding rate of 89 lb/acre at the PTBS and 42 lb/acre at the CBES. A higher seeding rate was needed at the PTBS because of low soil-moisture conditions at the time of planting. Soybeans were planted using a no-till drill at both locations with a row spacing of 7.5 inches. Plots at the PTBS were sprinkle-irrigated about 10 d after planting to insure adequate stands. Plots were further irrigated by flooding at the PTBS three times throughout the growing season. Plots at the CBES were furrow-irrigated three times throughout the season. Weeds and insects were controlled using University of Arkansas Cooperative Extension Service recommendations.

Following wheat harvest and residue burning, but prior to cultivation and soybean planting, aboveground wheat-residue levels were measured by cutting and collecting the residue within a 2.7-sq. ft. metal frame. The residue sample was subsequently oven dried at 158°F (70°C) for 48 hrs and weighed to express the residue level on a lb/acre basis.

Stand counts (i.e., plant population) were obtained at 8 and 30 d after planting by averaging the number of soybean plants within two 3.3-ft (1-m) sections of row in opposite corners of the plots. Vegetative growth stages were determined 30 d after planting using a soybean growth-staging system (Anonymous, 2000), which is based on the number of fully developed trifoliates above the first node. Leaf area index (LAI) was measured in the soybeans 86 d after planting using a LI-COR LAI-2000 plant canopy analyzer (Li-Cor, Inc., Lincoln, NE; Wells and Norman, 1991).

Soil temperature at a 1-inch depth was measured periodically throughout the growing season with a probe thermometer. Volumetric soil moisture content was also measured periodically throughout the soybean growing season in the 0- to 2.5-inch depth range using a Theta Probe, which records dielectric voltage readings and converts them to volumetric water contents using a soil-specific calibration equation.

Treatment effects (i.e., tillage, burning, and residue level) and their interactions were determined by analysis of variance using SAS software (SAS 8.1, SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Wheat-Residue Level

Despite the addition of N at 90 and 180 lb N/acre to achieve two different amounts of aboveground wheat residue, the N-fertilization rate (i.e., low versus high) did not significantly affect the amount of wheat residue that remained on the soil surface following wheat harvest. The low-residue-level treatment averaged 3,496 (± standard error = 328) lb/acre of wheat residue, while the high-residue-level treatment averaged 2906 (±212) lbs/acre of wheat residue.

Soybean Seedling Populations

Neither tillage nor wheat-residue level significantly affected soybean stand counts (i.e., plant population) by 8 d after planting at either location. However, burning significantly affected ($P = 0.031$) soybean populations at the CBES (Fig. 1a), but not at the PTBS (Fig. 1b). Soybean populations averaged 46,748 (±4,250) and 23,374 (±2,125) plants/acre for the burned and non-burned treatments, respectively, at the CBES and averaged 53,122 (±8,500) and 61,622 (±12,749) plants/acre for the burned and non-burned treatments, respectively, at the PTBS. Neither soil temperature nor moisture (data not shown) differed significantly in the burn treatments at either location to explain differences in soybean population 8 d after planting.

By 30 d after planting, there was still a significant burning effect ($P = 0.022$) at the CBES, where the soybean population averaged 59,497 (±6,375) and 40,373 (±2,125) plants/acre for the burn and no-burn treatments, respectively (Fig. 1a), but not at the PTBS (Fig. 1b). However, there was a significant tillage effect ($P = 0.029$) at the PTBS, where the soybean population averaged 282,612 (±21,249) and 78,621 (±10,624) plants/acre for NT and CT, respectively, but not at the CBES. Wheat-residue level did not affect soybean populations 30 d after planting at either location.

Vegetative Growth Stages

Soybean growth and development through the vegetative growth stages varied by location. At the CBES, the soybean crop was at a significantly more advanced vegetative growth stage in the NT versus CT ($P = 0.013$), no-burn versus burn ($P = 0.007$), and low-residue versus high residue level ($P = 0.008$) treatments (Fig. 2). There were significant residue level × tillage ($P = 0.041$), residue level × burn ($P = 0.044$), and residue level × tillage × burn ($P = 0.025$) interactions at the CBES. In contrast, there were no significant treatment effects or treatment interactions on soybean vegetative growth stages at the PTBS. There were also no consistent trends in soil temperature and/or moisture (data not shown) within 30 d after planting to suggest that significant treatment differences in soybean vegetative growth stages at the CBES were related to treatment-induced differences in soil temperature or moisture.

Leaf Area Index

By 86 d after planting, any treatment effects on soybean growth and development throughout the growing season should have either manifested themselves or the soybean crop should have adjusted to the imposed treatments and compensated for early-season differences to mask late-season treatment differences in soybean growth and development. Despite early-season differences in soybean populations and vegetative growth stages at the CBES, there were no treatment effects on LAI 86 d after planting (Fig. 3). Mean LAI ranged from 3.25 (±0.2) to 3.80 (±0.2) $m^2\ m^{-2}$ across all treatments at the CBES. In contrast, tillage ($P = <0.001$), burning ($P = 0.008$), and wheat-residue level ($P = 0.013$) significantly affected soybean LAI at the PTBS despite fewer early-season differences in growth and development at the PTBS compared to the CBES. In addition, there was a significant ($P = 0.009$) tillage × residue level interaction. Effects on soybean LAI indicate that the treatments alone or in some combination affected the canopy architecture, which influences light interception and photosynthesis and may or may not ultimately affect soybean yield.

PRACTICAL APPLICATIONS

Soybean growth and development response to imposed residue management treatments varied between study locations, but a few generalities were apparent. Tillage and residue burning affected soybean plant populations, but wheat-residue level did not. Tillage, residue burning, and wheat-residue level all affected soybean vegetative growth stage and LAI. After a single wheat-soybean cropping cycle, enough evidence exists to suggest that alternative wheat-residue management practices affect soybean growth and development equally, and in some cases more positively, when compared to the common practice of burning wheat residue followed by conventional tillage prior to sowing the subsequent soybean crop.

ACKNOWLEDGMENTS

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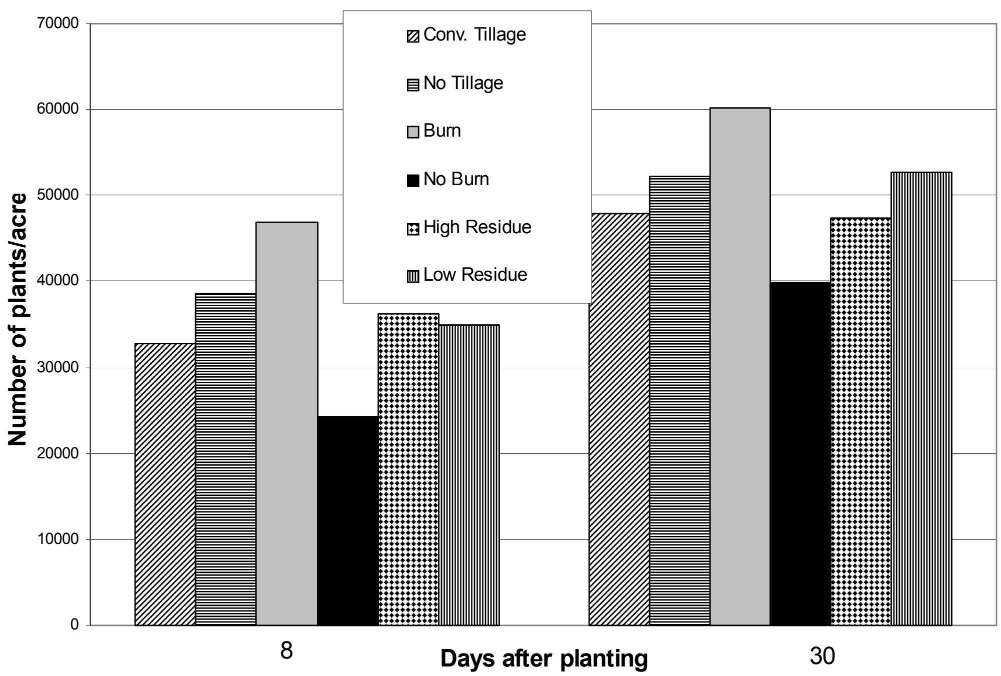

Fig. 1a. Standcounts at 8 and 30 days after planting, Cotton Branch Station.

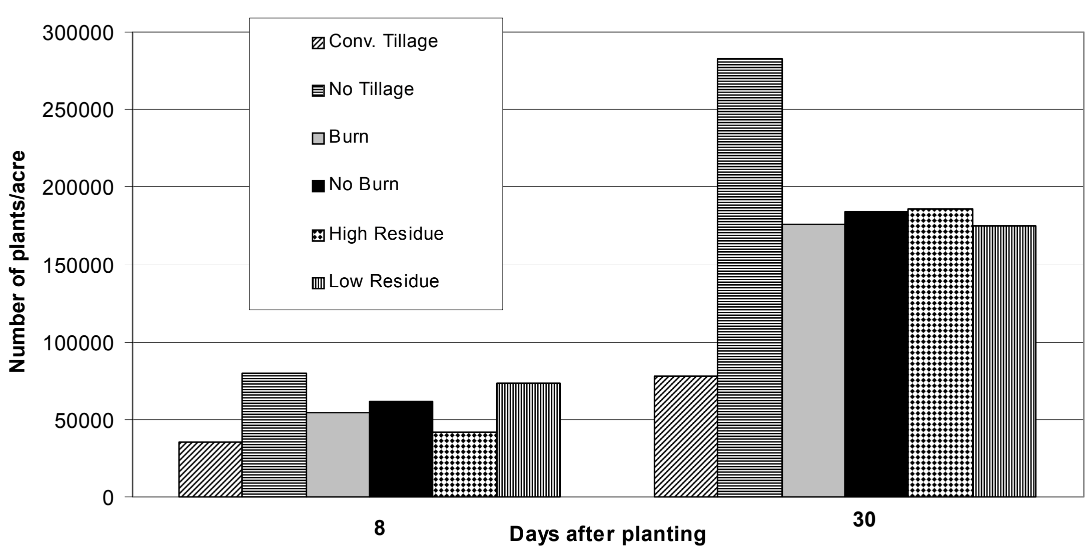

Fig. 1b. Standcounts at 8 and 30 days after planting, Pine Tree Station.

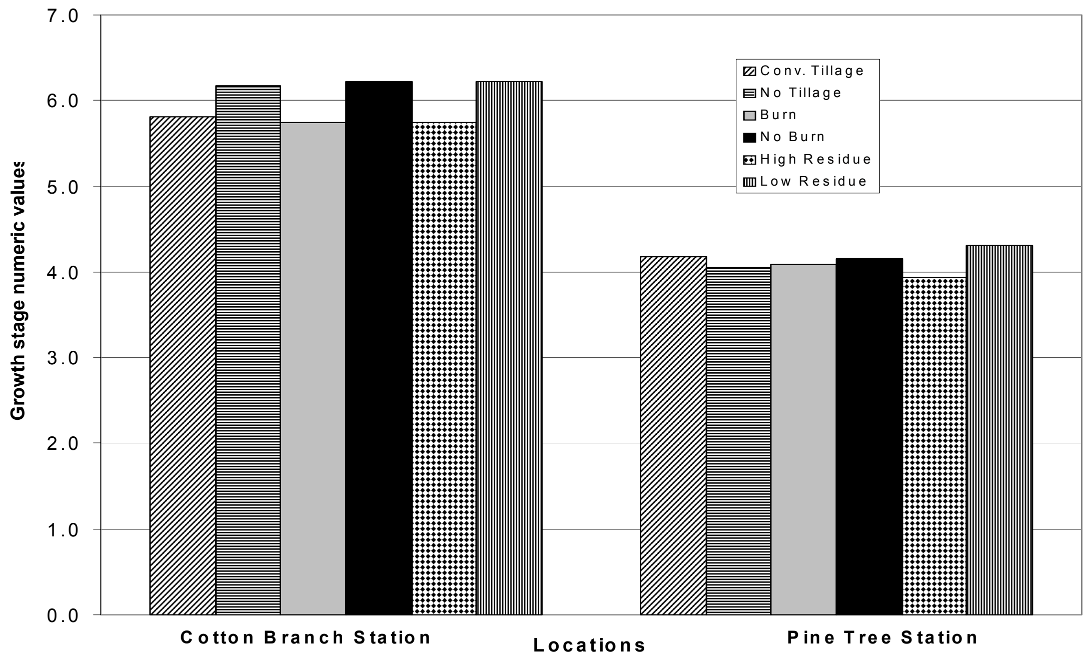

Fig. 2. Vegetative growth stages at 30 days after planting.

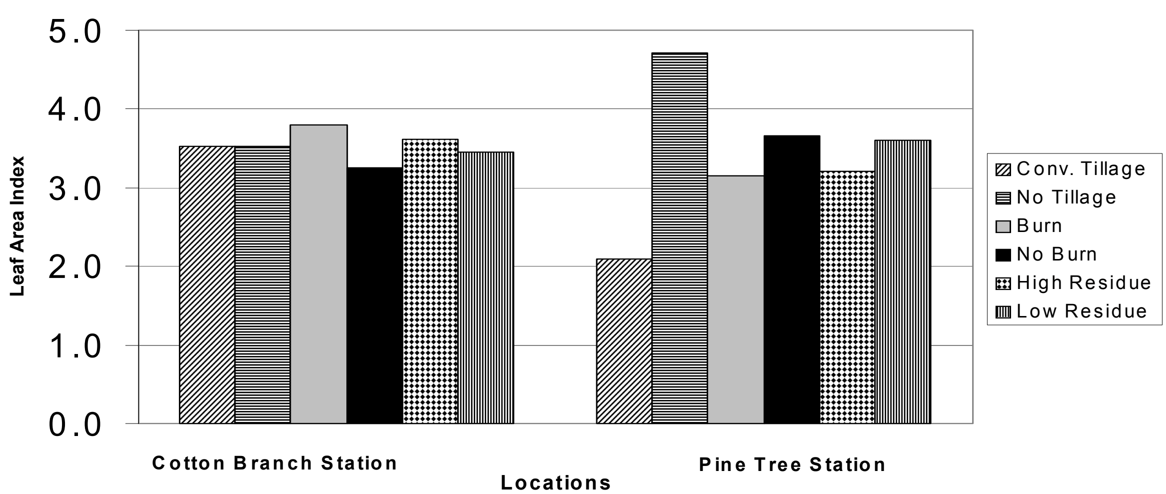

Fig. 3. Leaf area indices at 30 days after planting.

A Four-Year Study of Cotton Yield Response to Potassium Nutrition With or Without Irrigation

D. L. Coker and D. M. Oosterhuis

RESEARCH PROBLEM

Potassium (K) nutrient deficiency costs the cotton (*Gossypium hirsutum* L.) producer in terms of fiber yield and quality. Throughout the growing season, climatic and numerous other factors may regulate the occurrence of and plant response to K deficiency. Sporadic K deficiencies have been noted in Arkansas cotton as the developing bolls exert a greater demand on plant K resources. Additional information is needed about the use of supplementary, foliar-applied K to rectify K deficiencies in field-grown cotton under varying soil K and moisture levels. Thus, our study objective was to evaluate the potential response of cotton yield and quality to foliar K application under water-deficit stress and soil K deficiency.

BACKGROUND INFORMATION

The change to modern cotton cultivars, which fruit in a shorter period of time, mature earlier, and have greater total-K requirements, has placed an emphasis on understanding plant uptake and utilization of K throughout the growing season (Oosterhuis, 1995). Although K may be taken up in luxury amounts by the cotton plant prior to peak demand, K deficiencies often occur late in the growing season when the large, developing boll load becomes the dominant sink for available K. Factors that interfere with the strong source-sink relationship of K in cotton will directly influence the efficiency of K use and the potential for high lint yields (Mullins and Burmester, 1990; Oosterhuis, 1995). Although yield and economic advantages of timely foliar-K applications to supplement soil-applied K have been documented (Oosterhuis, 1999; Weir, 1999), the impact of mid-season water-deficit stress on the efficiency of foliar-K uptake and yield response to foliar-K fertilization needs further investigation.

RESEARCH DESCRIPTION

Cotton growth, K partitioning, physiology, and lint yield under varying water levels and K fertility were studied in 1999 in field plots located at Rohwer (Coker and Oosterhuis, 1999), in 2000 at Clarkedale and Rohwer (Coker and Oosterhuis, 2000), in 2001 at Clarkedale (Coker et al., 2002), and at Fayetteville in 2002. This report describes the 2002 study with reference to the previously conducted studies (cited above) with identical treatments. Eight treatment combinations of well-watered (irrigated) or dryland (non-irrigated) conditions; high (preplant, soil-applied K) or low-soil K (unfertilized or no preplant K); and with or without foliar K were arranged in a split-split plot design with five or six replications. In 2002, the cultivar Suregrow 215 BR was planted on a well-drained Captina silt loam on the Main Agricultural Experiment Station Farm located in Fayetteville, AR. Each plot consisted of four 30-ft long rows spaced 39 inches apart. Preplant granular KCl fertilizer was hand broadcast to designated plots (high soil K) prior to planting at recommended rates based on University of Arkansas fertilizer recommendations for cotton. The average Mehlich 3 extractable soil K was 241 lb K/acre (Table 1). Preplant K fertilizer application rates ranged from 50 to 96 lb K_2O/acre. Foliar KNO_3 was applied (4.4 lb K_2O/acre/week or 10 lb KNO_3/acre) for four consecutive weeks starting one week after first flower with a CO_2 backpack sprayer calibrated to deliver 10 gal/acre. Irrigation events were scheduled in well-watered plots according to the University of Arkansas Irrigation Scheduling Program. An infrared thermometer was used to measure the temperature of the uppermost, full-expanded main-stem node leaves starting at the first flower stage in all plots to monitor plant stress (data not shown). At major phenological stages, measurements were made of photosynthesis, specific leaf weight, ^{13}C discrimination, chlorophyll, adenosine tri-phosphate, soluble carbohydrates, membrane integrity, antioxidant enzymes, and Rubidium translocation in the uppermost fully-expanded leaves. Final lint yield and components of yield were determined from each plot by hand picking a 3.28 ft length from each of the two center rows and counting and weighing the bolls. Lint yield and components of yield comparisons were made using the SAS General Linear Model procedure and PDIFF option within LSMEANS statements.

RESULTS

Although we observed similar yield responses to soil-applied K at Fayetteville in 2002, the yield responses to foliar-applied K were noticeably greater compared to responses observed during previous seasons at Rohwer or Clarkedale (Table 1). Foliar-applied K increased lint yield ($P \leq 0.05$) by 211 lb/acre when preplant K fertilizer was applied (high soil K). When preplant K fertilizer was not applied (low soil K), the mean lint yield response to foliar-applied K was approximately 90 lb/acre, although it was not statistically different than lint yield without foliar-applied K. Thus far, our studies have shown a small lint yield increase to foliar-applied K when preplant K was not applied (low soil K) as opposed to when preplant K fertilizer was applied (high soil K) when averaged across all three test sites during the past four years.

In 2002, cotton lint yields were significantly greater ($P \leq 0.05$) when foliar-K applications were made to dryland (rainfed or non-irrigated) cotton, but not to irrigated cotton. However, when averaged across all three test sites, dryland-cotton lint yields have tended to show slightly greater response to foliar-K application as compared to irrigated-cotton yields. Lint yield response to soil-applied K was significant ($P \leq 0.05$) for irrigated (well-watered) cotton and tended to be positive, although not statistically significant, under dryland conditions in 2002. Across all locations and growing seasons, soil-applied K (high soil K) has increased the mean irrigated cotton lint yield by 5.9%, but had no significant effect on dryland-cotton yields in our studies.

PRACTICAL APPLICATION

Thus far, our studies have shown that the preplant soil K status should be strongly considered when making decisions about foliar K fertilization. Studies during the past three years show significant responses to foliar-applied K on soils with preplant soil-test K <250 lb K/acre, which supports our previous findings (Oosterhuis, 1995). Our results also show that the potential for foliar-K feeding to increase cotton lint yield of dryland (non-irrigated) cotton is similar to that observed for irrigated cotton in the Mississippi Delta. Our current studies also show that soil-applied K fertilizer was beneficial to cotton-lint yields produced under irrigated, but not necessarily dryland conditions in plots where the preplant soil-test K values ranged from medium to high (>250 lb K/acre, Mehlich 3 soil K). Hence, the use of appropriate preplant, soil-applied K fertilizer rates may be particularly important to maximize cotton yields under irrigated conditions. In contrast, foliar-applied K, which can stimulate root uptake of soil K, can be beneficial to cotton-lint yield under dryland or irrigated conditions depending on preplant soil test K values.

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Support for this research was provided by the Arkansas Fertilizer Tonnage Fees (administered by Soil Test Review Board), the Potash and Phosphate Institute, and IMC Global. We thank Larry Fowler for contributing to the management of these studies and Scott Brown for helping with physiological measurements.

