5-1-1992

Arkansas Soil Fertility Studies 1991

Wayne E. Sabbe
University of Arkansas, Fayetteville

Citation

Sabbe, W. E. (1992). Arkansas Soil Fertility Studies 1991. *Arkansas Agricultural Experiment Station Research Series.* Retrieved from https://scholarworks.uark.edu/aaesser/189

ARKANSAS SOIL FERTILITY STUDIES 1991

Wayne E. Sabbe, editor

RKANSAS AGRICULTURAL EXPERIMENT STATION
vision of Agriculture University of Arkansas
ay 1992 Research Series 421

Edited by Nancy Griffith Wyatt

Agricultural Experiment Station, University of Arkansas Division of Agriculture, Preston E. La Ferney, Vice President for Agriculture; Gerald J. Musick, Director. PS1M592PM.

ISSN:0099-5010 CODEN:AKAMA6

ARKANSAS SOIL FERTILITY STUDIES 1991

Department of Agronomy
University of Arkansas
Fayetteville, Arkansas 72701

Arkansas Agricultural Experiment Station
Fayetteville, Arkansas 72701

INTRODUCTION

Contained within this publication are progress reports on the specific aspects of the soil fertility program at the University of Arkansas in 1991. In most instances, the reports are not final reports, but they may contain data from several years. Further details on each report can be obtained from the respective project leaders.

Special thanks to county extension staffs, staffs at the Research and Extension Centers, branch stations, farmers and cooperators, fertilizer and lime industry, agricultural business and others who have donated time and effort in assisting with the programs. Funding for the soil fertility programs originated from state and federal government sources, private industry, state check-off from the commodities, fertilizer and lime tonnage fees and competitive grants.

Additional copies of this publication may be obtained from Agricultural Publications, Agriculture Building 110, University of Arkansas, Fayetteville, AR 72701.

ACKNOWLEDGMENT

The fertilizer tonnage fees funded the publication of this research series.

Edited by:
Wayne E. Sabbe
Agronomy Department
University of Arkansas

CONTRIBUTORS

R.K. Bacon, Associate Agronomist, Agronomy Department, Fayetteville
W.H. Baker, Research Assistant Agronomist, Soil Test Lab, Marianna
C.A. Beyrouty, Associate Agronomist, Agronomy Department, Fayetteville
B.R. Bondada, Graduate Assistant, Agronomy Department, Fayetteville
M.V. Brown, Research Assistant, Horticulture & Forestry, Fayetteville
M. Bryles, Consultant, Adams Land Company, Leachville
J.R. Clark, Resident Director, Fruit Substation, Clarksville
J.B. Fitzgerald, Graduate Assistant, Horticulture & Forestry, Fayetteville
P.B. Francis, Assistant Professor, Southeast Research and Extension Center, Monticello
B.S. Frizzell, Research Specialist, Southeast Research and Extension Center, Monticello
E.E. Gbur, Agricultural Statistician, Agronomy Department, Fayetteville
K.A. Gravois, Assistant Agronomist, Rice Research and Extension Center, Stuttgart
B.C. Grigg, Graduate Student, Agronomy Department, Fayetteville
M.G. Hanson, Research Assistant, Agronomy Department, Fayetteville
J.A. Hattey, Research Assistant, Agronomy Department, Fayetteville
R.S. Helms, Extension Specialist, Rice Research and Extension Center, Stuttgart
E.M. Holman, Graduate Assistant, Agronomy Department, Fayetteville
R.G. Hurren, Visiting Scholar, Agronomy Department, Fayetteville
K.M. Irvin, Research Specialist, Fruit Substation, Clarksville
L.D. Janes, Research Assistant, Agronomy Department, Fayetteville
T.C. Keisling, Agronomist, Soil Test Lab, Marianna
R.L. Maples, former Assistant Agronomist, Soil Test Lab, Marianna
H.J. Mascagni, former Assistant Agronomist, Northeast Research and Extension Center, Keiser; currently LSU, St. Joseph, Louisiana
M.L. May, former Agronomist, Southwest Research and Extension Center, Hope; currently American Soybean Association, St. Louis, Missouri
J.S. McConnell, Associate Agronomist, Southeast Research and Extension Center, Monticello
W.N. Miley, former Extension Specialist, Little Rock; currently, private consultant, North Little Rock
D.M. Miller, Assistant Agronomist, Agronomy Department, Fayetteville
K.A. Moldenhauer, Assoc. Agronomist, Rice Branch Station, Stuttgart
P.M. Moore, Assistant Professor, Southeast Research and Extension Center, Monticello
T.E. Morelock, Horticulturist, Horticulture and Forestry Department, Fayetteville
D.R. Motes, Resident Director, Vegetable Substation, Alma
J.H. Muir, Assistant Agronomist, Arkansas State University, Jonesboro
R.J. Norman, Associate Agronomist, Rice Research and Extension Center, Stuttgart

D.M. Oosterhuis, Agronomist, Agronomy Department, Fayetteville

P.W. Parker, Research Specialist, Northeast Research and Extension Center, Keiser

W.K. Patterson, Assistant Professor, Horticulture and Forestry Department, Fayetteville

J.M. Phillips, Associate Agronomist, Southwest Research and Extension Center, Hope

C.R. Rom, Associate Professor, Horticulture & Forestry Department, Fayetteville

R. Rom, University Professor Emeritus, Horticulture & Forestry Department, Fayetteville

W.E. Sabbe, Agronomist, Agronomy Department, Fayetteville

N.A. Slaton, Area Rice Specialist, Rice Research and Extension Center, Stuttgart

Y.H. Teo, Graduate Student, Agronomy Department, Fayetteville

N.P. Tugwell, Entomologist, Entomology Department, Fayetteville

J.J. Varvil, Research Specialist, Soil Test Lab, Marianna

P.J. Watson, Graduate Assistant, Agronomy

B.R. Wells, Agronomist, Agronomy Department, Fayetteville

D.C. Wolf, Agronomist, Agronomy Department, Fayetteville

CONTENTS

IDENTIFICATION OF SOILS WITH PROPERTIES THAT MAY INHIBIT DEEP ROOT GROWTH

M.G. Hanson, C.A. Beyrouty and E.E. Gbur

INTRODUCTION

There has been little research on subsoil fertility in Arkansas. Soil tests generally involve only the upper 6 in. of soil, yet the subsoils of many southeastern states frequently restrict deep root growth due to such factors as Ca deficiency or H and Al toxicity (Adams and Lund, 1966). These conditions can cause shallow rooting, which prevents utilization of moisture (Rios and Pearson, 1964) and of nutrients stored deep in the soil profile, thereby reducing seed yields, dry matter and plant vigor. Knowledge of subsoil chemistry should provide a more complete understanding of the factors affecting shallow rooting. Amelioration of chemical imbalances should promote deep rooting and allow for more efficient use of subsoil water and nutrients, thus reducing the need for frequent irrigation and enhancing growth under non-irrigated conditions.

PROCEDURE

Sixteen agronomic soils from eastern Arkansas, representing 13 Alfisols and three Entisols, were collected during the winter of 1991. These soils make up 1 million of the approximate 10 million acres cultivated in eastern Arkansas. Taxonomic classification of the soils are presented in Table 1.

Five replications of each soil were sampled at 6-in. increments to 36 in. with a bucket auger. Each sample was air dried, pulverized and sieved. Soil pH was determined in a 1:1 soil-water suspension, available P by the Bray P-1 extract and Murphy Riley colorimetric procedure and 1*N* KCl exchangeable Al by the Aluminon colorimetric method. Calcium, Mg, K, Na, Fe, Mn, Cu, Zn, S and B were extracted with Mehlich III and analyzed with an inductively coupled argon plasma unit.

A bioassay with wheat (*Triticum aestivum* L.) was conducted to identify soils with potential Al toxicity (Hill et al., 1989; Ahlrichs et al., 1992; Baligar et al., 1990). The bioassay was conducted on two replications of a composite of each soil at each 6-in. depth increment to 30 in. Soils were moistened to field capacity, equilibrated for 24 h and placed into paper cups. Three germinated seedlings of the Al-sensitive cultivar 'Cherokee' were transplanted into each soil and grown in complete darkness for 72 h at 26 C. Plants were harvested, roots separated from soil, and lengths measured with the Tennant method (Tennant, 1975). The soil with the longest root length throughout its profile was selected as the non-toxic control for comparison purposes. Relative root length (RRL) was calculated by dividing the root length for each sample by the root length obtained in the control at the same depth increment and multiplying by 100.

Multiple regression analysis was performed between absolute root lengths and the chemical parameters measured on the soil samples. Selection techniques were used to identify several sets of potential independent variables. Each candidate regression model was examined in detail to determine the best fitting model.

RESULTS AND DISCUSSION

Table 2 shows the results from the bioassay for four of the 16 soils. The Rilla soil was selected as the non-toxic control. Twelve of the 16 soils studied had RRL equal to or less than 70% of the maximum root length in at least one depth increment. Relative root lengths of 70% or less suggest soil acidity problems under field conditions (Ahlrichs et al., 1992; Wright et al., 1989). Compared to all other soils, the Calhoun, Falaya and Henry soils consistently had the lowest RRL throughout their profiles. The RRL of the Henry was lowest among all soils at each depth increment and ranged between 39 and 71%. Based upon the critical RRL value of 70%, the Calhoun and Henry soils would potentially inhibit rooting below 6 in. and the Falaya would inhibit rooting below 12 in. Of all soils analyzed in this study, RRL of 70% or less were found with four soils at the 0- to 6-in. depth increment, one soil at the 6- to 12-in. depth increment, four soils at the 12- to 18-in. depth increment, and three soils at the 18- to 24-in. depth increment.

Exchangeable Al was the only element found to be highly correlated ($P = .0001$) with root length for all 16 soils (Fig. 1). This relationship was linear with an R^2 of 0.46 and did not depend upon soil or depth increment. A similar linear relationship between Al and root length was found (*P* = .0001) when regression was conducted for the Calhoun, Falaya and Henry soils, which were the three soils causing the greatest root inhibition (Fig. 1, insert). However, there was less variability in the data with an R^2 of 0.72, suggesting that the low root lengths measured on these three soils were primarily attributed to high levels of exchangeable Al. These results contradict those of Wright et al. (1989) who found that exchangeable Al was not a good predictor of root growth because it did not reflect solution concentrations of Al.

From the regression equations, the average exchangeable Al concentration that would result in a RRL of 70% for all 16 soils is 1156 lb/acre, whereas for the three most Al-toxic soils, the value is 1052 lb/acre.

Exchangeable Al profile distributions for the non-toxic Rilla and the Al-toxic Calhoun, Falaya and Henry soils are presented in Fig. 2. The Rilla had the lowest exchangeable Al concentrations throughout the profile, ranging from 4.4 lb/acre in the 0- to 12-in. depth increment to 360 lb/acre in the 24- to 30-in. depth increment. These values were not high enough to restrict root length in the bioassay. The Calhoun, Falaya and Henry soils had Al concentrations greater than 600 lb/acre below the 18-in. depth. The Henry had the lowest RRL in the bioassay and, of all 16 soils, had the highest Al concentrations below 12 in.

CONCLUSIONS

Results from this study suggest that the subsoil chemistry of several major agronomic soils in eastern Arkansas may restrict deep rooting. Preliminary results suggest that Al toxicity within 6 in. of the surface may inhibit deep rooting on some soils. Regression analysis showed that levels of exchangeable Al of 1156 lb/acre caused a 30% reduction in RRL. It is yet to be determined how this reduction translates into plant growth and vigor in the field. Additional studies must be conducted to quantify this relationship. In addition to possible Al toxicity, 95% of all soils evaluated in this study were found to be deficient in P and K at the 0- to 6-in. depth, and 100% were deficient below 6 in. (data not shown). Neutralization of exchangeable Al or selection of Al-tolerant cultivars, where toxic concentrations of exchangeable Al exist near the surface, may enhance deeper rooting in some of these soils. Thus greater utilization of available water from the subsoil and higher crop yields than are currently obtained under dryland conditions may result. Other agronomic soils in Arkansas may respond to subsoil applications of P and K fertilizer. Research is continuing in this area to further identify subsoil chemical imbalances.

ACKNOWLEDGMENT

This research was funded by the Arkansas Soybean Promotion Board.

LITERATURE CITED

1. Adams, F., and Z.F. Lund. 1966. Effect of chemical activity of soil solution aluminum on cotton root penetration of acid subsoils. Soil Science 101:193-198.
2. Ahlrichs, J.L., G. Ejeta, W.H. Smart and T.G. Toulemonde. 1992. Plant tolerance of soil induced stress: The aluminum case. Turkish Soil Science Society Proceedings (in press).
3. Baligar, V.C., R.J. Wright, K.D. Ritchey and N.K. Fageria. 1990. Bioassay technique to assess acid soil constraints for growth of wheat (*Triticum aestivum*) roots. p.419-424. *In* M.L. van Beusichem (ed.) Plant nutrition - physiology and applications. Kluwer Academic Publishing.
4. Hill, P.R., J.L. Ahlrichs and G. Ejeta. 1989. Rapid evaluation of sorghum for aluminum tolerance. Plant Soil 114:85-90.
5. Rios, M.A., and R.W. Pearson. 1964. The effect of some chemical environmental factors on cotton root behavior. Soil Science Society of America Proceedings 28:232-235.
6. Tennant, D. 1975. A test of a modified line intersect method of estimating root length. Journal of Ecology 63:995-1001.
7. Wright, R.J., V.C. Baligar and J.L. Ahlrichs. 1989. The influence of extractable and soil solution aluminum on root growth of wheat seedlings. Soil Science 148:293-302.

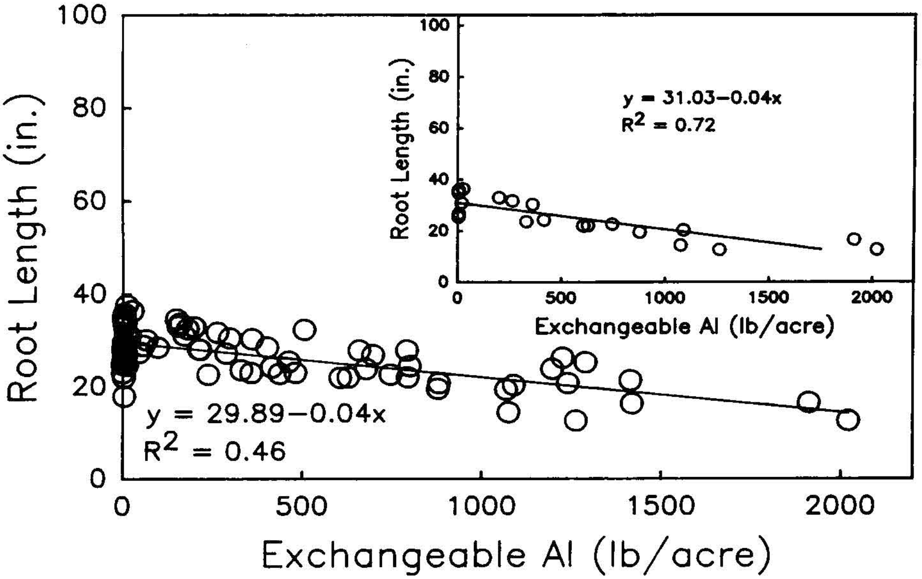

Fig. 1. Correlation of root length with exchangeable Al for 16 soils. The insert represents the three soils causing the greatest root inhibition.

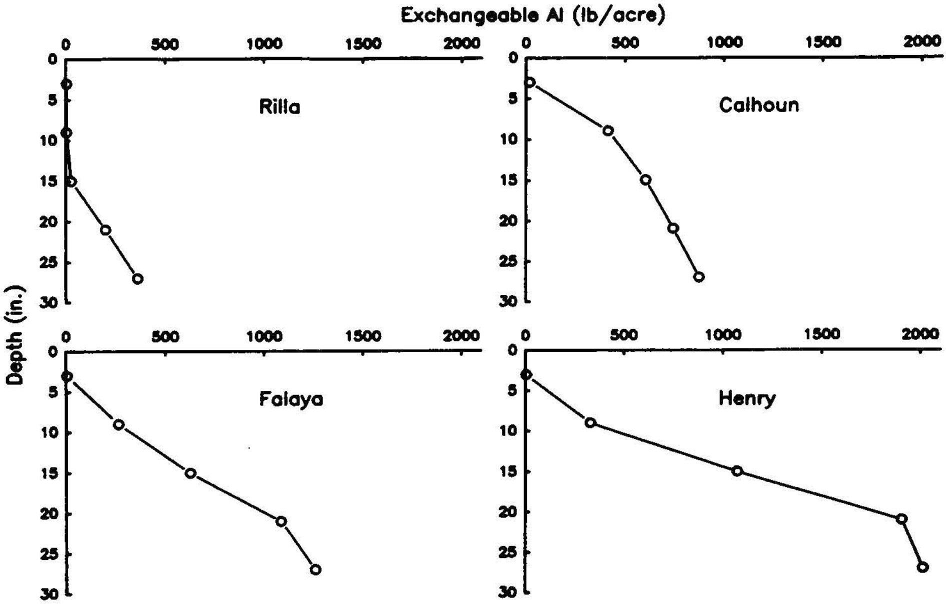

Fig. 2. Exchangeable Al profile distributions for the non-toxic Rilla and the Al-toxic Calhoun, Falaya and Henry soils.

Table 1. Classification of the soils.

Series	Taxonomic Class
1. COLLINS	Coarse-silty, mixed, acid, thermic Aquic Udifluvents
2. MEMPHIS	Fine-silty, mixed, thermic Typic Hapludalfs
3. FALAYA	Coarse-silty, mixed, acid, thermic Aeric Fluvaquents
4. HILLEMANN	Fine-silty, mixed, thermic Albic Glossic Natraqualfs
5. MHOON	Fine-silty, mixed, nonacid, thermic Typic Fluvaquents
6. DUNDEE	Fine-silty, mixed, thermic Aeric Ochraqualfs
7. HENRY	Coarse-silty, mixed, thermic Typic Fragiaqualfs
8. CROWLEY	Fine, montmorillonitic, thermic Typic Albaqualfs
9. DUBBS	Fine-silty, mixed, thermic Typic Hapludalfs
10. STUTTGART	Fine, montmorillonitic, thermic Typic Natrudalfs
11. LORING	Fine-silty, mixed, thermic Typic Fragiudalfs
12. GRENADA	Fine-silty, mixed, thermic Glossic Fragiudalfs
13. CALLOWAY	Fine-silty, mixed, thermic Glossaquic Fragiudalfs
14. HEBERT	Fine-silty, mixed, thermic Aeric Ochraqualfs
15. RILLA	Fine-silty, mixed, thermic Typic Hapludalfs
16. CALHOUN	Fine-silty, mixed, thermic Typic Glossaqualfs

Table 2. Relative root lengths[1] from 72-hour bioassay in soils at five depth increments.

	Depth increments (in.)				
Soil	0-6	6-12	12-18	18-24	24-30
			%		
RILLA	100	100	100	100	100
CALHOUN	86	69	60	69	64
FALAYA	74	91	61	62	41
HENRY	71	68	39	50	41

[1] Relative to the following root lengths in the Rilla soil at each depth increment: 91 cm at 0-15 increment, 89 cm at 15-30 increment, 93 cm at 30-45 increment, 84 cm at 45-60 increment, and 77 cm at 60-75 increment.

THE IMPACT OF SULFUR FERTILIZATION ON PRODUCTION, QUALITY AND FERTILIZER EFFICIENCY OF A BERMUDAGRASS-TEMPORARY WINTER PASTURE GRAZING SYSTEM.

Paul B. Francis and J. Mike Phillips

INTRODUCTION

A growing trend in Arkansas is the utilization of a bermudagrass forage base that is overseeded to rye, wheat and/or annual ryegrass for winter grazing. This system is very successful for many livestock operations provided that forage production, quality and nutrient concentrations are in correct balance. Previous research has indicated that many Coastal Plains soils are deficient in sulfur and that significant increases in forage protein content, production and nitrogen use efficiency can result from sulfur fertilization. Two field studies, one at Monticello, Arkansas, and the other at Hope, Arkansas, were initiated in April 1991 to investigate sulfur needs for Coastal Plains soils of southern Arkansas.

PROCEDURES

The study at Hope was conducted on the Ronnie J. Burke Farm on a Smithdale fine sandy loam soil (fine-loamy, siliceous, thermic Typic Paleudults) established with 'Tifton 44' hybrid bermudagrass. The bermudagrass was established in 1985 and had been heavily fertilized with poultry litter since establishment prior to the study. At Monticello, an identical study was conducted on the University of Arkansas at Monticello teaching farm on a Sacul loam (clayey, mixed, thermic, Aquic Hapludults) field established with mixed 'Alicia' and 'Coastal' hybrid bermudagrass in 1980. The field had not been fertilized for at least five years prior to the study.

A latin square design of six sulfur treatments (Table 1) was applied to plots 7 x 20 ft in size beginning in May 1991. The sulfur source was ammonium sulfate. Phosphorus was applied according to soil test results: 0 lb/acre at Hope and 60 lb/acre at Monticello from

0-48-0. Nitrogen was applied initially and after each cutting at 100 lb/acre from 34-0-0, and potassium was applied initially and after every other cutting at 120 lb/acre from 0-0-60. Sulfur treatments were applied initially and after every other hay cutting.

Soil samples were collected at the 0- to 6- and 6- to 12-in. depths prior to the study and after the last bermudagrass hay cutting in the fall. Forage was harvested in 28- to 34-day intervals and subsamples collected for nutrient and forage quality analysis. At Monticello, species composition was recorded approximately every 30 days, and rainfall and daily high and low temperatures were recorded from a weather station located 300 ft from the study area. Plots were overseeded the first week of October with a rye/annual ryegrass mix (var. 'Elbon' and 'Marshall', respectively) applied with a no-till drill. The planned duration of the study is three years.

RESULTS AND DISCUSSION

Dry Matter Yields

Forage production at both sites was highest the first cutting and fairly well distributed over the remaining cuttings because of seasonal rainfall (Tables 2 and 3). Total hay yields at both sites were high over all treatments, ranging from 11,751 to 14,245 lb dry matter/acre. At both locations, there were no noticeable sulfur treatment responses until the third and fourth cuttings. At Monticello, total dry matter yields of all sulfur treatments except 36 lb/acre were significantly higher than the control. At Hope, variation in the data decreased with each cutting, and the 6- and 36-lb/acre treatments were significantly higher for season totals than the control.

There is some evidence from the first season data that the sulfur treatments are significantly affecting hay dry matter yields. However, it is not possible to draw any conclusions of sulfur fertilizer effects on dry matter yield from just one year of data. It will be interesting to note the results of the next two years of sulfur treatments.

Soil Test Results

Laboratory results from initial and end of season soil sampling are incomplete. However, the results from initial sampling at the Hope location are given in Table 4. Soil tests were extremely high for P and K. This is probably due to the long-term effects of poultry litter applications prior to the study.

Forage Quality Results

Laboratory tests of routine forage mineral content (including sulfur), fiber contents, protein and digestibility are incomplete for the 1991 growing season at the time of report writing. Reliable conclusions on the effects of sulfur treatments on the variables measured will not be possible until the completion of the next two years of the studies.

ACKNOWLEDGMENTS

The authors would like to express their sincere appreciation to Ronnie J. Burke and the University of Arkansas at Monticello for allowing the study to be conducted on their property.

Table 1. Sulfur rates and timing on bermudagrass (lb/acre).

Initially	Following Harvest 2	Following Harvest 4
0	0	0
6	6	6
12	12	12
24	24	24
36	36	36
48	48	48

Table 2. Tifton 44 bermudagrass production as influenced by sulfur fertilization rates near Hope, Arkansas, 1991.

S	Dry Matter (lb/acre)				
(lb/acre)	June 10	July 9	Aug. 6	Sept. 12	Total
0	3203	3247	3299	3291	13,040
6	3055	3216	3830	3561	13,662
12	2769	3181	3566	3443	12,959
24	3065	2853	3198	3322	12,438
36	3163	3372	3729	3981	14,245
48	2867	2860	3322	3529	12,578
LSD @ 0.01	NS	NS	384	267	458
C.V. %	10.94	11.71	6.70	4.61	2.12

Table 3. Mixed Alicia and Coastal bermudagrass production as influenced by sulfur fertilization at Monticello.

S	Dry Matter (lb/acre)				
(lb/acre)	June 12[1]	July 11	Aug. 12	Sept. 17	Total
0	5859 a	1484 a	2407 a	2009 a	11,751 a
6	6285 a	1761 ab	2903 ab	2350 ab	13,298 b
12	6181 a	1577 a	2880 ab	2676 b	13,313 b
24	6105 a	2034 b	3091 b	2573 b	13,804 b
36	5919 a	1910 ab	2720 ab	2517 b	12,515 ab
48	6115 a	1885 ab	3075 b	2559 b	13,633 b
Rain (in.)	5.05	1.10	4.55	3.34	14.04
C.V. %	10.7	19.3	14.5	11.9	7.9

[1] Column means followed by the same letter are not significantly different according to Duncan's New Multiple Range Test, alpha = 0.05.

Table 4. Initial soil test results for sulfur rate study near Hope, Arkansas, 1991.

Depth	S			Nutrient (lb/acre)				
(in.)	(lb/acre)	pH	O.M.(%)	P	K	Ca	Mg	S
0-6	0	5.9	1.1	934	332	1885	144	13
	6	5.8	1.0	941	412	1602	110	12
	12	5.7	1.0	973	308	1831	134	13
	24	5.8	1.1	922	420	1879	124	13
	36	5.8	1.0	914	388	1653	120	11
	48	5.9	1.1	961	365	1782	140	14
6-12	0	5.8	0.5	727	270	1062	109	7
	6	5.7	0.5	722	313	881	79	7
	12	5.6	0.5	740	264	928	93	7
	24	5.7	0.5	755	301	1051	105	7
	36	5.8	0.5	663	321	866	78	5
	48	5.8	0.5	710	342	937	91	9

NITROGEN RATES FOR CORN

J.H. Muir, H.J. Mascagni, P.W. Parker and W.E. Sabbe

INTRODUCTION

Recent investigations on fertilizer nitrogen (N) for corn production on Sharkey clay (Vertic Haplaquepts) had indicated that application rates exceeding 300 lb N/acre may be needed for maximum yield under irrigation. Therefore, the objective of this study was to determine if the current recommendation for fertilizer N for irrigated corn on the Sharkey clay soil is correct.

PROCEDURE

The study was continued at the Northeast Research and Extension Center, Keiser, Arkansas, 1991 (Table 1). 'Pioneer 3165' was planted 30 May 1991 in 38-in. rows. Each plot was 4 rows wide and 45 ft long. One-half of each N treatment (i.e. 0, 50, 100, 150, 200, 250, 300, 350 and 400 lb N/acre) was applied prior to planting with the remainder sidedressed at the 7-leaf growth stage. Urea was the N source for each application date. Final stand was 24,000 plants/acre. The experimental design was a randomized complete block with six replications. The study was irrigated four times during the growing season. Plots were hand harvested on 4 October 1991 and consisted of the center two rows of 42 ft length. Grain yields were calculated at 15.5% moisture.

RESULTS AND DISCUSSION

Planting date was about four weeks later than normal in 1990 and about seven weeks late in 1991, exposing the crop to higher-than-normal air temperatures during the filling period in both years. Yields may have been reduced due to this in 1990 and were apparently further reduced in 1991 (Table 2). The grain yield increased significantly with increased rates of N fertilizer up to the 250-lb N/acre in 1990 and up to the 200-N/acre rate in 1991, then plateaued. Essentially no yield differences occurred among the rates exceeding 200 to

250 lb N/acre in either year. Thus, while the data substantiate the current recommendation (200 to 240 lb N/acre for the highest yield goal), the need for additional N might exist under more normal management practices.