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Table 1. Yield response of field-grown cotton over four seasons to mid-season foliar K and preplant soil-applied K averaged over the water, soil K, and foliar K treatments, respectively, at the Rohwer, Clarkedale (Clark), and Fayetteville (Fay) locations since 1999.

Treatment	Lint yield						
	Rohwer 1999	Rohwer 2000	Clark. 2000	Clark. 2001	Fay. 2002	Mean	Mean difference
	(lb/acre^{-1})						[lb/acre (%)]
Avg. over water[z]							
High soil K, no foliar K	1135	1123	948	1359	1286	1170	
High soil K, with foliar K	1133	1116	956	1342	1497[y]	1209	+39(3.3%)
Low soil K, no foliar K	1113	1088	887	1287	1239	1123	
Low soil K, with foliar K	1153	1074	985[y]	1359	1331	1180	+57(5.1%)
Avg. over soil K[z]							
Well watered, no foliar K	1366	1452	1241	1434	1354	1369	
Well watered, with foliar K	1394	1448	1292	1446	1416	1399	+30(2.2%)
Dryland, no foliar K	882	758	593	1212	1171	923	
Dryland, with foliar K	894	742	649	1255	1412[y]	990	+67(7.3%)
Avg. over water and soil K							
No foliar K	1126	1105	917	1323	1262	1147	
With foliar K	1143	1094	970	1350	1414[y]	1194	+47(4.1%)
Avg. over foliar K							
Dryland, high soil K	847	724	640	1228	1336	955	
Dryland, low soil K	929	776	602	1239	1247	957	-2(0.2%)
Well watered, high soil K	1421	1514	1264	1473	1447	1424	
Well watered, low soil K	1338	1386[y]	1269	1407	1323[x]	1345	+79(5.9%)
Water x soil K	[w]	[w]	-	-	-		
Avg. over water and foliar K							
High soil K	1134	1119	952	1350	1391	1189	
Low soil K	1133	1081	936	1323	1285[x]	1152	+37(3.2%)
Preplant soil K level (lb/acre)							
Well watered	264	334	249	263	241	270	
Dryland	253	336	249	289	241	274	

[z] No significant (P≤0.05) interactions observed between main effects.
[y] Significant at P≤0.05 for the paired treatments.
[x] Significant at P≤0.10 for the paired treatments.
[w] Significant at P≤0.05 for treatment interaction ("-" = no interaction).

Phosphorus Fertilization and Previous Crop Effects on Nutrient Uptake and Grain Yield of Wheat

R.E. DeLong, N.A. Slaton, M.M. Anders, and W.F. Johnson, Jr.

RESEARCH PROBLEM

Fertilizer recommendations based on routine soil test information require constant correlation and calibration to ensure that accurate and economic guidelines are provided to growers. Soft red winter wheat (*Triticum aestivum* L.) grown in Arkansas commonly exhibits P deficiency symptoms in January and February when soils are cold and wet. A number of factors including the crop grown preceding wheat in the rotation can influence the P nutrition and fertilizer requirements of wheat. The objective of this study was to evaluate the effect of P fertilization on wheat growth, P uptake, and grain yield on two soils when following different crops in the rotation. Ultimately, the goal of this project is to develop a database on Mehlich 3-extractable soil P and wheat response to P fertilization.

BACKGROUND INFORMATION

In Arkansas, the crop grown before seeding soft red winter wheat is perceived to affect wheat growth, nutrition, and grain yield. Rice (*Oryza sativa* L.), soybean [*Glycine max* (L.) Merr.], grain sorghum [*Sorghum bicolor* (L.) Moensch], and corn (*Zea mays* L.) are the most common crops grown preceding wheat. Previous research has shown that wheat following flood-irrigated rice generally requires P fertilizer to produce maximum grain yields (Wells et al., 1989; DeLong et al., 2001). University of Arkansas fertilizer recommendations are currently based on soil nutrient concentrations from a modified Mehlich 3 extraction procedure (1:7 extraction ration rather than 1:10), but we are considering changing to the published 1:10 extraction ratio to be consistent with other laboratories that use this extraction procedure. Therefore, efforts are underway to collect correlation and calibration data for a number of crops, including wheat, to refine fertilizer recommendations when this change is made.

PROCEDURES

Studies were established in the fall of 2001 at the Cotton Branch Experiment Station (CBES), Marianna, AR, on a Calloway (fine-silty, mixed, active, thermic Aquic Fraglossudalfs) silt loam and the Rice Research and Extension Center (RREC), Stuttgart, AR, on a Dewitt (fine, smectitic, thermic Typic Albaqualfs) silt loam. The treatment factors were soft red winter wheat cultivar ('NK9663' and 'P26R24') and P fertilizer rate (0, 25, 50, 75, and 100 lb P_2O_5/acre applied as triple super phosphate). At each site, two separate studies were established with wheat seeded following different summer crops. At the CBES wheat followed sorghum and soybean and at the RREC wheat followed rice and soybean.

Wheat was seeded into conventional tilled seedbeds at the CBES on 1 November 2001 and the RREC on 26 October 2001 at 100 lb/acre. Before P fertilizer was applied, soil samples were collected to a depth of 15 cm in the unfertilized control plots and extracted with Mehlich 3 (1:10 extraction ratio and analyzed by ICAP) for P and other soil nutrient concentrations (Table 1). Phosphorus fertilizer treatments were applied to the soil surface 7 to 10 days after seeding. Fall N, 45 lb N/acre as urea, was applied to wheat that followed rice and grain sorghum in the rotation. Spring N was applied at the rate of 60 lb N/acre as ammonium sulfate at Feekes scale 5 and 60 lb N/acre as urea at Feekes scale 7. Whole plant samples for total dry-matter accumulation were collected from a 3-linear ft row at Feekes scale 5 (tillering), 10.1 (heading), and 11.4 (maturity). Samples were oven-dried at 60°C to a constant weight, weighed, ground, digested and analyzed for nutrient concentrations. Total P uptake was calculated by multiplying wheat dry matter/acre by wheat tissue P concentration. Only total P uptake at Feekes growth scale 10.1 is reported. At maturity, a small plot combine was used to harvest wheat for grain-yield determination. Grain yields were adjusted to a uniform 12% moisture content for statistical analysis. The treatments were arranged as a randomized complete block, 2 (cultivar) × 5 (P rate) factorial design with 4 replications. Each location and previous crop were analyzed separately.

RESULTS AND DISCUSSION

The interaction between cultivar and P fertilizer rate was not significant at any study site. At both locations, wheat cultivar P26R24 produced numerically or significantly higher grain yields than NK9663, regardless of the previous crop (Table 2). Application of P fertilizer resulted in numerical grain-yield increases at both locations, regardless of the previous crop. Significant grain-yield increases from P fertilizer rate, averaged across cultivars, occurred only at the RREC when wheat followed rice in the rotation. Application of 50 lb P_2O_5/acre significantly increased grain yields compared to the untreated check. Based on current soil-test guidelines for P, P fertilizer would have been recommended for wheat grown at the RREC, but not at the CBES. Although wheat yields between previous crops were not statistically compared at each location, grain yields were numerically higher following soybean compared to rice and sorghum, indicating the previous crop has a significant impact on wheat grain yields. Grain yields were also numerically higher at the CBES compared to the RREC. Although wet field conditions and abnormally cool February temperatures did apparently injure wheat in these studies, the conditions may have limited grain yield potential and potential responses to P fertilization.

At Feekes scale 5, wheat following soybean at the CBES showed prominent P deficiency symptoms, but P-deficiency symptoms were not observed after Feekes scale 7. In contrast, wheat plants at the same growth stage at the CBES following sorghum showed no or few P-deficiency symptoms. Wheat following soybean had lower P tissue concentrations (data not shown), but lower total dry-matter accumulation (data not shown) than wheat following sorghum, which diluted the tissue P and may have contributed to the expression of P-deficiency symptoms. Increased wheat growth after soybean at both locations may also be associated with the relative availability of soil N, P, or both N and P as influenced by previous crop residues or management practices. Also, wheat at the RREC did not exhibit pronounced P deficiency symptoms despite having the lowest soil-test P.

Total P uptake at Feekes scale 10.1 was statistically equal between the two cultivars, averaged across P application rates, in all four studies (data not shown). At Feekes scale 10.1, total P uptake was not affected by P fertilizer rate for wheat following sorghum at the CBES (Table 3). When wheat followed soybean at the CBES or followed soybean and rice at the RREC, P fertilizer rate significantly ($P<0.10$) affected dry-matter accumulation (Table 3). Application of 50 lb P_2O_5/acre significantly increased P uptake compared to the unfertilized control in all three studies. When wheat followed rice at the RREC, the P fertilizer rates that significantly increased total P uptake also significantly increased wheat grain yields (Table 2).

Although previous crops and locations were not compared, P uptake was numerically higher at the CBES than the RREC and at the RREC the P uptake was greater when wheat followed soybean (Table 3). The crop rotations and soil chemical properties are different between these two sites. At the CBES, Mehlich 3 P was much higher than at the RREC (Table 1). The flood irrigation used for rice production at the RREC decreases P availability and soil test P, which partially explains why wheat following rice consistently requires P fertilization to maximize grain yields.

PRACTICAL APPLICATIONS

Current soil test P guidelines for wheat recommend P fertilization of wheat when Mehlich 3 P (1:7 ratio) is <50 mg P/kg (100 lb P/acre), which corresponds to approximately 70 mg P/kg (140 lb P/acre) (Baker et al., 2002). Based on the converted critical soil test P for wheat the recommendations correctly predicted wheat-yield response to P fertilization at only one (RREC wheat following rice) of four locations. Additional data are needed to accurately correlate and calibrate wheat-yield response to Mehlich 3 soil P and P fertilizer rate. The data also support observations that P fertilizer recommendations should be calibrated for soil-test P and the previous crop to provide wheat growers with accurate fertilizer recommendations for soft red winter wheat grown in various cropping systems in Arkansas.

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Table 1. Selected soil chemical properties before P fertilization of a Calloway silt loam at the Cotton Branch Experiment Station (CBES) and a Dewitt silt loam at the Rice Research and Extension Center (RREC) in 2001-2002.

	Soil test values			
Location - previous crop	pH[z]	P[y]	Ca[y]	Mg[y]
	--------- (Mehlich 3 mg kg^{-1}) ---------			
CBES - sorghum	7.2	54	1,228	145
CBES - soybean	6.7	53	855	118
RREC - rice	6.3	9	1,034	136
RREC - soybean	6.4	14	1,054	148

[z] Soil pH measured in 1:2 soil weight: water volume mixture by glass electrode.
[y] Extraction ratio was 1:10 soil weight:Mehlich 3 solution volume.

Table 2. Wheat grain yields by cultivar, averaged across P rates, and P rates, averaged across cultivars, for previous crops grain sorghum, soybean, and rice at the CBES and RREC in 2002.

	Grain yield at maturity			
Cultivar or	CBES		RREC	
P fertilizer	Sorghum	Soybean	Rice	Soybean
(lb P_2O_5/A)	---------- (bu/acre) ----------			
Cultivar				
NK9663	60.1	67.9	46.4	52.0
P26R24	68.9	71.2	47.7	57.3
$LSD_{(0.05)}$	2.2	2.4	NS[z]	4.8
P-value	0.01	0.01	0.57	0.03
P fertilizer rate				
0	62.8	68.3	39.9	51.8
25	65.8	69.8	44.4	57.5
50	65.6	68.5	51.4	55.3
75	63.9	69.8	49.9	52.3
100	64.7	71.4	50.1	55.8
$LSD_{(0.10)}$	NS	NS	7.1	NS
P-value	0.44	0.49	0.0509	0.57

[z] NS = not significant.

Table 3. Total P uptake by wheat as affected by P rate, averaged across cultivars, at Feekes scale 10.1 (Heading) for previous crops grain sorghum, soybean, and rice at the CBES and RREC in 2002.

	Total P uptake at Feekes Scale 10.1			
	CBES		RREC	
P fertilizer rate	Sorghum	Soybean	Rice	Soybean
(lb P_2O_5/A)	(lb P/acre)			
0	34.5	24.7	5.4	11.0
25	31.6	27.3	6.0	11.8
50	32.2	33.7	7.0	12.9
75	41.4	34.9	8.4	16.3
100	33.6	36.4	8.4	13.2
$LSD_{(0.10)}$	NS[z]	8.0	1.6	3.0
P-value	0.2594	0.0779	0.0053	0.0519

[z] NS = not significant.

Soybean Yield Response to Foliar- and Soil-Applied Boron Rates

L. Espinoza, M. Mozaffari, N.A. Slaton, R. Wimberly, R. Thompson, and R. Klerk

RESEARCH PROBLEM

Boron (B) is one of the essential micronutrients required for optimal crop production. Its role in plants is still not well understood due to the low plant requirement for B. However, B has been shown to help preserve membrane stability of cells, increase ion transport capacity, and is involved in pollen germination (Al-Molla, 1985). The identification and continued occurrence of B deficiency symptoms in some Arkansas soybean [*Glycine max* (Merr.) L.] production regions has prompted researchers to initiate trials to address the need for B fertilization of soybean in Arkansas. The primary objective of these preliminary studies was to assess the yield response of soybean to selected soil- and foliar-applied B rates.

BACKGROUND INFORMATION

Boron deficiency of soybean was first documented two years ago in some soybean production areas in Arkansas (Slaton et al., 2002). However, this nutritional problem probably was present, but less widespread, long before it was identified. Boron deficient fields were again identified during the 2002 season, and as in the previous season, they tended to be localized in counties north of I-40 and West of Crowley's ridge. Fields with severe B-deficient conditions experienced losses equivalent to 50% of their typical yields. Deficiency symptoms appeared across entire fields or as isolated spots in soybean fields that were otherwise healthy.

Visual deficiency symptoms include wrinkled leaves, stunted plants with short internodes, and death of the terminal, with the severity of symptoms varying among fields. A more detailed description of the symptoms is provided by Slaton et al. (2002). Deficiency symptoms during the 2001 season were observed after the first irrigation, close to the V10 growth stage. During the 2002 season however, symptoms were identified as early as the V6 growth stage.

PROCEDURES

A series of studies was established on three farmer fields to assess the yield response of soybean to various soil- and foliar-applied B rates. The Poinsett County site had no previous history of B deficiency. The Cross County 1 site exhibited B-deficiency symptoms in 2000 (Lanny Ashlock, personal communication). The test at the Cross County 2 site was established after severe B-deficiency symptoms were noticed at the V6 growth stage. Soil samples (4-inch sample depth) were extracted using the Mehlich 3 procedure at an extraction ratio of 1:10.

At the Poinsett County site (Skip Covington farm, Calloway silt loam) the grower drill-seeded (7- inch row spacing) soybean D&PL 5915 on 10 June 2002. Plots 15 ft wide by 30 ft long were established at the V2 growth stage. Boron (Solubor) was foliar applied at rates of 0.5, 1.0, and 2.0 lb B/acre at the V2 (2 July), V10 (29 July), and split applied at V2 and V10 using a backpack CO_2 sprayer calibrated to deliver 10 gal/acre. The split application was made by applying one-half of each B rate at V2 and the remaining one-half applied at V10. Before the V10 B application, whole plant and the most recently matured trifoliate leaves were sampled from each plot for analysis for B concentration. Tissue B concentrations are reported for only the control, all rates applied at V2, and the 0.5 lb B/acre rate applied at V10 (0.25 lb B/acre at V2). The grower managed plots with respect to preplant fertilization, pest management, seeding rates, and irrigation (flood-irrigated). A 28-ft long section of the middle three rows was hand harvested from each plot on 14 Nov 2002. Yields were adjusted to 13% moisture for statistical analysis. Treatments were arranged as randomized complete block, 3 (growth stage) by 3 (B rate) factorial design and compared to an untreated control. Each treatment was replicated five times. Tissue B concentration was analyzed as a randomized complete block design for B applied at the V2 growth stage.

At the Cross County 1 site (DeWitt silt loam) the soybean cultivar Northrup King 57-A4 was drill-seeded (7.5-inch row spacing) on 1 June 2002. Foliar applied B (Solubor) treatments were 0.5, 1.0 and 2.0 lb B/acre applied at the V2 stage, 0.5, 1.0, and 2.0 lb B/acre applied at the V10 stage, and 0.25, 0.5, and 1.0 lb B/acre applied at both the V2 and V10 growth stages. Foliar applications were made using a backpack CO_2 sprayer. Plots were arranged as a 3 (B rate) by 3 (growth stage) completely randomized block, with each treatment replicated six times. A second study evaluating soil-applied B was also established at this site. Boron (Granubor) was broadcast applied after soybean emergence at rates of 0, 1, 2, 4, 6, and 8 lb B/acre. Plots at both sites were 10 ft wide by 25 ft long, with 3 ft alleys separating plots. Plots were arranged as complete randomized blocks with 6 replications. Plots at both sites were harvested with a small plot combine on 19 November with the effective harvested area being 125 ft^2.

The Cross County 2 site (Calloway silt loam) was seeded on 36-inch rows with the cultivar D&PL 5915. Plots 12 ft wide by 25 ft long, arranged as complete randomized blocks, were established on 9 July when plants were in the V6 stage. Boron (Solubor) was applied at rates equivalent to 0, 1, 2, 4, and 6 lb B/acre using a backpack CO_2 sprayer. Treatments were replicated four times. The middle two rows from each plot were hand-harvested on 13 November, placed in a bag, and subsequently transported to the Cotton Branch Station where they were shelled.

Soil samples at the Cross County locations were collected prior to the application of B, with tissue samples collected at the R2 stage. Soil and tissue samples were analyzed according to standard procedures. Soybeans were grown according to the farmers' conventional practices, with both sites being irrigated. Reported yields were normalized to a moisture content of 13% and 60 lb/bushel. Yield and tissue-B concentration data were analyzed with the PROC GLM and lsmeans procedure of SAS at a significance level of 95 or 90%.

RESULTS AND DISCUSSION

Soil pH at all three test sites was >7.5 and Mehlich 3 extractable soil-B was <3 lb B/acre and are representative of most soybean fields in northeast Arkansas (Table 1). Very subtle B-deficiency symptoms were noted in the test area at Poinsett County, but no B-deficiency symptoms were noted at the test area or in the remainder of the field at the Cross County site 1. The grower had applied 1 lb B/acre as Granubor with preplant P and K fertilizers to the field area surrounding the test site. As mentioned previously, the Cross County 2 test was established on a field that exhibited severe and relatively uniform B deficiency by the V6 growth stage.

Soybean yields at the Poinsett County site were not affected by B fertilization, however there was a trend for yields to increase when foliar-applied B was applied, especially at the V2 stage (Table 2). Delayed harvest due to wet soil conditions resulted in some yield loss from shattering as evidenced by the low yields shown in Table 2. The problems at harvesting may have masked potential significant yield differences among treatments. Boron concentrations in soybean tissues increased with increasing B rates. Tissue-B concentrations were less than the 20 mg B/kg critical concentration for all B rates <1.0 lb B/acre. Tissue-B concentration data suggest that 1 to 2 lb B/acre application rates applied at the V2 stage were needed to raise soybean tissue B concentrations above the critical threshold.

At the Cross County 1 site a significant ($P<0.10$) soybean yield response to foliar B rate was observed, but only when B was split-applied at rates totaling 2.0 lb B/acre. Tissue-B concentrations were all within the 20 - 60 mg B/kg suggested sufficiency level. However, there was a significant increase in B tissue concentration for rates >1.0 lb B/acre when compared to the control, regardless of application time (Table 3).

No significant yield responses to soil-applied B rates were observed (Table 4). There was a trend for yields to increase with the 1 lb B/acre rate, and then to decrease with B rates >2 lb B/acre. Boron tissue concentrations were within the suggested sufficiency levels for treatments <2 lb B/acre and were in the suggested B-toxicity range (>60 mg B/kg) for soybean receiving >2 lb B/acre. This situation, perhaps, is responsible for the observed trends.

A B deficiency was also identified at the Cross County 2 site when soybean plants were at the V6 growth stage. Boron concentrations in soybean tissue were initially below 20 mg B/kg (deficient), but increased proportionally with increasing B application rates and appeared to fall into the toxicity range (>60 mg B/kg) in plots receiving rates equivalent to 4 and 6 lb B/acre (Table 5). Boron-deficient plants did not fully recover after B was applied, but there was a trend for yields to increase when 1 and 2 lb B/acre were applied and then decreased with the 4 and 6 lb B/acre rates.

PRACTICAL APPLICATIONS

Preliminary studies to assess the yield response of soybean to soil- and foliar-applied boron applications were conducted. The yield response to foliar-applied B during the 2002 season was significant in one out of three studies, but there was a trend for yields to increase with increasing B rates at the other locations. It appears that under B-deficient conditions, 1 lb B/acre is necessary to raise the tissue concentrations to the suggested sufficiency range of 20-60 mg B /kg. Under the conditions of these preliminary tests, soil and foliar rates >2 lb B/acre raised the B-tissue levels to the toxicity range (>60 mg/kg). These preliminary results demand further evaluation of the response of soybean to B fertilization under both deficient and B-sufficient conditions. There is a need to continue building a database that will allow for the development of recommendations to address this nutritional disorder. Until more information is gathered to allow for more specific practices, farmers in the affected areas should consider applying 1.0 lb B/acre as part of their preplant fertilization program.

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Table 1. Selected soil chemical properties from three test sites located in grower production fields used for soybean B fertilization studies in 2002.

		Mehlich 3 extractable nutrients								
Site	pH	P	K	Ca	Mg	S	Mn	Cu	Zn	B
		(lb/acre)								
Poinsett	8.1	95	358	4918	564	13	564	3.8	2.9	1.5
Cross 1	7.8	24	186	3690	636	27	636	2.3	8.3	2.8
Cross 2	8.3	58	234	4956	567	12	189	3.2	2.7	1.4

Table 2. Effect of rate and timing of foliar B applications on soybean yield, trifoliate leaf, and whole-plant B concentration for soybean grown on a silt loam soil in Poinsett County during 2002..

B rate	Application time	Soybean yield	Trifoliate leaf	Whole-plant
(lb/acre)		(bu/acre)	-------------------- (mg B/kg) --------------------	
0	None	20.3	11.0	11.3
0.5	V2	26.4	16.5	16.9
1.0	V2	28.6	26.4	22.3
2.0	V2	23.7	35.6	27.3
0.5	V10	24.2	—	—
1.0	V10	23.8	—	—
2.0	V10	21.5	—	—
0.5	V2 + V10	25.8	12.8	12.3
1.0	V2 + V10	23.2	—	—
2.0	V2 + V10	27.7	—	—
LSD(0.05)		NS[z]	3.3	3.6
P-values for main effects and treatment interactions				
B rate		0.8969	<0.0001	<0.0001
Time of application		0.4656	—	—
Rate x time interaction		0.6588	—	—

[z] NS = not significant.

Table 3. Soybean yield response to foliar B application rate and time (growth stage) at the Cross County 1 site in 2002.

B Rate	Application time	Cross County 1	B tissue concentration
(lb B/acre)		(bu/acre)	(mg/kg)
0 (control)	none	53.1	30.8
0.5	V2	54.3	36.0
1.0	V2	55.1	38.5*[z]
2.0	V2	54.8	43.6*
0.5	V10	54.3	34.4
1.0	V10	53.2	42.2*
2.0	V10	55.4	41.4*
0.25	V2 + V10	52.1	34.9
0.5	V2 + V10	54.2	35.1
1.0	V2 + V10	58.3	41.7*
LSD (0.05)		NS	
P-values for main effects and treatment interactions			
B rate		0.057	
Time of application		0.564	
Rate × time interaction		0.871	

[z] * = significantly different from the control treatment at 95% significance level.

Table 4. Trifoliate leaf B concentrations and soybean yield response to varying soil-applied B rates at the Cross County 1 site.

B application rate	Yield	B tissue concentration
(lb B/acre)	(bu/acre)	(mg/kg)
0	50.1	28.2
1	53.5	51.8
2	52.5	57.4
4	51.4	68.3
6	50.1	78.4
8	50.1	83.9
p- value	0.28	<0.0001
LSD	NS	10.6

Prescription-Based Nitrogen Fertilization of Vine-Ripened Tomatoes

P.B. Francis, P.E. Cooper, and J.G. Trauger

STATEMENT OF RESEARCH PROBLEM

Production of vine-ripened tomatoes (*Lycopersicon esculentum*) is a significant source of income for many limited resource farmers in southern Arkansas. Due to the perishable nature of the commodity, gross revenue is highly sensitive to fruit yields, fruit quality, and markets immediately following harvest. Nitrogen fertilization management can have a significant impact on fruit yield, quality, and harvest cycles. Nitrogen management may include combinations of preplant N, scheduled drip-line N injections, and drip-line injections based on petiole sap NO_3-N monitoring. The primary objective of this research was to identify efficient N management strategies for optimal fruit yields and quality.

BACKGROUND INFORMATION

Nitrogen fertilization in black-plastic mulched, drip-irrigation production systems of vine-ripened tomato can involve N applied all preplant, all injected, or combinations of preplant and injected N. It is important to identify efficient N management programs that optimize yield and fruit quality and reduce or eliminate excessive N losses to the environment.

Total fruit yield, quality, size, weekly yields, and certain disease incidences have all been related to N fertility management in tomatoes (Motis et. al., 1998; Francis and Cooper, 1998; Lacasio et al., 1997; Cook and Sanders, 1991; Barker and Ready, 1989; and Maynard, 1979). Nitrogen management practices that maximize fertilizer recovery efficiency and optimize fruit yield and quality, all of which are related to N rates and timing, will maximize gross returns. This is especially critical given that commercial production of vine-ripened tomatoes is a significant source of income for many limited resource farmers in southern Arkansas.

The availability of inexpensive, hand-held NO_3-N meters has great potential for N management in tomatoes. Several researchers have noted the correlation of quick, in-field petiole NO_3-N sap tests with plant N status for crops such as potato (*Solanum tuberosum,* Zhang et. al., 1996), cauliflower (*Brassica oleracea* var. *Botrytis*, Kubota et al., 1996), broccoli (*Brassica oleracea* var. *Italica*, Kubota et. al., 1997) and tomato (Anderson et. al., 1999; Taber, 2001). This report is a summary of three years of N-management studies in tomatoes. The overall objective was to identify efficient N-management programs and evaluate the feasibility of in-field petiole sap NO_3-N monitoring.

PROCEDURES

Field studies were conducted on the Roger Pace farm near Monticello, AR, in the 2000, 2001, and 2002 growing seasons. Tomatoes (var. 'Mt. Spring') were grown on raised, black-plastic mulched, micro-irrigated beds 5 ft apart with plants spaced 21 inches apart. Each year, preplant applications of 45 lb P_2O_5/acre as 0-46-0 and 90 lb K_2O/acre as 0-0-60 were incorporated prior to mulching. In the 2000 growing season, a severe outbreak of Tomato Spotted Wilt Virus (TSWV) reduced stands by over 60%, resulting in a lost study. TSWV losses in the 2001 and 2002 season were less than 16%. Plots were composed of six plants, with fruit from the inside two plants harvested three times a week and graded to U.S. No. 1 XL, U.S. No. 1 L, U.S. No. 2, or unclassified. The experimental design during each year was a randomized complete block with four replications.

In 2001, N treatments were limited to drip-line injections of season totals of 0, 60, 120 , 180, and 240 lb

N/acre (mulched acre) applied once a week incrementally from either ammonium nitrate or urea. In addition, a 'prescription' treatment was also added, which involved weekly monitoring of undiluted petiole sap NO_3-N of the most recently matured leaf using a hand-held CardyÒ nitrate meter and injecting 20 lb N/acre as ammonium nitrate when measured sap NO_3-N was within ± 50 ppm of the lower threshold of published NO_3-N sufficiency ranges (Hochmuth et.al., 1991). Readings were taken at mid-morning and petiole sap was extracted using a garlic press. Drip-line injections were accomplished using a manifold system to apply 60 oz of solution to each plot, followed by 2 to 5 hrs of mainline irrigation.

In 2002, combinations of preplant and injected N treatments from ammonium nitrate were studied. Preplant plus injected treatments were 0, 60, and 120 lb N/acre pre-plant with either 0, 10, and 20 lb N injected on an 'as needed' basis from weekly petiole sap NO_3-N monitoring as described for the 2001 study. Injected treatments were limited to season totals of 120 or 180 lb N/acre from ten weekly incremental applications. In 2002, the cooperator had established a very good stand of Austrian winter pea (*Pisum sativum* subsp. *arvense*) legume cover crop that was incorporated into the soil 10 days prior to bedding.

RESULTS AND DISCUSSION

In 2001, season total-N rate applied with the prescription-N treatment equaled that of the scheduled-N treatment of 120 lb N/acre (Table 1). Single degree-of-freedom contrast tests in a general linear model did not detect any yield or petiole sap NO_3-N differences between N sources (analysis not shown). There were no significant differences in yields of U.S. No. 1 XL grade tomatoes for N treatments of 120 lb N/acre or higher. A single degree of contrast test in a general linear model did detect a significant difference (Prob >F 0.03) between the 0- and 60-lb N/acre treatments versus the 120 lb N/acre or higher treatments (analysis not shown). Therefore, the optimal level of N fertilization rate in 2001 was 120 lb N/acre applied in ten weekly, equivalent injections, or from injections of 20 lb N/acre when needed based on petiole sap NO_3-N monitoring. At the beginning of harvest, a clear relationship between applied N and petiole NO_3-N existed (Table 2). Petiole NO_3-N levels below 268 ppm at this stage were related to lower fruit yields.

There were no treatment effects on cumulative yield of U.S. No. 1 XL grade tomatoes at the end of the 2002 harvest (Table 3). The excellent winter legume cover crop no doubt increased soil levels of mineralized N as evidenced by petiole NO_3-N levels on 14 May of 530 ppm for the unfertilized control (0 lb N/acre treatment, Table 4). Petiole NO_3-N was related to total N applied (preplant + injected) through 4 June. However, on the 18 June sampling, petiole NO_3-N was related more to the cumulative amount of injected N (Table 5), indicating plant uptake and translocation of injected N into the sap flow. Recent studies have shown that tomato yields are more related to petiole sap NO_3-N concentrations from early- to mid-fruit than from late fruit set to harvest (Taber, 2001; Krusekopf et. al., 2002). The 14 May 2002 petiole NO_3-N measurements were taken during mid-fruit set growth, and all treatments were above or just below the minimum recommended threshold of 600 ppm (Tables 4 and 5). These results support using petiole sap NO_3-N monitoring during initial fruit set as an N-management tool.

PRACTICAL APPLICATIONS

Mid-morning readings from a quick in-field sap NO_3-N meter at early fruit set (about early to mid-May for southern Arkansas) of plasticulture micro-irrigated tomatoes can be used to determine if supplemental drip-line injections of N are needed. Nitrogen management can be accomplished using combinations of preplant and/or injected N applications by using the petiole sap NO_3-N test as a monitoring tool. Nitrogen application rates >120 lb total N/acre did not increase fruit yields of the Mt. Spring variety. Using petiole NO_3-N monitoring and drip-line N amendments gives the producer a mechanism for making adjustments of N fertilization that helps account for variations in native soil N, weather, disease pressure, and fruit loads.

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Table 1. Cumulative yields of U.S. No. 1 XL grade tomatoes during 2001 season.

Injected N rate	Nitrogen source[z]	Cumulative yield, by harvest time (day/month) 22 June	29 June	6 July	11 July
(lb/acre)		------------------- (lb/plant) ---------------			
0	---	1.13	2.13	2.24	2.56
60	AN	1.25	2.59	3.09	3.94
60	UR	1.44	3.03	3.86	4.61
120	AN	2.18	2.90	3.63	4.49
120	UR	1.35	2.48	4.01	5.31
120[y]	AN	2.00	2.93	4.26	5.66
180	AN	1.11	2.54	3.31	4.24
180	UR	1.72	2.69	4.69	5.85
240	AN	1.46	2.98	4.69	5.46
240	UR	1.91	3.06	4.27	5.19
$LSD_{.05}$		NS	NS	2.05	2.46

[z] AN = ammonium nitrate (34-0-0), UR = urea (46-0-0).
[y] Prescription-based treatment.

Table 2. Petiole sap NO_3-N at early harvest, 21 June 2001.

N applied to date	NO_3-N
(lb/acre)	(ppm)
144	322
108	465
80[z]	307
72	268
36	142
0	101
$LSD_{0.05}$	48

[z] Prescription-based treatment.

Table 3. Cumulative yields of U.S. No. 1 XL grade tomato during 2002 season.

Preplant N rate	Injected N rate	Total N rate	Cumulative yield, by harvest time (day/month) 14 June	21 June	30 June	6 July
(lb/acre)			---- (lb/plant) ----			
0	0	0	0.86	2.12	4.33	6.74
0	60	60	0.78	1.68	4.51	6.95
0	80	80	0.78	1.54	3.49	6.56
0	120	120	0.84	1.54	5.18	7.62
0	180	180	1.31	1.96	4.07	7.13
60	0	60	1.51	2.50	4.08	6.67
60	30	90	0.87	1.72	3.69	7.04
60	60	120	0.96	1.54	3.32	6.41
120	0	120	0.26	1.33	3.36	5.19
120	40	160	1.99	3.10	4.28	7.56
120	60	180	1.11	1.69	3.86	7.38
$LSD_{.05}$			0.94	1.15	NS	NS

Table 4. Petiole sap NO_3-N concentration in relation to total N applied (preplant + injected) at three specified sampling dates during 2002.

	14 May Total N		4 June Total N		18 June Total N	
	Total N	NO_3-N	Total N	NO_3-N	Total N	NO_3-N
	(lb N/acre)	(ppm)	(lb N/acre)	(ppm)	(lb N/acre)	(ppm)
	0	530	0	97	0	109
	6	695	18	353	30	237
	12	455	36	475	60	227
	18	768	54	435	80	373
	20	523	60	451	90	285
	60	960	70	214	100	208
	70	1008	80	205	120	104
	80	743	120	206	150	258
	130	680	130	270	160	233
	130	1033	140	383		
	140	865				
Sufficiency range		600-800		400-600		200-400
P-value		0.0034		<0.0001		0.2328
R^2		0.29		0.40		0.10

Table 5. Petiole sap NO_3-N concentration in relation to cumulative amounts of injected N during 2002.

	14 May		4 June		18 June	
	Injected N rate	NO_3-N	Injected N rate	NO_3-N	Injected N rate	NO_3-N
	(lb N/acre)	(ppm)	(lb N/acre)	(ppm)	(lb N/acre)	(ppm)
	0	530	0	97	0	109
	0	723	0	191	0	108
	6	695	10	242	30	234
	10	1020	18	353	40	220
	12	455	20	294	60	343
	18	768	36	495	80	373
	20	770	54	435	90	363
			60	473		
Sufficiency range		600-800		400-600		200-400
P-value		0.7077		0.0015		0.0002
R^2		0.03		0.32		0.38

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

J.S. McConnell, B.A. Meyers, and M. Mozaffari

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, premature 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).

Objectives of these studies were to evaluate the growth, development, and yield of intensively managed cotton as a function of soil- and plant-N fertilization and dynamics under different irrigation methods.

BACKGROUND INFORMATION

Both over- and under-fertilization of cotton with N may result in reduced yield. 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, yields were found to increase with increasing N fertilization throughout the previous years of this test. 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 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 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-rates and irrigation methods was initiated at the Southeast Branch Experiment Station on an Hebert silt loam soil in 1982. This experiment, the McConnell-Mitchell Plots, is conducted on the oldest continuous plots 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). N-fertilization was discontinued for the 2000 and subsequent growing season to examine the effects of residual soil nitrate-nitrogen (NO_3^--N) on cotton development. Soil samples were taken from the plots and analyzed for residual NO_3^--N to a depth of five feet (Table 3).

The McConnell-Mitchell Plots were planted 14 May 1999, 18 May 2000, and 23 April 2002. The 2001 growing season was marked by an early June hail storm that destroyed the stand of cotton. The cotton was replanted on 15 June 2001, but seedling disease decimated the stand a second time. The crop was not replanted again and the plots were fallowed, as it was deemed too late to get meaningful results.

RESULTS AND DISCUSSION

Interaction of irrigation with N-treatments and residual N significantly impacted yields all three years of the study (Table 4). During the last three years, high frequency center-pivot irrigation increased cotton yields compared to furrow irrigation or dryland production. Addtionally, furrow-irrigated cotton produced greater yields than dryland cotton during this period.

Yields were found to increase with increasing N fertilization in each irrigation block in 1999, although there were a few reversals and not all differences were significant. Yields were maximized in both high frequency center-pivot and furrow-irrigated cotton with 150 lb N/acre (split two ways). Yield response of the cotton in the dry land block was limited due to lack of rainfall.

Plant response to residual N in 2000 seemed to mirror the N-fertilization of previous years. Yields were again maximum where the 150- and 120-lb N/acre treatments had been applied in the center-pivot and furrow-irrigated blocks and were influenced little in the dryland block.

In 2001, the test site was fallow for the first time in the history of the McConnell-Mitchell plots. Hail and seedling disease prohibited a successful stand. Weeds were controlled on the site season long with Roundup®.

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 NO_3^--N was limited in 2002. Cotton grown under high frequency center-pivot irrigation did not significantly respond in yield to the residual soil NO_3^--N, and cotton under dryland and furrow irrigation had only minimal yield response. As the residual NO_3^--N is consumed by subsequent crops, it will have less impact on plant development and yield.

PRACTICAL APPLICATIONS

Irrigated cotton was generally found to produce higher yields than cotton grown under dryland conditions. Fertilizer nitrogen requirements of cotton for maximal yield tended to be greater under irrigated production conditions than under dryland production conditions. Residual soil N was sufficient the first year to maintain yields when previous years of N-fertilization were high. After two growing seasons and one fallow season, the yield response to residual NO_3^--N was much less.

ACKNOWLEDGMENTS

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Table 1. Duration, tensiometer thresholds and depths, and water application rates for three irrigation methods.

Irrigation methods	Duration	Tensiometer Threshold	Tensiometer Depth	Water applied
		-(cbar)-	-(in.)-	-(in.)-
High frequency	Planting to P.B.[z]	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] P.B.=Peak bloom

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

Total N-Rate	Preplant	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 fertilization rates (split applied, half pre-plant and half at first square) under three irrigation methods of the McConnell-Mitchell study in 2000.

Depth	Nitrogen fertilization rate 0	30	60	90	120	150	Mean
- (in.) -	(lb NO_3^-N/acre)						
Furrow irrigated							
0 - 6	2.0	1.7	2.3	2.0	2.7	3.0	2.3
6 - 12	1.7	2.3	1.3	1.7	2.0	2.0	2.3
12 - 18	2.0	3.0	2.7	2.0	3.0	4.3	3.8
18 - 24	3.0	2.7	3.3	2.3	4.3	7.3	4.8
24 - 30	2.7	3.0	3.0	2.7	4.3	6.7	4.5
30 - 36	2.0	3.0	3.0	2.7	4.7	6.3	4.1
36 - 42	2.7	2.7	2.7	2.7	4.3	7.0	4.1
42 - 48	2.7	2.3	2.7	2.3	4.3	9.0	4.0
48 - 54	2.7	2.7	2.7	2.7	3.7	7.7	3.9
54 - 60	2.3	2.0	3.3	2.0	6.7	5.7	3.6
Mean	2.4	2.5	2.7	2.3	4.0	5.9	
Dryland							
0 - 6	6.0	6.0	6.0	28.7	87.3	65.0	29.4
6 - 12	5.0	8.7	6.0	32.7	107.7	102.0	39.1
12 - 18	4.3	6.0	5.0	35.0	138.3	134.7	45.9
18 - 24	3.7	5.0	6.0	36.3	125.3	110.7	46.2
24 - 30	3.7	3.7	5.7	31.0	90.7	104.3	46.9
30 - 36	2.7	3.3	5.0	21.7	58.3	67.7	31.7
36 - 42	2.7	3.0	3.7	11.7	54.0	36.7	22.3
42 - 48	2.3	2.7	3.0	7.0	36.7	21.3	13.0
48 - 54	2.7	2.7	4.0	6.0	21.0	14.7	9.1
54 - 60	13.0	6.0	30.3	2.0	33.3	56.7	24.6
Mean	4.6	4.7	7.5	21.4	75.2	71.4	
Center Pivot Irrigated							
0 - 6	1.0	1.0	3.0	3.0	2.0	1.7	1.9
6 - 12	1.3	1.0	2.3	3.0	3.3	5.3	3.1
12 - 18	1.7	1.3	3.0	2.7	3.3	11.0	4.9
18 - 24	2.0	1.3	2.0	1.0	2.3	19.7	5.4
24 - 30	2.0	3.3	1.7	2.0	3.3	18.0	6.0
30 - 36	1.7	2.7	1.3	2.7	3.7	9.7	5.5
36 - 42	2.0	2.3	1.7	2.7	4.3	7.3	7.7
42 - 48	2.0	2.3	2.7	3.3	5.7	6.3	7.5
48 - 54	1.7	2.7	1.7	3.3	5.7	4.0	5.0
54 - 60	6.0	3.7	2.0	2.3	5.0	6.7	4.1
Mean	2.1	2.2	2.1	2.6	3.9	9.0	

Table 4. Seed cotton yield response of cotton to 10 nitrogen (N) fertilization rates and splits under three irrigation methods from 1999, 2000, and 2002 at the Southeast Branch Experiment Station near Rohwer, Arkansas.