Table 1. Initial soil test values for nitrogen rates for corn study, Northeast Research and Extension Center, Keiser, Arkansas, 1991.

pH	OM	NO_3-N	P	K	Ca	Mg
	%	-----	-----	lb/acre	-----	-----
6.1	1.7	13	120	517	6013	1156

Table 2. Effect of applied nitrogen rate on corn grain yield of 'Pioneer 3165', Northeast Research and Extension Center, Keiser, Arkansas, 1990 and 1991.

N Treatment	Yield 1990	Yield 1991
lb/acre	------bu/acre	------
50	50.4	16.0
100	80.3	21.4
150	113.9	68.6
200	138.6	104.4
250	164.8	122.2
300	181.3	135.9
350	183.8	146.7
400	181.4	151.8
LSD (.05)	18.1	16.5

NUTRITION OF SOYBEAN ON ACID SOILS

J.H. Muir and W.E. Sabbe

INTRODUCTION

Soil acidity is a major soil fertility concern in Arkansas. Lime use has been decreasing for the last 10-12 years while lime needs have been increasing, due largely to the increased use of acid-forming nitrogen fertilizers. Acidity has been estimated to be a major yield-limiting factor on 30% or more of the acreage in Arkansas. Lime use quite likely will not increase significantly in the near future because of lime costs, land ownership/tenant situations and commodity prices. Additionally, lime will rarely be used where rice is in the crop rotation.

Given the lime need/consumption situation in Arkansas, the adverse effects of acid soil on crop production may best be overcome by the use of cultivars adapted to acid soils. In order to develop cultivars adapted to acid conditions, a knowledge of the differences in nutrition of lines tolerant of and sensitive to acid conditions is necessary. Therefore, such a study was initiated at Jonesboro, Arkansas, in 1989.

The objectives of this study are to: 1) determine differences in plant nutrition of soybean lines grown under acid soil conditions in order to identify nutritional characteristics of lines tolerant of acid soil conditions, 2) evaluate growth, yield and nutrient requirements of soybean grown under acid conditions.

PROCEDURE

A pH gradient was developed across the experimental area by applying lime and aluminum sulfate from one end of the field to the other in the spring of 1989 as follows:

Tier	Treatment
5	2 ton/acre lime
4	1 ton/acre lime
3	Nothing
2	1 ton/acre Aluminum sulfate
1	2 ton/acre Aluminum sulfate

Treatments were reapplied in the spring of 1991 because of the reduction in the pH gradient (Table 1).

Soybean cultivars sensitive to and tolerant of acid soil conditions were planted across this pH gradient. Cultivars selected and their known acidic soil reactions are given in Table 2 and soil test data in Table 3.

Soil and leaf samples are being collected periodically throughout the growing season to relate soil conditions with nutrient uptake. Leaf samples were taken from different heights on the plant at full bloom to determine differences in nutrient uptake and translocation under different pH conditions for varieties of varying tolerance to acid conditions.

RESULTS AND DISCUSSION

Soil treatments applied in the spring of 1989 resulted in a pH range of 5.4 to 7.1 by the fall of 1989 and a range of 4.3 to 7.4 in fall of 1991 (Table 1). No visual symptoms of abnormalities were observed in this first year. Soil pH did not affect soybean yield in 1989, nor did yields differ with cultivar (Table 4). However, soybean yield was reduced under acidic soil conditions in the second year of the study (Table 5). There were no differences in yield among cultivars, nor was the interaction between soil pH and cultivars significant. Chlorosis and leaf crinkling were observed on numerous plants in the acid plots in July 1990; however, most of these symptoms disappeared following a rain.

Yields were significantly lower in the two acid areas in 1991 (Table 6). There were also differences in yield among cultivars. Visual symptoms of abnormalities were observed. Plants in the acid areas had a pale green color in contrast to the dark green color in the areas with higher pH. There was no cultivar x pH interaction, indicating that all cultivars reacted the same to soil acidity.

Table 1. Influence of lime and aluminum sulfate treatments on pH of the experimental area, Jonesboro, Arkansas.

	Tier				
Date	1	2	3	4	5
September 1989	5.4	5.8	6.5	6.9	7.1
May 1991	5.9	5.9	6.3	6.7	6.8
October 1991	4.3	5.0	6.0	7.1	7.4

Table 2. Selected characteristics of cultivars included in nutrition of soybean on acid soils study, Jonesboro, Arkansas, 1989.

	Reaction to excess	
Cultivar	Manganese	Aluminum
'Bragg'	Sensitive	Sensitive
'Forrest'	Sensitive	?
'Lee 74'	?	Sensitive
'Essex'	Tolerant	?
'Lee'	Tolerant	Tolerant

Table 3. Soil test data (top soil) for nutrition of soybean on acid soils study collected in September 1989, Jonesboro, Arkansas.

	Tier				
Parameter	1	2	3	4	5
pH	5.4	5.8	6.5	6.9	7.1
OM(%)	0.8	0.8	0.8	1.0	0.9
NO_3-N (lb/acre)	5	3	5	11	13
K "	150	150	151	152	160
Ca "	1794	1842	1990	2605	3096
Na "	159	181	175	122	114
Mg "	400	404	448	466	468
Fe "	147	152	154	141	133
Mn "	482	441	374	349	335
Cu "	4.2	3.8	4.0	3.7	3.6
Zn "	5.2	5.0	5.6	6.3	6.6
B "	0.1	0.0	0.0	0.0	0.0
S "	443	226	43	32	31
P "	66	56	49	50	49
EC	266	172	53	61	77

Table 4. Soybean yield for five cultivars (averaged across tiers), Jonesboro, Arkansas, 1989.

Cultivar	Yield
	(bu/acre)
'Forrest'	37.2
'Lee 74'	36.2
'Bragg'	33.9
'Lee'	33.2
'Essex'	32.6
LSD(.05)	3.0

Table 5. Effect of soil pH on yield of five soybean cultivars, Jonesboro, Arkansas, 1990.

	Grain yield at pH of					
Cultivar	5.4	5.8	6.5	6.9	7.1	Avg
	bu/acre					
'Forrest'	30.4	31.6	33.5	33.6	34.2	32.7
'Bragg'	26.2	31.6	34.9	35.8	30.0	31.7
'Lee'	25.6	27.4	36.8	32.0	29.0	30.2
'Lee 74'	26.7	25.6	29.8	29.8	30.8	28.5
'Essex'	29.2	27.5	30.2	37.6	36.4	32.2
Average	27.6	28.7	33.0	33.8	32.1	
LSD(.05):						
Cultivar		NS				
Soil pH		3.1				
Cultivar x soil pH		NS				

Table 6. Effect of soil pH on yield of five soybean cultivars, Arkansas State University, Jonesboro, Arkansas, 1991.

	Grain yield at pH of					
Cultivar	4.3	5.0	6.0	7.1	7.4	Avg
	bu/acre					
'Forrest'	18.1	16.0	30.1	31.0	28.4	24.7
'Bragg'	14.0	14.6	19.8	23.3	20.3	18.4
'Lee'	14.4	15.4	25.9	21.3	29.4	21.3
'Lee 74'	13.5	16.3	26.2	29.0	26.5	22.3
'Essex'	14.7	17.1	31.0	30.0	27.0	24.0
Average	14.9	15.9	26.6	26.9	26.3	

LSD (.05) = 6.1 bu/acre

DEEP PLACEMENT OF P_2O_5, K_2O AND LIME: AN ASSESSMENT OF THE POTENTIAL FOR INCREASED SOYBEAN YIELDS

T. C. Keisling

INTRODUCTION

The recent development of a deep-dry-fertilizer-and-lime applicator has made it possible to apply fertilizer and lime in a vertical band 2 in. wide from 6 to 15 in. deep. Mixing of fertilizer with this large a volume of soil makes it possible:

1. to apply some very high fertilizer rates without causing salt damage (this also results in better fertilizer efficiency due to the "banding" effect);
2. to place fertilizer in soil profile position where the root environment is more favorable for nutrient uptake;
3. to place lime in vertical band where it can ameliorate the adverse effects of soil acidity on root growth resulting in more extraction of subsoil water and nutrients.

The studies reported herein are an assessment of the potential of the deep application of lime and fertilizer to increase soybean yields.

PROCEDURE

Due to the extremely wet spring, three late-planted sites were selected. Their descriptions and soil test values are given in Table 1 and Table 2, respectively. All three experiments were planted about the last week of June. Plots were selected so that each plot consisted of a planter width in Cross and Monroe counties, Arkansas, and two rows in Phillips county, Arkansas. Due to time and equipment limitations, only the two center rows of each plot were treated in Cross and Phillips counties while only one of the center rows was treated in Monroe county. In each case, treatments (Table 3) were applied immediately prior to planting. Harvesting was accomplished by hand harvesting the appropriate rows in each plot and adjusting the moisture of the yields to 13.5%. Visual observations of plant growth were made weekly through the growing season.

RESULTS AND DISCUSSION

No unusual plant foliage systems or growth patterns were noted. Yield results are given in Table 3. No significant differences in grain yields were obtained.

ACKNOWLEDGMENTS

This research was made possible through funds provided through the Arkansas fertilizer tonnage fee, PPI and TVA. Equipment necessary to transport and harvest the tests was provided by Dr. Bill Baker and Mr. Bob Turner. Mr. Brandon Theisse, Mr. Ricky Thompson and Mr. Stephen Culp helped to locate and coordinate this activity in their counties. We also want to acknowledge all the farmers involved for donating their time, land and equipment.

Table 1. Location and description of experimental sites.

County	Soil Series	Irrigation	Variety	Row Spacing
Cross	Crowley and Hilleman silt loams, 0 to 1% slope	Flood	Walters	36 in.
Monroe	Foley-Calhoun-Bonn silt loams, 0 to 1% slope	Flood	-------	30 in.
Phillips	Loring silt loam, 1 to 3% slope	None	AS5403	38 in.

Table 2. Soil test values at the beginning of the experiments.

			Soil Test Value											
Depth	pH	OM	P	K	Ca	Na	Mg	Fe	Mn	Cu	Zn	S	NO_3	E.C.
(in.)		%	-----	-----	-----	-----	-----	lb/acre	-----	-----	-----	-----	-----	µmho
Cross County														
0-6	6.3	0.9	18	313	2839	243	450	425	207	4.1	13.7	35	66	238
6-12	6.9	0.6	10	122	2467	334	497	162	390	4.2	15.0	24	11	84
12-18	5.1	0.5	7	77	1018	342	250	171	363	3.8	1.5	78	7	86
Monroe County														
0-6	5.3	0.8	24	118	1382	162	285	360	192	2.2	1.6	23	12	56
6-12	5.0	0.7	33	71	892	166	266	367	240	2.2	1.5	41	5	41
12-18	5.0	0.3	28	136	806	545	585	258	61	2.2	2.6	50	3	39
Phillips County														
0-6	5.9	0.8	27	247	2864	191	306	323	237	4.5	2.4	31	27	74
6-12	6.7	0.6	12	96	2810	197	316	243	286	4.5	6.3	30	10	43
12-18	6.5	0.6	9	247	4740	230	1652	156	109	4.8	0.9	36	2	44

Table 3. Soybean yield from deep placement tests in 1991.

Treatment No.	P_2O_5	K_2O	Agric. Lime	Subsoiled	Yield Cross	 Monroe	 Phillips
	------------lb/acre------------				------------bu/acre------------		
1.	0	0	0	no	42	31	29
2.	0	0	0	yes	41	30	29
3.	120	0	0	yes	42	29	30
4.	0	180	0	yes	41	29	29
5.	0	0	1000	yes	44	26	30
6.	120	180	1000	yes	43	34	28

INTENSIVE MANAGEMENT STUDIES WITH WHEAT

B.R. Wells, R.K. Bacon and M.L. May

INTRODUCTION

Maximum yield research with wheat was conducted in Arkansas over the interval from 1982 through 1987 with funding from the Foundation for Agronomic Research (PPI/FAR). Results of these studies indicated that grain yields approaching or exceeding 100 bu/acre are possible given proper climatic conditions (Bacon et al., 1985; Bacon and Wells, 1989). These studies also indicated that these yields largely resulted from more intensive management rather than from increased inputs above those currently recommended by the Cooperative Extension Service. In those studies use of a broad-spectrum foliar fungicide to control diseases at Feekes' growth stage 8 to 10 consistently resulted in higher grain yields. Use of the fungicide became more important if the N fertilizer rates were increased above those currently recommended. In most cases the use of the fungicide only maintained the yield as the N rate increased. In a related study Freeze and Bacon (1990) showed no advantage of a narrow (4-in.) row spacing as compared to conventional spacings of 6 to 8 in. for wheat grown under high inputs. In addition, seeding rates above those currently recommended did not increase yields. In another series of studies, use of sulfur fertilizer was found to be beneficial on permeable sandy loam soils (Wells et al., 1985). The objectives of this research are: 1) to evaluate promising new wheat cultivars for their ability to respond to intensive management practices, 2) to compare urea and ammonium nitrate as spring N sources, and 3) to evaluate the need for S fertilization on silt loam and clay loam soils.

PROCEDURES

The intensive management study was conducted in 1989/1990 and 1990/1991 at three locations: the Rice Research and Extension Center (RREC), Stuttgart, Arkansas, on a Crowley silt loam; the Northeast Research and Extension Center (NEREC), Keiser, Arkansas, on a Sharkey silty clay; and in Lafayette County, Arkansas (Spirit Lake), on a Caspiana silt loam. The experimental design was a strip-strip split plot with four replications. The two strip treatments were 1) fall fertilization (control, 30 lb/acre of N and 30 lb/acre of N + 30 lb/acre of P) and 2) spring N fertilization and foliar fungicide application (100 and 150 lb N/acre with or without foliar fungicide application); thus the main plots in each replication were the 12 combinations of fall and spring treatments (3 fall fertilizer x 4 spring N - fungicide combinations). The sub-plots consisted of five wheat cultivars ('Florida 302', 'AR 26415', 'Coker 9877', 'Pioneer 2555' and 'Pioneer 2548'). The subplot size was 5 by 15 ft. The fall fertilizer treatments were made at the time of seeding. The spring N fertilizer was applied in late February for the 100-lb N/acre rate whereas the high N rate treatments received 100 lb N/acre at this time followed by an additional 50 lb N/acre three to five weeks later. Foliar fungicide treatments (Tilt at Spirit Lake and Bayleton plus Dithane at RREC and NEREC) were applied at the standard, recommended rates and times. At maturity a 10-ft segment of each plot was harvested for grain yield. The grain was dried and weighed and the moisture content and test weight determined. Statistical analyses were conducted on all data using the ANOVA procedure from either MSTAT (Spirit Lake, 1990) or PC-SAS (RREC and NEREC, 1990; all locations, 1991). Means separations were by use of LSD at either the 5 or 10% level of probability.

An additional N rate by cultivar study was conducted at RREC in 1990/1991 to evaluate the N response of the wheat cultivars in the University of Arkansas foundation wheat program. The cultivars in this study were 'Cardinal', 'Caldwell', 'Wakefield', AR26415 and 'Saluda'. The N rates were 0, 60, 90, 120 and 150 lb/acre, spring applied with and without the application of a fungicide. All other treatments were as described above.

Companion studies were conducted at each location 1) to evaluate the need for sulfur fertilization and 2) to compare urea to ammonium nitrate as N sources. Test size and management practices were as listed above. The treatments consisted of either 0 or 20 lb/acre of S as calcium sulfate for the sulfur study and urea or ammonium nitrate as the N source for the second study. Each study was replicated 10 times. Statistical analyses were as described above.

RESULTS AND DISCUSSION

1989/1990 Study

Grain yields varied from approximately 60 to 80 bu/acre among treatments at the RREC and NEREC locations whereas yields were very low (approximately 20 bu/acre) at Spirit Lake. The low yields at Spirit Lake resulted from continued soil saturation during May resulting from seep water through the levee during the extensive flooding of the Red River.

Fall fertilization with N had no effect on grain yields at RREC and Spirit Lake whereas 30 lb/acre of fall N increased yields by 4 bu/acre at NEREC (Tables 1, 5 and 9). Addition of P in the fall increased yields by 11 bu/acre at RREC. There was a similar trend at NEREC; however, the 3-bu/acre yield increase was not statistically significant. Fall P had no effect on yield at Spirit Lake. Soils where rice has been grown in rotation with upland crops characteristically have reduced P availability to upland crops. Therefore, the large response to P at the RREC location is simply a reflection of this reduction in availability of soil P under this rotation program.

There were significant yield and test weight differences among cultivars at all three locations (Tables 2, 6 and 10). Florida 302 had the lowest yields and test weights at all three locations. Yields of AR 26415 were equivalent to those of Florida 302 at RREC and NEREC; however, the test weights were higher. Coker 9877, Pioneer 2555 and Pioneer 2548 all yielded significantly higher at all locations. Pioneer 2548 had the highest yields and test weight at RREC whereas Pioneer 2555 had the highest yield at NEREC. These results may possibly indicate a differential response of these two Pioneer cultivars to differences in soil texture. Pioneer 2548 may be more suited to silt loams while Pioneer 2555 may perform best on clay textured soils. This was also found to be true in tests conducted by the wheat breeding program; however, the results from the variety testing program did not show an advantage for Pioneer 2555 on the clay soil at NEREC. Test weights of Coker 9877 and the two Pioneer cultivars were significantly higher than that of Florida 302 at all three locations.

Grain yield response to spring N rate and foliar fungicide application varied with cultivar and location (Tables 3, 7 and 11). Yields increased as the spring N rate was increased to 150 lb/acre at NEREC whereas no increase occurred at RREC and yields were reduced at Spirit Lake. Coker 9877 showed far less yield response to application of a foliar fungicide at RREC and NEREC as compared to the other cultivars even though it was one of the highest-yielding cultivars.

Florida 302 showed yield increases of approximately 10 bu/acre associated with the foliar fungicide application at both RREC and NEREC. The yield response to the increased N rate at the NEREC location was probably the result of prolonged water logging of this clay soil in March and early April, resulting in large N losses through denitrification. The differential response of the cultivars to fungicide application is likely related to their genetic resistance to specific diseases.

Test weight responses to spring N rate and foliar fungicide application at the RREC and NEREC locations are similar to the yield responses noted in the previous paragraph (Tables 4 and 8). Coker 9877 showed almost no response in terms of test weight to application of the fungicide whereas Florida 302 showed a significant test weight increase with the fungicide application.

The companion study to evaluate the need for sulfur fertilization across an array of soil textures indicated no grain yield response to sulfur addition at any of the three locations (Table 12). Sulfur has been shown to be a limiting factor for wheat yields on the permeable sandy loam soils; however, the soils at these locations were silt loam to clay loam in texture. The spring of 1990 was a very wet spring with excessive rainfall that should have created a sulfur deficiency on a soil predisposed to the problem. The lack of response to sulfur fertilization on these soils tends to confirm our current recommendation that sulfur fertilization is only needed on highly permeable sandy loam soils where the sulfate sulfur leaches readily from the root zone of the wheat plant.

The N source studies indicated no differential response to N source at RREC and Spirit Lake; however, use of urea increased yields by 5 bu/acre at NEREC (Table 13). There is no readily apparent explanation for this response at the NEREC.

1990/1991 Studies

Yields for the 1990/1991 studies were drastically reduced by the extended rainfall experienced in 1991. This rainfall maintained the soil in a saturated condition throughout grain-fill and enhanced diseases. Statistical analysis of the data for the intensive management study indicated significant effects only for cultivar and spring N-fungicide for both grain yields and test weights at all three locations. There were no significant interactions between any of the inputs.

Grain yields for the cultivars at the three locations are shown in Table 14. Pioneer 2548 consistently ranked near the top for yield at all three locations. Coker 9877 had yields similar to those of Pioneer 2548 at RREC and Spirit Lake; however, at NEREC its yield was drastically reduced due to winter-kill, which occurred with an ice storm in late December following heavy, soil saturating rainfall. Florida 302 consistently had the lowest yields among the five cultivars.

Test weights were very low at the NEREC and Spirit Lake locations and somewhat lower than normal at RREC (Table 15). Pioneer 2548, AR26415 and Coker 9877 had the highest test weights while Florida 302 had the lowest test weights at all the locations.

Increasing the spring N rate from 100 to 150 lb/acre tended to reduce yields at the NEREC and Spirit Lake locations whereas a slight trend toward a yield increase was noted at the RREC location (Table 16). There was a significant winter grass problem at the RREC location, and this may have contributed to the N response by competing with the wheat for the fertilizer N. Addition of the fungicide showed a trend toward increasing yields at both N rates; however, this trend was greater at the 150-lb/acre N rate. These data continue to substantiate previous findings where addition of N fertilizer above recommended rates may or may not result in slight yield increases while increasing disease pressure and thus the need for a fungicide.

In the supplemental N and S studies, no differences were noted for wheat yields between the N sources at any location (data not shown). Addition of S increased yields by 9 bu/acre at Spirit Lake; however, no effect was noted at the other two locations.

Grain yields for the supplemental N rate x cultivar x fungicide study conducted at RREC are given in Table 17. Grain yields of the cultivars were at a maximum with 60 lb/acre of N in the absence of a fungicide and at either 60 or 90 lb/acre of N with a fungicide. In this study there was a consistent trend toward increased grain yields in the presence of a fungicide at all N rates from 0 to 150 lb/acre with the size of the response increasing with increased N rate. Again, this points out that additional N fertilizer, especially above the recommended rates, increases the need for a fungicide. Highest grain yields in this study were from the cultivars Cardinal and Wakefield.

Test weights for this supplemental study are given in Table 18. Test weights tended to decrease with increasing N rate for all five cultivars, and this trend was more evident in the absence of a fungicide. Cardinal and Wakefield tended to have higher test weights as compared to Caldwell, AR 26415 and Saluda.

CONCLUSIONS

Tentative conclusions may be drawn from these tests by comparing the results to previous studies and current recommendations. First, these studies further indicate the necessity of an application of phosphorus fertilizer on silt loam soils where rice is in the rotation. Second, the studies again showed, as had our earlier maximum yield studies, the response of most cultivars to the addition of a foliar fungicide. However, this response is a function of the cultivar, and on some cultivars, such as Coker 9877, it is less likely that addition of a fungicide will be economically feasible due to the small yield response obtained. The data also showed that fungicide use will probably improve test weights in those instances in which yield increases are obtained. The sulfur study gave additional confirmation to our current recommendation that sulfur fertilizer is needed only on the more permeable sandy loam and loam soils. Also, the studies continue to indicate that spring N fertilizer rates above those currently recommended have only limited potential, if any, to increase grain yields; however, these increased N rates increase disease levels and thus the need to apply a fungicide.

REFERENCES

1. Bacon, R., B.R. Wells and F.C. Collins. 1985. Breaking the 100 bu yield barrier in soft winter wheat. Better Crops with Plant Food. 69(2):8-9.
2. Bacon, R. and B.R. Wells. 1989. Diseases, insects and nitrogen rates affect soft red winter wheat management. Better Crops with Plant Food. 73(1):20-22.
3. Freeze, D.M., and R.K. Bacon. 1990. Row spacing and seeding rate effects on wheat yields in the mid-south. J. of Prod. Agri. 3(3):345-348.
4. Wells, B.R., R.K. Bacon, W.E. Sabbe and R.L. Sutton. 1985. Response of sulfur deficient wheat to sulfur fertilizer. J. of Fert. Issues. 3(2):72-74.

ACKNOWLEDGMENT

Support for this research was provided by the Arkansas Wheat Promotion Board and from Fertilizer Tonnage Fees.

Table 1. Response of wheat to fall nitrogen and phosphorus fertilization, Intensive Management Study, RREC[1], 1989-1990.

Fall Fertilization	Yield	Test Weight
	bu/acre	lb/bu
Control	66 a[2]	56.0 a
30 lb/acre of N	64 a	56.0 a
30 lb/acre of N + 30lb/acre of P	77 b	56.6 b

[1] Rice Research and Extension Center, Stuttgart, Arkansas.

[2] Means within a column followed by the same letter are not significantly different at the 5% level of probability

Table 2. Response of wheat cultivars under intensive management, Intensive Management Study, RREC[1], 1989-1990.

Cultivar	Yield	Test Weight
	bu/acre	lb/bu
Florida 302	60 d	53.1 d
AR26415	60 d	55.8 c
Coker 9877	77 b	57.2 b
Pioneer 2555	68 c	55.9 c
Pioneer 2548	81 a	59.1 a

[1] Rice Research and Extension Center, Stuttgart, Arkansas.

[2] Means within a column followed by the same letter are not significantly different at the 5% level of probability.

Table. 3. Yield response of wheat cultivars to spring nitrogen rate and fungicide treatments, Intensive Management Sudy, RREC[1], 1989-1990.

		Cultivar(Grain yield)				
N rate	Fungicide	Fla 302	Ar 26415	Coker 9877	Pion. 2555	Pion. 2548
lb/acre		---bu/acre---				
100	-	55	55	74	66	78
100	+	65	63	75	68	83
150	-	56	57	78	67	78
150	+	66	66	80	72	84

LSD (0.05) = 4 bu/acre

[1] Rice Research and Extension Center, Stuttgart, Arkansas.

Table 4. Test weight response of wheat cultivars to spring nitrogen rate and fungicide treatments, Intensive Management Study, RREC[1], 1989-1990.

		Cultivars (test weight)				
N rate	Fungicide	Fla 302	Ar 26415	Coker 9877	Pion. 2555	Pion. 2548
lb/acre		----------------	----------------	lb/bu	----------------	----------------
100	-	51.5	54.1	56.2	54.6	58.3
100	+	53.8	56.5	56.8	56.0	59.3
150	-	52.3	54.9	57.5	55.6	59.0
150	+	55.0	57.4	58.2	57.3	59.9

LSD (0.05) = 0.6 lb/bu

[1] Rice Research and Extension Center, Stuttgart, Arkansas.

Table 5. Response of wheat to fall nitrogen and phosphorus fertilization, Intensive Management Sudy, NEREC[1], 1989-1990.

Fall Fertilization	Yield	Test Weight
	bu/acre	lb/bu
Control	67 c[2]	58.0 a
30 lb/acre of N	71 ab	58.2 a
30 lb/acre of N + 30 lb/acre of P	74 a	58.3 b

[1] Northeast Research and Extension Center, Keiser, Arkansas.

[2] Means within a column followed by the same letter are not significantly different at the 5% level of probability

Table 6. Response of wheat cultivars under intensive management, Intensive Management Sudy, NEREC[1], 1989-1990.

Cultivar	Yield	Test Weight
	bu/acre	lb/bu
Florida 302	62 d[2]	55.5 d
AR26415	62 d	59.8 a
Coker 9877	77 b	56.8 c
Pioneer 2555	83 a	59.8 a
Pioneer 2548	70 c	58.9 b

[1] Northeast Research and Extension Center, Keiser, Arkansas.

[2] Means within a column followed by the same letter are not significantly different at the 5% level of probability.

Table. 7. Yield response of wheat cultivars to spring nitrogen rate and fungicide treatments, Intensive Management Sudy, NEREC[1], 1989-1990.

		Cultivar (Grain yield)				
		Fla	Ar	Coker	Pion.	Pion.
N rate	Fungicide	302	26415	9877	2555	2548
lb/acre		----------------	----------------	bu/acre	----------------	----------------
100	-	54	55	73	78	64
100	+	64	61	75	82	70
150	-	61	65	80	84	69
150	+	69	66	81	88	78

LSD (0.05) = 4 bu/acre

[1] Northeast Research and Extension Center, Keiser, Arkansas.

Table 8. Test weight response of wheat cultivars to spring nitrogen rate and fungicide treatments, Intensive Management Sudy, NEREC[1], 1989-1990.