N Rate						
PP[z]	FS[z]	FF[z]	HF[y]	FI[y]	DL[y]	Mean
	(lb/acre)		(lb seed cotton[x]/acre)			
1999						
75	75	0	3805	3548	1505	3166
50	50	50	3437	3287	1796	3138
30	60	60	3560	3306	1607	3008
60	60	0	3674	3098	1394	2960
40	40	40	3693	3533	1772	3172
45	45	0	3278	3045	1757	2839
30	30	30	3299	2817	1694	2777
30	30	0	3383	2812	1757	2834
15	15	0	2556	1912	1786	2202
0	0	0	2459	1550	1389	1964
LSD(0.05)=358[w]						
LSD(0.05)=549[v]						
Mean			3344	2890	1646	
2000						
75	75	0	2968	2161	1245	2207
50	50	50	3034	2126	1295	2152
30	60	60	3138	2223	1255	2205
60	60	0	2783	1923	1186	2042
40	40	40	2882	1999	1382	2112
45	45	0	2753	1951	1233	1979
30	30	30	2541	2003	1314	1949
30	30	0	2784	1885	1182	1977
15	15	0	2329	1665	1312	1744
0	0	0	2643	1677	1027	1721
LSD(0.05)=244[w]						
LSD(0.05)=880[v]						
Mean			2801	1961	1242	
2002						
75	75	0	3847	3413	2901	3379
50	50	50	3900	3464	3114	3485
30	60	60	3864	3369	3202	3470
60	60	0	3692	3466	2998	3378
40	40	40	3886	3214	3391	3489
45	45	0	3733	3342	3204	3419
30	30	30	3616	3330	3245	3395
30	30	0	4041	3146	3056	3407
15	15	0	3602	3037	3297	3304
0	0	0	3481	2867	2886	3071
LSD(0.05)=340[w]						
LSD(0.05)=493[v]						
Mean			3766	3265	3128	

[z] Pre-plant (PP), first square (FS) and first flower (FF).
[y] High frequency (HF), furrow irrigated (FI), dryland (DL).
[x] Lint yield may be estimated by dividing the seed cotton yield by 3.
[w] LSD(0.05) for comparing means within the same irrigation method.
[v] LSD(0.05) for comparing means within different irrigation methods.

Varietal Responses of Cotton to Nitrogen Fertilization

J.S. McConnell, B.A. Meyers, and M. Mozaffari

RESEARCH PROBLEM

Optimizing yield and earliness of cotton (*Gossypium hirsutum* L.) with nitrogen fertilization is an ongoing concern of cotton producers in Arkansas (Maples and Frizzell, 1985). Genetically engineered cotton varieties are currently being used in large portions of the cotton-producing acreage, particularly 'Bollgard' and Roundup® Ready varieties. New cotton varieties developed using traditional plant-breeding techniques are also being utilized by producers. 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, N requirements of the new varieties are questioned by producers. The objective of this study was to determine the response of new cotton varieties to N-fertilization; particularly yield, earliness, and fiber quality response.

BACKGROUND INFORMATION

New cotton cultivars have increased the genetic diversity of cotton grown in the Delta. The genetic variability of currently available varieties indicates that crop growing practices, such as fertilization, might differ from older varieties to achieve optimal yields and earliness. Optimizing N fertilization for individual cotton varieties is a 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 were introduced into the Delta region. Three years of data, 2000 through 2002, are available from the current test. Varieties currently under evaluation are: Deltapine 747 (DP 747), a rapid maturing variety; Stoneville 474 (ST 474), a moderate-maturing variety; Deltapine 5415 (DP 5415), a full-season variety and the parent line of Nucot 32B; and Nucot 32B (NU32B), a full-season variety with genetic resistance to heliothis species.

Nitrogen fertilizer rates were 0, 50, 100, and 150 lb N/acre. The source of the N was urea. The N-fertilizer treatments were split applied with half the total N-rate applied after emergence and half when the crop reached the first-square stage. The urea-N was incorporated with shallow plowing after each application. The test was furrow-irrigated using tensiometers to trigger irrigation. The studies were planted on 18 May 2000, 5 June 2001, and 23 April 2002. In 2001, the initial stand was destroyed by an early June hailstorm. The study was replanted on 5 June 2001. Cotton planted this late frequently exhibits aberrant growth from normal, yet the 2001 yields were acceptable and the trends in yield due to the treatments were similar to other years. 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 seed-cotton yield, plant-height, plant-population, and node-development information. All data were analyzed using the Statistical Analysis System (SAS). The experimental design was randomized complete block. 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

The yield of cotton varieties was not found to significantly interact with differing N-fertilization rates in any year of the current test (Table 2). The main effect of N-fertilizer rate significantly affected cotton yield each year with 100 lb N/acre producing maximal yield for all four varieties. Non-significant, numerical yield increases occurred between the 100 and 150-lb N/acre rates in 2000 and 2002.

Yields of varieties were different two out of three years (2001 and 2002). The highest yielding variety was ST474 in 2001, while DP747 and NU32B had the greatest yields in 2002. No significant difference in yield of the varieties occurred in 2000. No pattern was discerned that would indicate a substantial yield advantage of one variety over the others tested.

Although the interaction of varieties and N-rates was not significant, a trend of increasing yield with increasing N rate was observed for ST474 through the 150 lb N/acre treatment all three years of the test. Other varieties appeared to respond to the 150 lb N/acre with increased yields occasionally, but not with the same frequency as ST474.

PRACTICAL APPLICATION

The yields of all the cotton varieties tested were maximized with N fertilization rates of 100 lb N/acre. Interactions between cotton varieties and N-fertilization were not found to influence cotton yields. Occasionally, yields were increased in some varieties with N-rates above 100 lb N/acre, especially ST474, but not significantly.

ACKNOWLEDGMENTS

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Table 1. Residual nitrate-nitrogen (NO_3-N), phosphorus (P), potassium (K), 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	K	pH	EC
(in.)	(lb/acre)	(lb/acre)	(lb/acre)	(pH units)	(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

Table 2. Seedcotton yields (lint yield may be estimated by dividing by 3) of four cotton varieties [Deltapine 747 (DP 747), Stoneville 474 (ST474), Deltapine 5415 (DP5415), and Nucot 32B (NU32B)] as affected by 0, 50, 100, and 150 lb urea-N/acre at the Southeast Branch Experiment Station near Rohwer, AR, from 2000 to 2002.

N fertilizer	Cotton variety				
rate	DP747	ST474	DP5415	NU32B	N rate mean
	(lb seedcotton/acre)				
2000					
150	4051	4353	4090	4255	4185
100	3899	4291	3821	3915	3995
50	3400	3173	3103	3483	3300
0	2287	1636	1611	1878	1853
Variety mean	3347	3311	3123	3383	--
LSD(0.05)Variety[z] and N rate by variety interaction[y] were NS					195[x]
2001					
150	4012	4511	3456	3876	3902
100	3915	4123	3723	3978	3945
50	3381	3769	3439	3425	3496
0	2780	2624	2702	2789	2718
Variety mean	3514	3729	3310	3485	--
LSD(0.05)Variety[z] = 182 lb/acre; N rate by variety interaction[y] was NS					214[x]
2002					
150	5392	5554	3877	5503	5057
100	5242	4788	4181	5063	4849
50	4124	3896	3814	4163	3999
0	2638	2314	1912	2454	2293
Variety mean	4439	4100	3333	4296	--
LSD(0.05)Variety[z] = 288 lb/acre; N rate by variety interaction[y] was NS					404[x]

[z] LSD(0.05) for variety main effects.
[y] No significant difference observed between variety and N rate.
[x] LSD(0.05) for N-rate main effects.

Nitrogen Fertilization of Ultra-Narrow-Row Cotton: Final Report

J.S. McConnell, M. Mozaffari, B.A. Meyers, R.E. Glover, and R. Benson

RESEARCH PROBLEM

Recent developments in cotton (*Gossypium hirsutum* L.) production technology in the Delta include drill planting cotton in an ultra-narrow-row (UNR) production system. Ultra-narrow-row cotton is a low-input production system designed to maximize economic returns. The premise is that UNR cotton will be lower yielding, but the reduction in input costs will result in a larger profit margin. Research that provides information on production parameters is scant. Nitrogen (N) fertilization rates required to optimize yields and earliness for UNR cotton are unknown. The objectives of these studies were to determine optimal N fertilization for UNR cotton.

BACKGROUND INFORMATION

Crops grown in very narrow rows intercept and utilize sunlight more efficiently, but equipment, particularly for harvesting high-quality cotton, has always required wide rows. Technology development for UNR cotton production, including harvest equipment, has increased recently. Potential benefits of UNR cotton production include: reduced production costs, utilization of soils not ordinarily suited to cotton production, decreased soil erosion, and utilization of the same equipment for cotton, soybean, and cereal crops. Potential drawbacks of UNR cotton include: increased weed pressure in low-stand areas; different equipment is required from conventionally row-spaced cotton (precision drill planter, finger stripper harvester); and lint quality may decline. Variety differences, fertility requirements, effect of planting date, and other parameters for optimal growth and yield of UNR cotton are unknown.

PROCEDURES

A pilot study of the responses of UNR cotton to N-fertilization was conducted in 1997 at the Southeast Branch Experiment Station (SEBES) near Rohwer, Arkansas. The current test was begun in 1998 with N-rates of 0-, 25-, 50-, 75-, 100-, and 125-lb urea-N/acre at SEBES. The experimental design was a randomized complete block. N-treatments were applied to the soil surface without incorporation when the crop reached the two true leaf stage. The test was expanded for the 1999 growing season to include a second study site at the Northeast Research and Extension Center (NEREC) near Keiser, Arkansas. The test was planted on 26 May 1999 (SEBES), 23 May 1999 (NEREC), 16 May 2000, and 17 May 2001. The soil (Hebert silt loam) at the test site was sampled and analyzed for nutrient content at the SEBES site (Table 1).

Measurements taken on the UNR cotton included seed-cotton yield, plant height, plant population, boll load, and boll weight. All data were analyzed using the Statistical Analysis System (SAS). F-tests and least significant differences (LSD) were calculated at the α=0.05 level of probability.

RESULTS AND DISCUSSION

The results of the pilot study and the first year of the current experiment correlated well. The N- fertilization rate necessary to produce maximal yield, boll load and boll weight was 50 lb N/acre. Although trends of higher values were observed with greater N rates, the differences were not always significant from the 50 lb N/acre treatment. Plant height increased with increasing N fertilization up to 100 lb N/acre.

Drought conditions masked the impact of N fertilization of the UNR cotton at SEBES in 1999 (Table 2). Nitrogen fertilization of conventionally row-spaced cotton has been shown to be ineffective under severe water deficit (McConnell et al., 1998). The N treatments were not found to significantly affect any of the measured parameters. Results from the 2000 growing season at SEBES showed increased yields with N treatments up to 100 lb N/acre. Plant height and boll load increased throughout the range of N treatments. The 2001 growing season was marked by a prolonged period of water-saturated soil conditions and occasional plant submergence early in the growing season. These conditions retarded the growth, development and yield of the cotton. Because of these adverse growing conditions, no significant differences were observed in 2001.

Results from NEREC were similar to the first year's at SEBES (Table 3). Maximal yields were achieved with only 25 lb N/acre. Plant height was found to significantly increase up to 75 lb N/acre. No significant differences were observed in either the plant populations or boll loads at NEREC.

PRACTICAL APPLICATION

Current University of Arkansas N fertilizer recommendations for cotton use a base value of 100 lb N/acre. Subtractions from this base value are recommended with differences in soil texture, soil calcium content, and crop history of the field (Chapman, 2000). The N-fertilizer recommendation for the SEBES study site would be 90 lb N/acre to optimize cotton yield. The responses of UNR cotton to N fertilization treatments indicate that the N required for maximal yield will be less than the 90 lb N/acre recommended for cotton grown in conventionally spaced rows. Yields of UNR cotton were not often found to significantly increase with N rates above 50 lb N/acre. Additionally, the 50 lb N/acre treatment was usually found to maximize both the boll load and boll weight. The parameters measured in these studies suggest that the N fertilization to optimize UNR cotton is substantially different from the recommended N-rates for conventionally grown cotton.

ACKNOWLEDGMENTS

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Table 1. Initial soil analyses by depth for nitrate-nitrogen (NO_3^-N), phosphorus (P), potassium (K), and electrical conductivity (EC) at the ultra-narrow-row nitrogen fertility study site at the Southeast Branch Experiment Station near Rohwer, AR, from 1997 to 2001.

Depth	NO_3^-N	P	K	pH	EC
(in.)	(lb/acre)	(lb/acre)	(lb/acre)	(pH units)	(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	5.9	34
LSD (0.05)	0.4	6	18	0.2	3

Table 2. Lint yield, plant height, plant population, boll load, and boll weight of cotton grown in ultra-narrow rows with 0, 25, 50, 75, 100, 125 lb urea-N/acre at the Southeast Branch Experiment Station near Rohwer, AR, from 1999 to 2001.

N-rate	Lint yield	Plant height	Plant population	Boll load	Boll weight
(lb N/acre)	(lb/acre)	(in.)	(plt/acre)	(boll/acre)	(g/boll)
1999					
125	700	10.6	130,687	264,400	2.70
100	638	11.4	139,763	253,077	2.55
75	598	12.8	157,914	223,863	2.76
50	548	12.1	148,233	230,950	2.45
25	547	11.4	140,368	233,863	2.41
0	474	12.2	150,048	191,796	2.49
LSD (0.05)	NS	NS	NS	NS	NS
2000					
125	648	25.5	107,091	271,055	2.67
100	527	23.7	104,671	232,333	2.46
75	482	22.8	113,326	218,417	2.41
50	384	18.9	98,621	182,115	2.34
25	335	18.8	114,784	183,239	1.98
0	310	17.6	117,982	147,628	2.22
LSD (0.05)	110	2.9	NS	40,124	2.94
2001					
125	231	7.9	246,854	75,024	3.00
100	246	9.4	284,608	88,093	3.05
75	247	9.4	198,451	88,738	2.74
50	212	9.5	231,123	101,646	2.42
25	170	8.4	189,981	87,125	3.36
0	156	8.2	191,191	85,915	3.02
LSD (0.05)	NS	NS	NS	NS	NS

Table 3. Lint yield, plant height, plant population, boll load, and boll weight of cotton grown in ultra-narrow rows with 0, 25, 50, 75, 100, 125 lb urea-N/acre at the Northeast Research and Extension Center near Keiser, AR, in 1999.

N-Rate	Lint yield	Plant height	Plant population	Boll load
(lb N/acre)	(lb/acre)	(in.)	(plt/acre)	(boll/acre)
125	989	20.7	212488	341499
100	1004	20.4	261816	333910
75	958	23.7	239049	314938
50	965	20.4	292171	417387
25	883	17.5	250432	394621
0	608	16.7	250432	318732
LSD (0.05)	267	2.7	NS	NS

Cotton Response to Potassium and Phosphorus Fertilization in a Silt Loam

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RESEARCH PROBLEM

Potassium (K) and phosphorus (P) are two macronutrients required for cotton production (*Gossypium hirsutum* L.). Cotton yield or quality can be impacted if sufficient amounts of either nutrient are not available for plant uptake. Two field experiments were conducted to evaluate the effect of K and P fertilization on cotton yield and petiole concentrations of K and P.

BACKGROUND INFORMATION

Potassium plays a pivotal role in lint development and P is essential for energy transfer within the cotton plant. A one ton crop of cotton removes 63 lb P_2O_5/acre and 126 lb K_2O/acre (Jones, 2002). Insufficient quantities of either nutrient can adversely affect cotton yield or quality. Similar to N, petiole K concentration is used as a diagnostic tool to assist growers with making in-season foliar K application decisions. Cotton production practices have dramatically changed during the past three decades. An example is the introduction of new, fast-fruiting cultivars. These cultivars may have different nutritional requirements than the obsolete cultivars that were originally used to develop our current fertilizer and petiole K monitoring recommendations. In order to provide Arkansas growers with up-to-date technical information, new field experiments are needed to evaluate the effect of K and P fertilizer rates on cotton yield and nutrient concentrations in the petiole.

PROCEDURES

Two separate, replicated field experiments were conducted at the University of Arkansas Cotton Branch Experiment Station (CBES) in Marianna, AR, during the 2002 growing season to evaluate the effect of K and P fertilization on cotton yield and petiole K and P concentrations, respectively. The soil at the experimental site is mapped as Loring silt loam. Prior to planting, two composite soil samples were collected from the top 6 inches of each plot; each composite sample consisted of eight 1-inch diameter samples from the eight cotton rows. Soil samples were extracted with Mehlich-3 solution (1:10 ratio) and concentration of elements in the soil extract was measured by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). Nitrate, pH, and EC were measured by standard University of Arkansas soil testing procedures and results were tabulated (Tables 1 and 2). Cotton (Stoneville 4892) was planted in 38-inch row spacings on 21 May using recommended conventional tillage practices for both experiments.

Individual K fertility plots were 90 ft long and 25 ft wide and P plots were 200 ft long and 25 ft wide. Potassium fertilizer was applied at 0, 30, 60, and 120 lb K_2O/acre as muriate of potash (KCl) and P was applied at 0, 30, 60, and 90 lb of P_2O_5/acre as triple super phosphate. Both fertilizers were mechanically incorporated into the soil prior to planting. All experimental plots received a blanket application of 60 lb N/acre as NH_4NO_3 at the pinhead square stage. The design of both experiments was a randomized complete block with four replications of each treatment. Cotton petiole samples were collected for 10 consecutive weeks starting on 1 July and ending on 5 September. The first two weeks, 24 petioles from the fifth node from the top were randomly collected from each plot. The final eight weeks, 16 petioles from the fifth node from the top were randomly collected from each plot. Cotton petioles were dried overnight at 70°C and ground to pass a 1-mm seive. A 0.075-g sub-sample was also 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. At maturity, seedcotton yield was measured from the center four rows of each plot with a 4-row cotton picker equipped with an AgLeader™ cotton yield monitor. Analysis of variance was used to evaluate the effect of K or P fertilizer rates on cotton yield and petiole nutrient concentrations with significant treatment means separated by the Waller-Duncan test.

RESULTS AND DISCUSSION

K Fertilization

Seedcotton yield ranged from 1685 to 1846 lb/acre (calculated lint yield 590 to 684 lb/acre) and was not significantly affected by K fertilizer rate (Table 3). This was somewhat unexpected since according to current recommendations a yield response to K fertilizer is anticipated when preplant soil-test K concentrations are <200 lb K/acre. Petiole K concentrations increased as K fertilizer application rate increased for the first seven sample times but were not affected at the final two sample dates (Table 4). Within each sample time, petiole K started to decline one week after the first bloom (July 22) and consistently decreased throughout the rest of the growing season (Table 4). This is consistent with the general trend of K utilization by growing cotton plants. Petiole K was consistently below the lower sufficiency range (listed in Table 4) for all treatments amended with <120 lb K_2O/acre. This suggests that on this soil the current K sufficiency ranges, established with older cultivars, may not be accurate for prescribing in-season K fertilizer applications or that perhaps the subsoil contains a significant amount of plant available K.

P Fertilization

Seedcotton yield ranged from 2412 to 2717 lb/acre (calculated lint yield range 824 to 951 lb/acre) and was not significantly affected by P fertilizer application rate (Table 5). This was not unexpected since preplant soil-test P was high enough (Table 2) that only a small amount (10 lb P_2O_5/acre) of P fertilizer was recommended by University of Arkansas cotton fertilization guidelines. This indicates that the current upper limit of soil-test P for cotton appears to be appropriate or could possibly be lowered. Petiole-P concentrations were not affected by P fertilizer application rate and there was no consistent trend in concentration changes for petiole P during the season (Table 6).

PRACTICAL APPLICATION

Potassium fertilizer application failed to increase cotton yields on a Loring silt loam with preplant soil-test K ranging from 192 to 199 lb K/acre. However, petiole K concentration increased as K fertilizer rate increased. In this experiment the current lower sufficiency range for petiole K was not an accurate assessment of the need for K fertilization since cotton yield did not respond to K fertilization. Sufficiency ranges may need to be recalibrated for petiole monitoring to be an effective diagnostic tool for prescribing in-season foliar K application. No yield response to P fertilization was observed when preplant Mehlich-3 extractable (1:10 ratio) soil-test P ranged from 72 to 76 lb/acre. This soil-test P is equivalent to approximately 50 lb/acre in current recommendation where 1:7 soil:solution ratio is used. The current upper levels of soil-test P for cotton appears to be appropriate for identifying soils that are not responsive to fertilizer application. However, to prevent excessive P buildup in Arkansas soils additional soil-test calibration data are needed.

ACKNOWLEDGMENTS

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Table 1. Selected chemical properties before fertilizer application of the top 15 cm of soil at K fertilization study conducted at the Cotton Branch Experiment Station during 2002.

K rate	pH	Mehlich-3 extractable nutrients[z]					
		NO_3-N	P	K	Mg	Ca	B
(lb K_2O/acre)		(lb/acre)					
0	6.4	26	75	194	419	2626	0.9
30	6.3	38	73	199	419	2714	1.0
60	6.5	34	73	194	417	2681	3.4
120	6.3	28	74	192	424	2798	0.9

[z] Modified Mehlich-3 extraction procedure (1:10 extraction ratio).