		Cultivars (test weight)				
		Fla	Ar	Coker	Pion.	Pion.
N rate	Fungicide	302	26415	9877	2555	2548
lb/acre		----------------	----------------	lb/bu	----------------	----------------
100	-	55.0	59.4	56.6	58.9	58.4
100	+	56.4	59.9	56.5	59.6	59.1
150	-	54.5	59.7	56.7	59.9	58.3
150	+	56.2	60.2	57.2	60.6	59.8

LSD (0.05) = 0.7 lb/bu

[1] Northeast Research and Extension Center, Keiser, Arkansas.

Table 9. Response of wheat to fall nitrogen and phosphorus fertilization, Intensive Management Study, Lafayette County, Arkansas, 1989-1990.

Fall Fertilization	Yield	Test Weight
	bu/acre	lb/bu
Control	21 a[1]	43.4 a
30 lb/acre of N	20 a	43.1 a
30 lb/acre of N + 30 lb/acre of P	20 a	42.6 a

[1] Within a column, means followed by the same letter are not different at the 5% level of probability.

Table 10. Response of wheat to spring nitrogen rate and fungicide application, Intensive Management Study, Lafayette County, Arkansas, 1989-1990.

Nitrogen	Fungicide	Grain	Test Yield	Lodging Weight
lb/acre	form./acre	bu/acre	lb/bu	score
100	no Tilt	19.4 b[1]	43.6 ab	3.05 b
100	4 oz Tilt	24.0 a	45.1 a	2.91 b
150	no Tilt	16.4 c	40.1 c	3.60 a
150	4 oz Tilt	20.2 b	43.2 b	3.17 b

[1] Within a column, means followed by the same letter(s) are not different at the 5% level of probability.

Table 11. Response of wheat cultivars under intensive management, Intensive Management Study, Lafayette County, Arkansas, 1989-1990.

Cultivar	Yield	Test Weight	Height	Lodging
	bu/acre	lb/bu	in.	score
Florida 302	15.0 e[1]	39.9 e	36.7	3.6 a
AR 26415	17.7 d	43.7 b	36.0	3.1 b
Coker 9877	23.8 a	46.2 a	37.9	2.3 c
Pioneer 2555	21.2 c	42.3 d	37.7	3.6 a
Pioneer 2548	22.2 b	43.4 c	35.2	3.2 b

[1] Within a column, means followed by the same letter(s) are not different at the 5% level of probability.

Table 12. Yield response of wheat cultivars to spring nitrogen rate and fungicide treatments, Intensive Management Study, Lafayette County, Arkansas, 1989-1990.

		Grain Yield of Cultivar				
N rate	Fung.	Fla 302	AR 26415	Coker 9877	Pion. 2555	Pion. 2548
lb/acre		bu/acre				
100	-	15.3 ij[1]	16.8 hi	22.5 cd	21.0 def	21.2 de
100	+	17.9 gh	22.6 cd	27.7 a	24.1 bc	27.7 a
150	-	10.8 k	14.3 j	20.5 ef	17.2 hi	19.2 fg
150	+	16.0 hij	17.1 hi	24.6 b	22.4 cde	20.9 def

[1] Means followed by the same letter(s) are not different at the 5% level of probability.

Table 13. Response of Florida 302 wheat to sulfur fertilizer applied with the spring nitrogen at three locations, 1990.[1]

Location	Yield		Test Weight	
	+S	-S	+S	-S
	--------bu/acre-------		---------lb/bu--------	
RREC[2]	47	47	49.3	49.6
NEREC	53	55	55.8	55.2
Spirit Lake	21	21	40.7	41.7

[1] Sulfur fertilization did not influence grain yields or test weights at any of the locations.

[2] RREC = Rice Research and Extension Center, Stuttgart, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas; Spirit Lake, Lafayette County, Arkansas.

Table 14. Response of Florida 302 wheat to source on nitrogen fertilizer at three locations, 1990.

Location	Yield		Test Weight	
	U	AN	U	AN
	---------bu/acre---------		-----------lb/bu-----------	
RREC[1]	54	55	52.9	53.2
NEREC	55 a[2]	50 b	55.0	55.5
Spirit Lake	24	22	42.1	42.1

[1] RREC = Rice Research and Extension Center, Stuttgart, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas; Spirit Lake, Lafayette County, Arkansas.

[2] Means for grain yield at the NEREC location were significantly different at the 5% level of probability.

Table 15. Wheat yields as influenced by cultivars and locations, 990/1991.

Cultivars	Location		
	RREC[1]	NEREC	Spirit Lake
	---------------------------bu/acre---------------------------		
Florida 302	29	16	21
AR 26415	32	34	25
Coker 9877	41	22	30
Pioneer 2555	33	34	26
Pioneer 2548	40	35	27
LSD.05	2	2	2

[1] RREC = Rice Research and Extension Center, Stuttgart, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas; Spirit Lake, Lafayette County, Arkansas.

Table 16. Wheat test weights as influenced by cultivars and locations, 1990/1991.

	Locations		
Cultivars	RREC[1]	NEREC	Spirit Lake
	-----	lb/bu	-----
Florida 302	53	43	38
AR 26415	57	50	44
Coker 9877	57	45	44
Pioneer 2555	53	47	41
Pioneer 2548	58	48	44
LSD.05	1	1	3

[1] RREC = Rice Research and Extension Center, Stuttgart, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas; Spirit Lake, Lafayette County, Arkansas.

Table 17. Wheat yields as influenced by spring nitrogen rate, fungicide application and location, 1990/1991.

	Spring N Rate (lb/acre)				
	100		150		
Location	(fungicide) +	-	+	-	LSD .05
	-----	-----	bu/acre	-----	-----
RREC[1]	35	32	37	35	4
NEREC	32	29	28	24	4
Spirit Lake	30	26	27	23	NS

[1] RREC = Rice Research and Extension Center, Stuttgart, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas; Spirit Lake, Lafayette County, Arkansas.

Table 18. Wheat yields as influenced by cultivar, spring nitrogen rate and fungicide, RREC[1], 1990/1991.

Cultivar	Cardinal		Caldwell		Wakefield		AR26415		Saluda	
Fungicide	+	-	+	-	+	-	+	-	+	-
N Rate (lb/acre)	-----	-----	-----	-----	bu/acre	-----	-----	-----	-----	-----
0	30	26	26	16	35	29	23	21	25	23
60	43	40	37	31	44	36	36	28	38	29
90	48	39	37	24	45	32	33	27	36	26
120	45	38	35	29	48	32	33	24	35	23
150	45	39	35	26	45	29	32	24	38	29

LSD.05 = 5 bu/acre

[1] Rice Research and Extension Center, Stuttgart, Arkansas.

Table 19. Wheat test weights as influenced by cultivar, spring nitrogen rate and fungicide, RREC[1], 1990/1991.

Cultivar	Cardinal		Caldwell		Wakefield		AR 26415		Saluda	
Fungicide	+	-	+	-	+	-	+	-	+	-
N Rate (lb/acre)	-----lb/bu-----									
0	57	57	54	52	56	55	55	54	55	54
60	56	55	54	53	57	52	52	51	55	53
90	57	54	54	50	55	52	52	50	54	51
120	55	54	53	50	56	51	49	46	53	50
150	56	54	53	48	55	50	50	48	52	48

LSD.05= 2 lb/bu

[1] Rice Research and Extension Center, Stuttgart, Arkansas.

NITROGEN TIMING ON WHEAT YIELDS ASSOCIATED WITH THE WHEAT MONITORING PROGRAM

J.A. Hattey, W.E. Sabbe and B.R. Wells

INTRODUCTION

The wheat monitoring program coordinated within the University of Arkansas Division of Agriculture recommends fertilizer nitrogen applications dependent upon the growth stage (GS) and the total nitrogen concentration of the wheat plant. In the fall of 1990, research was conducted at three locations to further define the applicability of the current program/recommendations. The three locations were Main Experiment Station (MES), Fayetteville, Arkansas; Northeast Research and Extension Center (NEREC), Keiser, Arkansas; and the Southeast Branch Station (SEB), Rohwer, Arkansas. A wheat cultivar suitable for each location ('Saluda' at MES; 'Florida 302' at SEB; 'Pioneer 2555' at NEREC) was planted and grown under normal dryland management conditions. In early 1991, three rates of fertilizer (0, 50 and 100 lb N/acre) were applied to provide for three nitrogen regimes. At selected GS (4, 7 and 9) either 0 or 30 lb N/acre was applied within each nitrogen regime. Therefore, individual plots received either 0, 30, 60 or 90 lb N/acre in addition to the initial nitrogen regime. One plot within each nitrogen regime was plant sampled and fertilized according to the current wheat monitoring program. Grain yields were obtained with a plot harvester and corrected to 12% moisture.

There was a significant difference in grain yields among locations (LOC), and the three-way interaction of location by winter N rate (WN) by GS of spring N application was significant (data not shown).

NITROGEN RATE/TIMING

MES

There were significant grain yield differences due to WN rates and, within WN rates, differences due to GS (Table 1). The 0 WN plots, regardless of subsequent N rates, were not able to produce grain yields equivalent to the highest yields with initial rates of 50 or 100 WN. Within the 0 and the 50 WN, subsequent applications at GS 4+7+9 (total of 90 lb N/acre) produced grain yields significantly higher than at any other single GS or combination of GS. Also, the later the application of only 30 lb N/acre, the lower the yield within both the 0 and 50 WN. Application of 30 lb/N acre at GS 9 produced grain yields no different than those where no nitrogen was applied.

NEREC

The 0 WN rate plots at NEREC did not produce yields equal to the highest yields from the 50 and 100 WN plots, regardless of subsequent 30-lb N/acre applications. All single applications of 30 lb N/acre increased the yield above the 0 rate except at GS 9 for both the 0 and 50 WN treatments. For the 0 WN, delaying the initial application until GS 7 or 9 did not produce yields equal to the highest yields under this initial N application. At 100 WN, there were no differences.

SEB

The 0 WN treatment did produce yields equal to the highest yields at both the 50 and 100 WN. The application of 30 lb N/acre at all three applications (i.e. GS 4+7+9) for a total of 90 lb N/acre did equal the highest yields at this location. At the 0 WN rate, any single initial application later than GS 4 did not result in yields different from the check. For the 50 WN treatment, only an additional 90 lb N/acre produced yields different from initial 50 WN application. No subsequent GS application at the 100 WN application produced grain yields different from the 100 WN rate only.

WHEAT MONITORING PROGRAM

At the NEREC and SEB locations, within each WN rate, the wheat monitoring treatment produced grain yields equal to the highest yield (Table 2). Wheat monitoring yields at the MES location were not equal to the highest yield within each WN rate; however, the wheat monitoring yields were equal to those produced under essentially equivalent amounts of nitrogen fertilizer for each WN rate.

At each location, where no nitrogen was applied early (0 WN), the grain yields were statistically inferior to the highest grain yield. Within each location for the 0 WN, the best grain yields were obtained with the highest nitrogen rate (90 lb N/acre). The current monitoring program appeared successful in obtaining the optimum yields at two locations (SEB and NEREC) for all WN rates. However, at MES--

where the greatest yields occurred--the current monitoring program did not produce yields equal to the highest yield within each of the initial WN rates.

Table 1. Wheat grain yields as affected by fertilizer nitrogen timing and rates.

		Total N	Yield		
WN[1]	GS	lb/acre	NEREC[2]	MES	SEB
			bu/acre		
0	0	0	12.6	29.9	26.2
0	4	30	35.1	52.2	36.0
0	4,7	60	40.8	53.9	39.5
0	4,7,9	90	40.8	64.5	44.9
0	4,9	60	37.9	51.1	39.1
0	7	30	29.0	41.0	34.6
0	7,9	60	30.3	45.5	37.6
0	9	30	18.0	28.3	30.4
50	0	50	35.6	47.7	36.1
50	4	80	51.3	61.5	42.1
50	4,7	110	49.5	68.9	45.0
50	4,7,9	140	47.0	78.1	50.2
50	4,9	110	51.0	63.5	45.4
50	7	80	51.1	59.9	38.5
50	7,9	110	48.4	62.1	44.6
50	9	80	42.7	50.2	37.5
100	0	100	49.9	64.6	46.7
100	4	130	48.6	75.1	51.1
100	4,7	160	45.9	78.8	48.5
100	4,7,9	190	49.4	83.5	46.5
100	4,9	160	48.9	72.8	47.6
100	7	130	50.4	70.1	51.6
100	7,9	160	46.2	78.2	47.5
100	9	130	51.5	68.0	50.5
Within WN ($LSD_{.05}$)			7.3	5.5	6.8
Within and among GS ($LSD_{.05}$)			9.1	7.9	9.7

Regression Equations

NEREC $Y = 13.5 + 0.51N - 0.0018N^2$ $R^2 = 0.94$

MES $Y = 28.9 + 0.42N - 0.0007N^2$ $R^2 = 0.99$

SEB $Y = 25.1 + 0.29N - 0.00092N^2$ $R^2 = 0.94$

where Y = yield in bu/acre; N = nitrogen in lb N/acre fertilizer

[1] WN = winter nitrogen rate; GS = growth stage.

[2] NEREC = Northeast Research and Extension Center, Keiser, Arkansas; MES = Main Experiment Station, Fayetteville, Arkansas; SEB = Southeast Branch Station, Rohwer, Arkansas.

Table 2. Grain yields from nitrogen rates/timing as recommended by the Wheat Monitoring Program.

	Monitoring Program				Highest
Location	Initial	Recommended	Total	Yield	yields
	------------ lb N/acre ------------			--------- bu/acre ---------	
MES[1]	0	67(5)[2]	67	57.5	64.5(90)[3]
	50	50(5)	100	67.6	78.1(140)
	100	34(6/7)	134	70.9	83.5(190)
SEB	0	50(5/6)	50	46.0	44.9(90)
	50	50(7)	100	51.3	50.2(140)
	100	0	100	47.2	51.6(130)
NEREC	0	90(4)	90	43.5	40.8(90)
	50	0	50	41.6	51.3(80)
	100	0	100	53.7	51.5(130)

[1] MES = Main Experiment Station, Fayetteville, Arkansas; SEB = Southeast Branch Station, Rohwer, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas.

[2] Figure in parentheses indicates growth stage of N application.

[3] Highest yield within each WN and associated N rate (Table 1).

RICE RESPONSE TO PHOSPHORUS FERTILIZATION ON SOILS TESTING LOW IN PHOSPHORUS

R.J. Norman, C.A. Beyrouty, D.M. Miller,
P.M. Moore, Y.H. Teo and N.A. Slaton

INTRODUCTION

Phosphorus (P) is generally not recommended on flood-irrigated rice because of the high levels of soil P solubilized under anaerobic conditions. However, in 1990, an evaluation of four soils testing below 22 lb P/acre showed a yield response to P fertilizer at the 20-lb/acre rate on three of the soils (Beyrouty et al., 1991). We have continued our survey identifying potential P-responsive soils, and we are attempting to determine if a relationship exists between various measures of soil P content and response of rice to added P. Our ultimate goal is to predict the soils on which rice is likely to respond to P fertilization and to select an appropriate soil test that will accurately allow this prediction.

PROCEDURES

Field tests were conducted in which rice response to rates of P were evaluated. The two soils selected for this study were the Crowley silt loam in Arkansas county, Arkansas, and the Hillemann silt loam located in Cross county, Arkansas. These soils tested 10 and 16 lb/acre of P, respectively, using the Mehlich III extractant and were among the lowest-testing soils on which rice was grown in Arkansas in 1991. Soybean was grown on both fields in 1990.

The rice cultivars 'Tebonnet' and 'Katy' were drill seeded on the Crowley and Hillemann silt loams, respectively, at approximately a 90-lb/acre rate in mid- to late-May.

At the 4- to 5-leaf stage, P was applied preflood at 0, 20, 40 or 80 lb/acre as triple superphosphate (0-46-0). The statistical design was a randomized complete block with six replications. Plots nine rows wide (7-in. spacing) by 15 ft in length were flooded immediately after

P application and the flood maintained until maturity. Weed and disease control and N fertilization for each test site were identical to those for the surrounding fields and managed by the respective rice producers. At maturity, the center four rows of each plot were hand harvested, the dry weight and moisture content of the grain were determined, and yields were calculated at 12% moisture. Statistical analyses were conducted using SAS.

Two greenhouse studies were also conducted to determine if responses could also be measured under short-term, controlled-environment conditions. In a study to evaluate P response in three soils, approximately 6.6 lb of either the Crowley silt loam or the Hillemann silt loam sampled from Cross county (Hillemann I) and Poinsett county (Hillemann II) was fertilized with triple super phosphate at rates equivalent to 0, 4.5, 9 or 36 lb P/acre. The soils and fertilizer were uniformly mixed and packed into 1-gal pots. Pots were seeded with the rice cultivar Katy. At the 3-leaf stage, pots were thinned to five plants, fertilized with urea at the rate of 150 lb/acre and flooded. Plants were harvested 4 weeks after emergence, and plant tissue was dried at 40C for 48 hr and weighed. The design was a randomized complete block with four replications. Statistical analyses were conducted using SAS.

The second study was conducted to evaluate P response variability within a field. Four separate composites of the Hillemann were taken from different locations in a field in Poinsett county. Approximately 2.2 lb of each composite was fertilized with triple superphosphate at rates equivalent to 0, 40 or 80 lb P/acre and KCl at the 40-lb K/acre rate. The soils and fertilizer were uniformly mixed and packed into pots. Pots were seeded with the rice cultivar 'Newbonnet' and thinned to four plants upon emergence. Six days after emergence, pots were fertilized with urea at the rate equivalent to 120 lb N/acre and flooded. Plants were harvested six weeks after emergence. Plant tissue was dried at 40C for 48 hr and weighed. The design was a randomized complete block with four replications. Statistical analyses were conducted using SAS.

RESULTS AND DISCUSSION

Results from the field study showed a significant response to P fertilization on the Crowley silt loam only (Table 1). Compared to the non-fertilized control, application of 40 lb/acre P resulted in a 12% yield increase. This response contrasts with results from the previous year when no yield increase was noted following P fertilization to a

Crowley silt loam. Although not statistically significant, there was a trend for a yield increase at the 20-lb/acre rate on the Hillemann silt loam. It is interesting that yields actually decreased at higher rates of P.

Phosphorus fertilization resulted in dry weight increases on two of the three soils studied in the greenhouse (Table 2). A 63% increase in dry weight was measured on both Hillemann soils in response to the application of 36 and 9 lb P/acre, respectively. Although a yield response was found in the field on the Crowley, no dry weight response was measured in the greenhouse.

Although variability in the magnitude of dry weight response to P fertilization was measured on the four composites of the Hillemann, the P rate at which the response occurred was the same (Table 3). Dry weights were significantly increased at all four locations within the same field at the 40-lb/acre rate of P.

Results from these studies confirm that responses to P fertilization by rice may be expected on some soils. However, the consistent identification of P-responsive soils is the ultimate goal of this research. We will compare several soil tests with yield responses to P application in the field to determine the best method for making P fertilizer recommendations.

ACKNOWLEDGMENTS

Funding for this research was provided by the Rice Research and Promotion Board and fertilizer tonnage fees.

LITERATURE CITED

1. Beyrouty, C.A., D.M. Miller, R.J. Norman, B.R. Wells, R.S. Helms, H.M. Chaney and N.A. Slaton. 1991. Rice response to phosphorus fertilization on soils testing low in phosphorus. Ark. Soil Fert. Studies. Ark. Agri. Exp. Sta. Res Ser. 411.

Table 1. Yield response of rice to four rates of phosphorus fertilizer applied to two soils in the field in 1991.

Phosphorus Rate	Crowley	Hillemann
	lb/acre	
0	6798 b[1]	5348 ab
20	7162 ab	5842 a
40	7698 a	5075 b
80	7015 ab	5133 b
LSD (0.05)	833	698

[1] Means followed by the same letter within a soil are not significantly different at $P = 0.05$.

Table 2. Dry matter response of 'Katy' to four rates of phosphorus fertilizer applied to three soils in the greenhouse.

Phosphorus rate	Crowley	Hillemann I[1]	Hillemann II
lb/acre		g/pot	
0	0.75 a	0.54 b	0.83 ab
4.5	0.98 a	0.47 b	0.59 b
9.0	0.75 a	0.54 b	1.35 a
36.0	0.90 a	0.87 a	1.45 a

[1] Hillemann I was from Cross County, and Hillemann II was from Poinsett County.

Table 3. Dry weight response of 'Newbonnet' to three rates of phosphorus fertilizer applied to four different composites of the Hillemann II soil.

	Location[1]			
Phosphorus rate	A	B	C	D
lb/acre		g/pot		
0	1.1 b[2]	1.3 b	1.1 c	0.7 b
40	2.9 a	3.1 a	4.1 b	2.4 a
80	3.5 a	3.4 a	4.9 a	2.9 a

[1] Locations A, B, C and D represent four different composite samples of the Hillemann soil taken from the same field.

[2] Means followed by the same letter within a soil are not significantly different at $P = 0.05$.

GRAIN YIELD RESPONSE OF 'DELMONT', 'LACASSINE', 'ORION' AND 'ROSEMONT' TO NITROGEN FERTILIZATION

**R.J. Norman, B.R. Wells, R.S. Helms,
K.A.K. Moldenhauer and K.A. Gravois**

INTRODUCTION

This rice cultivar x nitrogen (N) fertilizer interaction study is a continuing project in the rice-soil fertility research program. Its purpose is to determine the response of new rice (*Oryza sativa* L.) cultivars to N fertilizer prior to their release to growers, thus enhancing the potential for top performance in commercial fields. Promising new rice selections from breeding programs in Arkansas, California, Louisiana, Mississippi and Texas are included in these studies. 'Orion' is a medium grain cultivar developed by the Arkansas breeding program. 'Delmont' and 'Rosemont' are long grain semidwarf cultivars developed by the Texas breeding program. 'Lacassine' is a long grain semidwarf rice cultivar developed by the Louisiana breeding program. Farmer check-off funds administered by the Arkansas Rice Research and Promotion Board support and enable this study to be conducted at four locations each year. Results contained in this report are from 1991 for the three semidwarfs studied and from 1990 and 1991 for the medium grain cultivar, Orion.

PROCEDURES

The locations and soils were as follows: Rice Research and Extension Center (RREC), Stuttgart, Arkansas, Crowley silt loam (Typic Albaqualfs); Northeast Research and Extension Center (NEREC), Keiser, Arkansas, Sharkey clay (Vertic Haplaquepts); Pine Tree Station (PTS), Colt, Arkansas, Calloway silt loam (Glossaquic Fraquidalfs); and the Southeast Branch Station (SEBS), Rohwer, Arkansas, Perry Clay (Vertic Haplaquepts).

The experimental design was a randomized complete block with six replications. The N fertilizer rates were 0, 60, 90, 120, 150 and

180 lb N/acre applied as urea in three split applications (i.e., preflood, proper internode elongation and 10 days after proper internode elongation) as recommended by the Arkansas Cooperative Extension Service. The rice was drill seeded at a seeding rate of 100 lb/acre in nine row plots (row spacing of 7 in.), 15 ft in length. Weed control was achieved with standard herbicide applications. All plots were flooded when the rice was at the 4- to 5-leaf stage and remained flooded until the rice was mature, unless previous history at the site required draining and drying for the control of straighthead. At maturity, 12 ft of the center four rows of each plot were harvested with a small combine, the grain was dried and weighed, and yields were determined as lb/acre at 12% moisture. Statistical analyses were conducted using SAS.

RESULTS AND DISCUSSION

Delmont grain yields peaked at 150 lb N/acre at NEREC, RREC and SEBS (Table 1). Only 120 lb N/acre was required for Delmont to reach maximum grain yield at PTS. No parabolic yield curves were observed for Delmont at any of the locations; only asymptotic or ever-increasing curves were found.

Lacassine, a semidwarf like Delmont, had grain yield increases at each of the locations somewhat similar to those of Delmont for a given rate of N applied (Table 2). Lacassine showed no significant grain yield increase when more than 150 lb N/acre was applied at NEREC and SEBS. While grain yield increases through 180 lb N/acre were found at RREC, Lacassine reached a maximum grain yield when 120 lb N/acre was applied at PTS. Again, no parabolic yield curves were observed at any of the locations. This indicates that, except for PTS, more than 180 lb N/acre needs to be applied to these new semidwarfs to confidently determine their proper N rate and their maximum grain yield potential.

Rosemont, another semidwarf, reacted at each of the locations similar to the other semidwarfs studied (Table 3). Rosemont reached maximum grain yield when 150 lb N/acre was applied at NEREC, RREC and SEBS. Rosemont showed no significant grain yield increase when more than 90 lb N/acre was applied at the PTS.

All of the semidwarfs studied required 150 lb N/acre or more to reach maximum grain yield at three of the four locations at which the study was conducted. Semidwarfs studied in the past have required 150 to 210 lb N/acre to reach maximum grain yield. These new semidwarfs appear to be similar to the earlier-released semidwarfs in the N rate required to reach maximum yield potential. Also, grain yield potentials of the new semidwarfs appear to be in the range of the earlier-released semidwarfs. An additional year of research will be performed on these new semidwarfs to determine their proper N fertilizer rate and yield potential.

Orion was the only medium grain rice cultivar studied and the only rice cultivar studied in 1991 that was in its second year of the study (Table 4). Orion showed no significant grain yield increases when more than 150 lb N/acre was applied at NEREC in 1991, SEBS in 1990 and 1991 and RREC and PTS in 1991. No significant grain yield increase was found for Orion when more than 120 lb N/acre was applied in 1990 at RREC and NEREC. From these data it appears that Orion can obtain a maximum grain yield in Arkansas when 120 to 150 lb N/acre is applied. Due to the height of Orion and the parabolic yield curve displayed at several of the locations, no more than 150 lb N/acre should be applied to Orion.

Table 1. Grain yield of 'Delmont' rice as influenced by nitrogen fertilizer rate and location.

	Grain yield by location			
N rate	NEREC[1]	PTS	RREC	SEBS
lb N/acre	lb/acre			
0	2926	4060	2935	2146
60	4881	6107	3872	3085
90	5713	6291	5283	3894
120	7060	7368	6101	5902
150	7954	7619	6885	6783
180	8575	7598	7626	6995
LSD 0.05	732	542	789	755

[1] NEREC = Northeast Research and Extension Center, Keiser, Arkansas; PTS = Pine Tree Substation, Colt, Arkansas; RREC = Rice Research and Extension Center, Stuttgart, Arkansas; SEBS = Southeast Branch Station, Rohwer, Arkansas.

Table 2. Grain yield of 'Lacassine' rice as influenced by nitrogen fertilizer rate and location.

	Grain yield by location			
N rate	NEREC[1]	PTS	RREC	SEBS
lb N/acre	---------- lb/acre ----------			
0	2378	3731	3241	1980
60	4207	5820	3974	2985
90	5086	5959	4819	5142
120	6111	7023	5709	6092
150	7136	7316	7060	7632
180	7723	7475	7996	7763
LSD 0.05	659	1215	533	847

[1] NEREC = Northeast Research and Extension Center, Keiser, Arkansas; PTS = Pine Tree Substation, Colt, Arkansas; RREC = Rice Research and Extension Center, Stuttgart, Arkansas; SEBS = Southeast Branch Station, Rohwer, Arkansas.

Table 3. Grain yield of 'Rosemont' rice as influenced by nitrogen fertilizer rate and location.

	Grain yield by location			
N rate	NEREC[1]	PTS	RREC	SEBS
lb N/acre	---------- lb/acre ----------			
0	2851	2715	2429	1620
60	4935	5693	2802	2747
90	5929	6592	4098	3974
120	5996	7406	4645	5532
150	8473	7337	6591	6877
180	8756	7035	6480	6975
LSD 0.05	748	858	1076	557

[1] See footnote 1, Table 2.

Table 4. Grain yield of 'Orion' rice as influenced by nitrogen fertilizer rate and location.

	Grain yield by location						
	NEREC[1]		RREC		SEBS		PTS
N rate	1990	1991	1990	1991	1990	1991	1991
N/acre	---------- lb/acre ----------						
0	5294	2550	5130	3391	3929	1976	4901
60	7592	5485	6981	5535	6507	4911	7731
90	8566	6644	7336	6363	7145	6472	8534
120	9539	7736	8266	6776	8488	6780	8673
150	9293	8239	7681	7761	9410	7686	10001
180	8972	8131	7465	8002	9669	7735	9286
LSD 0.05	647	532	555	705	645	789	590

[1] See footnote 1, Table 2.

USE OF PLANT AREA MEASUREMENTS TO ESTIMATE MID-SEASON NITROGEN RATES FOR RICE

B.R. Wells, R.J. Norman and R.S. Helms

INTRODUCTION

The ability to more accurately estimate mid-season nitrogen (N) rates for rice has the potential to save N fertilizer, to minimize any adverse environmental effects and to optimize grain yields. In California, N concentration in rice leaf tissue is used as the criterion; however, research in Arkansas has not shown this method to provide reliable information due to a) large changes in N concentration over relatively short time spans during late tillering and b) large sample-to-sample variability within the field. More recently efforts to estimate mid-season N needs have included estimates of chlorophyll content using the Minolta SPAD meter and measurements of rice plant area. The study reported here has the objective of relating rice plant area measurements made at panicle initiation to grain yields as influenced by cultivar and both early- and mid-season N fertilizer rates.

MATERIALS AND METHODS

The study was conducted at three locations: the Rice Research and Extension Center (RREC), Stuttgart, Arkansas, on a Crowley silt loam (Typic Albaqualfs); the Northeast Research and Extension Center (NEREC), Keiser, Arkansas, on a Sharkey clay (Vertic Haplequepts); and the Pine Tree Station (PTS), Colt, Arkansas, on a Calloway silt loam (Glossiquic Fragiudalfs).

The experimental design was a split plot with early-season N rates of 0, 40, 80, 120 or 160 lb/acre as the main plots and mid-season N rates of 0, 30, 60 or 90 lb/acre as the sub-plots. The treatments were replicated either three or four times, depending on location and cultivar. Separate studies were conducted with each of three cultivars at each location. The cultivars were ‘Orion’, ‘Alan’ and ‘Maybelle’. The rice was drill seeded at 100 lb/acre in 9-row plots (7-in. row spacings), 15 ft in length. Weed control was achieved with standard herbicide applications. All plots received the early-season N application prior to flooding when the rice was at the 4- to 5-leaf stage of development. Mid-season N applications were made into the flood water. Plant area measurements, Minolta SPAD readings and 'Y' leaf samples for determination of N concentration were taken weekly beginning two weeks after flooding and continuing until panicle initiation. Plant area was measured as the plant height by leaf spread with the plant treated as a triangle. At maturity, 12 ft from the center four rows of each plot was harvested with a small combine, the grain weighed, moisture content determined and the yields calculated as lb/acre at 12% moisture content. Statistical analysis were conducted using procedures developed by SAS, Inc. Means separations were by LSD at the 5% level of probability.

RESULTS

Grain yield responses to early- and mid-season N applications are shown in Tables 1-6. Alan was the only cultivar with a significant early- by mid-season N rate interaction. Yield responses to the early-season N applications were considerably greater than those from the mid-season N applications.

Maximum grain yields for Orion (Table 1) were associated with an early-season N rate of 80 lb/acre at all three locations. Grain yield response to mid-season N rate was much less and varied with location; the optimum rate varied from 30 to 90 lb/acre. Maybelle responded to higher early-season N rates as compared to Orion (Table 2). Yields of Maybelle at RREC and NEREC appeared not to have reached a maximum even with the 160-lb/acre early-season N rate whereas at PTS maximum yields were associated with an early-season N rate of 120 lb/acre. Yields increased with a 30-lb/acre mid-season N application at RREC and with a 90-lb/acre mid-season N application at NEREC. Yields of Maybelle were not affected by the mid-season N application at PTS.

There were significant interactions for grain yields of Alan between early- and mid-season N rate treatments at all three locations (Tables 3, 4 and 5). Yields at RREC (Table 3) increased with increased early-season N rates to 80 lb/acre. At the 0-lb/acre early-season N rate, a mid-season N rate of 60 lb/acre was needed to maximize yields whereas at 40 lb/acre early-season N only 30 lb/acre of mid-season N was needed. At early-season N rates of 80 lb/acre or greater, no response was received from mid-season N applications.

Yields of Alan at PTS (Table 4) increased with increasing early-season N rates up to 80 lb/acre. Mid-season N rates of 90 to 30 lb/acre were needed to optimize yields when the early-season N rate varied from 0 to 80 lb/acre. No mid-season N fertilizer was needed to optimize yields when the early-season N rate was greater than 80 lb/acre. Grain yields were reduced at the 160-lb/acre early-season N rate irrespective of the rate of mid-season N applied. Grain yields of Alan at NEREC (Table 5) responded to early-season N applications up to 120 lb/acre. Mid-season N applications increased grain yields at early-season N rates of 0, 40 or 80 lb/acre.

Minolta SPAD readings and plant areas measured at panicle initiation increased with increasing early-season N rates (Tables 6, 7 and 8). Plant areas associated with optimum grain yields associated with early-season N applications for Orion appear to range from 700 to 800 cm^2, whereas SPAD readings at these same N rates were 35 to 38. Maximum SPAD readings were approximately 40; however, these readings were associated with early-season N rate treatments above those needed to maximize grain yields. The lack of a significant interaction for grain yields between early- and mid-season N rate treatments makes it difficult to estimate either plant areas or SPAD readings where differential mid-season N rates should be applied. Optimum plant areas are considerably lower for Orion than for Mars. Apparently this is the result of the erect angle of the leaves for Orion; therefore, the plant area is smaller.

Plant area and SPAD measurements for Maybelle at panicle initiation are given in Table 7. Plant areas associated with maximum grain yields associated with early-season N rate varied from 870 to over 1000 cm^2 with location. These values are higher than those reported for Maybelle in 1990; however, it appears that the 1991 Maybelle differed from the 1990 cultivar by being approximately one week earlier in maturity, of shorter plant height and with broader leaves. This is apparently the result of changes made in this cultivar by the Texas and Mississippi rice breeding programs (Personal communication, J. Stansel). Optimum SPAD readings appear to be in the range of 37 to 39. As with Orion, the lack of a significant interaction for grain yields between early- and mid-season N rates makes it difficult to estimate plant areas and SPAD readings below optimum to differentiate mid-season N rates.

Plant area and SPAD measurements made at panicle initiation for Alan are given in Table 8. Plant areas of approximately 800 to 1000 cm^2 were associated with maximum grain yields at varying early-season N rates without the addition of any mid-season N fertilizer.

SPAD meter readings above 35 appeared to indicate an adequate level of N for optimum yields without addition of mid-season N fertilizer. As plant area or SPAD measurements decreased below 800 cm^2 and 35, respectively, increasing amounts of mid-season N fertilizer were required to optimize grain yields.

Results from the 1991 studies continue to indicate that either plant area or the SPAD meter may be used to estimate the need to apply mid-season N fertilizer to rice. The data also indicate that rice cultivars vary as to the optimum size and color associated with proper N nutrition at panicle initiation. Therefore, it will be necessary to continue to evaluate new rice cultivars as they are released if this program is to be of value to rice farmers.

ACKNOWLEDGMENT

Support for this research was provided by the Arkansas Rice Research and Promotion Board.

Table 1. Grain yield response of 'Orion' rice to preflood and mid-season nitrogen fertilization by location, 1991.

		Location		
N Time	N Rate	RREC[1]	PTS	NEREC
	lb/acre		lb/acre	
Preflood				
	0	3891	5912	3829
	40	6061	8715	6164
	80	7654	9892	7840
	120	8068	9447	8036
	160	7425	9138	7156
Mid-season				
	0	6385	8445	6008
	30	6609	8456	6776
	60	6635	8657	6962
	90	6851	8927	6659
LSD (0.05) Preflood		985	585	925
LSD (0.055) Mid-season		253	352	ns

[1] RREC - Rice Research and Extension Center, Stuttgart, Arkansas; PTS - Pine Tree Experiment Station, Colt, Arkansas; NEREC - Northeast Research and Extension Center, Keiser, Arkansas.

Table 2. Grain yield response of 'Maybelle' rice to preflood and mid-season nitrogen fertilization by location, 1991.

N Time	N Rate	RREC[1]	PTS	NEREC
		Location		
	lb/acre	lb/acre		
Preflood				
	0	1520	3309	2998
	40	3569	4827	6026
	80	5373	7517	7599
	120	5681	7909	8715
	160	5955	7781	9400
Mid-season				
	0	4198	6142	6575
	30	4404	6260	6729
	60	4481	6289	7063
	90	4596	6385	7424
LSD (0.05) Preflood		692	934	613
LSD (0.05) Mid-season		273	ns	308

[1] RREC - Rice Research and Extension Center, Stuttgart, Arkansas; PTS - Pine Tree Experiment Station, Colt, Arkansas; NEREC - Northeast Research & Extension Center, Keiser, Arkansas.

Table 3. Grains yields of 'Alan' rice as influenced by preflood and mid-season nitrogen fertilization, Rice Research and Extension Center, Stuttgart, Arkansas, 1991.

Preflood N Rate	Mid-season N rate 0	30	60	90
lb/acre	lb/acre			
0	3563	4065	4910	4967
40	5363	5752	5495	5911
80	5915	6049	5757	5867
120	6225	6217	5798	5387
160	5818	5322	4598	4477
LSD (0.05) -				

Table 4. Grain yields of 'Alan' rice as influenced by preflood and mid-season nitrogen fertilization, Pine Tree Station, Colt, Arkansas, 1991.

Preflood	Mid-season N rate			
N rate	0	30	60	90
lb/acre	-----------------	lb/acre	-----------------	
0	4679	5234	5635	5574
40	6681	6903	7024	7511
80	7321	8124	7471	8290
120	7577	7592	7506	7720
160	7125	7010	6987	6944
LSD (0.05) -				

Table 5. Grain yields of 'Alan' rice as influenced by preflood and mid-season nitrogen fertilization, Northeast Research and Extension Center, Keiser, Arkansas, 1991.

Preflood	Mid-season N rate (lb/acre)			
N Rate	0	30	60	90
lb/acre	-----------------	lb/acre	-----------------	
0	2615	3471	3254	3311
40	4291	5270	6117	6713
80	7318	7424	7638	8190
120	7923	7713	8335	8302
160	7836	7004	7482	7860
LSD (0.05) -				

Table 6. Plant area and SPAD meter measurements of 'Orion' rice as influenced by early-season nitrogen rate and location, 1991.

	Location					
Preflood	RREC[1]		PTS		NEREC	
N rate	Chl[2]	PA[3]	Chl	PA	Chl	PA
		cm^2		cm^2		cm^2
0	25	219	22	189	26	223
40	27	430	27	436	31	537
80	34	662	35	757	35	786
120	38	706	38	942	39	942
160	41	857	40	985	40	1024
LSD (0.05)	3	104	3	70	2	48

[1] RREC - Rice Research and Extension Center, Stuttgart, Arkansas; PTS - Pine Tree Experiment Station, Colt, Arkansas; NEREC - Northeast Research and Extension Center, Keiser, Arkansas.

[2] Chl - Chlorophyll estimate by SPAD meter reading

[3] PA - Plant area in cm^2

Table 7. Plant area and SPAD meter measurements of 'Maybelle' rice as influenced by early-season nitrogen rate and location, 1991.

Preflood	Location					
	RREC[1]		PT		NEREC	
N rate	Chl[2]	PA[3]	Chl	PA	Chl	PA
		cm^2		cm^2		cm^2
0	25	201	20	207	23	213
40	29	557	25	546	28	714
80	35	715	31	705	34	866
120	39	742	35	870	37	1036
160	39	890	37	889	39	1066
LSD (0.05)	2	108	5	94	2	75

[1] RREC - Rice Research and Extension Center, Stuttgart, Arkansas; PTS - Pine Tree Experiment Station, Colt, Arkansas; NEREC - Northeast Research and Extension Center, Keiser, Arkansas.

[2] Chl - Chlorophyll estimate by SPAD meter reading

[3] PA - Plant area in cm^2

Table 8. Plant area and SPAD meter measurements of 'Alan' rice as influenced by early-season nitrogen rate and location, 1991.

Preflood	Location					
	RREC[1]		PTS		NEREC	
N rate	Chl[2]	PA[3]	Chl	PA	Chl	PA
		cm^2		cm^2		cm^2
0	25	256	19	264	23	199
40	30	741	27	574	28	655
80	35	880	31	677	32	945
120	39	1046	34	1028	36	1151
160	40	1099	38	1061	38	1229
LSD (0.05)	1	151	3	159	1	86

[1] RREC - Rice Research and Extension Center, Stuttgart, Arkansas; PTS - Pine Tree Experiment Station, Colt, Arkansas; NEREC - Northeast Research and Extension Center, Keiser, Arkansas.

[2] Chl - Chlorophyll estimate by SPAD meter reading

[3] PA - Plant area in cm^2

INFLUENCE OF SOIL MOISTURE, APPLICATION TIME AND A UREASE INHIBITOR ON RICE NITROGEN UPTAKE AND YIELD

R.J. Norman, D.C. Wolf and B.R. Wells

INTRODUCTION

The time required to flood a rice field in Arkansas is from two to 10 days, depending on the pumping capacity and size of the field. Consequently, urea applied preflood may remain on the soil surface for up to 10 days prior to being incorporated by the flood water, possibly leading to substantial ammonia volatilization losses. In addition, under rainy conditions, the urea may be applied on a muddy soil surface or into the flood water. In all of these situations, the use of a urease inhibitor may be of benefit in reducing losses.

MATERIALS AND METHODS

The study was conducted in 1990 at the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas, on a Crowley silt loam, Typic Albaqualf. The soil pH, organic C and total N were 7.1, 9.1 g/kg and 0.9 g/kg, respectively. The study consisted of applying 134 kg N/ha as 2.0 atom % ^{15}N-labeled urea with and without the urease inhibitor NBPT on dry and wet soil 10, 5 and 0 days prior to establishment of the permanent flood. An additional two treatments were included that consisted of application of the urea into the flood water with and without NBPT immediately after the flood was established. The experimental design was a randomized complete block with three replications. The NBPT was coated onto the urea on a 0.5% w/w basis according to instructions of Enimont America.

'Lemont' rice was drill seeded in 18-cm rows at a seeding rate of 430 seeds/m^2. The rice was allowed to emerge and grow under nonflooded conditions until establishment of the permanent flood. Weeds were controlled with a tank mix of propanil plus butachlor. At the fourth leaf stage, or 10 days prior to establishment of the flood, 0.58-m^2 galvanized collars were driven into the soil 10 cm to the depth of the pan. The collars extended 20 cm above the soil surface. Each collar formed a microplot 30 cm in length and 4 rows wide.

At panicle differentiation, 2 rows of plants from each microplot were hand cut at the soil surface, dried at 65 C, weighed and ground to pass a 1-mm sieve, and total N as well as atom % ^{15}N was determined.

At maturity, the remaining two rows were hand cut at the soil surface, separated into grain and straw, dried at 65 C, weighed and ground to pass a 1-mm sieve, and total N was determined.

RESULTS

Shown in Table 1 are the grain N, total N and fertilizer N uptake along with the grain and total dry matter yields. Application of the urea into the flood water resulted in the lowest yields and the lowest N uptakes of all treatments studied. Application of the urea onto dry soil resulted in higher total N uptake and fertilizer N uptake as well as grain yield compared to application on wet soil. Total N and fertilizer N uptake was generally increased with shorter time between urea application and flood, but this did not result in significantly higher rice grain yields. However, there was a trend towards higher yields the shorter the time interval between urea application and flood date. The use of NBPT almost always resulted in a trend towards higher total N and fertilizer N uptake at a given application time and soil condition, but in no situation did the use of NBPT result in a significantly higher grain yield.

Table 1. Influence of application time, soil condition and NBPT on rice nitrogen uptake and yield.

Application time	NBPT	Soil cond.	Grain N	Total N	Fertilizer N	Grain weight	Total dry weight
days prior to flood			-------- kg/ha --------		% of applied	-------- kg/ha --------	
10	-	dry	67.7cd[1]	116.1bc	71.2c	6268 a	12157 ab
10	+	dry	70.7bc	114.3bc	75.2bc	6371 a	12364 a
10	-	wet	56.4f	91.3g	41.7e	5132 c	10332 c
10	+	wet	57.4f	94.6fg	45.4e	5361 bc	10837 c
5	-	dry	73.9ab	120.6abc	81.7ab	6509 a	12708 a
5	+	dry	77.6a	124.2a	83.8a	6635 a	12972 a
5	-	wet	61.0ef	97.5efg	59.4d	5304 bc	10539 c
5	+	wet	64.2de	106.0d	62.8d	5683 b	11331 bc
0	-	dry	77.4a	124.3a	82.9a	6670 a	12903 a
0	+	dry	77.5a	123.6ab	83.4a	6544 a	12708 a
0	-	wet	61.4ef	100.7def	64.4d	5579 bc	11124 c
0	+	wet	63.3de	104.2de	63.8d	5648 b	11319 bc
0	-	flood	42.0g	75.8h	31.1f	3788 d	8610 d
0	+	flood	42.7g	74.9h	29.6f	3961 d	8679 d

[1] Means within a column followed by the same letter are not significantly different at the $P < 0.05$ according to Duncan's Multiple Range Test.

FERTILIZER NITROGEN UPTAKE BY RICE FROM GRANULAR UREA OR UREA, AMMONIUM OR NITRATE IN A UAN SOLUTION

B.R. Wells and R.J. Norman

INTRODUCTION

Rice (*Oryza sativa*, L.) production in the southern United States is conducted utilizing a delayed flood cultural system. With this system the rice is seeded into a moist seedbed, allowed to germinate and then flooded at the 4- to 5-leaf stage of development. The rice grows as an upland crop for four to six weeks after seeding. This management system precludes use of preplant nitrogen (N) fertilizer due to the large denitrification losses that occur after flooding. Therefore, the typical N fertilizer program consists of split applications of an ammonium type fertilizer applied just prior to flooding and again either once or twice just after the rice has shifted from the vegetative to the reproductive development stage (Wells and Turner, 1984). Typically the N source utilized for this program is urea due to its cost per pound of N, high N analysis and the cost of aerial applications. One problem with the use of a solid material such as urea for aerial applications is that of uneven distribution. Use of a liquid such as urea-ammonium nitrate (UAN) solution would aid in reducing this distribution problem. However, previous work has shown that a UAN solution may be an inferior N source for rice (Norman et al., 1988; Wells, 1968). Wells (1960), using ^{15}N-labeled ammonium nitrate, showed that seedling rice preferred the ammonium form of N irrespective of soil conditions whereas at mid-season the plant utilized either form of N. Based on these studies it has largely been concluded that the lower efficiency of a UAN solution is associated with the nitrate content and is largely a problem with the initial preflood N application. An additional problem with UAN solutions is the free ammonia content that, if present, has been shown to cause foliar burn (Wells et al., 1984).

Currently, use of UAN solutions for rice is still questioned by farmers, extension personnel and researchers, mainly for the reasons listed above. Definitive data are needed on the N uptake and utilization by rice from each N chemical form in UAN (urea, ammonium and nitrate) as related to time of application. This would allow for the most efficient use of UAN solutions in the rice fertility program and might provide definitive information as to improvement of formulations of UAN solutions specifically for rice. The objectives of this research are: a) to determine the uptake efficiency by rice of the components of foliarly applied UAN (urea, ammonium or nitrate) as influenced by time of application and b) to compare these with broadcast applications of urea applied at the same time intervals.

MATERIALS AND METHODS

The test was conducted at the University of Arkansas Rice Research and Extension Center (RREC), Stuttgart, Arkansas, on a Crowley silt loam soil (Typic Albaqualfs) that had been cropped to soybeans in 1989. The experimental design was a randomized complete block with four replications. Treatment details are in Table 1.

The nitrogen rate for all treatments was 135 lb/acre applied in a 3-way split, 75 lb N/acre at preflood, 30 lb N/acre at internode elongation (IE) and 30 lb N/acre at IE + 10 days. For treatments 1 through 12, non-labeled urea or UAN solutions were applied for the two times of application not specified as receiving labeled fertilizer. The labeled UAN solutions were formulated in our laboratory with urea, ammonium or nitrate labeled as specified in the treatment list. The non-labeled UAN solution was also formulated in our laboratory. The material contained 50% of the N as urea, 25% of the N as ammonium and 25% of the N as nitrate.

The rice cultivar was 'Newbonnet', which was seeded at the rate of 100 lb/acre.

Microplots (6.25 ft^2) bordered with galvanized steel were used due to the high cost of the labeled fertilizer. The galvanized steel borders extended 4 in. into the soil and 8 in. above the soil. This prevented any movement of the fertilizer nitrogen beyond the borders of the plot. The rice surrounding the individual plots was not fertilized to prevent possible contamination of the plots during watering.

The following measurements were taken from the study: plant samples for total and fertilizer N uptake at: a) 3 weeks after preflood N application for treatments 1-4, b) 5 days after fertilizer application at IE and IE + 10 days for treatments 5-12, and c) dry matter, total N uptake and grain yields at maturity for treatments 13 and 14. These sampling sequences have been shown to be the most accurate for measuring fertilizer N uptake by rice (Wilson et al., 1989).

Each sampling consisted of a complete microplot.

Statistical analyses were conducted by procedures from SAS, Inc. (1985), and means separations were by LSD at the 5% level of probability.

RESULTS AND DISCUSSION

Total N uptake at each sampling time and grain yields were greater with granular urea as the N source as compared to UAN solution (Table 2) whereas the harvest index was not affected by N source. Total N uptake continued to increase up to physiological maturity.

Fertilizer N recovery was influenced by the N source (granular urea vs. UAN solution), form of N in the UAN (urea, NH_4, NO_3) and the time of N application (Pf, IE or IE + 10 days) (Table 3). Fertilizer N uptake was highest with the granular urea at all three times of N application and increased with increasing age of the rice plant at the time of N application. Nitrogen uptake from the urea contained in the UAN solutions was highest for the N application made at IE whereas N uptake from the NO_3 increased with increased age of the rice plant at the time of application. Nitrate nitrogen from the UAN solution was taken up very inefficiently from the preflood application (9.7%) whereas 83.5% of the nitrate was taken up by the rice from the N application made at IE + 10 days. Uptake of NH_4 from the UAN solution plateaued at IE and was similar at IE + 10 days.

Fertilizer N recovery by the rice was higher from the granular urea than from the UAN solution irrespective of the time of N application (Table 4). Nitrogen uptake from the granular urea increased with increasing age of the rice plant whereas N uptake from the UAN solution peaked with the application made at IE then declined at the late application. This resulted from the reduction in efficiency of the urea in the UAN at the IE + 10 day application. The rice recovered 74.2% of the N from the granular urea and 53.1% from the UAN solution.

Previously researchers had indicated that the lower efficiency of UAN solution as compared to granular urea or ammonium sulfate as N sources for rice was the result of the nitrate in the UAN solution. This study has shown that the nitrate is largely responsible for the lower efficiency associated with early-season (preflood) applications of UAN; however, the data indicate that the urea contained in the UAN solution is also utilized less efficiently and the loss of efficiency increases with increasing age of the rice plant at the time of N application. One possible reason for this reduced efficiency could be ammonia volatilization from the urea portion of the UAN when the UAN is applied to the leaf surface as a foliar application. The leaf surface has been reported to have substantial urease activity; thus N loss from urea by ammonia volatilization is possible. The results of this study would appear to indicate that the urease activity of the leaf surface may increase with increasing plant age, thus leading to greater N losses from N applications made to older plants. Leaf surface also increases with plant age; thus more foliarly applied UAN remains on the leaves as plant age increases, and this may contribute to additional NH_3 volatilization.

Results from this study also indicate that the rice plant is capable of efficiently utilizing NO_3-N from applications made at or later than IE. This confirms studies conducted by Wells in 1960. Based on these results, it appears that formulation of a nitrogen solution with a minimum amount of NO_3-N could result in an increased efficiency for the N application made at preflood whereas the nitrogen solution used at IE should contain less urea and more ammonium nitrate. Also, use of a urease inhibitor might be beneficial.

ACKNOWLEDGMENT

Support for this research was provided by the Fluid Fertilizer Foundation.

REFERENCES

1. Norman, R.J., B.R. Wells and R.S. Helms. 1988. Effect of nitrogen source, application time and dicyandiamide on rice yields. J. Fert. Issues 5:78-82.
2. SAS Institute. 1985. SAS Users's Guide: Basic, Version 5. SAS Institute, Inc., Cary, NC.
3. Wells, B.R. 1960. Nitrogen absorption by rice as determined by the use of the stable isotope ^{15}N. Thesis on file, University of Arkansas Mullins Library, Fayetteville, AR.
4. Wells, B.R. 1968. Nitrogen solutions in rice. Ark. Farm Res. 17(2):10.
5. Wells, B.R., F.N. Lee, M.L. Courtney and P.A. Shockley. 1984. Nitrogen solutions: An alternate N source for top-dress applications to rice. J. Fert. Issues 1(1):15-18.
6. Wells, B.R. and F.T. Turner. 1984. Nitrogen use in flooded rice soils. p. 349-362. *In* R.D. Hauck (ed.). Nitrogen in crop production. ASA, CSSA and SSSA, Madison, WI.
7. Wilson, C.E., R.J. Norman and B.R. Wells. 1989. Seasonal uptake patterns of fertilizer nitrogen applied in split applications to rice. SSSAJ 53:1884-1887.

Table 1. Fertilizer sources, ^{15}N labeling and time of nitrogen application for treatments included in the study.

Tmt. No.	Fertilizer treatment	Time of application
1.	Granular urea, ^{15}N labeled	Preflood (Pf)
2.	UAN, urea ^{15}N labeled	Preflood
3.	UAN, $^{15}NH_4$ labeled	Preflood
4.	UAN, $^{15}NO_3$ labeled	Preflood
5.	Granular urea, ^{15}N labeled	IE[1]
6.	UAN, urea ^{15}N labeled	IE
7.	UAN, $^{15}NH_4$ labeled	IE
8.	UAN, $^{15}NO_3$ labeled	IE
9.	Granular urea, ^{15}N labeled	IE + 10 days
10.	UAN, urea ^{15}N labeled	IE + 10 days
11.	UAN, $^{15}NH_4$ labeled	IE + 10 days
12.	UAN, $^{15}NO_3$ labeled	IE + 10 days
13.	Urea, non-labeled	Pf, IE, IE + 10 days
14.	UAN, non-labeled	Pf, IE, IE + 10 days

[1] Internode Elongation (first elongating internode average length of 0.5 in.).

Table 2. Total nitrogen uptake, grain yields and harvest index of rice as influenced by nitrogen source and time of application.

	Sampling Time			
N Source	Pf + 3 weeks	IE +5 days	IE+10 days + 5 days	Maturity
		N UPTAKE (lb/acre)		
Urea	69 a[1]	109 a	140 a	160 a
UAN	49 b	83 b	104 b	135 b
		GRAIN YIELD (lb/acre)		
Urea	--	--	--	6476 a
UAN	--	--	--	5720 b
		HARVEST INDEX[2]		
Urea	--	--	--	0.35 a
UAN	--	--	--	0.35 a

[1] Means within a column followed by the same letter are not significantly different at the 5% level of probability.