Table 2. Selected chemical properties before fertilizer application of the top 15 cm of soil from P fertilization study conducted at the Cotton Branch Experiment Station during 2002.

P rate	pH	Mehlich-3 extractable nutrients[z]					
		NO_3-N	P	K	Mg	Ca	B
(lb P_2O_5/acre)		(lb/acre)					
0	6.7	14	76	255	271	1736	0.6
30	6.6	13	72	244	253	1601	0.5
60	6.7	13	72	235	250	1646	0.6
90	6.7	12	72	240	248	1612	0.8

[z] Modified Mehlich-3 extraction procedure (1:10 extraction ratio).

Table 3. The effect of K fertilizer rate on cotton yield at the Cotton Branch Experiment Station during 2002.

K rate	Seedcotton yield	Lint yield	Lint yield
(lb K_2O/acre)	(lb/acre)		(bale/acre)
0	1685	590	1.21
30	1954	684	1.46
60	1846	646	1.34
120	1839	644	1.33
Significance	NS[z]	NS	NS

[z] NS= not significant at P = 0.05 probability level.

Table 4. Effect of K fertilizer rate on cotton petiole K concentration at the Cotton Branch Experiment Station during 2002.

K rate	Seedcotton yield	July 8	July 15[z]	July 22	July 29	Aug. 5	Aug. 12[y]	Aug. 19	Aug. 26	Sept. 3
		Sampling date								
(lb K_2O/acre)	(lb/acre)	[Petiole K (%)]								
0	1685	2.5	1.8	3.2	3.0	1.7	1.2	1.2	1.0	1.0
30	1954	2.8	2.1	3.8	3.4	2.1	1.6	1.5	1.5	0.9
60	1846	3.2	2.5	4.1	3.6	2.4	2.0	2.0	1.5	1.3
120	1839	4.1	3.1	4.6	4.3	2.9	2.4	2.3	1.2	1.2
Lower sufficiency level[x]		4.0	4.0	4.0	3.5	3.0	2.5	2.0	1.7	1.3
Significance		**[v]	**	*	+	**	**	**	NS[w]	NS
MSD (0.05)[u]		0.4	0.4	0.8	1.2	0.3	0.5	0.6	NS	NS

[z] First bloom on 19 July.
[y] Cut-out occurred on 17 August; first open boll on 9 September.
[x] Published by Snyder et al., 1995.
[w] NS = not significant.
[v] **, *, + significant at P = 0.01, 0.05, and 0.10 probability level, respectively.
[u] Minimum Significant Difference as determined by Waller-Duncan test.

Table 5. The effect of P fertilizer rate on cotton yield at the Cotton Branch Experiment Station during 2002.

P rate	Seedcotton yield	Lint yield	Lint yield
(lb P_2O_5/acre)	(lb/acre)		(bale/acre)
0	2412	844	1.75
30	2593	908	1.88
60	2354	824	1.71
90	2717	951	1.98
Significance	NS[z]	NS	NS

[z] NS = not significant at P = 0.05 probability level.

Table 6. Effect of P fertilizer rate on cotton petiole P concentration at the Cotton Branch Experiment Station during 2002.

P rate	Seedcotton yield	July 8	July 15[z]	July 22	July 29	Aug. 5	Aug. 12[y]	Aug. 19	Aug. 26	Sept. 3
		Sampling date								
(lb P_2O_5/acre)	(lb/acre)	[P (mg/kg)]								
0	1685	2.5	1.8	3.2	3.0	1.7	1.2	1.2	1.0	1.0
0	2412	1068	916	2030	2157	1734	999	1599	1822	1876
30	2593	1063	898	2038	2340	1766	992	1622	1629	1759
60	2354	1014	904	1997	2428	1691	1034	1536	2236	2123
90	2717	1266	937	2199	2558	1616	931	1580	1787	2054
Significance		NS[x]	NS	NS	NS	NS	NS	NS	NS	NS

[z] First bloom on 19 July.
[y] Cut-out occurred on 17 August with first open boll on 9 Sept.
[x] NS = not significant at P = 0.05 probability level.

Cotton Response to Nitrogen Fertilization in a Silt Loam

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

RESEARCH PROBLEM

Proper nitrogen (N) nutrition is a fundamental requirement for successful cotton (*Gossypium hirsutum* L.) production. Nitrogen deficiency limits cotton lint yield by limiting vegetative growth whereas excessive N will limit lint production by promoting excessive vegetative growth. A replicated field study was conducted to investigate the effect of N fertilizer application rate (0 to 120 lb N/acre) on cotton yield and petiole-N concentration.

BACKGROUND INFORMATION

Research conducted since the 1920s has clearly demonstrated that cotton yield in many Arkansas soils can be increased by application of N fertilizer (Maples et al., 1990). Nitrogen fertilization of cotton in Arkansas is based on preplant soil-test NO_3-N levels and petiole NO_3-N concentrations between first bloom and boll opening. Application of this diagnostic approach has enabled many Arkansas growers to produce high cotton yields. However, there have been many changes in cotton production practices during the past three decades that could potentially influence cotton response to N fertilization. Nitrogen requirements of new shorter-season varieties may be different than older cultivars previously used. Continuous research is needed to provide Arkansas growers' with up-to-date technical information concerning the response of new cotton cultivars to N fertilization. Therefore continuous evaluation of the effectiveness of the petiole-N monitoring program, as a decision aid tool for in-season N fertilizer application, is also necessary. The objectives of this research were to evaluate cotton yield and petiole NO_3-N response to N fertilization.

PROCEDURES

A replicated field experiment was conducted on a Loring silt loam soil at the University of Arkansas Cotton Branch Experiment Station (CBES) located in Marianna, AR, during 2002. Prior to planting, two composite soil samples were collected from the top 6 inches of each plot, each composite sample consisted of eight 1-inch diameter samples from each of the eight cotton rows. Soil samples were extracted with Mehlich-3 solution (1:10 ratio) and concentration of elements in the soil extract was measured by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). Nitrate, pH, and EC were measured by standard University of Arkansas soil testing procedures. Cotton ('Stoneville 4892') was planted on 21 May. The experimental design was a randomized complete block with four N rates (0, 60, 120, and 180 lb N/acre side-dressed at pinhead square stage as NH_4NO_3) and four replications of each treatment. Individual plots were 200 ft long and 25 ft wide. Phosphorus and K were applied as prescribed by University of Arkansas soil-test recommendations. Standard cultural practices for pest control and irrigation, as recommended by the University of Arkansas Cooperative Extension Service, were followed. Cotton petiole samples were collected for 10 consecutive weeks starting on 3 July and ending on 5 September. The first two weeks, 24 petioles from the fifth node from the top were randomly collected from each plot. The final eight weeks, 16 petioles from the fifth node from the top were randomly collected from each plot. 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 aluminum sulfate spiked with 10 mg NO_3-N/kg and shaken for 30 minutes while stirring. Petiole NO_3-N concentration was determined using an ion specific electrode. At maturity, seedcotton yield was determined from the center four rows of each plot with a 4-row cotton picker equipped with an AgLeader™ yield monitor. Analysis of variance was performed to evaluate the effect of N fertilizer rate on cotton yield and petiole NO_3-N concentration and significant treatment means were separated with the Waller-Duncan test.

RESULTS AND DISCUSSION

Selected chemical properties of soil in the experimental plots are listed in Table 1. According to current University of Arkansas guidelines, optimal cotton production at this site required 60 lb N/acre. However, seedcotton yields were not significantly increased by N application with yields ranging from 2420 to 2580 lb/acre (calculated lint yield ranged from 848 to 902 lb/acre, Table 2).

Petiole-N concentration increased early in the season, peaked one week after first bloom (24 July), and then decreased until one week after the cutout date, regardless of N rate (Table 3). Petiole-NO_3-N significantly increased with increasing N rate, regardless of sampling date. At first bloom, petiole-NO_3-N concentration was 30% higher at 180 lb N/acre compared to 60 lb N/acre and as the season progressed this difference became larger. Two weeks after cutout, petiole-NO_3-N in plants amended with 180 lb N/acre was seven times higher than plants amended with 60 lb N/acre (Table 3). Petiole-NO_3-N concentrations in the unfertilized control were consistently below the Arkansas lower sufficiency range indicating additional N was needed for optimal yield production, but we did not observe a yield response to sidedress N application rate. Foliar N application would have been erroneously recommended for plots amended with 60 lb N/acre after 31 July. These evidences suggest that the current Arkansas lower sufficiency levels for cotton petiole-NO_3-N may be too high for the shorter-season varieties currently in use.

PRACTICAL APPLICATIONS

In this field experiment petiole-NO_3-N concentrations increased as N rate increased. Petiole-NO_3-N in control plots was consistently below the current critical levels for Arkansas. However, plants with petiole-NO_3-N levels higher than the established lower sufficiency range did not produce higher cotton yields. This suggests that the current petiole-NO_3-N monitoring program may need revisions to be applicable to fast-fruiting cultivars currently in use.

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Table 1. Selected chemical properties before fertilizer application of the top 15 cm of a Loring silt loam used for an N-rate trial at the Cotton Branch Experiment Station during 2002.

		Mehlich-3 extractable nutrients[z]					
N rate	pH	NO_3-N	P	K	Mg	Ca	B
(lb N/acre)		---------- (lb/acre) ----------					
0	6.4	31	105	266	308	2200	1.4
60	6.4	28	104	280	308	2200	1.1
120	6.4	26	107	276	316	2050	1.2
180	6.4	30	110	274	315	2180	1.2

[z] Modified Mehlich-3 extraction (1:10 extraction ratio).

Table 2. The effect of N fertilizer application rate on cotton yield at the Cotton Branch Experiment Station in 2002.

N rate	Seedcotton yield	Lint yield	Lint yield
(lb/acre)	---------- (lb/acre) ----------		(bale/acre)
0	2420	848	1.77
60	2580	902	1.88
120	2530	885	1.85
180	2465	863	1.79
Significance	NS[z]	NS	NS

[z] NS = not significant at P = 0.05 probability level.

Table 3. Effect of N fertilizer application rate on cotton petiole NO_3-N concentration in an N rate trial conducted at the Cotton Branch Experiment Station during 2002.

	Seedcotton	Sampling date								
N rate	yield	July 10	July 17[z]	July 24	July 31	Aug. 7	Aug. 14[y]	Aug. 21	Aug. 28	Sept. 5
(lb N/acre)	(lb/acre)	---------- [Petiole NO_3-N (mg/kg)] ----------								
0	2420	3570	4189	11313	3520	1012	478	727	475	1417
60	2580	6264	6246	18469	8859	3313	862	1343	755	1209
120	2530	7447	8377	20828	12804	7878	3516	4427	1893	1527
180	2465	12535	9713	23138	15172	11005	5987	6171	3300	2260
Lower sufficiency level[x]		5000	>10000	>9000	>7000	>5000	>3000	>2000	>2000	>1000
Significance		**[w]	**	**	**	**	**	**	*	+
MSD (0.05)[v]		2476	2269	3697	3406	2865	1812	2311	1957	923

[z] First bloom on 19 July.
[y] Cut-out occurred on 17 Aug; first boll opened on 9 Sep.
[x] Recommendations for Arkansas published by Snyder et al., 1995.
[w] **, *, + significant at P = 0.01, 0.05, and 0.10 probability level, respectively.
[v] Minimum Significant Difference as determined by Waller-Duncan Test

Preliminary Evaluation of Boron Status of Soybean Fields in Arkansas

M. Mozaffari, N.A. Slaton, L. Espinoza, and R.E. DeLong

RESEARCH PROBLEM

Boron is an essential micronutrient for soybean [*Glycine max* (Merr.) L.] growth and development. Boron deficiency will reduce soybean yields by stunting plant growth and reducing branching and pod formation. The primary objective of this study was to determine B concentrations in soybean tissues, soils, and irrigation waters by surveying random soybean fields in Arkansas. This information will be useful in identifying the geographic areas and soil properties that may be associated with B deficiency of soybean and/or require B fertilization or alternative management practices that will assist growers in avoiding economic losses due to B deficiency. This report describes the first year of a three-year study on the B status of soybean fields in Arkansas.

BACKGROUND INFORMATION

Arkansas farmers produced more than 91 million bushels of soybean in 2001. Proper crop nutrition is a requirement for producing good soybean yields. During the 2001 growing season, symptoms consistent with B deficiency appeared in many soybean fields in eastern Arkansas (Slaton et al., 2002). Soybean plants that exhibited the B-deficiency symptoms had lower B concentrations than normal appearing plants. Field observations raised concern that B deficiency may be limiting soybean yields and consequently growers' income. An assessment of current B status of soybean fields in eastern Arkansas is needed to identify potential problem areas and factors that influence B availability. This information will then be used to identify and develop research and extension programs to help soybean growers manage their B fertility in a profitable manner.

PROCEDURES

Eleven major soybean-producing counties of eastern Arkansas were selected for study in 2002 (Table 1). Plant and soil samples were collected from field areas at least 100 ft from the edge of the field and 100 ft from the irrigation source inlet. The most recently matured trifoliate leaf was collected from 30 soybean plants staggered across five rows. Five whole plants were also sampled from each field by collecting one plant from each of the five rows used for trifoliate leaf sample collection. Latitude and longitude coordinates from the sample site of each field were recorded. Whole-plant and trifoliate leaf samples were collected when soybean plants were at full bloom (R2 growth stage). Soil samples were collected from the top 6 inches in each row and composited. When possible, irrigation water samples were also collected from the well or reservoir. Soybean tissue nutrient (P, K, Ca, Mg, Na, S, Fe, Mn, Cu, Zn, and B) concentrations were determined by digestion with concentrated HNO_3 and 30% H_2O_2 as described by Jones and Case (1990) and measured by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). Soil pH and Mehlich-3 (1:10 extraction ratio) extractable nutrients, including B and Ca, and irrigation water pH and B were also measured. The B concentrations in soybean plant tissues, soil, and irrigation water are presented with descriptive statistics (Table 1). A correlation analysis was also performed to relate plant (whole-plant or trifoliate leaf) B concentrations to soil and irrigation water chemical properties (B and pH).

RESULTS AND DISCUSSION

Chemical characteristics of soil, plant, and water samples were summarized for all counties combined and by county and are listed in Table 1. In general, irrigation water was alkaline and contained low concentrations of B. Although the total amount of B applied via irrigation water cannot be calculated without quantitative information on the amount of irrigation water applied during the growing season, the water B concentrations are considered low and would not result in B toxicity of crops grown in Arkansas. Wilcox and Durham (1967) suggested that irrigation-water B concentrations >0.3 mg B/L could possibly lead to B toxicity of plants, depending on plant susceptibility to B toxicity. It is not known whether the B concentrations of irrigation-water sources in Arkansas are sufficient to supply the B requirements for crops such as soybean, but it is clear that the use of these irrigation-water sources has not lead to an accumulation of B in the surface soil horizons. Mehlich-3 extractable B ranged from 0.1 to 4.1 lb B/kg soil. The mean and median soil B concentrations were 0.8 and 0.6 lb B/kg, respectively. Only three soils contained >2.0 lb B/kg, indicating generally low B concentrations in soils used for soybean production in the study area. Arkansas, Craighead, Lee, and Phillips county had the lowest soil B concentrations while soils from Mississippi and Jefferson county, both cotton-producing counties where soybean is grown primarily on clay soils, had the highest B concentrations. The average soil pH of all sampled soybean fields was 6.5 and ranged from 4.2 to 7.6.

Trifoliate-leaf tissue-B concentrations ranged from 7 to 91 mg B/kg relative to the critical B level of 20 mg/kg reported by Benton (1998). The median trifoliate-leaf B concentration was 42 mg B/kg and only one sample, from Jefferson County, had a leaf-B concentration above the toxic concentration of >63 mg B/kg suggested by Prasad and Power (1997). Mean leaf-B concentrations for Craighead and Jackson counties were 20 and 23 mg B/kg, respectively. Tissue-B concentrations as low as 7 and 16 mg B/kg were found suggesting that B deficiency was limiting soybean yields in some of the fields in these two counties. Arkansas, Jefferson, and Lee county had the highest leaf-B concentrations. Whole-plant B concentrations tended to be slightly lower than the trifoliate leaves with a range from 8 to 87 mg B/kg and a median value of 36 mg B/kg. The northeast Arkansas counties (i.e., Craighead and Jackson) west of Crowley's Ridge and north of I-40 had the lowest tissue-B concentrations and are the same areas where B deficiency has been observed in commercial soybean fields in 2001 and 2002. In contrast, B deficiency of soybean has not been observed in counties south of I-40 or east of Crowley's Ridge which tended to have mean, median, and B concentration ranges well above the established critical trifoliate-leaf concentration of 20 mg B/kg. Correlation of plant, soil, and irrigation water properties failed to show highly significant relationships that might be useful in explaining why B deficiency occurs in certain areas (Table 2).

PRACTICAL APPLICATIONS

Survey results from the first year show that B is most likely to limit soybean growth and yield in counties west of Crowley's Ridge and north of I-40, especially on silt loam soils. Although soils in other soybean-producing areas included in the 2002 survey also have high soil pH and low Mehlich 3 extractable soil B, tissue samples indicate that B nutrition is not limiting in these areas (i.e., southeast Arkansas). Information on soybean response to B fertilizer application and improved diagnostic tools are needed to provide Arkansas growers' with the technical information they need to eliminate soybean yield losses due to B deficiency.

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Table 1. Boron and pH content of soybean fields in 11 soybean-producing counties in Arkansas in 2002.

	pH		B			
County	Soil mean (range)	Irrigation water mean (range)	Irrigation water mean (range)	Soil mean (range)	Leaf mean (range)	Whole-plant mean (range)
			(mg B/L)	(lb B/acre)	---------------- (mg B/kg)	--------------
All counties	6.5 (4.2-7.6)	7.5 (6.8-8.0)	0.009 (0.005-0.024)	0.8 (0.1-4.1)	40 (7-91)	35 (8-87)
Arkansas	6.3 (5.1-7.6)	7.5 (7.2-7.8)	0.016 (0.005-0.033)	0.6 (0.3-0.9)	45 (37-53)	39 (33-47)
Chicot	6.5 (5.6-7.1)	7.7 (7.5-7.8)	0.009 (0.005-0.021)	1.1 (0.2-1.9)	43 (32-56)	39 (35-48)
Craighead	6.4 (5.5-7.0)	7.3 (7.3-7.3)	0.005 (0.005-0.005)	0.3 (0.2-0.4)	20 (16-27)	23 (19-26)
Crittenden	6.0 (5.0-6.6)	ND[z]	ND	0.6 (0.1-1.0)	49 (42-56)	45 (40-50)
Jackson	6.7 (6.4-6.9)	7.3 (6.8-7.7)	0.005 (0.005-0.005)	1.4 (0.4-4.1)	23 (7-35)	22 (8-37)
Jefferson	6.8 (6.3-7.3)	7.4 (7.1-7.8)	0.010 (0.005-0.019)	1.4 (0.8-2.6)	61 (47-91)	56 (44-87)
Lee	6.7 (6.0-7.1)	ND	ND	0.5 (0.2-0.9)	49 (45-52)	36 (33-40)
Mississippi	6.7 (6.1-7.1)	7.2 (7.2-7.2)	0.005 (0.005-0.005)	1.4 (1.2-1.6)	41 (39-44)	40 (36-46)
Phillips	5.4 (4.2-6.4)	ND	ND	0.2 (0.1-0.4)	46 (35-57)	39 (36-42)
Prairie	6.6 (6.4-6.8)	7.5 (7.2-7.8)	0.005 (0.005-0.005)	0.6 (0.2-1.0)	ND	ND
St. Francis	6.9 (6.2-7.2)	7.7 (7.4-8.0)	0.009 (0.005-0.024)	0.7 (0.1-1.2)	35 (28-45)	27 (19-40)

[z] ND = no data.

Table 2. Correlation matrix relating soil, water, and plant properties using the data from all 11 counties combined.

	Soil pH	Soil B	Water B	Leaf Ca	Leaf B	Plant Ca	Plant B
Soil pH							
r[z]	1.00	0.30	-0.33	-0.07	-0.17	0.44	-0.24
p		0.039	0.111	0.641	0.270	0.004	0.129
n	49	49	25	43	43	40	40
Soil B							
r	0.30	1.00	0.05	0.08	0.12	0.10	0.19
p	0.038		0.799	0.593	0.438	0.527	0.229
n	49	49	25	43	43	40	40
Water B							
r	-0.33	0.05	1.00	0.26	0.32	0.05	0.01
p	0.111	0.799		0.248	0.152	0.837	0.953
n	25	25	25	21	21	20	20
Leaf Ca							
r	-0.07	0.08	0.26	1.00	0.49	0.36	0.33
p	0.641	0.594	0.248		0.001	0.022	0.035
n	44	44	21	44	44	40	40
Leaf B							
r	-0.17	0.12	0.32	0.49	1.00	0.20	0.85
p	0.269	0.438	0.152	0.001		0.20	<0.0001
n	44	44	21	44	44	40	40
Plant Ca							
r	0.44	0.103	0.05	0.36	0.20	1.00	0.10
p	0.0044	0.526	0.837	0.022	0.208		0.549
n	40	40	20	40	40	40	40
Plant B							
r	-0.24	0.20	0.01	0.33	0.85	0.097	1.00
p	0.129	0.229	0.953	0.035	<0.0001	0.549	
n	40	40	20	40	40	40	40

[z] r = correlation coefficient; p = probability level; n = number of samples.

Corn Response to Phosphorus and Potassium Fertilization at Different Soil-Test Levels

J.H. Muir and J.A. Hedge

RESEARCH PROBLEM

Modern corn (*Zea mays* L.) hybrids, more intensive management systems, and crop rotations not previously used may result in different phosphorus (P) and potassium (K) fertilizer requirements than those traditionally recommended. Studies on nitrogen (N) requirements for corn in Arkansas in the 1980s identified a need to modify N recommendations for modern hybrids on fine-textured soils (Muir et al., 1992). The studies described in this manuscript were initiated in 1997 to evaluate the response of corn grain yield to P and K fertilization on a range of soil test P and K values.

BACKGROUND INFORMATION

Current P and K fertilizer recommendations for corn are based on research conducted several years ago and may not be adequate for corn grown in current production systems. Calibration studies are continuously needed to confirm the validity of current P and K recommendations or to provide unbiased evidence to justify modification of these recommendations.

RESEARCH DESCRIPTION

In 1997, P and K calibration studies were initiated on a Calloway silt loam soil at Arkansas State University (ASU) located in Jonesboro. A site with a range of P and K soil-test values was located in order to impose fertilizer rate treatments on blocks that varied in initial Mehlich 3-extractable P and K. The site had a range of soil-test K, but had a limited range of soil-test P. Soil-test K ranged from 85 to 272 lb K/acre (Mehlich 3, 1:7 extraction ratio) and soil-test P ranged from 17 to 50 lb P/acre (Mehlich 3, 1:7 extraction ratio). Phosphorus and K fertilizer rates of 0, 0.5, 1.0, and 2.0 times the recommended rates (1× rates were 70 lb P_2O_5/acre and 90 lb K_2O/acre) for the lowest soil test P and K values were broadcast and incorporated before planting each year.

The ASU location was lost after the 2001 season. A new trial was initiated at the Pine Tree Branch Station in 2002 on a Calhoun silt loam soil. Soil test P and K values (Mehlich 3, 1:7 extraction ratio) averaged 44 lb P/acre and 204 lb K/acre, respectively. Treatments included in the trial were 0, 80, 120, and 160 lb P_2O_5/acre as triple super phosphate and 0, 70, 105, and 140 lb K_2O/acre as muriate of potash (KCl). Phosphorus and K treatments were applied to the 2002 trial on 29 March and the hybrid Pioneer 3223 was planted on 10 April. Urea was applied preplant at a rate of 120 lb N/acre to the entire experimental area on 9 April. An additional sidedress application of 213 lb N/acre as 32% urea ammonium nitrate was applied to the entire experimental area on 29 May. The experimental design was a randomized complete block design with four replications.

RESULTS

Phosphorus fertilization had no significant influence on corn grain yield at the PTBS during 2002 (Table 1). However, yields in 2002 were relatively low suggesting another factor may have been more limiting than P. Previous trials conducted at the ASU site (Tables 2 and 3) showed significant yield responses to P fertilization on soils with initial Mehlich 3-extractable P ranging from 20 to 30 lb P/acre in 3 of 5 years. At the ASU site, Mehlich 3-extractable soil P in topsoil samples taken after corn harvest increased as P fertilizer rate increased (Tables 2 and 3). Linear regression showed that each year soil-test P increased between 0.06 to 0.29 lb P/acre per 1 lb P_2O_5 fertilizer applied. The rate of soil-test P increase was much lower (0.06 to 0.07 lb/acre per 1 lb P_2O_5 fertilizer) in 1998 compared to post-harvest samples taken in 1997, 1999, and 2000 (0.23 to 0.29 lb/acre per 1 lb P_2O_5 fertilizer). Thus, data suggest that 3.5 to 17 lb P_2O_5/acre fertilizer are required to increase soil-test P (Mehlich 3, 1:7 extraction ratio) by 1 lb/acre on a Calloway silt loam cropped to continuous corn. The data also show that soil-test P can vary from year to year.

Corn grain yield was significantly increased from K fertilization at the PTBS in 2002 on a soil with a soil-test K of 204 lb K/acre (Table 4). A yield response to applied K at soil-test values above 200 lb K/acre had not been measured during the previous five years in studies conducted at ASU (Table 5). Like P, Mehlich 3-extractable soil K in post-harvest soil samples increased linearly as K fertilizer rate increased at the ASU site (Table 5).

PRACTICAL APPLICATIONS

Results in previous years (Muir and Hedge, 2002) indicate that corn frequently responds to P and K fertilization at soil test levels that currently result in P and K fertilizer recommendations. The results from the 2002 trial indicated similar results for K. Results to date do not show a response to applied P and/or K at soil test levels too high to warrant a recommendation under the current guidelines. Results from six years of P and K calibration trials indicate that current soil test guidelines are accurate in determining P and K fertilizer recommendations for corn produced on Arkansas soils.

ACKNOWLEDGMENTS

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Table 1. Influence of P fertilization on corn grain yields in a study conducted at the Pine Tree Branch Station on a Calhoun silt loam with an initial soil-test P of 44 lb P/acre (Mehlich 3, 1:7 extraction ratio) during 2002.

P fertilizer rate	Corn grain yield
(lb P_2O_5/acre)	(bu/acre)
0	106
80	112
120	116
160	98
$LSD_{(0.05)}$	NS[z]

[z] NS = not significant

Table 2. Corn grain yield and soil-test P as affected by P fertilization rate on soils with different initial soil-test P levels for studies from 1997 - 1999 at Arkansas State University, Jonesboro, Arkansas.

Soil-test P level[z]	Annual P fertilizer rate	Soil-test P[y] Initial[xy]	Fall 1997	Fall 1998	Corn grain yield 1997	1998	1999
	(lb P_2O_5/acre/yr)	(lb P/acre)			(bu/acre)		
Low	0	21	19	17	159	133	142
	35	22	25	23	152	136	152
	70	21	27	22	165	142	164
	140	23	53	27	173	145	153
Medium	0	31	24	20	168	134	148
	35	29	28	22	173	134	151
	70	27	37	23	182	138	164
	140	28	62	30	174	138	165
$LSD_{(0.05)}$		NS	12	3	NS	9	12

[z] The low soil-test P category represents initial Mehlich 3 (1:7 extraction ratio) concentrations of <25 lb P/acre and the medium soil-test P category represents initial Mehlich 3 (1:7 extraction ratio) concentrations of >25 lb P/acre.
[y] Soils extracted with modified Mehlich 3 procedure (1:7 extraction ratio).
[x] Initial soil-test P in Spring 1997 at the beginning of study before P fertilizer was applied.

Table 3. Corn grain yield and soil-test P affected by P fertilizer rate on a Calloway silt loam with different soil-test P concentrations for studies conducted during 2000 and 2001 at Arkansas State University, located in Jonesboro.

	Soil-test P[z,y]		Corn grain yield	
P fertilizer rate	1999	2000	2000	2001
(lb P_2O_5/acre)	(lb Mehlich 3-P/acre)		------ (bu/acre) ----	
0	21	16	185	173
35	26	22	191	187
70	32	29	196	141
140	52	56	198	190
LSD $_{(0.05)}$	5	7	NS[x]	13

[z] Mehlich 3, 1:7 extraction ratio.
[y] Soil samples taken in the Fall of 1999 and 2000.
[x] NS = not significant

Table 4. Influence of K fertilization on corn grain yields in a study conducted at the Pine Tree Branch Station on a Calhoun silt loam with an initial soil-test K of 204 lb K/acre (Mehlich 3, 1:7 extraction ratio) during 2002.

K fertilizer rate	Corn grain yield
(lb K_2O/acre)	(bu/acre)
0	103
70	96
105	103
140	132
LSD $_{(0.05)}$	22

Table 5. Corn grain yield and soil-test K levels as affected by K fertilization on soils with different initial soil-test K levels in studies conducted at Arkansas State University located in Jonesboro, AR.

	Annual K	Soil-test K[z]									
Soil-test	fertilizer		Fall	Fall	Fall	Fall	Corn gain yield				
K level	rate	Initial[y]	1997	1998	1999	2000	1997	1998	1999	2000	2001
	(lb K_2O/acre/yr)	---------------------- (lb K/acre) --------------------					------------------------(bu/acre) ----------------------				
Very low	0	111	72	113	125	103	154	125	136	179	183
	45	106	99	130	182	129	158	128	146	184	199
	90	108	107	139	199	160	169	151	174	198	203
	180	109	144	189	277	166	168	150	156	209	194
Low	0	135	95	126	158	117	169	118	146	191	189
	45	138	106	173	188	119	159	121	140	189	198
	90	133	109	157	189	127	150	138	160	203	192
	180	138	158	228	291	199	182	131	161	211	198
Medium	0	157	104	147	165	119	176	138	152	186	188
	45	165	113	158	210	144	184	133	155	195	167
	90	162	139	173	242	144	181	150	161	196	195
	180	159	187	238	294	241	164	147	169	197	192
High	0	226	121	151	200	129	177	147	160	187	178
	45	195	128	164	213	131	183	127	167	192	181
	90	204	160	214	280	172	183	143	163	181	176
	180	245	212	280	333	232	179	135	150	180	154
LSD $_{(0.05)}$		11	25	21	25	28	NS[x]	NS	NS	NS	NS

[z] Mehlich 3, 1:7 extraction ratio.
[y] Spring 1997.
[x] NS = not significant

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 requirements 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 optimal soil temperatures. The low soil temperatures may result in slow root growth and phosphorus (P) deficiency even though soil-test P is 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 are 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 loss of N to 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 initiated on the Pine Tree Branch Station located near Colt, AR, in 2002 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 as urea ammonium nitrate (UAN 32-0-0) applied 2 inches below and 2 inches to the side of the seed at planting, b) 210 lb N/acre as urea (46-0-0) applied in four preplant/sidedress ratios (0.33, 0.50, 1.00, and 3.00), and c) 0 and 50 lb N/acre as ammonium nitrate (33.5-0-0) at tasseling. The preplant N was applied on 9 April. The hybrid Pioneer 3223 was planted on 11 April. Sidedress and tasseling applications of N fertilizer were made on 23 May and 1 July, respectively. Treatments were arranged in a randomized complete block, 2 (starter N rate) × 4 (Preplant:sidedress ratio) × 2 (Tassel N rate) factorial design with 4 replications.

RESULTS

There was no significant response to the different preplant/sidedress applications, N rate applied at tasseling, nor to any possible interaction among the main effects. Corn yield responded only to starter fertilizer rate in 2002 (Table 1). This is in line with results of trials evaluating various starter fertilizers during the previous three years (Tables 2 and 3). Starter fertilizer has produced a significant yield increase every year in these trials.

PRACTICAL APPLICATIONS

Starter fertilizer continues to show promise in corn production. Further data are needed to fully evaluate the best ratio of preplant/sidedress N and to document the benefits of N applications made at tasseling. Results to date consistently show a significant yield response to starter fertilizer on the order of 10 bu/acre or more. Producers should consider whether the cost of applying a starter fertilizer is worth the possible yield increase.

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Table 1. Influence of starter fertilizer on corn yield in a study conducted at the Pine Tree Branch Station during 2002.

Starter N fertilizer rate	Corn grain yield
(lb N/acre)	(bu/acre)
0	113
15	125
LSD (0.05)	12

Table 2. Influence of starter fertilizer on corn yields in a study conducted at Arkansas State University in Jonesboro during 1999.

Corn hybrid	Starter fertilizer[z]	Plant population	Corn grain yield
		(×1000/acre)	(bu/acre)
P 3335	N	15,488	118
P 3335	NP	17,061	113
P 3245	P	16,698	111
P 3335	P	16,998	107
P 3245	N	15,730	106
NK 7590	NP	16,577	104
P 335	Control	15,730	103
NK 7590	Control	19,844	103
P 3245	Control	14,399	103
NK 454	Control	16, 214	102
NK 7590	P	14,762	99
NK 454	N	15,125	99
NK 454	NP	17,424	98
P 3245	NP	12,705	95
NK 7590	N	15,609	94
NK 454	P	13,310	86
LSD (0.05)		3,598	23

[z] Starter fertilizers contained N (15.5 lb N /acre), P (25 lb P_2O_5/acre), or N and P.

Table 3. Influence of starter fertilizer on corn grain yields in studies conducted at Arkansas State University, located in Jonesboro during 2000 and at the Pine Tree Branch Station located near Colt during 2001.

Starter fertilizer[z]	Corn grain yield 2000	2001
	---------- (bu/acre) --------	
P	147	111
N	127	114
NP	127	106
Control	114	92
$LSD_{(0.05)}$	18	16

[z] Starter fertilizers contained N (15 lb N/acre), P (13 lb P_2O_5/acre), or N and P.

Effect of Soil- and Foliar-Applied Boron on the Yield of Cotton Under Two Nitrogen Regimes

D.M. Oosterhuis and R.S. Brown

RESEARCH PROBLEM

Boron (B) is routinely applied in commercial cotton (*Gossypium hirsutum* L.) production as soil and foliar applications irrespective of soil-B status. However, this recommendation was based largely on research conducted 30 years ago, and there has been no recent work to substantiate this with modern cultivars and production practices. Furthermore, there is only a limited understanding of B use by the cotton plant, and the effect of B on the physiology of the cotton plant has not clearly been documented. The objective of this study was to evaluate yield response of soil- and foliar-applied B at low and high soil-nitrogen levels. In a companion study the effect of B deficiency on the growth of the cotton plant was characterized (Oosterhuis and Zhao, 2001; Zhao and Oosterhuis, 2002).

BACKGROUND INFORMATION

Boron is an essential element required by cotton for optimal growth and development. Current production recommendations in Arkansas call for initial preplant soil applications of 1.0 lb to 2.0 lb B/acre or from two up to six foliar applications of 0.1 lb to 0.2 lb B/acre. This is based largely on research conducted by Miley (1966), Baker et al. (1956), and Maples and Keogh (1963). Recently, reports of yield response to soil or foliar applications of B have been inconsistent. For example, Howard and Gwathmey (1998), Abaye et al. (1998), and Heitholt (1992) reported no yield response to B utilizing non-buffered spray solutions, whereas Howard and Gwathmey (1998) observed that buffering B spray solutions to pH 4.0 increased yields relative to buffering to pH 6.0.

RESEARCH DESCRIPTION

The field study has been conducted for the past three years at the Delta Branch Research Station at Clarkedale, AR, in the northeast part of the state. Nitrogen rates for the low and high N treatments were 50 and 100 lb N/acre, respectively, for the 2000 and 2001 seasons and 0 and 100 lb N/acre, respectively, for the 2002 season. The study was planted the first week in May each season utilizing cotton cultivar SG747. Each season, the studies were arranged in a split-plot design and replicated five times. Initial soil boron concentrations ranged from 0.9 to 1.9 lb B/acre as determined by Mehlich 3-extractable B at a 1:7 extraction ratio. Soil-applied B consisted of 1.0 lb B/acre applied at pinhead square and foliar-B applications consisted of three 0.2 lb B/acre applications 1, 2, and 4 weeks after first flower. 'Buffer Xtra Strength' (Helena Chemical Co., Memphis, TN) was used to buffer spray solution to a pH of 4.0 to 5.0.

RESULTS

In general, soil- or foliar-B treatments had only small non-significant affects on lint yields (Table 1). Nitrogen level also showed only small non-significant differences in terms of yield (Table 1). In 2002, the high N treatment out-yielded the low N treatment by 39 lb/acre lint compared to the low N treatment when averaged over B treatments (Table 1). Buffered foliar applications did not significantly affect lint yield (data not shown, see Oosterhuis et al., 2001).

PRACTICAL APPLICATION

Results of this three-year study indicated that soil- or foliar-applied fertilizer B may not always be necessary as a routine procedure for obtaining high cotton yields. There were no positive responses to applied soil-B or foliar-B in either the high N or low N soil level. These results should be interpreted in relation to initial soil B status. There was no positive response to buffered foliar spray solutions of B.

ACKNOWLEDGEMENTS

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Table 1. Effect of soil and foliar B application on cotton yields at Clarkedale, AR.

Treatment	Lint yield			
	2000	2001	2002	3 yr. avg.
	(lb/acre)			
High N-control	1348	965	829	1047
High N-soil B	1462	921	834	1072
High N-foliar B	1302	911	835	1016
Low N-control	1296	998	809	1034
Low N-soil B	1352	961	775	1029
Low N-foliar B	1392	902	808	1034
LSD(0.05)	NS[z]	NS	NS	NS

[z] NS = non-significant (P=0.05).

Seasonal Turfgrass Quality of Bermudagrass and Zoysiagrass, as Affected by Various Soluble and Slow-Release Nitrogen Sources

M. Richardson, J. Robbins, J. Boyd, and D. Karcher

RESEARCH PROBLEM

Bermudagrass and zoysiagrass are the major turfgrass species in Arkansas, where they are used on golf courses, sports fields, home lawns, and in sod production. Although both of these species utilize the C4 photosynthetic pathway and have similar growth habits, they respond quite differently to applications of nitrogen (N) fertilizer. While a number of studies have investigated the N fertilizer needs of bermudagrass turf, the number of studies that have addressed zoysiagrass fertilization are very limited. Because of the widespread use of zoysiagrass and bermudagrass turf in Arkansas, a more thorough understanding of their N fertility needs is of value.

BACKGROUND INFORMATION

The maintenance of a high-quality turfgrass site requires frequent applications of N to promote growth and maintain good color and density. Depending on the type of site under maintenance, a turfgrass manager may use either soluble forms of N such as urea, NH_4NO_3, or NH_4SO_4 or slow-release forms of N such as methylene urea or sulfur-coated urea. Although soluble forms of N are generally less expensive than slow-release products, they will usually cause short-term bursts of turf quality, followed by equally quick drops in quality. Therefore, they must be applied frequently to maintain quality over an entire growing season. Slow-release products will typically produce a more uniform turfgrass quality over a longer period of time, but the quality is often slow to appear after application and is dependent on the release characteristics of the material. No studies have been conducted in Arkansas to compare the N needs of zoysiagrass and bermudagrass turf. In addition, limited research has been conducted on the use of various ratios of soluble and slow-release N sources and their effects on seasonal turfgrass quality. This study, which was initiated in 2000 and repeated in 2001 and 2002, was designed to investigate the effects of various N sources and rates on the seasonal turfgrass quality of bermudagrass and zoysiagrass.

RESEARCH DESCRIPTION

The overall design of this research involved two grass species (*Cynodon dactylon* cv. Tifway and *Zoysia japonica* cv. Meyer); two test locations (University of Arkansas Research and Extension Center, Fayetteville, AR; Lonoke County Extension Office, Lonoke, AR); three fertilizer raw materials; and three fertilizer rates. The fertilizer raw materials included ammonium sulfate (AS), polymer-coated urea (PCU), and polymer-coated sulfur coated urea (SCU). The three fertilizer materials were either applied alone or in combination to yield the following fertilizer source treatments: 1) 100% AS; 2) 100% PCU; 3) 100% SCU; 4) 33% AS / 67% PCU; 5) 33% AS / 67% SCU; 6) 67% AS / 33% PCU; and 7) 67% AS / 33% SCU. The fertilizer rates included applications of 1.0, 1.5, and 2.0 lb N/1000 ft^2 (~44, 66, and 88 lb N/acre) and the N treatments were applied on both 1 May and 1 August. Plot size was 3 ft × 6 ft (0.9 m × 1.8 m). The experimental design was a randomized complete block design with a factorial treatment structure of fertilizer rates and sources, with location and species considered fixed effects. Each treatment was replicated four times. Turf was irrigated as needed to prevent stress and plots were evaluated weekly for turfgrass quality. Turf quality was visually assessed on a scale of 0 to 9, with 9 being the highest possible quality. Quality rating values were averaged across 12 evaluation times for statistical analysis.

RESULTS

As expected, turf quality varied during the growing season but was not significantly affected by location (data not shown). Therefore, for brevity, the data were averaged across locations for this report. Turf quality was affected by both N rate and N source and there was a significant N source × N rate interaction. In general, bermudagrass had a greater response to the higher N rates with significant increases in turf quality at 1.5 and 2.0 lb N/1000 ft^2 compared to the 1.0 lb N/1000 ft^2 (Tables 1 and 2). Zoysiagrass demonstrated a stepwise increase in quality in response to both a 1.0 and 1.5 lb N/1000 ft^2 but did not show a further increase in quality at 2.0 lb N/1000 ft^2 (Tables 1 and 2). Collectively, these data suggest that the quality of 'Meyer' zoysiagrass can be maintained using lower N rates than 'Tifway' bermudagrass.