[2] Harvest index - grain weight/total biomass

Table 3. Percent fertilizer ^{15}N uptake by the rice plant as influenced by nitrogen form and time of application.

N Source	N Form	Time of N application[1] Pf	 IE	 IE + 10 days
		%	%	%
Urea	Urea	64.6 d[2]	83.2 b	89.9 a
UAN	Urea	49.0 e	63.7 d	53.2 e
UAN	NH_4	51.1 e	86.7 ab	84.7 ab
UAN	NO_3	9.7 f	72.4 c	83.5 ab

[1] Pf - Preflood; IE - Internode elongation

[2] Means followed by the same letter are not significantly different at the 5% level of probability.

Table 4. Percent fertilizer ^{15}N uptake by the rice plant as influenced by nitrogen source and time of application.

N Source	Time of application[1] Pf	 IE	 IE + 10 days
	%	%	%
Urea	64.6 a[2]	83.2 b	89.9 a
UAN	39.1 b	72.3 b	69.2 b

[1] Pf -preflood; IE - Internode elongation

[2] Means within a column followed by the same letter are not significantly different at the 5% level of probability.

RESPONSE OF RICE TO AMENDED UREAS AS NITROGEN SOURCES

B.R. Wells and R.J. Norman

INTRODUCTION

Nitrogen (N) is the major nutrient required in large quantities by rice growing on most Arkansas soils. The aquatic environment in which rice is grown leads to inherent instability of most inorganic forms of N in the anaerobic soil. Ammonium N located either at the soil surface or in the floodwater is subject to volatilization whereas nitrate N within the anaerobic soil may be lost by either leaching or denitrification. Both forms may be converted to organic N by immobilization. Therefore, N management for flooded rice culture is more exacting than for most upland crops.

Research conducted over many years has shown that split applications of N timed to correspond to the peak N demands of the rice cultivar are the most efficient method to apply N fertilizer to rice under the drill-seeded, delayed-flood cultural system used in Arkansas. However, this system entails extensive aerial applications that appreciably increase the cost of the N fertility program. Therefore, there is continuing interest in alternative N sources that can be applied either preplant or preflood using ground equipment and will be equivalent in efficiency with the split applications.

Recently AGRICO has formulated a urea-based fertilizer that includes additional compounds (nitrification inhibitors) that may add stability to the urea when applied either preplant or preflood. This product was included in studies conducted by the University of Arkansas in 1990 and 1991. Chisso-Asahi Fertilizer Co., Ltd. of Japan has also begun marketing a polyolefin-coated urea through Helena Chemical Co. This product is sold under the trade name of Meister, and its release rate may be varied by varying the amount of coating applied to the urea. These products hold promise as materials that may allow more flexibility in the N fertilizer management program for rice.

The purpose of this study was to evaluate SuperU and Meister as alternative N sources for rice production in Arkansas.

MATERIALS AND METHODS

SuperU Studies

The studies were conducted on a Sharkey clay (Vertic Haplaquepts) soil at the University of Arkansas Northeast Research and Extension Center (NEREC), Keiser, Arkansas, and on a Crowley silt loam (Typic Albaqualfs) at the Rice Research and Extension Center (RREC), Stuttgart, Arkansas. 'Tebonnet' (NEREC, 1990) or 'Alan' (1991) rice was drill seeded at a rate of 110 lb/acre into a stale seedbed at NEREC where the weeds had been controlled with an application of glyphosate. Normal seedbed preparation was used with Alan at RREC. In 1990 N at rates of 0, 60, 90, 120 and 150 lb/acre was applied as either SuperU or urea at preflood when the rice was at the 4- to 5-leaf stage of development. Partial applications of urea for the split application treatments were also made at this time. Additional N applications for the split treatments were made at 1/2-in. internode and seven days later. In 1991 the study was revised to include N rates of 0, 60, 100 and 140 lb/acre. N timing included preplant incorporated, preflood and split applications of the SuperU and split applications of urea. The plots were flooded following the 4-leaf-stage application and remained flooded until approximately two weeks before harvest. At maturity the four center rows of each plot (12-ft length) were harvested for grain yields. The grain was weighed, the moisture content determined and grain yields calculated as lb/acre at 12% moisture content. Statistical analysis of the yield data was conducted using the programs of SAS, Inc. Means separations were by LSD at the 5% level of probability.

Polyolefin-Coated Urea Study

The study was conducted on a Crowley silt loam at RREC in 1991. Three formulations of the coated urea (Meister 10, 15 and 20) applied preplant incorporated were compared to split topdress applications of urea at N rates of 0, 50, 100, 150 and 200 lb/acre. The cultivar was 'Lemont'. According to data from studies conducted with rice in Japan, the Meister 10 has the fastest N release rate of the three compounds whereas Meister 20 has the slowest N release. Seeding rates, water management, harvest methods and statistical analysis were as described for the SuperU study.

RESULTS AND DISCUSSION

Grain yields for the 1990 SuperU study are given in Table 1. Grain yields increased from approximately 2900 lb/acre without N fertilizer to approximately 8000 lb/acre with either Super U applied preflood or urea applied in split applications at 120 lb N/acre. There was a trend toward higher yields at the low N rate (60 lb/acre) and to lower yields at the higher N rate (120-150 lb/acre) when urea was applied preflood as compared to either SuperU applied preflood or urea applied in split applications.

Grain yields for the 1991 SuperU studies are given in Table 2. Yields at the NEREC location were similar for SuperU applied preflood or in split application or urea applied in split applications. Application of the SuperU before seeding resulted in lower yield. Yields at RREC were more variable; however, yields tended to be higher when the SuperU or urea was applied in split applications as compared to the SuperU applied prior to seeding.

There were no significant N rate by N source interactions for grain yields for the polyolefin urea study conducted at RREC in 1991; therefore, only the main effects will be discussed. There were significant yield differences with N source (Table 3). Yields of Lemont were lowest with split applications of urea, whereas highest yields were obtained with use of Meister 20 (slowest N release rate). Yields with Meister 15 or 10 were intermediate, indicating the possibility that their rate of N release was too rapid to promote optimum growth and yield of this semi-dwarf cultivar. These data may indicate that optimum yields of cultivars such as Lemont are achieved when a continuing N supply is available from the soil or fertilizer through the early grain filling stages of development. At the prevailing temperatures during rice growth in Arkansas, Meister 20 should still be releasing N beyond 100 days after application whereas Meister 10 would have undergone complete release by 70 to 80 days (personal communication, Chisso-Asahi Fert. Co., Ltd.). Grain yields varied with N rate as follows: 0 N - 4927 lb/acre, 50N - 6784 lb/acre, 100N - 6975 lb/acre, 150N - 7364 lb/acre, 200N - 7371 lb/acre. These data indicate good yield response to N with an optimum rate approximately the same as the recommended rate for Lemont (180 lb N/acre).

Based on the results from these studies, SuperU appears to be equal to urea as a preflood or split topdress fertilizer for rice; however, it does not appear to be effective for preplant N application. Although we have conducted only one study with the polyolefin-coated ureas, they do appear to hold promise as a preplant incorporated fertilizer.

In addition, it appears that the N release rate can be varied to meet the demands of cultivars varying in maturity. The economics of these new materials have not been addressed; therefore, additional information as to costs per pound of N are needed before any conclusions on their use can be made.

ACKNOWLEDGMENTS

Support for these studies was provided by AGRICO, Chisso-Asahi Fertilizer Co., Ltd. and Helena Chemical Co.

Table 1. Grain yields of 'Tebonnet' rice as influenced by nitrogen source, rate and time of application, Northeast Research and Extension Center, Keiser, Arkansas, 1990.

		N Rate (lb/acre)				
N Source	N Time[1]	0	60	90	120	150
		lb/acre				
Control	--	2906	--	--	--	--
SuperU	pf	--	6227	7096	8131	7115
Urea	pf	--	6990	6855	7676	7657
Urea	sa	--	5621	7330	7926	8117

LSD (.05) = 946 lb/acre C.V. = 8.1%

[1] pf - preflood; sa - split application

Table 2. Grain yields of rice as influenced by nitrogen source, nitrogen rate, nitrogen timing and location, 1991.

			Location	
N Source	N Rate	N Timing	RREC[1]	NEREC
	lb/acre		-----------lb/acre-----------	
--	0	--	4513	2962
SuperU[2]	60	ppi[3]	5273	3843
"	100	"	6214	4719
"	140	"	5995	6816
"	60	pf[4]	6649	6459
"	100	"	5579	7719
"	140	"	5880	7397
"	60	t-sa[5]	6331	5332
"	100	"	6940	7685
"	140	"	6526	8389
Urea	60	"	5807	5863
"	100	"	6065	7351
"	140	"	6796	7721
LSD(0.05)			1530	818

[1] RREC = Rice Research and Extension Center, Stuttgart, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas.

[2] SuperU - Trademark of AGRICO Co., granular urea plus nitrification inhibitor.

[3] ppi - preplant incorporated

[4] pf - preflood, rice at the 4- to 5-leaf stage of development

[5] t-sa - topdress, split application, N fertilizer added in increments at preflood, internode elongation and internode elongation plus 10 days.

Table 3. Polyolefin-coated urea as a nitrogen source for rice, 1991.

N Source	Grain Yield
	lb/acre
Urea	6354
Polyolefin coated urea	
(M-10)[1]	6659
(M-15)	6805
(M-20)	6919
LSD (0.05)	387

[1] M-10, 15, or 20: formulations of polyolefin-coated urea with varying rates of N release.

YIELD RESPONSE OF RICE TO WATER AND NITROGEN MANAGEMENT

C.A. Beyrouty, R.J. Norman, B.R. Wells,
P.J. Watson and E.E. Gbur

INTRODUCTION

Research has suggested that groundwater levels in the Quaternary aquifer in some areas of the Grand Prairie will drop at least 28 ft by 1993 (Peralta et al., 1985). Increases in pumping costs could represent a 12% reduction in profits for the rice producer. Currently rice is flood irrigated at the 4- to 5-leaf stage, and the flood is removed 14 days prior to harvest. Approximately 2 acre-ft of water is required to irrigate rice throughout the growing season. Under current water management, when sources of ground water become inadequate for rice production, the producer will have the option of finding an alternative source of water or growing a different crop. However, we have been conducting research since 1987 to determine if rice can satisfactorily grow in a limited flooding environment. Results with the cultivar 'Tebonnet' have been very promising and suggest that response depends upon soil series and nitrogen timing. Consequently, we have continued our studies to evaluate the yield response of three rice cultivars to water and N management.

PROCEDURES

A field study was conducted in 1991 on a Crowley silt loam (Typic Albaqualfs) at the Rice Research and Extension Center near Stuttgart, Arkansas. Soil characteristics of the upper 4 in. were pH (1:1 wt/wt soil:water mixture), 5.4; organic matter, 0.9%; extractable P, 9 lb/acre; exchangeable K, 151 lb/acre.

Three rice cultivars, 'Alan',Tebonnet and 'Texmont', were seeded on 15 May in 9-row plots measuring 15 ft by 6 ft with 7-in. spacing between rows. Each cultivar was subjected to four water management and three N timing treatments. The water management treatments were 1) flood applied at 4- to 5-leaf stage and removed 21 days after heading (normal flood), 2) flood applied at 0.5-in. internode elongation (IE) and removed 21 days after heading (delayed flood), 3) same as treatment 1 but flood removed 14 days after heading (normal flood-early removal), and 4) same as treatment 2 but flood removed 14 days after heading (delayed flood-early removal). Plots subjected to a delayed flood were flush irrigated until application of the permanent flood. Flush irrigation was applied when tensiometers placed at the 4-in. soil depth read -0.3 bar or less. This resulted in six flush irrigations before the permanent flood was applied on 7 July. Water from the flush irrigations remained on plots for 15 to 18 hours before removal. A permanent flood was applied to normal-flooded plots on 12 June.

Nitrogen treatments consisted of a 1) 3-way split application as recommended (normal N), 2) 3-way split application with the second and third splits applied at panicle differentiation (PD) minus 10 days and at PD, respectively (early N) and 3) all N applied preflood (preflood). Nitrogen was applied as urea at recommended rates (University of Arkansas Cooperative Extension Service, 1990). When N was applied to non-flooded plots, fertilizer was applied to a dry soil surface followed by flushing as described previously.

Plots were maintained weed free with Propanil and Thiobencarb applied on 24 May at 2 lb/acre active ingredient each and on 10 June at 3 lb/acre active ingredient each. Bensulfuron was also applied on 17 June at 0.5 lb/acre active ingredient.

Flood treatments were arranged as individual strips within each of two blocks. Cultivars were randomly located in two blocks within each strip. Nitrogen treatments were superimposed on each cultivar-water treatment combination. The experimental design was a split-split plot with water management as the whole plot, cultivar as the first split and N timing as the second split. Each treatment combination was replicated four times.

RESULTS AND DISCUSSION

A significant flood by cultivar interaction was found for rice yields (Table 1). Removal of the flood 8 days earlier than recommended before harvest did not affect yields, confirming similar findings by Gounce et al. (1990). A 25-day delay in the application of the flood water did reduce yields of Tebonnet and Texmont 9% below those of the normal flood treatments. Yields of Alan, however, were not affected by delayed application of the flood water. Although not significant, there was a trend for a 240-lb/acre increase in the yield of Alan subjected to the delayed flood.

Nitrogen timing did not affect yields under any water management regime. Although research has shown that the most efficient uptake of N by the rice plant occurs with a 3-way split (Wilson et al., 1989), the results from this study suggest that optimum yields may be obtained when the N is properly managed as a single application prior to flood application. Similar results were found by Wells and Shockley (1978). It must be kept in mind, however, that flooding immediately followed N application on these small plots with little opportunity for ammonia volatilization or nitrification to occur.

Results from this study suggest that rice can be satisfactorily grown under a limited flood water regime. This study will be repeated at least one more season. If results remain positive, a larger-scale study will be conducted on producers' fields to evaluate weed control techniques and potential water savings. It may be that even a 9% yield reduction is satisfactory if counterbalanced by savings in the costs of energy for pumping water and aerial applications of fertilizers and herbicides.

ACKNOWLEDGMENTS

Funding for this research was provided by the Arkansas Rice Research and Promotion Board.

LITERATURE CITED

1. Counce, P.A., T.J. Siebenmorgen, E.D. Vories and D.J. Pitts. 1990. Time of draining and harvest effects on rice grain yield and quality. J. Prod. Agric. 3:436-445.
2. Peralta, R.C., A. Yazdanian, P.J. Killian and R.N. Shulstad. 1985. Future quaternary groundwater accessibility in the grand prairie-1993. Ark. Agri. Exp. Sta. Bull. No. 877.
3. University of Arkansas Cooperative Extension Service. 1990. Rice production handbook. University of Arkansas Coop. Ext. Serv. Misc. Publ. MP 192.
4. Wells, B.R. and P.A. Shockley. 1978. Response of rice to varying flood regimes on a silt loam soil. IL RISO. 27:81-88.
5. Wilson, C.E., R.J. Norman and B.R. Wells. 1989. Seasonal uptake patterns of fertilizer nitrogen applied in split applications to rice. Soil Sci. Soc. Am. J. 53:1884-1887.

Table 1. Yield response of three rice cultivars to flood water management.

Flood treatment	Alan	Tebonnet	Texmont
	---------- lb/acre ----------		
Normal	6325	6697	6750
Delayed	6586	6103	6136
LSD (0.05) = 533			

IMPACT OF WATER AND NITROGEN MANAGEMENT ON NUTRIENT UPTAKE BY RICE

B.C. Grigg, C.A. Beyrouty, R.J. Norman,
B.R. Wells and E.E. Gbur

INTRODUCTION

Alternative water management of rice (*Oryza sativa* L.) may impact availability and uptake of nutrients. Timing of N fertilization is important in flush-irrigated rice as it can influence the amount of N lost to NH_3 volatilization and denitrification. Inadequate P levels in the soil can inhibit rice growth; however, P availability is enhanced by flooding due to reduction of ferric phosphate to a more soluble form, ferrous phosphate (Patrick et al., 1985; Naphade and Ghildyal, 1974). Potassium deficiencies occur less often than N and P deficiencies in flooded rice (Patrick et al., 1985). Uptake of K increases under flooded conditions (Gorantiwar et al., 1973; Patrick et al., 1985) and is partially attributed to increased availability due to reduction of Fe^{3+} and Mn^{4+} (Patrick et al., 1985).

Water management of rice may also affect micronutrient availability and uptake. Zinc deficiency in rice has been observed around the world (Patrick et al., 1985) and is found more frequently in soils that are subjected to flooding, possibly caused by higher concentrations of free carbonates under flood, which rapidly complex Zn ions (Patrick et al., 1985). Iron deficiencies are uncommon in flooded rice due to reduction and enhanced solubility of Fe in the soil (Patrick et al., 1985). Manganese toxicity can occur when flooding acid soils or soils high in Mn and Fe, but it is seldom a problem with rice (Patrick et al., 1985).

The objective of this study was to evaluate the effects of alternative water management of paddy rice on the uptake and tissue concentration of N, P and K.

MATERIALS AND METHODS

Field experiments were conducted in 1989 and 1990 at the Rice Research and Experiment Station, Stuttgart, Arkansas. Treatments were:

1. Continuous flood applied at the 4- to 5-leaf stage (V) and maintained until 4 weeks after heading (NORMAL FLOOD).
2. Delayed flood applied at panicle differentiation (PD) and maintained until 4 weeks after heading, preceded if necessary by flush irrigation to maintain soil water potential between -0.03 and -0.05 MPa (DELAYED FLOOD).
3. Delayed flood applied at PD and maintained until 4 weeks after heading, preceded if necessary by flush irrigation when soil water potential reached -0.03 and -0.05 MPa. This differed from treatment 2 as the second and third N splits were applied 10 days prior to normal application (DELAYED FLOOD-EARLY N).
4. Full-season flush irrigation applied when soil water potential reached -0.03 and -0.05 MPa (FLUSH IRRIGATION).

Nitrogen as urea was applied as a three-way split with 60, 25 and 25 lb/acre broadcast at V, PD and PD + 10 days, respectively, except with treatment 3, where N was broadcast at V, PD - 10 days and PD.

Shoot samples were taken at active tillering, panicle initiation, booting and anthesis and were dried at 60 C in a forced air oven, ground and passed through a 40-mesh sieve. Samples (0.2 g) were wet ashed using sulfuric acid and hydrogen peroxide and analyzed for total N concentration using steam distillation, total P concentration by the Murphey and Riley procedure, and K concentration by atomic emission. Sample concentrations were used to calculate tissue concentration and nutrient uptake.

The experimental design for both years was a split plot in time, with water management as the whole plot and growth stage the split plot. Data were analyzed by analysis of variance. Mean separations were conducted when appropriate using the protected least significant difference procedure at $P < 0.05$. Due to similar trends between 1989 and 1990, only 1990 data are discussed.

RESULTS AND DISCUSSION

Nitrogen plant concentration was not affected by water management (data not shown). Nitrogen uptake (Fig. 1), however, was affected by treatment. The most rapid rate of uptake occurred between active tillering and booting for all but the flush-irrigated rice. This follows the pattern of N uptake described by Sims and Place (1968). Rice subjected to normal flood responded with the highest N uptake by booting (Fig. 1)--115 lb/acre; in contrast, N uptake was lowest with flush-irrigated rice by booting with 65 lb/acre.

Since N tissue concentrations were not different among treatments, differences in N uptake were considered due to differences in shoot dry weight among treatments (data not shown). This concurs with findings by Sims and Place (1968) who stated that N uptake generally paralleled dry matter production and increased with plant age.

Rapid P uptake occurred between active tillering and anthesis for all but the flush irrigated treatment (Fig. 2). Normal flooded rice responded with the highest uptake by anthesis with uptake of 18 lb/acre. Flush-irrigated rice had the lowest P uptake with 5 lb/acre by anthesis. Delaying flood application resulted in intermediate values of P uptake. Phosphorus uptake, like N uptake, appeared to increase with increased dry matter, as P tissue concentrations were not affected by water management.

Potassium tissue concentration declined between booting and anthesis to a low of 0.09% for flush-irrigated rice and approximately 0.15% for other treatments (Fig. 3a). Potassium uptake was significantly affected by water management (Fig. 3b). Normal flooding resulted in the highest uptake of K with approximately 142 lb/acre by booting in both years. Flush irrigation of rice resulted in the lowest values of K uptake of 59 lb/acre by booting. Delayed flood treatments resulted in intermediate values. These data in conjunction with tissue concentration of K suggest that K is more available to the rice plant under flooded conditions than under nonflooded conditions, concurring with the findings of others (Patrick et al., 1985; Gorantiwar et al., 1973).

SUMMARY

Water management was found to significantly affect nutrient uptake. Normal flood exhibited high levels of nutrient uptake, delayed flood exhibited intermediate levels, and flush irrigation exhibited low levels after panicle initiation. Although uptake of nutrients was adversely affected by reduced water inputs, no significant differences in yield were noted (data not shown) between normal flood and delayed flood treatments, suggesting adequate levels of nutrients in rice.

Results of this study indicate that differences in N and P uptake among rice subjected to different water management practices were primarily a response to differences in dry matter production; therefore, under these experimental conditions, nutrient management need not be altered in conjunction with use of delayed flood application to rice.

ACKNOWLEDGMENTS

Funding for this research provided by the Arkansas Rice Research and Promotion Board.

LITERATURE CITED

1. Gorantiwar, S.M., I.K. Jaggi and S.S. Khanna. 1973. Nutrient uptake by rice under different soil moisture regimes. J.Indian Soc. Soil Sci. 21:133-136.
2. Naphade, J.D., and B.P. Ghildyal. 1974. Influence of the state of oxidation and reduction on soil characteristics nutrient uptake and rice growth. Il Riso. 23:277-282.
3. Patrick, W.H., D.S. Mikkelsen and B.R. Wells. 1985. Plant nutrient behavior in flooded soil. p. 197-228. *In* Fertilizer technology and use. 3rd ed. SSSA. Madison, WI.
4. Sims, J.L., and G.A. Place. 1968. Growth and nutrient uptake of rice at different growth stages and nitrogen levels. Agron. J. 60:692-696.

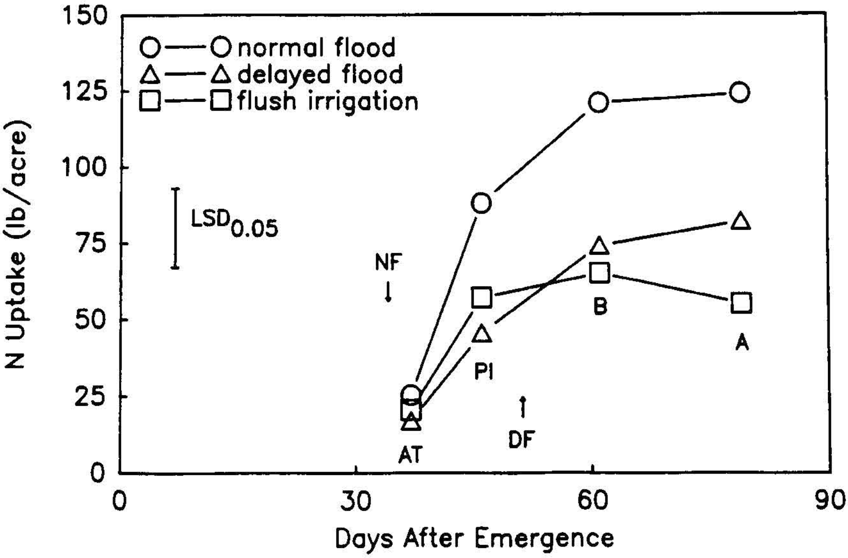

Fig. 1. Nitrogen uptake as affected by water management. AT=active tillering, PI=panicle initiation, B=booting and A=anthesis. NF=normal flood application and DF=delayed flood application. LSD is for within and between development stages.

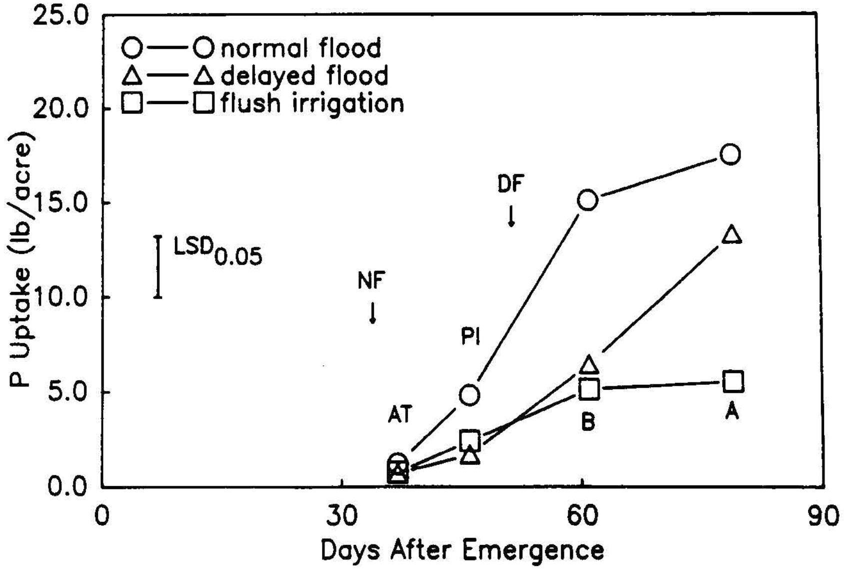

Fig. 2. Phosphorus uptake as affected by water management. AT=active tillering, PI=panicle initiation, B=booting and A=anthesis. NF=normal flood application and DF=delayed flood application. LSD is for within and between development stages.

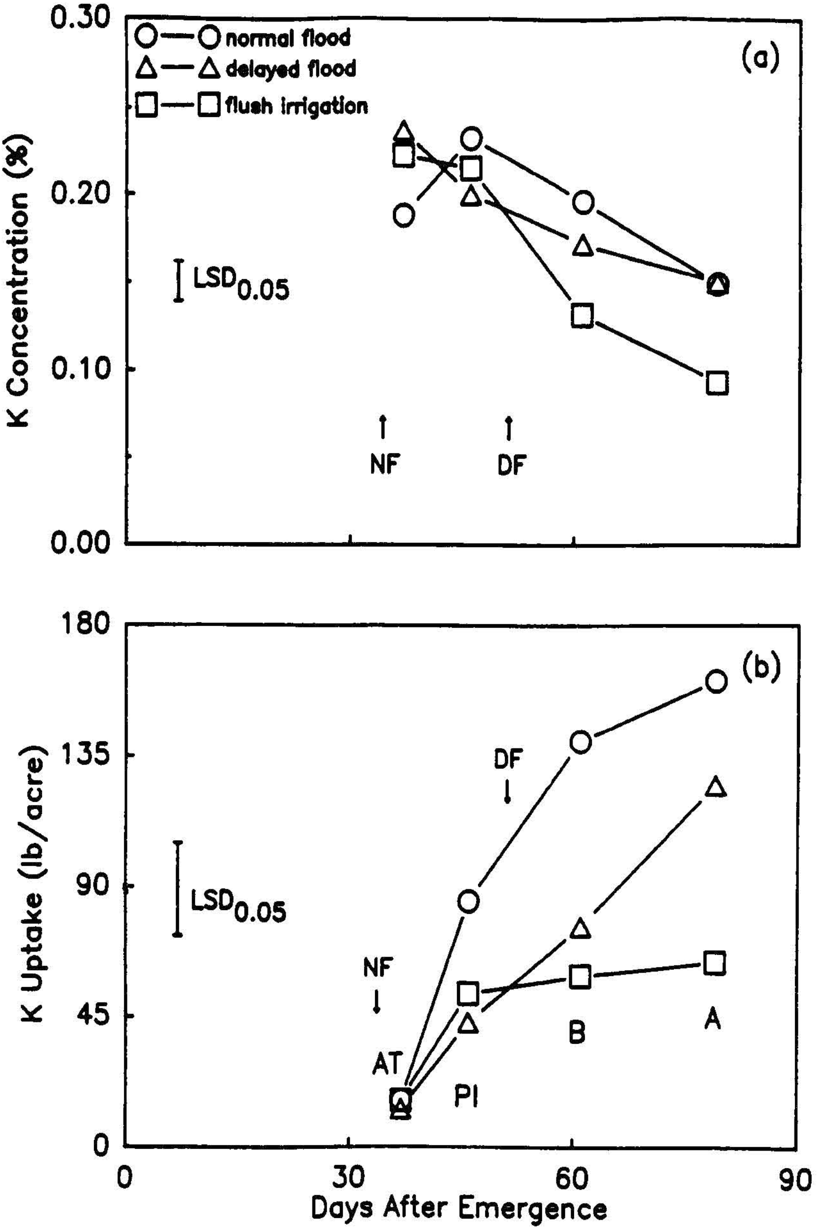

Fig. 3. Potassium tissue concentration (a) and K uptake (b) as affected by water management. AT = active tillering, PI = panicle initiation, B = booting and A = anthesis. NF = normal flood application and DF = delayed flood application. LSD is for within and between development stages.

NUTRIENT UPTAKE RELATED TO ROOT MORPHOLOGY AND ABSORPTION CHARACTERISTICS OF RICE

Y.H. Teo, C.A. Beyrouty, E.E. Gbur and P.J. Watson

INTRODUCTION

Optimum food production depends upon efficient use of fertilizer to minimize production costs, conserve natural resources and reduce groundwater pollution. The efficiency of fertilizer uptake by plants may be improved by selecting cultivars that can absorb a greater proportion of the nutrients in the soil. A greenhouse study (Teo and Beyrouty, 1990) showed that total nitrogen (N), phosphorus (P) and potassium (K) uptake by rice (*Oryza sativa* L.) differed among cultivars ('Lemont', 'Mars' and 'Katy'). These differences in nutrient uptake were attributed to variation in root morphology and to the ion absorption characteristics of the root.

The objective of this study was to investigate differences in root growth and ion absorption characteristics of rice cultivars under a field situation.

PROCEDURE

A nutrient uptake study was conducted at the Rice Research and Extension Center, Stuttgart, Arkansas, on a Crowley silt loam (Typic Albaqualfs, pH = 5.0), using three rice cultivars (Katy, Mars and Lemont). Plots (9 ft wide by 32 ft long) were seeded on 14 May 1991. Emergence was 21 May for the three cultivars. Plots were flooded at the 4-leaf stage (11 June). Urea nitrogen was applied to all plots as a three-way split. At preflood 120, 65 and 50 lb N/acre was applied for Lemont, Katy and Mars, respectively. At 0.5-in. internode elongation, 30 lb N/acre was applied for Lemont and Mars and 35 lb N/acre was applied for Katy. These N rates were also applied 10 days later. Stages of growth and timing of rice management practices were determined by visual inspection and the DD_{50} computer program.

Shoots were harvested from 1.6 ft of row from each plot at 36, 41 and 59 days after emergence. At 36 and 41 days after emergence rice was at the tillering stage, and at 59 days after emergence rice was at 0.5-in. internode elongation. Plant samples were dried in an oven at 65 C, and dry weights determined and analyzed for total N, P and K.

Soil-root cores were taken to a depth of 16 in. at each harvest date. Roots were separated from soil by wet sieving, and fresh root weights (FW) were measured. Root lengths (L) were determined with the line-intercept method. Root radius (r_0) was calculated using the equation: $r_0 = (FW/(L\pi))^{0.5}$, whereas root surface area (SA) was calculated using the equation: $SA = 2r_0\pi L$.

The data were analyzed as a split plot in which the whole plot was a randomized block design with three replications and cultivar as the factor. The split plot factor was harvest date. A protected LSD (P = 0.05) was used to separate means, where appropriate.

Nutrient depletion studies were conducted with the same cultivars in the growth chamber at the University of Arkansas, Fayetteville, in 1989. The experiment conducted was by the procedure of Claassen and Barber (1974). The Michaelis-Menten kinetics equation was used to describe ion absorption into the root in which the maximal absorption rate (I_{max}) was determined. The I_{max} is the maximum nutrient absorption rate into the root ($g/ft^2/s$) at high nutrient concentration.

RESULTS AND DISCUSSIONS

For the field studies there was a significant cultivar effect on total N and P uptake when data were averaged across sampling times (Table 1). Cultivars did not differ in uptake of K. Total N uptake was about 35% higher for Katy and Mars than for Lemont. However, total P uptake for Lemont was about 16% higher than for Mars and Katy. Although the roots were about 17% longer for Katy than for Mars and Lemont, Katy had the smallest r_0. Consequently, root surface areas did not differ among cultivars (Table 2). The differences in nutrient uptake, therefore, are not attributed to the variations in root morphology.

We found, however, that differences in total uptake among the cultivars in the field appear to be related to the ion absorption characteristic (I_{max}) of the cultivars measured in a growth chamber study (Table 3). Katy, with the highest N and lowest P and K uptake, had the highest I_{max} value for N and lowest I_{max} values for P and K. Similarly, Lemont had the lowest I_{max} value for N and highest I_{max} for P and K and had the lowest total N and highest total P and K uptake. Mars was intermediate among the cultivars.

SIGNIFICANCE OF FINDINGS

These findings suggest that differences in nutrient uptake by these three rice cultivars were not due to variation in root morphology but were apparently due to differences in the ion uptake characteristics. Ion uptake paramters are not routinely determined. However, knowledge of these values is important in the prediction of potential nutrient uptake capabilities of the different rice cultivars. This study also indicates that root absorption properties can be used in selecting cultivars to increase nutrient uptake.

ACKNOWLEDGMENTS

Funding for this research was provided by the Arkansas Rice Research and Promotion Board.

LITERATURE CITED

1. Claassen, N., and S.A. Barber. 1974. A method for characterizing the relation between nutrient concentration and flux into roots of intact plants. Plant Physiol. 54:564-568.
2. Teo, Y.H., and C.A. Beyrouty. 1990. Nutrient uptake related to shoot and root growth of rice. Arkansas Soil Fertility Studies 1990. Univ. of Arkansas. Fayetteville. Research Series 411.

Table 1. Total uptake of nitrogen (N), phosphorus (P) and potassium (K) by three rice cultivars averaged across sampling time.

Cultivar	N	P	K
		lb/acre	
Katy	70.093 a[1]	5.882 b	60.514 a
Mars	66.640 a	5.968 b	61.886 a
Lemont	50.780 b	6.847 a	69.487 a

[1] Means followed by the same letter within the same column are not significantly different ($P = 0.05$).

Table 2. Mean root length (L), radius (r_o) and root surface area (SA) for three rice cultivars averaged across sampling time.

Cultivar	L	r_o	SA
	x 10^{12} ft/acre	in.	x 10^{10} ft^2/acre
Katy	8.104 a[1]	0.00279 c	1.18 a
Mars	6.950 a	0.00311 b	1.12 a
Lemont	6.923 a	0.00346 a	1.22 a

[1] Means followed by the same letter within the same column are not significantly different (*P* = 0.05).

Table 3. Maximal nitrogen (N), phosphorus (P) and potassium (K) influx rate for three rice cultivars measured in the growth chamber.

Cultivar	N	P	K
	----------	x 10^{-8} g/ft^2/s	----------
Katy	85.13 a[1]	2.09 a	4.37 b
Mars	60.68 a	2.03 a	7.88 ab
Lemont	38.56 a	3.49 a	10.44 a

[1] Means followed by the same letter within the same column are not significantly different (*P* = 0.05).

CLONAL APPLE ROOTSTOCK EFFECTS ON FOLIAR NUTRIENT CONTENT OF 'STARKSPUR SUPREME DELICIOUS'

Curt R. Rom and Roy C. Rom

INTRODUCTION

Proper orchard fertility management is essential for optimal growth and crop yield. Fruit tree nutrient status typically is monitored by periodic soil and plant tissue analysis (Bould, 1966; Shear and Faust, 1980). Leaf tissue analysis to diagnose apple orchard fertility is based upon the assumption that the leaf is the basic site of plant metabolism and reflects changes in nutrient supply. Foliar nutrient levels vary with leaf position, time of sampling, cropping, tree injury, pest infection/infestation and genotype. Because of the tree compound genetic system comprising commercial apple trees, variation due both to scion cultivar and to rootstock can occur (Awad and Kenworthy, 1963; Kennedy et al., 1980; Poling and Oberly, 1979; Rom et al., 1991a,b; Schneider et al., 1978; Tukey et al., 1962; West and Young, 1988; Whitfield, 1963). This paper is a final report of a 10-year rootstock trial and reports variations in foliar mineral content.

MATERIALS AND METHODS

General

'Starkspur Supreme Delicious' apple trees were planted in 1980 and 1981 on nine rootstocks in 27 locations in the U.S. as part of the NC-140 Cooperative Rootstock Trial. The overall objective of the national trial was to evaluate rootstock performance in diverse regional climates. The specific objective of the Arkansas (AR) planting was to determine clonal scion performance on nine clonal rootstocks in an Arkansas orchard environment. The Arkansas study was established at the Horticulture Research Farm (Walker Tract), Agricultural Experiment Station, Fayetteville, Arkansas. Details of the planting, design, rootstocks, growth and cropping have been reported (NC-140, 1991; Rom et al., 1991a).

The rootstocks used in the trial were (in order of decreasing tree size) MAC 24, OAR 1, M.7 EMLA, M.26 EMLA, Ottawa 3, M.9 EMLA, M.9, MAC 9 and M.27 EMLA. Rootstock names followed by the designation "EMLA" indicate virus-free clones developed by the East Malling and Long Ashton Research Station (United Kingdom) cooperative rootstock development program.

Trees were planted with the graft union 3-6 cm above the soil line at a spacing of 2 m by 5 m, trained to a free-standing central leader system and annually dormant pruned as needed to maintain good horticultural structure and growth balance. Only trees that leaned to the point of falling were supported with temporary trunk stakes. Trees were not cropped until the fourth season. Crop load was chemically thinned as needed using naphthaleneactic acid and carbaryl. Standard orchard procedures of orchard pest control were used. Trees received supplemental trickle irrigation.

The site, previously uncultivated pasture, had a rocky, sandy loam soil of a Linker series with a 1-3% westerly slope. Average soil organic matter ranged from 0.6 to 1.4% at planting and throughout the study. Soil was approximately 34% Ca base saturated with a low (< 10%) cation exchange capacity. Trees received annual N fertilizer from urea or ammonium nitrate (1988 only), applied at a rate of approximately 67-200 g N/tree with the same amount given to all trees in a given year. Boron and calcium chloride were applied as a foliar spray at a rate of 0.1 - 0.2 g/l and 0.3 g/l, respectively, in 1987 and 1989. Potassium chloride fertilizer (0-0-60) was applied at 115 g K/tree in 1986.

Soil and Foliar Analysis

Soil samples were obtained at planting and periodically (Table 1) to determine nutrient status. Samples were taken from each block of trees at two depths (topsoil 1-6 in., and subsoil 6-15 in.). Because the majority of fruit tree roots are in the top 18 in. of the soil profiles, data from the topsoil and subsoil were combined. At the time of planting, soil pH was 5.7 at 15-in. depth.

Because the AR site had the lowest soil pH of all sites in the national cooperative trial and this was similar to typical AR orchard sites, investigators decided not to adjust soil pH but to allow soil pH to follow a natural course as may occur in a standard orchard situation.

Foliar nutrient content was analyzed from current season midshoot leaves sampled between July 25 and August 15 each year. In 1981, the five replicates planted in 1980 were sampled. In 1982, three replicates each from the 1980 and 1981 blocks of the study were sampled. In 1983-1989, all replicates were sampled. Samples were rinsed with tap water, forced-air dried at 70-80 C and ground to pass through a number-15 mesh screen. Leaf nitrogen was assayed after a sulfuric acid/peroxide digest and distillation by micro-Kjeldahl techniques (1982-1988) or combustion by a LECO FP 228 Nitrogen Determinator (1989). Foliar K, Ca and Mg were analyzed after sulfuric acid/peroxide digest by atomic absorption spectrophotometry (1982-1988) or after a nitric acid/peroxide digest by inductively coupled plasmaspectrophotometer (Thermal Jarrell Ash Model 300 ICP) in 1989. Phosphorus was analyzed after a sulfuric acid/peroxide digest using ascorbic acid molybdate colorimetric method (1982-1988) or the ICP (1989). Manganese, Cu and Zn analysis used a nitric acid/peroxide digest followed by atomic absorption (1982-1987) or ICP (1989). Boron was determined colorimetrically using a azomethine-H procedure (1982-1988) or ICP (1989).

Statistical Analysis

Ten single-tree replications of each rootstock in a randomized complete block design were studied. Five replications were planted in each in 1980 and 1981. Data were analyzed as a randomized complete block, split-plot for planting year (1980 vs 1981 replicates). No interactions between planting year (tree age) and rootstock were significant (data not presented). Data pooled across planting year were analyzed with mean separation within sample years by the Duncan-Waller k-ratio test, 5% level. The averages from individual years are presented so that comparisons can be made relative to specific climatic conditions. Similarly, averages across years were analyzed for the main effects of rootstock to address specific questions about variation in the overall cooperative study. Averages were analyzed with mean separation by Duncan's Multiple Range test, 5% level.

RESULTS

Soil Characteristics

Arkansas' soil pH was the lowest of the 27 test sites at planting (average of 6.0), and soil pH in the tree-row root zone decreased from 5.7 to 4.9 during the trial (Table 1). Soil was considered as very low in P, low in K, Mg, Zn, Cu (data not presented) and B, had acceptable to low levels of Ca and acceptable to high levels of Mn. Extractable soil Ca content tended to decrease during the trial. Topsoil P, Ca and pH were lower than the subsoil (data not presented). Soil solution electrical conductivity was low, ranging from 62 to 152 x 10^6 micromhos/cm.

Analysis of Variation in Mineral Content

Sources of foliar mineral content variation were evaluated from the analysis of variance sums of squares (Table 2). Replication, rootstock, year and rootstock by year interaction were significant variation sources, except for N, where rootstock effects were nonsignificant, and Mn and B, where rootstock by year interactions were nonsignificant. Sample year was the greatest source of variation and accounted for from 44 to 78% of the experimental variation for N, P, K, Ca, Mg and B. Rootstock was the greatest source of Mn variation.

Foliar Nutrient Content

Rootstock did not affect foliar N level in four of the study years or averaged across all years (Table 3). A trend was apparent that trees on M.7 EMLA generally had among the highest N while trees on MAC 9 generally had the lowest N levels. Foliar N varied significantly among years with 1989 having the highest and 1985 having the lowest N content. A foliar N level below 2.25% dry weight for a spur-type growth habit tree would be considered to be low.

Foliar P content varied with rootstock during five study years (Table 3). Typically trees on M.7 EMLA and M.26 EMLA had the highest P content, and trees on M.9 and OAR 1 were generally the lowest. The P content was considered in a deficiency range for all trees in all years (Shear and Faust, 1980).

Trees on MAC 24 consistently had greater K contents than other rootstocks in most years and across all years, and trees on M.27 EMLA were lowest in foliar K (Table 3). Foliar K content decreased with time. Foliar K levels were in an adequate content range (Shear and Faust, 1980).

Rootstock did not affect leaf Ca content in 1982, 1985 or 1987, but significant rootstock differences occurred in other years (Table 3). Trees on M.9 EMLA, M.9 and MAC 9 had the highest Ca contents and M.7 EMLA and MAC 24 the lowest. Foliar Ca contents decreased with time and approached a deficiency range (0.7% dry weight) in 1985 and 1989.

Trees on M.26 EMLA consistently had the highest leaf Mg although there was no rootstock effect in 1983, 1985 and 1986 (Table 3). Trees on the stocks OAR 1, M.9 and MAC 9 typically had among the lowest leaf Mg contents.

Trees on Mac 9 and M.27 EMLA had significantly higher foliar Mn content than other stocks, approaching 1.5 times the average, while trees on M.7 EMLA and OAR 1 consistently had the lowest Mn content (Table 3). Foliar Mn of trees was approximately 5- to 10-fold higher than in other states reporting in similar studies (Rom et al., 1991b).

Trees on OAR 1 had significantly higher B levels than trees on other rootstocks within each year and averaged across years (Table 3). Trees on M.26 EMLA, M.9 EMLA and M.9 typically had the lowest B levels. Trees on M.7 EMLA and MAC 24 had lowest Zn levels (data not presented). Trees were in an adequacy range for B but approached deficiency range for Zn (<14 ppm dry weight) in most years.

Correlations among mineral content, yield and growth were calculated (Table 4). Although individual mineral element contents were significantly related to each other, to yield and to trunk cross-sectional area (TCSA), none accounted for more than 36% of the variation (N * Zn, r=-.60). It is interesting to note significant negative correlations between yield and the elements K, Ca, Mn and B, and between TCSA and Ca, Mg and Mn.

DISCUSSION

Environment, management and soil characteristics account for some differences in tree nutrient content. Year was the largest source of variation in foliar nutrient content for all nutrients with the exception of Mn (Tables 2 and 3). The variation could have been due to the different climatic conditions (especially rainfall and temperature), annual tree growth, rates of annual fertilizer applications and/or changing edaphic conditions.

Soil pH tended to decrease during the study, as did available soil Ca. It is interesting to note that leaf K, Ca and Mg likewise tended to decrease while foliar Mn content was highest in 1987 and 1989. Although recommended amounts of N fertilizers were applied based on foliar content, foliar N remained low between 1984 and 1988. The low soil pH may also have had limited N availability. Soil pH may have affected other nutrient levels. Trees were low in P, below the sufficiency range (Shear and Faust, 1980), due to low pH as well as low soil P (Table 1). Low foliar Zn (average 14.8 ppm) and Cu (average 5.2 ppm) in AR may be attributed to soil pH.

Conversely, trees had very high Mn levels (Table 3) and expressed symptoms of Mn toxicity-induced internal bark necrosis (IBN) (Barden et al., 1991). Manganese toxicity has been associated with low soil pH. The cultivar 'Delicious' is known to be an IBN-susceptible cultivar (Ferree and Thompson, 1970). Symptom expression was greatest on the most dwarf and least on the most vigorous rootstocks. Trees on M.27 EMLA and MAC 9 had the greatest IBN symptoms, and trees on M.26 EMLA and Ottawa 3 were next severely affected (Table 5). The expression of IBN symptoms increased with time on trees on M.9 and M.9 EMLA rootstocks. The least susceptible were trees on OAR 1 rootstocks. At the termination of the study, all trees with the exception of three on OAR 1 rootstocks showed Mn toxicity symptoms (data not presented). Half of the experimental trees on M.27 EMLA and 40% of those on MAC 9 died from IBN during the study, and the mortality occurred in the first four years of the orchard life. This suggests that, when grown on low pH soils, clonal dwarfing stocks in conjunction with susceptible scion cultivars are prone to Mn toxicity. These observations reaffirm the need to adjust soil pH prior to planting an orchard and annually test and correct with liming if necessary.

As was observed in this study, other reports noted variation of some nutrient contents due to rootstock. Generally, rootstock has been reported to have minimal or no consistent effect on N and K levels across a number of sites, years and cultivars (Awad and Kenworthy, 1963; Schneider et al., 1978; Tukey et al., 1962; West and Young, 1988; and Whitfield, 1963). Reports of rootstock variation in N and K ranged from 5 to 10% of the mean within studies and may have been due to differences in crop load, vegetative growth or variability in sampling. The nutrients K, Ca and Mg were most variable with coefficients of variation (CV) of 24, 28 and 21% (across years and replications), respectively. These CV's were greater than the variation for N, P and Mn.

Previous reports indicated that trees on M.9 had higher foliar Ca and Mg than trees on M.7 (Warne and Wallace, 1935; Whitfield, 1963). Data pooled across years suggest that trees on M.9 EMLA and M.9 had significantly higher Ca, approximately 18% greater leaf Ca, than M.7 EMLA. But there was no significant difference in leaf Mg content between M.9 EMLA and M.7 EMLA trees. Trees on MAC 9 had average leaf Ca compared to trees on other rootstocks. In other reports, trees on MAC 9 had among the highest Ca (Rom et al., 1991b). It is interesting to note that Autio et al. (1991) reported that fruit from MAC 9 had higher Ca levels and were firmer in storage than trees on other rootstocks.

The rootstocks M.9 and M.9 EMLA were compared in this trial and did not significantly differ in nutrient contents. Bould and Campbell (1970) reported that virus-free trees had higher nutrient content than infected trees in the first year of growth, but by the third year the differences were not significant. MAC 9, a seedling of M.9, had nutrient contents similar to M.9 and M.9 EMLA.

When nutrient element contents were compared to tree size and production data in previously published reports (NC-140, 1991; Rom et al., 1991a), no consistent relationships between tree size, productivity and nutrient content were apparent. Likewise, correlations demonstrated that although some relationships exist, tree size and yield explain very little variation in nutrient content. This observation concurs with Dzamic et al. (1980) who, working with 'Golden Delicious' on four rootstocks, reported no difference in leaf mineral content attributable to rootstock vigor. Lockard and Schnieder (1981) did not attribute rootstock-controlled tree size and precocity traits to rootstock differences in mineral nutrition.

CONCLUSION

In conclusion, it is horticulturally important to be aware of rootstock-caused variation in nutrient content. However, differences caused by rootstock were small and less variable than annual variation. Soil characteristics can have dramatic effects on foliar nutrient content and fertilizer efficiency. It is horticulturally necessary to adjust soil pH prior to planting and maintain adequate soil pH by annual liming. Some dwarfing rootstocks, such as MAC 9 (now named 'Mark'), M.9 and M.27 EMLA, may not be suitable for use on low pH soils, especially when combined with Mn toxicity-susceptible scion cultivars.

LITERATURE CITED

1. Autio, W.R., J.A. Barden and G.R. Brown 1991. Rootstock affects ripening, size, mineral composition and storability of 'Starkspur Supreme Delicious' in the 1980-81 NC-140 cooperative planting. Frt. Var. J. 45:247-251.
2. Awad, M.M. and A.L. Kenworthy. 1963. Clonal rootstock, scion variety and time of sampling influences in apple leaf composition. Proc. Amer. Soc. Hort. Sci. 83:68-73.
3. Barden, J.C., R.C. Rom, C.R. Rom, D.C. Ferree, B.H. Barritt, L.D. Tukey, W.C. Micke, N.W. Callan and D.B. Meador. 1991. Abnormalities in 'Starkspur Supreme Delicious' on nine rootstocks in the 1980-81 NC-140 Cooperative Planting. Frt. Var. J. 45:213-219.
4. Bould, C. 1966. Leaf analysis of deciduous fruits. *In* N.F. Childers (ed.). Fruit nutrition. pp. 651-584.
5. Bould, C. and A.I. Campbell. 1970. Virus, fertilizer, and rootstock effects on the nutrition of young apple trees. J. Hort. Sci. 45:287-294.
6. Dzamic, M., M. Javanic and R. Dzamic. 1980. Distribution of some elements in leaves and fruits of 'Golden Delicious' grown under different rootstocks under the same nutritional conditions. *In* Atkinson, D., J. E.

Jackson, R.O. Sharples and W.M. Waller (eds.). Mineral nutrition of fruit trees. Butterworths Press, London.

7. Ferree, D.C. and A.H. Thompson, 1970. Internal bark necrosis of the apple as influenced by calcium placement and soil manganese. MD. Agr. Expt. Sta. Bul. A-166.
8. Kennedy, A.J., R.W. Rowe and T.J. Samuelson. 1980. The effects of apple rootstock genotypes on mineral content of scion leaves. Euphytica 29:477-482.
9. Lockard, R.D. and G.W. Schnieder. 1981. Stock and scion relationships and the dwarfing mechanism. Hort. Rev. 3:315-375.
10. NC-140. 1991. Performance of 'Starkspur Supreme Delicious' on nine rootstocks over ten years in the NC-140 Cooperative Planting. Fruit Var. J. 45:192-200.
11. Poling, E.B. and G.H. Oberly. 1979. Effect of rootstock on mineral composition of apple leaves. J. Amer. Soc. Hort. Sci. 104:799-801.
12. Rom, C.R., R.C. Rom and M. Stasiak. 1991a. Performance of nine apple rootstocks in Arkansas. Ark. Farm Res. 40(5):9-11.
13. Rom, C.R., R.C. Rom, W. Autio, D.C. Elfving and R.A. Cline. 1991b. Foliar nutrient content of 'Starkspur Supreme Delicious' on nine clonal apple rootstocks. Frt. Var. J. 45:252-263.
14. Schneider, C.G., C.E. Chaplin and G.C. Martin. 1978. Effects of apple rootstock, tree spacing, and cultivar on fruit and tree size, yield and foliar mineral composition. J. Amer. Soc. Hort. Sci. 103:230-232.
15. Shear, C.B. and M. Faust. 1980. Nutritional ranges in deciduous tree fruits and nuts. Hort. Rev. 2:142-163.
16. Tukey, R.D., R. Langston and R.A. Cline. 1962. Influence of rootstock, bodystock, and interstock on the nutrient content of apple foliage. Proc. Amer. Soc. Hort. Sci. 80:73
17. Warne, L.C. and T. Wallace. 1935. The composition of the terminal shoots and fruits of 2 varieties of apple in relation to rootstock effects. J. Pom. 13:1-31.
18. West, S. and E. Young. 1988. Effects of rootstock and interstock on seasonal changes in foliar nutrient (N, P, K, Ca) composition of 'Delicious' and 'Golden Delicious' apple. Frt. Var. J. 42:9
19. Whitfield, A.B. 1963. The effects of stock and scion on the mineral composition of apple leaves. Ann. Rep. E. Malling Res. Sta. p. 107-109.

Table 1. Soil characteristics of NC-140 cooperative rootstock planting sites in Fayetteville, Arkansas, at soil depth of 1-15 in.

		lb/acre							EC[z] x 10^6
Year	pH	P	K	Ca	Mg	Mn	Zn	B	(µmho/cm)
1981	5.7	11	150	910	155	160	2.8	0.5	---
1982	5.0	11	126	604	90	–	--	--	152
1983	4.8	17	108	632	83	--	--	--	62
1987	5.1	18	144	727	117	490	2.0	0.8	---
1988	4.9	13	129	600	110	--	--	--	74

[z] Electrical conductivity.

Table 2. Sources of variation in foliar mineral content of 'Starkspur Supreme Delicious' apple on nine rootstocks grown in Arkansas, 1980-1989.

Source	N	P	K	Ca	Mg	Mn	B	Zn
	----Sums of Squares as % of total from Analysis of Variance-----							
Replication	3.5*	5.8*	8.9**	3.9**	4.5*	14.5	7.3*	54.8
Rootstock	2.0	5.8*	21.2**	7.2**	15.1**	50.5***	22.8**	45.2
Year	78.4***	62.5***	44.0***	72.3***	53.8***	28.7***	65.6**	--[z]
Rootstock x Year	15.8*	25.9**	25.7*	16.3**	26.4**	6.3	4.2	--

*signficant at 5%

**significant at 1%

*** = 0.1%, ns = nonsignificant

[z] Zn sampled only one year.

Table 3. The influence on nine clonal apple roostocks on foliar nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn) and boron (B) content of 'Starkspur Supreme Delicious' in Arkansas, 1982-1989.