Nitrogen source had a significant effect on seasonal turf quality for both species and at all rates (Table 1 and 2). One trend that was consistent across both species was that N treatments containing SCU tended to produce the best overall quality compared to blends containing PCU. This likely reflects a more uniform release of N in SCU compared to PCU. A variance in turf quality across all evaluation dates was computed from the means of each evaluation date to demonstrate how fertilizer source and rate affected the consistency of turf quality across the growing season (Tables 1 and 2). This is an important parameter, since consistency and uniformity are often more important than short-term increases in turf quality. When evaluating the data, it is clear across both species and most fertilizer rates that single-source fertilizers produced less consistency in turf quality than combinations of soluble and slow-release materials. The combination of slow-release and soluble materials leads to an early response to added N from the soluble component of the blend and longer-term responses from the slow-release material. Model generation to compute longevity of the various fertilizer sources has not been conducted at the time of this writing.

PRACTICAL APPLICATIONS

From the current studies and other studies being conducted by the turfgrass program, it is apparent that the current recommendation for zoysiagrass is likely too high, based on the fact that adequate quality was maintained throughout the season with only 2.0 to 3.0 lb total N/1000 ft^2 (~65 to130 lb N/acre). On the other hand, bermudagrass needs much higher N to maintain adequate, year-around quality. A good turfgrass fertilizer combination would contain a blend of soluble materials such as ammonium sulfate and a slow-release product such as sulfur-coated urea, with approximately 1/3 of the blend being the soluble N source. This type of fertilizer ratio produced exceptional turfgrass quality.

ACKNOWLEDGMENTS

The authors wish to acknowledge the Soil Testing and Research Board and the Fertilizer Tonnage Fees for financial support of this research.

Table 1. Average seasonal turf quality[z] and variance (∂) of the means in seasonal turf quality of 'Meyer' zoysiagrass across two locations in Arkansas as affected by fertility rate and fertility source. Fertilizers treatments were applied on both 1 May and 15 Aug.

	Fertilizer rate (lb N/1000 ft^2)					
	1.0		1.5		2.0	
Fertilizer source	Avg.	∂	Avg.	∂	Avg.	∂
100% AS	6.2	0.3	6.4	0.5	6.6	0.3
100% PCU	6.1	0.3	6.1	0.5	6.4	0.7
100%SCU	6.4	0.2	6.6	0.3	6.6	0.7
33 AS / 67 PCU	6.3	0.2	6.3	0.2	6.6	0.2
33 AS / 67 SCU	6.4	0.1	6.8	0.3	6.9	0.2
67 AS / 33 PCU	6.3	0.2	6.6	0.2	6.7	0.3
67 AS / 33 SCU	6.4	0.2	6.4	0.1	6.7	0.3
Control	5.4	0.2	5.4	0.2	5.4	0.2
LSD (0.05) = 0.2						

[z] Turf quality was visually assessed on a scale of 0-9, with 9 being the highest possible quality. Numbers represent the average of 12 evaluation periods throughout the season.

Table 2. Average seasonal turf quality[z] and variance ( ) of the means in seasonal turf quality of 'Tifway' bermudagrass across two locations in Arkansas as affected by fertility rate and fertility source. Fertilizers treatments were applied on both 1 May and 15 Aug.

	Fertilizer rate (lb N/1000 ft^2)					
	1.0		1.5		2.0	
Fertilizer source	Avg.	∂	Avg.	∂	Avg.	∂
100% AS	6.6	0.4	6.9	0.5	6.9	0.7
100% PCU	6.2	0.5	6.1	0.5	6.4	0.3
100%SCU	6.1	0.2	6.5	0.4	6.6	0.2
33 AS / 67 PCU	6.0	0.8	6.4	0.3	6.4	0.4
33 AS / 67 SCU	6.5	0.3	6.7	0.3	7.0	0.4
67 AS / 33 PCU	6.3	0.4	6.6	0.2	6.7	0.3
67 AS / 33 SCU	6.4	0.2	6.7	0.3	7.0	0.3
Control	5.3	0.4	5.3	0.4	5.3	0.4
LSD (0.05) = 0.3						

[z] Turf quality was visually assessed on a scale of 0-9, with 9 being the highest possible quality. Numbers represent the average of 12 evaluation periods throughout the season.

Remote Sensing Technologies Used as Management Tools in Cotton Production

W. Robertson, C. Jayroe, W. Baker, D. Plunkett, and T. Kirkpatrick

RESEARCH PROBLEM

Development of site-specific maps describing soil variability within individual fields using precision agriculture technologies provides an opportunity to improve fertilizer and chemical use in production agriculture. This study was conducted to determine the effectiveness of multispectral aerial imagery and Veris electrical conductivity data as tools to identify field variability.

BACKGROUND INFORMATION

The field observed in this study is located in Mississippi County approximately 4.5 miles south of Blytheville. This field is an example of the dramatic soil changes caused by the violent earthquakes of 1811-1812 along the New Madrid Fault. These earthquakes affected much of the mid-Mississippi River Valley, changing the terrain for hundreds of miles (Johnston and Schweig, 1996). Remote sensing techniques were implemented in order to gain a better understanding of the impact of this earthquake series on soil variation.

The remote sensing technologies utilized in this study were an attempt to indirectly determine variations in soil physical properties. By categorizing the canopy density from the remote sensing data into three yield classifications (low, medium, and high), an expected cotton production map can be developed (Vellidis et al., 1997). In-field variation of soil texture is a determining factor in the amount of fertilizer that is required at site-specific areas. A measure of the electrical conductance (EC) of soil is being studied to determine the correlation between these measurements and the textural differences of the soil. The Veris cart is one method of directly measuring soil EC (Moore and Wolcott, 2001).

PROCEDURES

Using a Duncan Tech camera (Duncan Technologies Inc., Auburn, CA), a multispectral aerial image of the field was acquired on 28 July 2002. The resolution of the imagery was approximately one meter. The imagery was processed using ArcView 3.2 with the Image Analysis extension (Environmental Systems Research Institute Inc., Redlands, CA). The imagery was used to divide the relative cotton density into three productivity classes (low, medium, and high).

Using a Kawasaki 2025 Mule (Kawasaki Motors Corp., USA, Santa Ana, CA), a Veris 2000 XA (Veris Technologies, Salina, KS) was used to collect soil EC data on 21 November 2002. The Veris collects conductivity readings at a probe depth of approximately 2 to 3 inches once every second. The swath distance for the each round made through the field was approximately thirty feet, and the average driving rate was 8 mph. The Veris data were then transferred into the ArcView 3.2 mapping system where the latitude and longitude coordinates where overlaid onto a color infrared digital orthoquarterquad (DOQQ). A new and more detailed map was created using the Veris data points. This map was based on an inverse distance algorithm that produced estimates every 0.5 m. The interpolated Veris data were then compared to the field variations that could be seen in the multispectral aerial image and the soil series information.

Surface soil samples taken to a depth of 6 inches were collected and then sent to the University of Arkansas Soil Test Laboratory for analysis of soil nutrient levels. The samples were collected on an irregular pattern at a density of approximately one sample per acre.

RESULTS AND DISCUSSION

The enhanced multispectral image clearly indicated the areas of the field where the pivot irrigation system could not reach (Fig. 1). The irrigated portion of the field shows through as a lighter colored 65.1 acre semi-circle area in the image. The darker corners of the image, totaling 8.9 acres, were not covered by the field irrigation system.

Sand blows are a common occurrence in this area. These features (darker shaded areas) were readily identified in the aerial imagery (Fig. 2). The sand-blow intrusion patterns revealed by the imagery were spatially related with the soil series information for this field. The soil-survey information maps out these sand-blow intrusions as the Crevasse soil series. This same relationship between the sand-blow intrusions and the Crevasse soil series was identified by the Veris soil EC information as having lower soil levels (Fig. 3). The spatial relationship between the Veris soil EC map and the multispectral image was well correlated (Fig. 3 and Fig. 2). Soil nutrient data were not found to correlate with field soil-survey texture variations (data not shown).

Field observations clearly indicated the sand blow intrusions severely limited cotton growth due to moisture stress. In order to quantify these low plant-density areas, the image was classified into three groups (low, medium, and high) (Fig. 4). The high category is the area in the field with the highest expected yield. The medium category did show indications of stress and would be expected to suffer some yield loss. The low category (12% of the field), which is the class that contains the sand-blow intrusions, would not be expected to produce an economic return based on input costs.

PRACTICAL APPLICATIONS

Cotton production zones were classified into high, medium and low stress levels based on remote imagery and Veris soil EC. Approximately 13% (9.6 acres) of the field would not benefit from production inputs due to moisture stress because of the sand blow-intrusions. These data suggest that it would be more viable from an economic viewpoint to limit inputs such as fertilizer, growth regulator, insecticide, and defoliant in areas of the field classified with low productivity. A variable-rate controller could be used to apply inputs based on site-specific production zones instead of treating the field as a uniform area.

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Fig. 1. Enhanced multispectral aerial image (04/28/02) illustrating the cotton canopy area covered by the irrigation system.

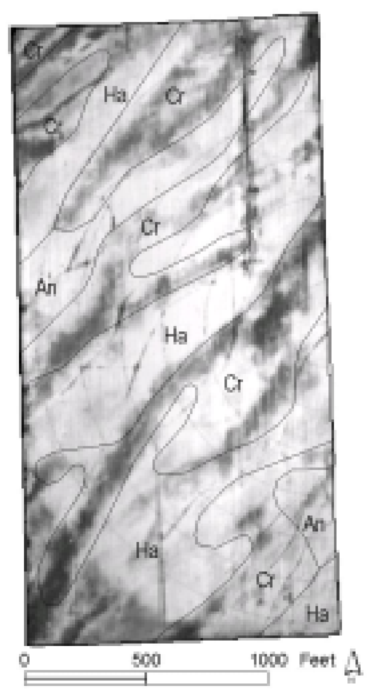

Fig. 2. Visual correlation of the spatial relationship between the soil series map units and the sand-blow intrusion areas as revealed by the enhanced multispectral image (Cr -Crevasse, Ha - Hayti, An - Amago).

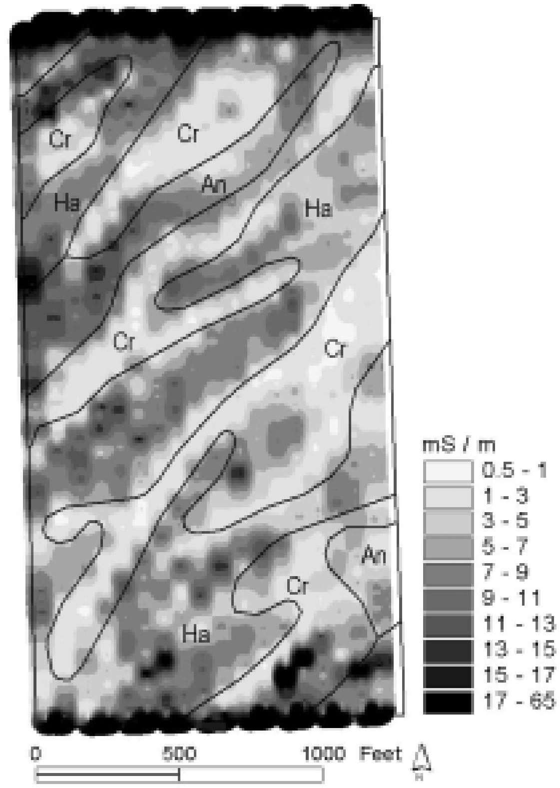

Fig. 3. Soil electrical conductivity map developed from Veris measurements used to indirectly access textural variations within the field.

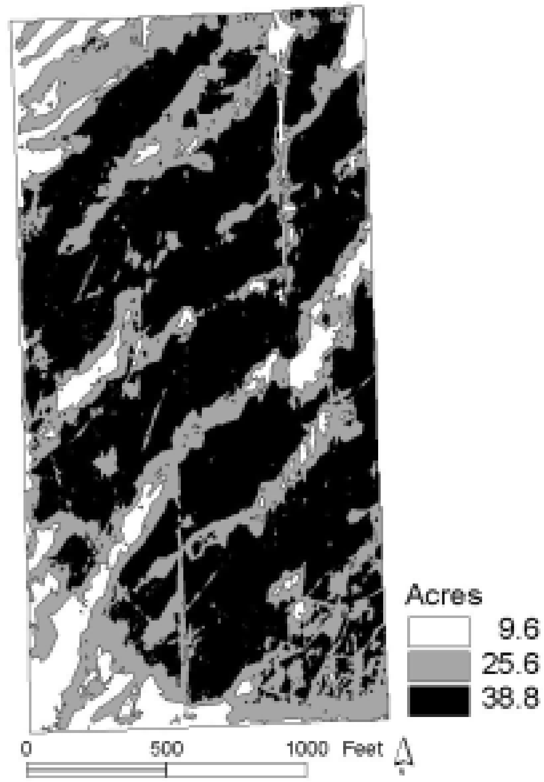

Fig. 4. Zone-specific variability of the enhanced multispectral image classified into three productivity zones (low-white, medium-grey, and high-black) indicating cotton yield potential.

Soybean Response to Soil and Foliar Boron Applications

J.R. Ross, N.A. Slaton, M. Mozaffari, and L. Espinoza

RESEARCH PROBLEM AND BACKGROUND INFORMATION

Boron deficiency of soybean [*Glycine max* (L.) Merr.] has been routinely observed in numerous soybean fields in northeast Arkansas since 2001. Boron deficiency of soybean has not previously been recognized as a common problem in Arkansas and research-based fertilization recommendations are not available. Slaton et al. (2002) noted that B deficiency frequently occurred during the vegetative growth stages of soybean, which lead to a provisional recommendation for growers to apply 1 lb B/acre near the time of seeding. These tentative B fertilization recommendations were made as a short-term remedy while research was initiated to collect replicated field data that would refine recommendations by defining the proper B rates and times of application.

In 2002, B deficiency was not observed or reported on fields that received preplant-B applications, but was again observed in numerous fields that did not receive B. This report describes the results of research trials initiated at the University of Arkansas Agricultural Experiment Stations during 2002. The overall objective of these studies was to evaluate soybean yield response to B fertilizer application rate and time (i.e., growth stage).

PROCEDURES

Foliar-B Application Study

A single study was established at the Pine Tree Branch Station (PTBS) located near Colt, AR, to evaluate the rate and growth stage of B application on soybean yield. The soil at the PTBS is an alkaline Calhoun silt loam, which is very similar to the soils where B deficiency has been documented. Selected soil chemical properties (4-inch sample depth) at the time of seeding are listed in Table 1. Rice (*Oryza sativa* L.) was grown on the test site in 2000 and 2001. 'Caviness' soybean was seeded in 15-inch rows on 30 May 2002. Phosphorus and K fertilizers (0-40-150) were applied to ensure P and K were not yield-limiting factors. Boron was applied at rates of 0, 0.25, 0.5, 1.0, and 2.0 lb B/acre at the V4 and R2 growth stages. The appropriate amount of Solubor (17.5% B), equal to each B rate, was mixed with water and applied to soybean foliage with a CO_2 backpack sprayer calibrated to deliver 10 gal/acre. The B treatments were arranged as a randomized complete block, 2 (growth stage) × 4 (B rate) factorial with an untreated check [0 lb B/acre (application rate) and none (application time)] and six replications.

Soil-Applied B Studies

Two studies were initiated to evaluate the effect of preplant soil B applications on soybean yield at the PTBS and at the Rice Research Experiment Station (RREC), near Stuttgart, AR. The residual effect of the B fertilizer rates applied in 2002 will be considered in tests on these same plots in 2003 and 2004. The soil at the PTBS is an alkaline Calhoun silt loam and was cropped to rice in 2000 and 2001. The soil at the RREC is a DeWitt silt loam and was fallow in 2001. Lime (8,000 lb/acre) was applied in March of 2002 at the RREC to increase soil pH (~5.5) and increase the likelihood of B deficiency. Boron-deficient soybean had not previously been observed at either location. Selected soil chemical properties (4-inch sample depth) for each site at the time of seeding are listed in Table 1.

At each location, 'Caviness' soybean was seeded in 15-inch rows on 30 May and 22 May at the PTBS and the RREC, respectively. Boron rates of 0, 1, 2, 4, 6, and 8 lb B/acre were applied to the soil surface at each site after seeding but before soybean emergence. At the PTBS, B was applied as a solution using Solubor (17.5% B) as the B source. The 1 lb B/acre rate was mixed with water and sprayed with a CO_2 backpack sprayer calibrated to deliver 10 gal/acre. Plots receiving B rates > 1.0 lb B/acre were sprayed multiple times until the desired rate was applied. At the RREC, Granubor (15% B) was uniformly broadcast by hand to each plot. Phosphorus and K fertilizers (0-40-150) were applied to each location to ensure P and K were not yield-limiting factors. The experiment was arranged in a randomized complete block design with six replications.

All test sites were flood-irrigated as needed throughout the growing season. At maturity, soybeans from all three studies were harvested by combine. Soybean yields were adjusted to a uniform moisture content of 13% for statistical analysis. Analysis of variance procedures were conducted with the PROC GLM procedure in SAS. Mean separations were performed by Fisher's protected least significant difference (LSD) at a significance level of 0.05 or 0.10.

RESULTS AND DISCUSSION

Foliar-B Application Study

Although excellent soybean yields were produced, yields did not respond to B fertilizer rate, time of application, or the interaction between the two main effects. Soybean yields for each B treatment are given in Table 2. Analysis of soybean tissue and harvested seed for B concentration has not been completed and will be reported in the 2003 report. The soil pH (7.9) and Mehlich 3-extractable B (0.9 mg B/kg soil) were typical of silt loam soils used for rice and soybean production in eastern Arkansas. However, Mehlich 3-extractable B, which is approximately 2× the B concentrations extracted by the hot water method (unpublished data from North American Proficiency Testing Samples), was slightly higher than the soil B (0.10 to 0.45 mg B/kg soil) reported in deficient fields during the growing season by Slaton et al. (2002).

Soil-Applied B Studies

Visual symptoms of B deficiency or toxicity were not observed in either study. Soybean yields were not significantly affected by preemergence soil-B applications at the RREC (Table 2). Excessive rainfall following seeding resulted in stand reduction and poor growth of some plots and is reflected by a high C.V. (18.4%) at this location. At the PTBS, preemergence B application rate significantly affected soybean yields (Table 3), however the unfertilized control yield was statistically similar to yields of all B application rates. The yield data suggest a trend for soybean yield reduction when B application rates exceeded 4 lb B/acre. Analysis of the soybean leaf tissues, which are not yet completed, collected at the R2 growth stage should indicate whether this trend is real or merely variation within the test area.

PRACTICAL APPLICATIONS

The single year of data collected in 2002 indicated B was not a yield-limiting factor at the test sites and indicates that a better understanding of the soil properties associated with B deficiency of soybean is needed. Research efforts located in grower fields, close attention to soil and environmental characteristics in B-deficient fields, and results from a statewide nutrient-concentration survey of soybean tissues obtained from commercial fields should provide further insight concerning the need for B fertilization of soybean in Arkansas. Until several years and locations of research data can be obtained, growers in the areas where widespread B deficiency has occurred should likely continue to consider preplant-B applications of 1.0 lb B/acre, especially on fields with high pH (> 7.0) and low Mehlich 3-extractable B (< 1.0 lb Mehlich 3 B/acre or 0.5 mg B/kg soil).

ACKNOWLEDGMENTS

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Table 1. Selected soil chemical properties (samples taken to a depth of 4 inches) for three B fertilization of soybean studies conducted at the Pine Tree Branch Experiment Station and the Rice Research Extension Center during 2002.

		Mehlich 3-extractable soil nutrients							
Location	pH	P	K	Ca	Mg	Fe	Mn	Zn	B
		(mg/kg[z])							
PTBS[y]	7.9	23	104	2048	327	322	120	1.9	0.9
PTBS[x]	6.5	20	96	1629	289	318	107	1.5	0.8
RREC[x]	7.8	10	102	942	183	224	138	0.7	0.7

[z] Values are the mean of 6 composite samples from the 0- to 4-inch soil depth collected from each unfertilized control of each study. Samples were extracted with Mehlich 3 solution at a soil:solution ratio of 1:10.

[y] Boron rate and growth stage of application study.

[x] Preemergence, soil-applied B rate studies.

Table 2. Soybean (Caviness) yield response to B application time and rate at the Pine Tree Branch Experiment Station during 2002.