Stock	1982	1983	1984	1985	1986	1987	1988	1989	Avg.[x]
				N (% dry weight)					
MAC 24	2.15	2.42a[1]	2.20ab	1.65	2.08ab	1.94	2.22ab	2.51	2.15
OAR 1	2.03	2.39a	2.19ab	1.62	1.87abc	1.84	1.96b	2.52	2.05
M.7 EMLA	2.09	2.33ab	2.29a	1.66	2.09a	1.83	2.48a	2.48	2.17
M.26 EMLA	2.19	2.42a	1.99bcd	1.61	1.85abc	1.8	2.16ab	2.35	2.05
Ottawa 3	2.69	2.41a	1.95cd	1.86	1.85abc	1.87	2.25ab	2.40	2.16
M.9 EMLA	2.07	2.27ab	2.01bcd	1.71	2.10a	1.88	2.12ab	2.45	2.07
M.9	2.23	2.22ab	1.95d	1.67	1.63c	1.96	2.17ab	2.35	2.02
MAC 9	2.15	2.28ab	1.98bcd	1.60	1.81bc	1.75	2.14ab	2.39	2.01
M.27 EMLA	2.14	2.09b	2.04bcd	1.84	1.95ab	1.88	2.23ab	2.68	2.11
	ns[y]			ns		ns		ns	ns
Average[x]	2.19b	2.31b	2.07c	1.69e	1.91d	1.86d	2.19b	2.46a	
				P (% dry weight)					
MAC 24	0.11ab	0.12ab	0.11c	0.11	0.11	0.05d	0.130a	0.11	0.11bc
OAR1	0.08cd	0.12ab	0.11c	0.11	0.11	0.04d	0.115bcd	0.11	0.10c
M.7 EMLA	0.11ab	0.12ab	0.15a	0.12	0.11	0.09a	0.127ab	0.12	0.12a
M.26 EMLA	0.13a	0.13a	0.11c	0.11	0.11	0.09a	0.121ab	0.11	0.11abc
Ottawa 3	0.09bcd	0.11ab	0.14b	0.12	0.11	0.04d	0.118abc	0.12	0.11abc
M.9 EMLA	0.07d	0.13a	0.14b	0.11	0.11	0.07abc	0.118abc	0.12	0.11ab
M.9	0.11ab	0.11ab	0.11c	0.11	0.11	0.07c	0.103bcd	0.11	0.10c
MAC 9	0.10abc	0.12ab	0.10c	0.10	0.11	0.07bc	0.108cd	0.10	0.105bc
M.27 EMLA	0.11abc	0.10b	0.11c	0.11	0.10	0.09a	0.105d	0.11	0.105bc
				ns	ns			ns	
Average	0.10b	0.12a	0.12a	0.11ab	0.11ab	0.07c	0.12a	0.11ab	

continued

Table 3. Continued

Stock	1982	1983	1984	1985	1986	1987	1988	1989	Avg.^{x}
				K (% dry weight)					
MAC 24	2.13a	1.85a	1.74a	1.36a	1.43ab	1.68a	1.51	1.34	1.59a
OAR 1	1.43ab	1.41cd	1.26d	1.17ab	1.48ab	1.32bc	1.32	1.13	1.30bcd
M.7 EMLA	1.80ab	1.38cd	1.33cd	1.28a	1.32abc	1.32bc	1.12	1.16	1.30cd
M.26 EMLA	1.99a	1.71ab	1.62ab	1.34a	1.57a	1.39b	1.25	1.38	1.48ab
Ottawa 3	1.11b	1.27d	1.35abc	1.11abc	1.22abc	1.22bcd	1.13	1.19	1.21cd
M.9 EMLA	1.420ab	1.62abc	1.35cd	0.96c	1.21bcd	1.19bcd	1.20	1.25	1.27cd
M.9	2.03a	1.75a	1.55abc	1.16ab	1.51a	1.16cd	1.16	1.15	1.39bc
MAC 9	1.75ab	1.57bcd	1.30cd	1.12abc	1.09cd	1.00d	1.06	1.30	1.25cd
M.27 EMLA	1.73ab	1.34cd	1.29cd	0.84c	1.00d	1.03d	1.30	1.10	1.16d
							ns	ns	
Average	1.71a	1.54b	1.42bc	1.15e	1.31cd	1.26de	1.23de	1.22de	
				Ca (% dry weight)					
MAC 24	1.35	1.13bc	1.45abc	0.65	1.07bc	0.89	1.09bc	0.81c	1.06b
OAR 1	1.55	1.44a	1.38abc	0.86	1.42a	1.06	1.05bc	0.95abc	1.21a
M.7 EMLA	1.47	1.04c	1.20c	0.80	1.02c	0.96	1.19ab	0.83c	1.06b
M.26 EMLA	1.61	1.09bc	1.29bc	0.69	1.24abc	1.03	1.23ab	0.89abc	1.13ab
Ottawa 3	1.20	1.10bc	1.42abc	0.82	1.31ab	1.01	1.51abc	0.94abc	1.16ab
M.9 EMLA	1.73	1.24abc	1.53a	0.98	1.02c	1.07	1.31a	1.04a	1.24a
M.9	1.98	1.33ab	1.50ab	0.83	1.32ab	1.02	1.03bc	0.90abc	1.24a
MAC 9	1.54	1.26abc	1.25bc	0.70	1.42a	1.05	1.09bc	0.98ab	1.15ab
M.27 EMLA	1.58	1.10bc	1.44abc	0.74	1.18abc	1.05	0.93c	0.83bc	1.11ab
	ns			ns		ns			
Average	1.56a	1.19c	1.38b	0.79e	1.22c	1.02d	1.16c	0.91d	

continued

Table 3. Continued

Stock	1982	1983	1984	1985	1986	1987	1988	1989	Avg.^{x}
				Mg (% dry weight)					
MAC 24	0.25b	0.34	0.32bc	0.30	0.32	0.27a	0.34bc	0.22d	0.30abc
OAR 1	0.31ab	0.30	0.30c	0.26	0.26	0.23bc	0.28d	0.23cd	0.27c
M.7 EMLA	0.31ab	0.34	0.34abc	0.29	0.28	0.27a	0.37ab	0.27a	0.31ab
M.26 EMLA	0.28ab	0.34	0.33bc	0.30	0.33	0.28a	0.38a	0.27a	0.32a
Ottawa 3	0.35ab	0.30	0.30c	0.27	0.26	0.25abc	0.31cd	0.22d	0.28bc
M.9 EMLA	0.26b	0.31	0.34abc	0.29	0.29	0.28a	0.31cd	0.25abc	0.29abc
M.9	0.27ab	0.33	0.36ab	0.25	0.25	0.22c	0.29c	0.21d	0.27c
MAC 9	0.24b	0.32	0.30c	0.27	0.28	0.26ab	0.24e	0.23cd	0.27c
M.27 EMLA	0.39a	0.33	0.38a	0.26	0.29	0.28a	0.29d	0.24bcd	0.31ab
			ns		ns	ns			
Average	0.30bc	0.32a	0.33a	0.28cd	0.28bc	0.26de	0.31ab	0.24e	
				Mn (ppm dry weight)					
MAC 24			268bc		200b	310b		249b	257bc
OAR 1			223c		184b	306b		260b	241c
M.7 EMLA			227c		193b	299b		225b	236c
M.26 EMLA			315abc		229b	296b		249b	274bc
Ottawa 3			302abc		214b	356b		252b	285bc
M.9 EMLA			287abc		191b	301b		244b	259bc
M.9			227ab		226b	348b		271b	296b
MAC 9			378a		306a	509a		396a	392a
M.27 EMLA			276a		363a	522a		422a	415a
Average			278ab		234b	360a		285ab	

continued

Table 3. Continued

Stock	1982	1983	1984	1985	1986	1987	1988	1989	Avg.[x]
				B (ppm of dry wt.)					
MAC 24						54.5ab		35.7b	45.1b
OAR 1						60.0a		41.2a	50.1a
M.7 EMLA						50.5bc		34.9b	43.1bc
M.26 EMLA						44.6cd		33.8b	39.2cd
Ottawa 3						50.4bc		34.5b	43.0bc
M.9 EMLA						46.4bcd		34.0b	40.2bcd
M.9						39.4d		32.5b	36.0d
MAC 9						50.0bc		35.2b	43.8bc
M.27 EMLA						49.3bc		32.3b	41.7bc
Average						49.5a		34.9b	

[z] Mean separation within columns and nutrient element by Duncan-Waller k-ratio test, 5% level.

[x] Mean separation within columns across rootstocks for year main effects and within rows across years for rootstock main effects within an element as an average by Duncan New Multiple Range test, 5% level.

[y] ns = not significantly different.

Table 4. Correlation coefficients (r) for foliar mineral contents and yield and growth of 'Starkspur Supreme Delicious' on nine apple rootstocks grown in Arkansas during the period 1981-1989.

	Correlation Coefficients (r)												
	Variables												INCR.
										INC.	% INC	YIELD	YIELD
Var	P	K	Ca	Mg	Mn	Zn	B	Cu	YIELD	TCSA[1]	TCSA	TCSA	EFF.	EFF.
N	.28^{y}[2]	ns[3]	ns	.09^{z}	ns	-.60^{y}	ns	ns	.30^{y}	ns	.09^{z}	ns	.17^{y}	.13^{y}
P		.16^{y}	.17^{y}	.30^{y}	-.19^{y}	-.56^{y}	ns	ns	.13^{y}	-.09^{z}	ns	.31^{y}	.13^{y}	ns
K			.36^{y}	.10^{z}	ns	.22^{z}	ns	ns	-.21^{y}	ns	ns	.29^{y}	-.27^{y}	-.21^{y}
Ca				.24^{y}	ns	.28^{y}	ns	ns	-.19^{y}	-.27^{y}	-.19^{y}	.16^{y}	-.21^{y}	-.11^{y}
Mg						.24^{y}	ns	ns	ns	-.11z	-.10z	.20^{y}	ns	ns
Mn						.20^{z}	ns	ns	-.19^{y}	-.34^{y}	-.39^{y}	-.30^{y}	ns	ns
B								--	-.44^{y}	ns	ns	-.34^{y}	-.42^{y}	-.28^{y}
Zn								.34^{y}	ns	ns	ns	ns	ns	ns
Cu									ns	ns	ns	ns	-.58^{y}	ns
Yield										.70^{y}	.40^{y}	-.27^{y}	.77^{y}	.32^{y}
TCSA											.75^{y}	-.29^{y}	.40^{y}	.14^{y}
Inc TCSA												.14^{y}	.13^{y}	ns
% TCSA													-.36^{y}	-.25^{y}
Yield Eff.														.48^{y}

[1] TCSA = total trunk cross sectional area; Incr. TCSA = Increase in TCSA each year; % Inc. TCSA = percent increase in TCSA each year Eff. = Yield efficiency (kg/cm^2 TCSA); Incr. Eff. = increment yield efficiency (kg fruit/incr. TCSA).

[2] y = significant at 1% level; z = significant at 5% level.

[3] ns = not significant.

Table 5. Ratings of internal bark necrosis (IBM) symptoms of manganese toxicity on 'Starkspur Supreme Delicious' on nine apple rootstocks, 1983-1989.

	IBN Rating					
Stock	1983[z]	1984[z]	1985[z]	1986[z]	1987[y]	1989[y]
MAC 24	1.1b	1.2c	2.0cd	1.8cd	2.3bc	2.7c
OAR 1	1.0b	1.1c	1.1d	1.1d	1.0d	1.3d
M.7 EMLA	1.1b	1.3c	2.0cd	1.8cd	2.6abc	2.8c
M.26 EMLA	2.5a	2.4b	2.9abc	2.1c	3.3abc	3.3abc
Ottawa 3	1.5b	2.7b	2.6abc	2.0c	2.9abc	3.7abc
M.9 EMLA	1.0b	1.3c	2.2cd	2.6bc	2.6bc	3.9abc
M.9	1.3b	1.9bc	2.5bc	3.2ab	3.2abc	4.2ab
MAC 9	2.9a	3.8a	3.6a	2.7a	3.5ab	4.5a
M.27 EMLA	3.1a	4.4a	3.7a	3.2ab	3.8a	3.6abc

[z] IBN rating scale used in 1983-1989: 1 = no IBN symptoms; 2 = mild symptoms; 3 = moderate symptoms; 4 = severe symptoms; 5 = symptoms causing tree death.

[y] IBN rating scale used in 1987 and 1989: 1 = no IBN symptoms; 2 = mild symptoms; 3 = moderate symptoms; 4 = severe symptoms; 5 = symptoms causing seriously reduced growth and production, some shoot death but no tree death.

[x] Mean separation within columns by Duncan's Multiple Range Test, 5% level.

NITROGEN FERTILIZATION OF HIGHBUSH BLUEBERRY: FIFTH YEAR RESULTS AND FINAL REPORT

J.R. Clark, R.L. Maples, K.M. Irvin and M.V. Brown

INTRODUCTION

Nitrogen (N) fertilization studies were begun in 1987 to evaluate N rate and source effects on highbush blueberries grown on a mineral soil. Since blueberry production in Arkansas is on soils that are not common for blueberry, the correct N rate is unknown. Also, the use of mulch in blueberry production probably has an effect on N utilization and optimum N rate. This report includes data from the 1991 growing season, which is the fifth and final year of this area of investigation.

PROCEDURE

These studies were continued on mature plants at two locations. At the Johnson County, Arkansas, location, mulched 'Bluecrop' and unmulched 'Bluejay' plants growing on a Linker fine sandy loam were provided an annual total of 20, 60 and 120 lb N/acre using urea. The second location was the University Farm in Fayetteville, Arkansas, where mulched 'Collins' blueberries, growing on a Captina silt loam, were provided an annual total of 0, 60, 120 and 180 lb/acre N using ammonium sulfate. The 180-lb/N/acre rate was added for the first time in 1991. All plants received N in multiple applications: budbreak, and six and 12 weeks later. All plants were trickle irrigated, and weeds were controlled with preemergent chemical applications. Flower bud counts on the previous year's growth were taken in March, and foliar samples containing mid-shoot leaves were taken in early August. Yield and berry weight data were collected in Fayetteville only. Each study contained four, four-plant replications arranged in a randomized complete block design. Data from each study were analyzed separately by SAS.

RESULTS AND DISCUSSION

Data from the unmulched 'Bluejay' study are presented in Table 1. Significant differences were found for foliar N, Ca and Mg. Nitrogen was lower for the 20-lb N rate compared to the two higher rates, which were similar. Calcium and Mg were higher for the lower N rate. Foliar N levels were in the sufficient range ($\leq$1.60% N) for all N rates. In the five years of this study, significant treatment differences in foliar N level occurred in three years. Magnesium levels were different in two of five years, although the yearly trend was for lower Mg with higher N rate. Calcium levels were different in 1991 only.

The results of the second study in Johnson County, using mulched 'Bluecrop' plants, are presented in Table 2. Significant differences were found for foliar N, Mg and Fe. Nitrogen was higher with the higher N rate, and the 60- and 120-lb/acre N rates were in the sufficient range. Iron was slightly higher for the highest N rate. In the five years of this study, foliar N level differences were found for three years, while Mg levels were different in two years. Iron levels were different in 1991 only.

Data from the study on mulched 'Collins' plants at the University Farm are presented in Table 3. Significant differences were found for N only. Highest foliar N levels were found for the higher N rates, although no statistical difference occurred between the 60-lb/N/acre rate and the higher rates. A trend in the data reflected higher yields with higher N rate. In the five years of this study, foliar N levels have been different in three years, while Mg, Mn and Fe have been different in one year each.

These studies reveal that N fertilization rates affect foliar N and, occasionally, foliar Mg, Fe, Ca and Mn. Generally, higher foliar N levels were found with increased N rates but not always different between 60 and 120 lb/N/acre. Further analysis of the multi-year data will be done to reveal overall results of these studies.

Table 1. Flower bud number and foliar analysis values for unmulched 'Bluejay' highbush blueberry receiving urea as the N source in 1991.

N rate	Bud no.[1]	N	K	Ca	Mg	P	S	Fe	Mn	Cu	Zn
		% dry weight						ppm			
20	4.4	1.63b	.51	.58a	.14a	.09	.09	67	363	4	18
60	4.3	1.82a	.48	.53ab	.10b	.09	.09	73	320	3	19
120	4.1	1.82a	.60	.41b	.10b	.08	.09	66	329	3	19
Sig.[2]	NS	.03	NS	.04	.01	NS	NS	NS	NS	NS	NS

[1] Bud no. is an average number of flower buds/shoot in March 1991.

[2] F-test significance; NS = non-significant at .05 level. Mean separation by LSD.

Table 2. Flower bud number and foliar analysis values for mulched 'Bluecrop' highbush blueberry receiving urea as the N source in 1991.

N rate	Bud no.[1]	N	K	Ca	Mg	P	S	Fe	Mn	Cu	Zn
		% dry weight						ppm			
20	3.8	1.54b	.27	.94	.22ab	.09	.08	64b	432	4	27
60	4.6	1.60ab	.30	.98	.23a	.09	.08	63b	507	4	17
120	5.2	1.69a	.32	.85	.19b	.09	.09	73a	517	4	17
Sig.[2]	NS	.05	NS	NS	.05	NS	NS	.04	NS	NS	NS

[1] Bud no. is an average number of flower buds/shoot in March 1991.

[2] F-test significance; NS = non-significant at .05 level. Mean separation by LSD.

Table 3. Flower bud number, yield, berry weight and foliar analysis values for mulched 'Collins' highbush blueberry receiving ammonium sulfate as the N source in 1991.

N rate	Bud no.[1]	Yield	Berry wt	N	K	Ca	Mg	P	S	Fe	Mn	Cu	Zn
		lb/acre	g	% dry weight						ppm			
0	4.2	3543	1.5	1.91b	.40	1.09	.15	.10	.15	97	808	5	22
60	4.2	4140	1.6	2.01ab	.48	1.37	.17	.12	.18	111	721	5	21
120	4.4	4647	1.5	2.25a	.35	1.05	.16	.10	.17	88	1067	4	26
180	-	4862	1.4	2.30a	.39	1.04	.15	.10	.16	88	848	5	16
Sig.[2]	NS	NS	NS	.03	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] Bud no. is an average number of flower buds/shoot in March 1991.

[2] F-test significance; NS = non-significant at .05 level. Mean separation by LSD.

ESTABLISHMENT PERIOD FERTILIZATION OF 'BLUECROP' BLUEBERRY: FOURTH YEAR RESULTS AND FINAL REPORT

J.R. Clark, R.L. Maples and K.M. Irvin

INTRODUCTION

This study was begun in 1988 to evaluate different nitrogen (N) fertilization levels using urea as the N source and to determine the effect of several other fertilizers on soil and plant characteristics during the establishment period (years 1-4) of a blueberry planting. This report includes the fourth and final year results of this study.

PROCEDURE

Plants used for this study were planted in 1988 at the Fruit Substation, Clarksville, Arkansas, on a Linker fine sandy loam. Standard cultural practices for highbush blueberry production were used, including peat moss addition to the planting hole at planting, sawdust/woodchip mulch applications, trickle irrigation and preemergent chemical weed control. Rates of application for urea were 0, 60 and 120 lb N/acre. Rates for other materials were based on a 120-lb N/acre rate or manufacturer's recommended rate (Table 1). Soil samples were taken in early August from the mulched area around the plots where fertilizer was applied. Foliar samples consisted of mid-shoot leaves on fruiting canes and were taken in early August also. Yield and berry weight data were taken during the fruiting season. There were three replications of three-plant plots arranged in a randomized complete block design. Data were analyzed by SAS.

RESULTS AND DISCUSSION

Soil analysis data had differences among treatment means for pH, nitrate, K, Ca, Mg, Fe, S, P and electrical conductivity (EC) (Table 2). Soil pH means were very similar to the previous year's data in that the highest pH was for the check treatment and the lowest for ammonium sulfate. Nitrate level was highest for urea 2, followed by ammonium sulfate. Potassium was highest for 13-13-13 and the check and lowest for ammonium sulfate. Calcium levels were highest for calcium nitrate and the check treatment. Magnesium was highest for the check and lowest for ammonium sulfate. Iron was highest for 13-13-13, and S was highest for ammonium sulfate, although not different among other treatments. Soil P was much higher for 13-13-13. Electrical conductivity was higher for ammonium sulfate but similar among all other treatments.

Yield, berry weight and foliar analysis data are presented in Table 3. No statistical differences were found among treatments for yield or berry weight. Yields ranged from a high of 3,665 lb/acre for the slow release fertilizer to 2,367 for 13-13-13. A large amount of variation in the data for yield and berry weight was present. Foliar analysis results indicated significant differences for K, Ca, Mg, P, S and Zn. Potassium and P were highest for 13-13-13, and Ca and Zn were highest for calcium nitrate. Magnesium was higher in the check plants, although not significantly different from two other treatments. Sulfur was highest for the ammonium sulfate treatment.

The differences in overall growth and health of the plants receiving different fertilizer treatments were very noticeable (no data shown). Generally, the plants receiving 13-13-13 had chlorotic leaves and numerous dead stems. The check plants had a slightly less green appearance than those receiving nitrogen fertilizer, which probably reflected a foliar N deficiency. Plants receiving the 120-lb N/acre rate of urea and those receiving ammonium sulfate showed the least chlorosis and most growth. Calcium nitrate, slow release and urea 1 plants were intermediate in overall growth and appearance.

The data from the four years of this study will be further analyzed and should reflect some obvious trends in fertilization effects. On a single-year basis, the data do not provide a clear result that reveals the optimum N rate for establishment period fertilization.

Table 1. Fertilizer treatments applied in the fourth year (1991) to 'Bluecrop' blueberry at the Fruit Substation, Clarksville, Arkansas.

Fertilizer	% N	lb/acre[1]	lb N/acre
Check	0	0	0
Urea 1	42.0	130	60
Urea 2	42.0	260	120
13-13-13	13.0	926	120
Ammonium sulfate	21.0	570	120
Calcium nitrate	15.5	780	120
17-6-10 Slow release[2]	17.0	545	93

[1] lb/acre is the total applied/year, applied in three applications, based on 1098 plants/acre spaced 4 ft x 10 ft.

[2] Slow-release fertilizer applied according to manufacturer's directions -- equivalent to 8 oz/plant applied one time in March.

Table 2. Soil analysis values for fertilizer establishment study treatments from August samples, 1991, Fruit Substation, Clarksville, Arkansas.

Treatment	pH	OM	NO_3	K	Ca	Na	Mg
			lb/acre				
Check	4.9 a	1.0	3.3c	132 a	527 ab	215	60 a
Urea 1	4.7 bc	1.1	6.0bc	102 ab	383 bc	217	41 b
Urea 2	4.4 d	1.0	16.7a	88 cd	330 c	202	37 bc
13-13-13	4.3 d	1.4	6.0bc	135 a	272 cd	211	27 cd
Amm. sulfate	3.9 e	1.0	11.0ab	66 d	175 d	217	15 d
17-6-10 SR	4.5 cd	1.1	4.0c	126 ab	297 cd	203	43 b
Cal. nitrate	4.8 ab	1.1	10.3b	91 cd	656 a	232	35 bc
Significance[1]	.01	NS	.01	.01	.01	NS	.01

Treatment	Fe	Mn	Cu	Zn	S	P	EC[2]
	lb/acre						
Check	146 d	128	11	33	34 b	95 c	32 b
Urea 1	150 d	142	10	27	40 b	100 c	34 b
Urea 2	180 bc	140	10	17	44 b	103 c	49 b
13-13-13	212 a	101	9	12	48 b	263 a	45 b
Amm. sulfate	195 ab	116	10	9	143 a	115 bc	89 a
17-6-10 SR	165 cd	131	11	16	51 b	146 b	39 b
Cal. nitrate	162 d	121	11	22	46 b	106 c	37 b
Significance[1]	.01	NS	NS	NS	.01	.01	.01

[1] F-test significance; NS = non-significant at .05 level. Mean separation by LSD.

[2] Electrical conductivity (μmhos/cm).

Table 3. Yield, berry weight and foliar analysis values for fertilizer establishment study on 'Bluecrop' highbush blueberry for fourth year of the study, 1991.

Treatment	Yield	Berry wt.	N	K	Ca	Mg
	lb/acre	g	-----------------% dry weight------------------			
Check	2683	2.0	1.52	.39 b	.88 a	.21 a
Urea 1	3025	2.2	1.54	.44 b	.81 ab	.19 ab
Urea 2	3188	2.2	1.56	.50 ab	.72 abc	.16 bc
13-13-13	2367	1.7	1.64	.62 a	.51 d	.16 bc
Amm. sulfate	2650	2.2	1.73	.42 b	.59 cd	.15 bc
17-6-10 SR	3665	1.8	1.51	.48 ab	.65 bcd	.18 ab
Cal. nitrate	2774	1.9	1.50	.40 b	.83 a	.13 c
Significance[2]	NS	NS	NS	.04	.01	.01

Treatment	P	S	Fe	Mn	Cu	Zn
	----% dry weight----		---------------------- ppm ----------------------			
Check	.092 b	.09 b	83	661	6	21 bc
Urea 1	.087 bcd	.09 b	91	780	6	30 bc
Urea 2	.081 de	.08 c	90	936	5	39 ab
13-13-13	.101 a	.09 b	119	989	6	24 bc
Amm. sulfate	.078 e	.11 a	136	948	6	18 c
17-6-10 SR	.089 bc	.09 b	105	537	5	22 bc
Cal. nitrate	.084 cde	.09 b	87	586	5	51 a
Significance[2]	.01	.01	NS	NS	NS	.02

[1] Yield based on a plant density of 1089 plants/acre; 4 ft x 10 ft spacing.

[2] F-test significance; NS = non-significant at .05 level. Mean separation by LSD.

NITROGEN RATE AND SOURCE EFFECTS ON SOIL ANALYSIS VALUES OF HIGHBUSH BLUEBERRIES

J.R. Clark, R.L. Maples, K.M. Irvin and M.V. Brown

INTRODUCTION

Nitrogen applications are recommended annually to blueberry plantings with the N source dependent on the pH. On soils with a pH of 5.3 or above, ammonium sulfate is the preferred source; below 5.3, urea is recommended. Rates of application of N fertilizers are usually in the area of 60 lb N/acre in most highbush blueberry production regions in the United States, but higher rates are recommended for Arkansas blueberries grown with mulch.

Soil analysis values are affected by N source, with ammonium sulfate more acidifying than urea. Also, rates probably affect soil analysis. In nutritional management of blueberry plantings, foliar samples should be taken following harvest. Accompanying soil samples should be taken at the time of foliar sampling to provide adequate information on which to base recommendations.

This report provides 1991 data from a multi-year study on N source and rate and sampling time effects on soil analysis values. Results of this study should provide information to more precisely define nutritional management guidelines for highbush blueberries in Arkansas.

PROCEDURE

The plantings used for data accumulation in 1991 had been receiving the same N treatments since 1988, except for the 180-lb/acre rate on 'Collins', which was begun in 1990. These plantings included a non-mulched plot of 'Bluejay' and a mulched plot of 'Bluecrop', both located in a commercial blueberry field in Johnson County, Arkansas, and growing on a Linker fine sandy loam. Also, a mulched plot of 'Collins' at the University Farm, Fayetteville, Arkansas, growing on a Captina silt loam, was included. The Johnson County plots received urea as the N source, and the University Farm plot received ammonium sulfate. Rates at the Johnson County location were 20, 60 and 120 lb/acre N; rates at the University farm were 0, 60, 120 and 180 lb/acre. Rates were based on a planting density of 1089 plants/acre. Nitrogen fertilizers were applied three times: once at budbreak and twice more at six-week intervals. Soil samples were taken in March, prior to fertilization, and in early August at the time of foliar sampling. Data were analyzed for each plot as a split-plot in time and means separated by LSD.