	Time of foliar B application	
B application rate	V4 stage	R2 stage
(lb B/acre)	[soybean yield, bu/acre (adjusted to 13% moisture)]	
0	72.4	
0.25	76.8	72.5
0.5	66.0	73.0
1.0	76.2	70.3
2.0	69.3	69.2
Time mean	72.1	71.2
LSD (0.10)	NS[z]	

[z] NS = not statistically significant.

Table 3. Soybean yield response to B application rate at the Pine Tree Branch Experiment Station (PTBS) and the Rice Research Extension Center (RREC) during 2002.

	Soybean yield	
B application rate	PTBS	RREC
(lb B/acre)	[bu/acre (adjusted to 13% moisture)]	
0	70.6	50.5
1	71.4	51.8
2	69.4	50.4
4	76.0	48.2
6	66.6	45.4
8	65.6	43.7
P-value	0.0892	0.6431
LSD (0.10)	6.1	NS[z]

[z] NS = not statistically significant.

Soybean Response to Phosphorus Fertilization Following Rice in the Rotation

N.A. Slaton, R.E. DeLong, R.J. Norman, S.D. Clark, and D.L. Boothe

RESEARCH PROBLEM AND BACKGROUND INFORMATION

In Arkansas, fertilizer guidelines for irrigated-soybean [*Glycine max* (L.) Merr.] grown on loessial soils recommend the application of P fertilizer when Mehlich 3 soil-test P (1:7 extraction ratio) is ≤40 lb P/acre (20 mg P/kg). Although soybean is not considered highly responsive to P fertilization, crops following flood-irrigated rice in the rotation often require P because the P is less available following extended periods of flooding (Brandon and Mikkelsen, 1979; Griffin and Brandon, 1983). However, P deficiency of soybean is not commonly observed in Arkansas even when following rice in the rotation. In this report we present three years of soybean response data from a long-term experiment, initiated in 1998, investigating rice and soybean response to P fertilization application rate and frequency. The overall objectives of this study were to 1) determine soil-test P response to P fertilization rate and frequency, and 2) document rice and soybean growth and yield responses to P fertilization when grown in rotation.

PROCEDURES

In 2002, soybean was grown for the third year on the same plots established in 1998 on a Calloway silt loam (pH =7.8) at the Pine Tree Branch Station (PTBS) near Colt, AR, and a DeWitt silt loam (pH = 5.2) at the Rice Research and Extension Center (RREC), near Stuttgart, AR. Soybean had previously been grown in these same plots in 1998 and 2000 and rice was grown previous to soybean in 1999 and 2001. Each year a composite soil sample was taken in February or early March from each plot to a depth of 4 inches and extracted with Mehlich 3 (1:7 extraction ratio) for soil nutrient concentrations, including P (Table 1).

In 2002, at the PTBS, 'Caviness' soybean was drilled (15-inch rows) into the undisturbed rice stubble from the previous year using a no-till drill on 30 May 2002. At the RREC, Caviness soybean was drilled (15-inch rows) into a conventionally tilled seedbed on 22 May 2002. Before soybean emergence, P was broadcast applied to the soil surface at rates of 0, 20, 40, 80, and 120 lb P_2O_5/acre on plots that received annual applications of P fertilizer (Annual: both soybean and rice crops receive P); and on plots that received P only when seeded to soybean (Soybean: no P applied when rice is grown). A third set of plots receive P fertilizer only when cropped to rice (Rice: no P applied when soybean is grown). Specific management information on studies conducted in 1998 and 2000 were described by Slaton et al. (1999, 2001). At the R2 growth stage, whole-plant samples were taken from a 3-ft row section for total dry-matter accumulation and analysis for tissue-P concentration (data not shown). Potassium fertilizer (0-0-60) was also applied to ensure that K was not a yield-limiting factor. Boron (1 lb B/acre, preplant soil application as Solubor) was also applied at the PTBS in 2002. At maturity, soybeans at both locations were harvested by combine. Soybean yields were adjusted to a uniform moisture content of 13% for statistical analysis. The treatments were arranged as a randomized complete block, 3 (frequency of application; Annual, Soybean, and Rice) × 4 (P application rate) factorial with an unfertilized control (0 lb P_2O_5/acre and None) and four replications. Yield data from each location were analyzed separately. Analysis of variance procedures were conducted with the PROC GLM procedure in SAS. Mean separations were performed by Fisher's protected least significant difference (LSD) method at a significance level of 0.05

or 0.10. Soil-test P means were plotted and subjected to simple linear regression to describe soil-test P response to annual P fertilizer rates.

RESULTS AND DISCUSSION

Grain Yield Response

Soybean yield responses to P fertilization during 1998, 2000, and 2002 are presented in Tables 2 and 3. The interaction between P rate and frequency of P fertilizer application has not significantly affected yields at either location since the study was initiated. In 1998, the frequency of P fertilization was not a treatment factor since it was the first year of the study. At the PTBS, soybean yield generally increased when P rates ^{3}40 lb P_2O_5/acre were first applied in 1998 (Table 2), but significant yield increases due to P-application rate, averaged across frequencies of application, have not reccurred. At the RREC, significant soybean yield responses have not occurred, but the data show a trend for increased yields due to P application during each year.

The frequency of P application did not show a consistent statistically significant effect on soybean yields at either location in 2000 (Table 3). Significant ($P < 0.10$) yield responses to P-application frequency, averaged across P rates, were noted at both locations during 2002. Although soybean yields among P rates were statistically significant at the PTBS in 2002, the unfertilized control (None) produced yields equal to all other P-application rates. At the RREC, soybean yields were statistically similar among the unfertilized control (None) and treatments receiving P every other year (Rice or Soybean). Annual application of P fertilizer produced significantly higher yields than the unfertilized control (None) or application every other year.

Soil Test P Response to P Fertilization

The relationship between P fertilizer rates applied annually and Mehlich 3-extractable P (1:7 extraction ratio) for two silt loam soils used for rice and soybean production is shown in Fig. 1. After two complete soybean-rice rotation cycles (4 years), annual P rates >120 lb P_2O_5/acre for the alkaline Calloway silt loam (PTBS) and ~56 lb P_2O_5/acre for the acidic DeWitt silt loam (RREC) were needed to maintain the initial soil test P concentrations measured in 1998. The relationship suggests that annual P-fertilizer rates above the rate of P removed by harvested rice and soybean seed are required to maintain the soil-test P on these silt loam soils used for rice and soybean production. Although these data do not indicate the soil-test P response to P-fertilizer rate in rotations not involving rice, the flooded-irrigated system used for rice production likely results in fixation of soil- and fertilizer-P. This theory is supported by the trends in annual soil-test P measured following each crop (Fig. 2). Figure 2 shows the absolute difference in soil-test P between years. For example, the absolute difference in 1999 was calculated by subtracting the initial soil-test P (from samples taken before P-fertilizer application in 1998) from the soil-test P measured in February 1999 (after soybean was fertilized and produced in 1998). Soil-test P in samples taken following soybean in the rotation increased in both 1999 and 2001 *(Note: The year indicates the year soil sample was taken after soybean grown during the previous year)* at the PTBS and in 1999 at the RREC. In contrast, soil-test P declined following rice in the rotation at the PTBS in 2000 and 2002 and at the RREC in 2000. Apparently the P fixed after flood removal is not extractable, at least for several months, with the Mehlich 3 method.

PRACTICAL APPLICATIONS

The lack of soybean yield responses to P-fertilization at the PTBS and RREC suggests that P is not a major yield-limiting factor at these two locations. Soybeans grown in the unfertilized control plots have not exhibited visual P-deficiency symptoms after P removal, without replacement via fertilization, by four harvested crops (two complete 1:1 soybean-rice rotations). Although P has been reported to limit the yield of soybean and other crops grown following rice in the rotation, dramatic differences in soybean yields among P-fertilizer treatments have not yet been observed in this study. Phosphorus fertilization has also not consistently and significantly affected rice yields during this study either. Despite annual application of P fertilizer, soils used for rice and soybean production commonly have very low to medium soil-test P but may not require routine P fertilization to maximize yields. Growers should not be concerned about low soil-test P for soils used for rice and soybean production since this is likely a result of the alternating anaerobic-aerobic conditions of this crop rotation. Most soils apparently have adequate plant-available P to sustain high rice and soybean yields, especially when current recommendations are followed. Phosphorus fertilization guidelines using the Mehlich 3 extractant require further research to establish whether a good correlation exists between Mehlich 3-extractable P and the yield of soybean grown on the silt loam soils following rice in the rotation.

ACKNOWLEDGMENTS

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Table 1. Selected soil chemical properties of the unfertilized controls (samples taken in February 2002 to a depth of 4 inches) for two long-term P fertilization studies conducted at the Pine Tree Branch Station (PTBS) and the Rice Research and Extension Center (RREC). Soil-test nutrient concentrations in mg/kg can be converted to lb P/acre by multiplying each × 2.

	Mehlich 3 (1:7 extraction ratio) soil-test concentrations									
Site	pH	P	K	Ca	Mg	S	Fe	Mn	Zn	B
		(mg/kg)								
PTBS	7.8	10	116	1779	386	11	204	116	4.4	0.5
RREC	5.2	6	146	632	92	13	258	102	0.6	0.5

Table 2. Soybean yield response to P-fertilizer application rate, averaged across P application frequency, at the Pine Tree Branch Station (PTBS) and the Rice Research and Extension Center (RREC) during 2002.

	PTBS			RREC		
P application rate	1998	2000	2002	1998	2000	2002
(lb P_2O_5/acre)	(bu/acre)					
0	36.9	39.3	49.8	20.5	47.1	48.8
20	37.7	44.8	51.4	26.2	47.7	52.7
40	43.9	41.8	45.8	22.9	49.8	53.8
80	39.3	44.7	48.0	26.7	49.5	56.6
120	42.2	40.6	47.7	24.1	50.6	58.6
P-value	0.0423	0.1825	0.3843	0.4211	0.5057	0.1562
LSD (0.10)	4.4	NS	NS	NS	NS	NS

Table 3. Soybean yield response to P fertilizer application frequency, averaged across P application rates, at the Pine Tree Branch Station (PTBS) and the Rice Research and Extension Center (RREC) during 2000 and 2002. (Note: 1998 was the first year of the study and only P application rate was a treatment factor).

	PTBS		RREC	
P application frequency	2000	2002	2000	2002
	(bu/acre)			
None	39.3	49.8	47.1	48.8
Rice	44.1	48.1	49.7	53.6
Soybean	41.9	51.2	50.0	53.6
Annual	43.0	45.7	48.6	58.7
P-value	0.5438	0.0949	0.6866	0.0826
LSD (0.10)	NS	5.7	NS	5.0

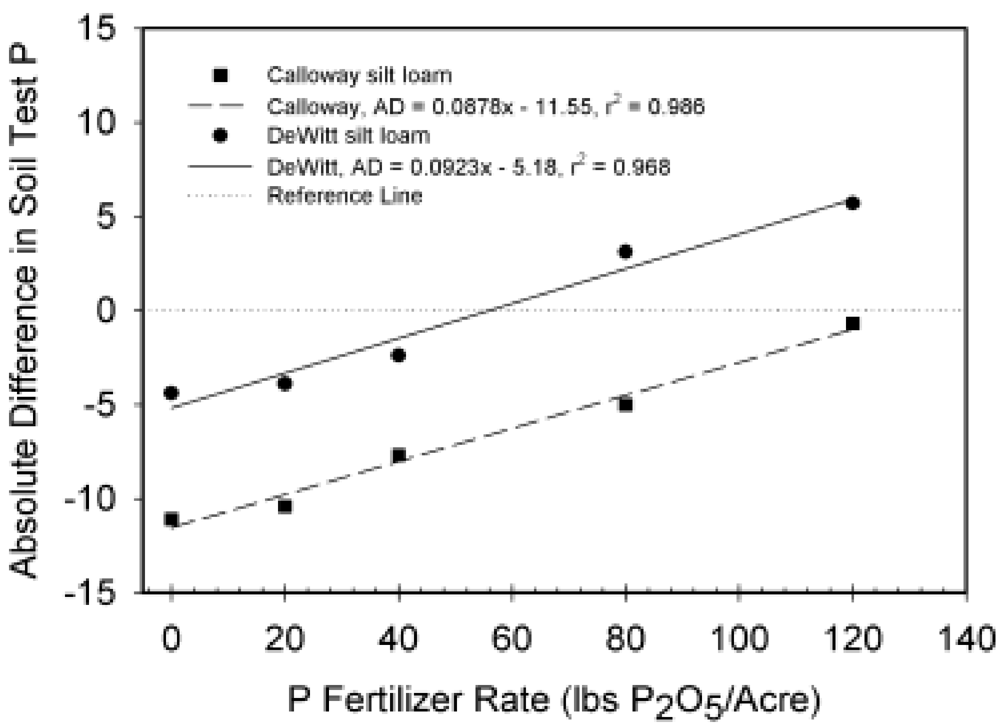

Fig. 1. The relationship between annual P fertilizer rate and the absolute difference of Mehlich 3 (1:7 extraction ratio) extractable soil P after two complete soybean-rice rotation cycles on a Calloway silt loam at the PTBS and a DeWitt silt loam at the RREC. Graphed values indicate the net increase or decrease in soil-test P between the initial 1998 values and those measured in February 2002. The dotted horizontal line (at 0 absolute difference) marks the point of no change in soil-test P concentration after four years. Data points below the dotted line indicate a net decrease and points above the dotted line indicate a net increase in soil-test P.

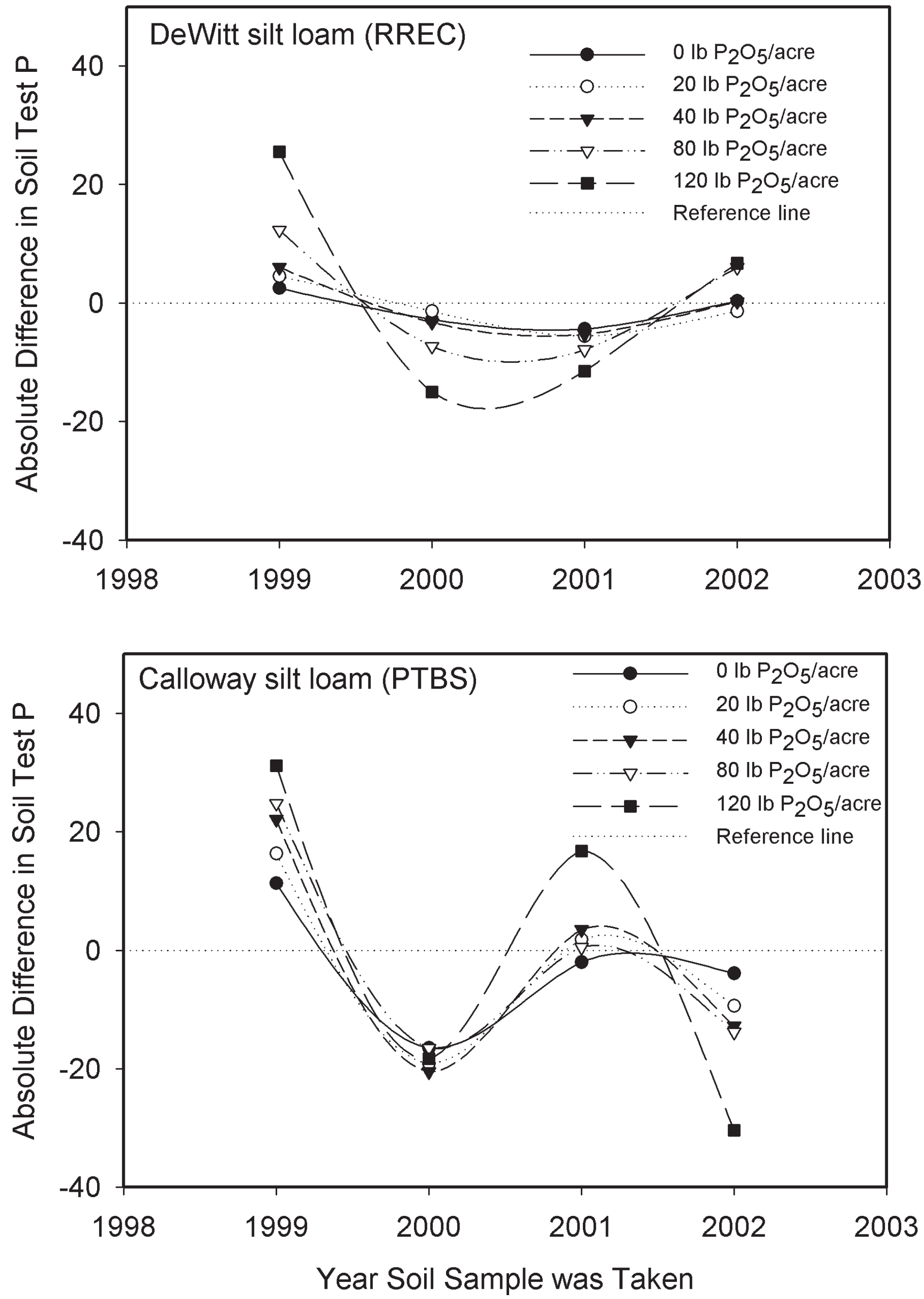

Fig. 2. Annual fluctuations in soil-test P, by annual P application rate, represented as the absolute differences between soil-test P of two consecutive years (e.g., 1999-1998, 2000-1999, etc.). Note: Soybean was grown in 1998 and 2000 and rice was grown in 1999 and 2001. Year, on the x-axis, denotes the year that the soil sample was taken with the previous year soil-test P subtracted to give the absolute difference.

Adaptation of Soybean Cultivars to Restrictive Soil Environments

J.D. Widick and J.M. Dunn

RESEARCH PROBLEM

Many modern soybean cultivars are capable of producing yields of more than 60 bu/acre when grown in high-yield environments (Dombek et al., 2001). Some soybean growers, however, have reported decreasing seed yields in recent years, even when modern cultivars and sound cultural management practices are used. Rice yields have also decreased in soybean-rice rotations grown in such environments. Research is being conducted in conjunction with an ongoing soybean breeding program to identify factors that limit soybean seed yield in specific environments and to develop new cultivars, which produce higher yields than conventional cultivars when grown in environments that limit productivity.

BACKGROUND INFORMATION

Yield potential of cultivars developed by conventional breeding programs is estimated by growing experimental strains in environments that maximize seed production. Growers who have soil conditions that restrict seed yield because of unidentified factors do not have a source of cultivar performance information from environments that are closely related to their own.

RESEARCH DESCRIPTION

Four fields, located in Craighead (1), Cross (1), and Monroe (2) counties, have been used in this study. Growers have reported that each field has produced progressively lower seed yields in recent years although cultivars grown have been highly productive in the Arkansas Soybean Performance Tests. Soil test results from two of the fields have been described in a previous publication (Widick and Harrell, 1999). Each year in these four study sites, a variety of diverse soybean genotypes were grown in yield-restrictive fields. Sources of these genotypes include commercial cultivars, experimental strains, plant introductions, and old cultivars. New germplasm is added for evaluation each year as new cultivars and experimental strains become available. Yield, agronomic characters, and foliar nutrient composition are measured. Leaflets of the uppermost trifoliolate leaves are sampled at the R3 growth stage to determine the nutritional status of plants as seed development begins (Fehr and Caviness, 1977). Selections for crossing are based on seed yield and plant growth each year. Foliar nutrient data are used to determine whether any nutrients are present in deficient or toxic levels. Seed of promising populations derived from crosses is increased at the Northeast Research and Extension Center (NEREC) located at Keiser, AR. Advanced strains developed from these populations are evaluated at NEREC and at the Pine Tree Branch Station (PTBS) to determine their yield potential in conventional soybean production environments. Tests to determine the effects of deep tillage and potassium (K) fertilization have been conducted in past years to help identify factors responsible for yield decreases in restrictive environments.

Strains derived from crosses among selections made in restrictive environments were grown for seed increase and for evaluation at the NEREC and at PTBS in 2001. In 2002, these strains were again grown at NEREC and PTBS for evaluation of yield potential in productive environments. Strains were also grown in a production field in St. Francis County. A late planting date of 25 June 2002 accompanied by dry soil conditions delayed emergence until after 1 July 2002. The test was irrigated as needed after plants reached the V4 growth stage. Cultural practices were those used by the farmer. Sufficient quantities of seed from newly developed strains are now available for testing in the restrictive environments where selection of parents were made. These tests will begin in 2003 and continue in future years.

RESULTS

Preliminary results from the St. Francis County test indicate 2002 seed yields ranged from 40 to 55 bu/acre even with late planting and delayed emergence. The test was harvested 13 November. Preliminary data from NEREC and PTBS indicate yields were higher than for the late-planted test in St. Francis County, but the on-station tests were planted one month earlier. Further conclusions will be made as complete data become available.

PRACTICAL APPLICATIONS

Conventional cultivars have been shown to interact with tillage depth and fertility. Further studies will be made using these newly developed genotypes in yield-restrictive environments. These new genotypes will be used to increase productivity of environments that have restricted yields of conventional cultivars.

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