RESULTS AND DISCUSSION

Data analysis revealed that N rate was a significant source of variation for pH, NO_3 and EC in all plantings (Tables 1, 2, 3). Month of sampling was significant for several dependent variables, depending on the planting (Tables 1, 2, 3). Interaction of N rate and month of sampling was significant for NO_3 and EC in the 'Bluejay' planting and Zn in the 'Bluecrop' planting (data not shown).

Soil pH was reduced and NO_3 and EC were increased with higher N rates. Although not statistically significant, Mg levels were usually reduced with higher N rate. The August samples had lower pH, probably as a result of soil acidification by N fertilizers. The trend in the data over several years is for pH to rise by the March sample date. A trend existed in the data for higher EC and NO_3 with August samples, probably related to fertilization. Sodium levels were higher in August samples in all three plantings, which could be a fertilizer-related occurrence.

The data from several years will be further analyzed to reveal overall effects of fertilization and sample data on soil analysis values. Results should reveal information to better predict nutritional needs of blueberry plantings, allowing more precise recommendations.

Table 1. Soil test values for nitrogen rate and month for non-mulched 'Bluejay' blueberry in Johnson County, Arkansas, 1991.

N Rate	pH	% OM[1]	NO_3	K	Ca	Na	Mg	P	S	Fe	Mn	Cu	Zn	EC[2]
			--------------------	--------------------	--------------------	--------------------	--------lb/acre--------	--------------------	--------------------	--------------------	--------------------	--------------------	--------------------	
20 lb	4.8a	1.3	12b	111	564	173	78	226	41	254	37	4	8	46b
60 lb	4.2b	1.5	36a	96	356	171	29	276	45	306	45	4	7	81a
120 lb	4.1b	1.7	54a	115	370	165	28	267	42	297	42	4	6	105a
Sig.[3]	.01	NS	.01	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	.01
Month														
March	4.5a	1.5	6b	85b	444	141b	43	260	42	290	34b	4b	6	32b
August	4.2b	1.5	61a	130a	415	198a	47	253	44	280	49a	5a	8	123a
Sig.[3]	.01	NS	.01	.05	NS	.02	NS	NS	NS	NS	.01	.02	NS	.01

[1] OM = % organic matter

[2] EC = electrical conductivity.

[3] Significance by F-test; NS = non-significant at .05 level. Mean separation by LSD.

Table 2. Soil test values for nitrogen rate and month for mulched 'Bluecrop' blueberry in Johnson County, Arkansas, 1991.

N Rate	pH	% OM[1]	NO_3	K	Ca	Na	Mg	P	S	Fe	Mn	Cu	Zn	EC[2]
			--------------------	--------------------	--------------------	--------------------	--------lb/acre--------	--------------------	--------------------	--------------------	--------------------	--------------------	--------------------	
20 lb	4.8a	1.7	13b	57	867	163	72	225	31	204	29	5	21	49b
60 lb	4.9a	1.7	19b	58	933	154	67	203	31	199	23	5	16	58b
120 lb	4.5b	1.7	46a	53	914	155	69	248	36	213	28	6	18	88a
Sig.[3]	.03	NS	.03	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	.04
Month														
March	4.8	1.9	23	58	987	109b	71	231	31	206	27	4b	16	57
August	4.7	1.6	32	53	829	205a	67	220	35	204	26	6a	19	76
Sig.[3]	NS	NS	NS	NS	NS	.01	NS	NS	NS	NS	NS	.01	NS	NS

[1] OM = % organic matter.

[2] EC = electrical conductivity.

[3] Significance by F-test; NS = non-significant at .05 level. Mean separation by LSD.

Table 3. Soil test values for nitrogen rate and month for mulched 'Collins' blueberry at the Main Station, Fayetteville, Arkansas, 1991.

N Rate	pH	% OM[1]	NO_3	K	Ca	Na	Mg	S	P	Fe	Mn	Cu	Zn	EC[2]
			lb/acre											
0 lb	5.6a	2.3	14b	145	2367	162	95	69	73	184	182	5	9	83 c
60 lb	5.6a	2.1	13b	139	2253	145	91	81	69	184	194	5	5	93 bc
120 lb	4.8b	2.2	36a	122	1893	161	72	147	64	192	200	9	7	150 a
180 lb	5.0b	2.2	21b	127	2066	155	79	127	53	193	197	4	5	119 ab
Sig.[3]	.02	NS	.02	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	.01
Month														
March	5.5a	2.4	19	158	2315a	102b	89	68b	66	189	192	4	6	82 b
August	5.0b	2.0	24	108	1974b	210a	79	144a	62	188	194	8	7	141 a
Sig.[3]	.01	NS	NS	.05	.04	.01	NS	.02	NS	NS	NS	NS	NS	.01

[1] OM = % organic matter.

[2] EC = electrical conductivity.

[3] Significance by F-test; NS = non-significant at .05 level. Mean separation by LSD.

ELEMENTAL ANALYSIS OF GRAPE PETIOLES AS AFFECTED BY CULTIVAR AND FLOWER CLUSTER THINNING

J.R. Clark, W.K. Patterson, W.H. Baker and J. Fitzgerald

INTRODUCTION

Foliar analysis, using the petiole as the leaf part for elemental analysis, is the preferred method to determine the nutritional status of grapes. Most Eastern grapes are sampled at veraison (berry coloring), with the sample consisting of the last mature leaf toward the terminal end of a grapevine shoot. The *Vitis labrusca* cultivar 'Concord', which is used mainly for juice, has been used in most foliar analysis studies. The University of Arkansas has developed several table grape cultivars that are hybrids of *V. labrusca* and *V. vinifera*. No information is available on the differences among these cultivars in petiole elemental content. This study was conducted to determine if differences exist in elemental content among Arkansas table grape cultivars and to determine the effect of flower cluster thinning on elemental content. The findings of this study should provide necessary data to fully utilize petiole analysis as a tool in nutritional monitoring of grape plantings.

PROCEDURE

The vines used for this study were located at the Fruit Substation, Clarksville, Arkansas, growing on a Linker fine sandy loam soil. The vines were seven years old and were trained to a Four Arm Kniffin training system. All vines were balance pruned in February 1991 using a 30 + 10 balanced pruning formula to adjust pruning severity to individual vine vigor. The vines had pests controlled using a commercial spray program, weeds controlled with preemergent herbicides and irrigation applied as needed. The cultivars included 'Venus', 'Mars' and 'Saturn'. The flower cluster thinning treatments consisted of thinning clusters prior to bloom to one cluster/shoot or unthinned. Flower cluster thinning usually involved removing one to three clusters from each shoot, and the basal cluster was retained on the thinned shoots.

Petioles were collected in late June (at veraison) and were taken from the last mature leaf on fruiting shoots. The petioles were then triple rinsed with distilled water, dried for 24 hours at 70 C and ground in a Wiley mill. Elemental analysis was done at the Soil Testing and Research Laboratory in Marianna, Arkansas.

There were two, three-vine replications of each cultivar/thinning combination. The data were analyzed as a two-factor randomized complete block by SAS.

RESULTS AND DISCUSSION

There were no significant effects for thinning treatment for any elements analyzed, nor were there any interactions of cultivar and thinning treatment (data not shown). Significant differences were found among cultivars for N, Ca, Mg, S and Mn (Table 1). 'Saturn' had the highest N, Mg and S content. 'Venus' was higher in Ca and Mn.

Of the cultivars sampled, 'Saturn' has the largest *V. vinifera* genetic component. 'Venus' is approximately 60% *V. vinifera* ,and 'Mars' is largely *V. labrusca*. The data reveal that Saturn had more elemental content statistical differences than the other cultivars. Also, the trend in the data for P and Fe content reflected a more distinctly different level for 'Saturn'. These differences could be due to the differences in genetic make-up of the cultivars.

Preliminary, unreported data from 1990 from these cultivars revealed trends similar to those from the 1991 data for N, Mg, Ca, S, Mn and Zn. Further analysis of the two-year data should more precisely define cultivar differences in petiole elemental content. This information can be used in a petiole sampling program tailored to Arkansas table grapes.

Table 1. Petiole elemental concentration of Arkansas table grape cultivars, 1991, from samples taken at veraison.

Cultivar	N	K	Ca	Mg	P	S	Fe	Mn	Cu	Zn
	% dry weight						ppm			
Mars	.87b	2.77	.89b	.19b	.13	.08c	21	144b	11	87
Saturn	1.31a	2.82	.92b	.42a	.19	.19a	27	204b	13	89
Venus	1.17a	2.52	1.09a	.20b	.14	.09b	17	458a	12	145
Sig.[1]	.01	NS	.02	.01	NS	.01	NS	.02	NS	NS

[1] F-test significance; NS = non-significant at .05 level. Mean separation by LSD.

RESPONSE OF 'FALL GREEN' SPINACH TO RATES OF NITROGEN AND SULFUR FERTILIZERS

B.R. Wells, T.E. Morelock and D.R. Motes

INTRODUCTION

Spinach (*Spinacia oleracea*, L.) producers in the Arkansas River Valley have experienced continuing problems with chlorosis, especially in the overwinter crop. Until recently, most growers tried unsuccessfully to correct the problem by applying additional nitrogen (N) fertilizer. We conducted a study in 1989 that proved the cause of the chlorosis was a sulfur (S) deficiency. Results from that study also caused us to question the possible interactions of N and S on both grain yields and quality (color) of the spinach crop. This study was conducted with the objective of determining any interactions between N and S fertilization on both yield and quality (color) of the overwinter spinach crop.

MATERIALS AND METHODS

The study was conducted for two years, 1990 and 1991, with 'Fall Green' spinach on a Roxanna fine sandy loam (Typic Udifluvents) at the University of Arkansas Vegetable Substation near Kibler, Arkansas. The experimental design was a split-plot with five replications. The main plots were spring-applied N rates of 40, 80, 120, 160, 200 and 300 lb/acre. The subplots were spring-applied S rates of 0, 10 and 20 lb/acre. The N source was ammonium nitrate, and the sulfur source was calcium sulfate (gypsum). The plots were seeded in November of both years; the spring N and S applications were made in late February, and the plots were harvested in early to mid-April. Leaf chlorophyll (color) readings (5 readings/plot) were taken with a Minolta SPAD meter, with degree of green color being indicated by higher readings. A reading in the mid-forties to low fifties indicates the dark green color that is desired for high-quality spinach. Above-ground plant tissue was harvested from 1 m^2 in the center of each plot. Leaf samples for N and S determination were taken at random from each plot. All data were subjected to statistical analysis by methods developed by SAS, Inc., and means separations were by LSD (0.05). Only the data for yields and leaf color are included in this report.

RESULTS

Spinach tissue weights increased with increasing N rates up to 120-160 lb/acre in 1990; however, low plant populations in 1991 resulted in variable responses to N rate (Table 1). The optimum S rate varied with the N fertilizer rate. With N rates of 80 or 120 lb/acre in 1990, a S rate of 10 lb/acre was adequate to optimize yields. Nitrogen rates above 120 lb/acre required 20 lb/acre of S. When 40 lb N/acre was applied, additions of sulfur had no effect on yields in 1990; however, in 1991 additions of S tended to increase yields. Minolta SPAD readings are given in Table 2. SPAD readings at the 40-lb/acre rate of N indicate a fair color in the absence of S and only marginal improvement with the addition of S. As N rates increased, SPAD readings decreased in the absence of S, and 20 lb/acre of S was required to optimize color at N rates above 120 lb/acre, as indicated by readings of 45-56. SPAD readings for the plots treated with 10 lb/acre of S showed a decreasing trend with increasing N rate in 1990; thus the results from the SPAD reading were similar to those received for tissue weights. These data indicate that neither tissue weights nor color of spinach can be improved by applying only N fertilization when S is deficient. Actually, N fertilization may intensify the chlorosis problem in the absence of S fertilization. Based on results of this study, an optimum fertility program for spinach on these soils would be a spring N application of approximately 160 lb/acre plus 20 lb/acre of S.

Table 1. Yield (wet weight) of 'Fall Green' spinach as influenced by nitrogen (N) and sulfur (S) rates.

	S Rate					
	0		10		20	
N Rate	1990	1991	1990	1991	1990	1991
lb/acre	g/m²					
40	2566	1031	2638	871	2802	1100
80	1754	1454	3022	1372	2994	1840
120	1542	2234	2982	2164	3162	2682
160	3174	1652	4605	1914	5538	1796
200	1646	2382	3510	2675	4162	2528
300	3006	1906	4168	2352	4940	2564

Table 2. Minolta SPAD meter readings for 'Fall Green' spinach as influenced by nitrogen (N) and sulfur (S) rates.

	S Rate					
	0		10		20	
N Rate	1990	1991	1990	1991	1990	1991
lb/acre	meter reading					
40	39	36	41	49	46	47
80	23	24	37	48	45	50
120	23	31	32	52	47	52
160	27	25	34	49	47	56
200	21	27	31	49	46	55
300	21	25	35	48	46	56

LOW-INPUT DRY-LAND COTTON PRODUCTION

T. C. Keisling

INTRODUCTION

A large percentage of the cotton acreage in Arkansas is dryland production. Little or no research has been conducted that specifically addresses management strategies that could enhance profitability of this production system. One way to increase profitability is to decrease expenses while maintaining yield amount and quality.

Experiments were begun in 1991 to assess:

a. Nitrogen (N) management strategies for dryland cotton;
b. Deep liming with the Stoneville deep-dry-lime-fertilizer applicator;
c. Reduced or no-till production; and
d. Narrow-row (30 in.) production.

PROCEDURES

Experiment 1

Three treatments were initiated:

1. N soil applied at currently recommended rate,
2. N applied as in treatment 1 plus additions in season as foliar according to petiole indications of plant status, and
3. N applied as in treatment 2 plus 1000 lb/acre lime applied in a band 2 in. wide and 6 to 15 in. deep.

The experimental design was a randomized complete block with six blocks. The test was located on a Memphis soil. On 1 June 1991, 45-30-90 N P_20_5,-K_20 lb/acre and lime treatments were applied. Cotton cultivar DPL50 was planted on 1 June 1991. Harvest was once over on 16 October 1991.

Experiment 2

The treatment design was a split split plot with till or no-till main plot; first split was 30- or 38-in. row, and second split was starter fertilizer application or none. The experiment had five replications.

Till or no-till strips were established in the fall of 1990 and planted tc cover crops. Cover crop vegetation was chemically burned down approximately two weeks prior to target planting date (15 May). Starter fertilizer at 15-15-0, N-P_20_5,K_20 lb/acre was applied 2 in. to the side and 2 in. below the seeds at planting time. Sufficient dry fertilizer was broadcast to bring all treatments up to 45-30-90, N-P_20_5-K_20 lb/acre. Tilled plots were disc harrowed twice and bedded on 30 May 1991 and drug off with a do-all in preparation for planting on 1 June 1991. All plots were planted with cotton cultivar DPL-50 on 1 June 1991.

RESULTS

Background soil test data are given in Table 1. Since the experiments were adjacent, a composite sample over the whole area was taken.

Experiment 1

Plant structure and yield are given in Table 2. Yield was significantly increased by the addition of deep lime. All plant structures were similar. Petiole analyses are given in Table 3. There were two instances in period 1 and 8 when differences were measured. To get some idea of profitability, Arkansas Cooperative Extension Budgets (Herrington et al., 1991) were completed and are summarized in Table 4. These results indicate that profitability can be increased by a factor of 2.5 by this single operation.

Experiment 2

Starter fertilizer was not found to influence lint yield, but both tillage and spacing increased lint yield (Table 5). Conventional tillage yielded significantly more lint than no-till at either row spacing. Narrow rows were significantly better than wide rows in either tillage systems. Budgets (Table 6) indicate that in 1991 narrow rows were worth $133.23/acre if cotton sold for 0.62/lb of lint. The loss in yield for no-till was not overcome by the reduction in tillage costs. Narrow rows in no-till were worth $84.86.

DISCUSSION

The yield enhancement by deep-placed lime was shown to be extremely profitable. That obtained with narrowing rows from 38 to 30 in. was also shown to be profitable on both conventional and no-till systems. Starter N and P fertilizer had no effect on yield. No-till systems are currently less profitable than conventional systems for cotton production on Arkansas silt loams.

ACKNOWLEDGMENTS

This research was made possible through funds provided via the Fertilizer Tonnage Fee. Other funds were provided by the Tennessee Valley Authority. Dr. Robert E. Coats, Jr. provided assistance with economic criteria. All contributors are gratefully acknowledged.

LITERATURE CITED

1. Herrington, E., Jr., C.A. Stuart, T.E. Windham and R.E. Coats, Jr. 1991. Estimating 1991 production costs in Arkansas. Ark. Coop. Ext. Tech. Bull. No. 127.

Table 1. Soil test values for the start of the experiment.

Depth	pH	OM	P	K	Ca	Na	Mg	Fe	Mn	Cu	Zn	S	NO_3	EC
		%	lb/acre											µmhos
0-6	6.7	0.5	180	484	2178	372	255	324	323	6.2	19	58	24	78
6-12	6.2	0.5	137	407	1807	286	188	306	263	5.8	6	34	21	66
12-18	6.3	0.5	145	457	2227	302	227	321	232	5.8	14	54	25	64

Table 2. Yield and selected plant structural characteristics for Experiment 1.

Treatment Number	Lint Yield lb/acre	First Sympodial Node	Number of Sympodia	Plant Height (in.)	Total Bolls Per Plant
1	653 b[1]	7 a	9 a	25 a	5 a
2	623 b	8 a	8 a	24 a	4 a
3	759 a	7 a	9 a	24 a	5 a

[1] Numbers in same column followed by the same letter are not significantly different at the 5% level according to Duncan's New Multiple Range Test.

Table 3. Petiole analysis for various elements for dry cotton for 1991.

	CNM Period								
Trt	1	2	3	4	5	6	7	8	10
					ppm N				
1	7048 a[1]	4130 a	2677	7823	4037 b	2123	1179	992	1116
2	7949 a	4724 a	2347	6206	4674 b	2185	1021	811	1152
3	6413 a	2084 a	2056	6460	5586 a	2790	850	917	1569
					ppm P				
1	2117 a	1441 a	940	1170	1772 a	1618	1223	838 b	1067
2	1867 b	1289 a	954	1265	1756 a	1705	1268	772 b	1029
3	1758 b	1333 a	943	1275	2130 a	1859	1388	986 a	1055
					% K				
1	4.37 b	3.25 a	2.70	3.82	3.77 a	3.28	2.80	1.90	1.63
2	4.23 b	3.18 a	2.45	3.70	3.82 a	3.37	2.87	1.78	1.58
3	4.72 a	3.25 a	2.62	3.62	4.42 a	3.63	2.98	2.13	1.77
					ppm S				
1	804 b	531 a	543	897	1145 a	1033	728	843	846
2	736 b	503 a	485	890	1213 a	1050	791	940	793
3	995 a	653 a	528	996	1463 a	972	721	925	808

[1] Numbers for same analysis in same column followed by same letter are not significantly different at the 5% level according to Duncan's New Multiple Range Test.

Table 4. Estimated costs and returns to deep-dry-lime applications.[1]

	Specified operating costs	
Cultural Practice	Conventional	Deep Lime
Resource or Input	---------------- Dollars ----------------	
Seed	8.30	8.30
Fertilizer	31.40	31.40
Lime + Application	10.01	14.00
Herbicide	57.38	57.38
Fungicide	0	0
Insecticide	16.20	16.20
Defoliant	26.15	26.15
Aerial Application	7.53	7.53
Machinery:		
Fuel, Oil, Lubricants	25.05	25.05
Repairs	44.30	44.30
Labor	22.18	22.18
Irrigation:		
Fuel, Oil, Lubricants	0	0
Repairs	0	0
Irrigation Labor	0	0
Custom Spread	6.08	6.08
Custom Haul	0	0
Custom Dry or Ginning	0	0
Miscellaneous	4.00	4.00
Crop Insurance Premium	0	0
Other		
Interest on OP.CAP.	11.85	12.03
Total Specified Operating Costs	270.43	274.60
	Returns Per Acre	
	---------------- Dollars ----------------	
Base price 0.64/lb of lint	137.89	211.16

continued

Table 4. Continued

	Specified operating costs	
Cultural Practice	Conventional	Deep Lime
Resource or Input	------------------- Dollars -------------------	
Tractors		
Depreciation	8.13	8.13
Interest	6.71	6.71
Equipment		
Depreciation	7.26	7.26
Interest	4.10	4.10
Special Equipment:		
Depreciation	32.21	32.21
Interest	13.55	13.55
Miscellaneous		
Depreciation	0	0
Interest	0	0
Irrigation:		
Depreciation	0	0
Interest	0	0
Taxes & Insurance	5.54	5.54
Interest	0.61	0.61
Overhead Labor	0	0
Other Overhead	0	0
Land & Property Tax	0	0
Management	0	0
Total Specified Ownership Costs	78.11	78.11
Total Specified Operating and Ownership Costs	348.54	352.71
	Returns Per Acre	
	------------------ Dollars ------------------	
Base price 0.64/lb of lint	59.78	133.05

[1] Not included in this report are charges for land risk, overhead labor, other overhead, crop insurance, real estate taxes and management.

Table 5. Lint yield as influenced by tillage and row spacing.

	Row Spacing	
Tillage System	30 in.	38 in.
	------------- lint yield (lb/acre) -----------	
Conventional	1117 a[1]	895 a
No-Till	755 b	611 b

[1] Numbers in same column followed by the same letter or in same row underlined with same line are not significantly different at the 5% level according to Duncan's New Multiple Range Test.

Table 6. Estimated costs and returns for various cotton production systems.[1]

	Specified Operating Costs			
Tillage Practice	Conventional		No-Till	
Spacing	30 in.	38 in.	30 in.	38 in.
Resource or Input	Dollars			
Seed	10.51	8.30	10.51	8.30
Fertilizer	31.40	31.40	31.40	31.40
Lime + Application	10.01	10.01	10.01	10.01
Herbicide	57.38	57.38	87.32	87.32
Fungicide	0	0	0	0
Insecticide	16.20	16.20	16.20	16.20
Defoliant	26.15	26.15	26.15	26.15
Aerial Application	9.54	7.53	9.54	7.53
Machinery:				
Fuel, Oil, Lubricants	25.05	25.05	18.84	18.84
Repairs	44.30	44.30	38.35	38.35
Labor	22.18	22.18	19.53	19.53
Irrigation:				
Fuel, Oil, Lubricants	0	0	0	0
Repairs	0	0	0	0
Irrigation Labor	0	0	0	0
Custom Spread	6.08	6.08	6.08	6.08
Custom Haul	0	0	0	0
Custom Dry or Ginning	0	0	0	0
Miscellaneous	4.00	4.00	4.00	4.00
Crop Insurance Premium	0	0	0	0
Other				
Interest on OP.CAP.	12.01	11.85	12.72	12.55
Total Specified	274.20	270.43	290.67	286.26
	Returns Per Acre			
	Dollars			
Base price 0.64/lb of lint	440.68	302.37	192.53	104.78

continued

Table 6. Continued.

	Specified Operating Costs			
Tillage Practice	Conventional		No-Till	
Spacing	30 in.	38 in.	30 in.	38 in.
Resource or Input	Dollars			
Tractors				
Depreciation	8.13	8.13	2.17	2.17
Interest	6.71	6.71	2.12	2.12
Equipment				
Depreciation	7.26	7.26	5.78	5.78
Interest	4.10	4.10	2.91	2.91
Special Equipment:				
Depreciation	32.21	32.21	32.21	32.21
Interest	13.55	13.55	13.55	13.55
Miscellaneous				
Depreciation	0	0	0	0
Interest	0	0	0	0
Irrigation:				
Depreciation	0	0	0	0
Interest	0	0	0	0
Taxes & Insurance				
Interest	0.61	0.61	0.61	0.61
Overhead Labor	0	0	0	0
Other Overhead				
Land & Property Tax	0	0	0	0
Management	0	0	0	0
Total Specified Ownership Costs	78.11	78.11	62.24	62.24
Total Specified Operating and Ownership Costs	352.31	348.54	352.91	348.42
	Returns Per Acre			
	Dollars			
Base price 0.64/lb of lint	362.57	224.26	130.29	42.62

[1] Not included in this report are charges for land risk, overhead labor, other overhead, crop insurance, real estate taxes and management.

LATE-SEASON FOLIAR NITROGEN FERTILIZATION OF COTTON 1988-1991

Derrick M. Oosterhuis, Bhaskar R. Bondada
and Phil N. Tugwell

INTRODUCTION

Foliar application of urea to cotton is a widely used practice in the Cotton Belt, but there is a lack of information concerning the effectiveness of late-season foliar nitrogen (N) applications by the cotton plant. The seasonal pattern of N distribution in the cotton plant has been documented (Oosterhuis et al., 1983), and we have recently described the pattern of N distribution along the fruiting branch with respect to developing bolls (Oosterhuis et al., 1989). These studies have shown that developing bolls have a high requirement for N that is not completely met by the subtending leaves from soil uptake, thereby indicating a requirement for additional N from foliar applications. Earlier studies of ours showed that foliar-applied ^{15}N urea is rapidly absorbed by the leaf to which it is applied and translocated into the closest boll as well as the next boll along the branch within 6 to 48 hours after application (Zhu and Oosterhuis, 1988). However, inadequate information exists regarding late-season foliar N applications and the effects on boll development and yield. Field studies were, therefore, conducted to investigate the value of late-season N applications and the effect of soil N status and to determine how late N applications can be beneficially applied.

PROCEDURES

All measurements were made on field-grown cotton (*Gossypium hirsutum* L. cv. Stoneville 506) planted near Marianna, Arkansas, in 1990 and 1991 and near Altheimer, Arkansas, in 1988 and 1990. Two levels of soil N were applied (low=80 lb N/acre; high=110 lb N/acre), half pre-plant and half side-dressed. Two foliar-N treatments (0, 1 or 2 applications) were used in 1988, and three foliar treatments (0, 1, 2 or 3 applications) were used in 1990 applied at weekly intervals starting early in August. In 1991 the three foliar treatments were applied as (a) a single application at the nodes-above-white-flower 7 stage (NAWF=7), (b) two applications at NAWF 7 and 6 and (c) three applications at NAWF 7, 6 and 5. All foliar sprays consisted of 10 lb N/acre of 23% N urea applied by a backpack sprayer using 10 L water/ha. Measurements of leaf area, dry matter, nodal development, boll development and petiole analysis were made during the season. Yield and components of yield were determined at final harvest. A ^{15}N-urea study was initiated in 1991 in which the canopy in 1 m of row was sprayed with ^{15}N-labelled urea (5% atom excess) solution at an equivalent rate of 10 lb N/acre. The bolls were subsequently harvested and analyzed for N to determine if the N had been absorbed and translocated to the developing bolls.

RESULTS AND DISCUSSION

In 1988 there were significant increases in yield from the foliar applications made to the cotton fertilized with the low soil N (80 lb N/ acre) but not from the cotton that received the higher level of soil N (110 lb N acre) (Table 1). Petiole analysis indicated a requirement for additional N in the cotton that received 80 lb N/acre but not in the cotton growing on the higher soil N (110 lb N/acre) treatment. These results indicated the importance of knowing both the soil N status and the plant N status in determining the possible benefits of late-season foliar N applications.

In 1990 there was a significant response to the foliar applications at Marianna but not at Altheimer. The study at Marianna received only a relatively low amount of soil N, and the yield response was to be expected. The lack of response at Altheimer was associated with the very adverse early-season conditions and resulting poor stands and very low yields. Results again showed that the soil and plant N status must be considered in relation to foliar-N applications.

There were no significant yield differences in 1991 (Table 1). This was probably related to the warm extended season after the foliar urea applications were completed, allowing the younger upper-canopy bolls, which would not usually have developed in time for harvest, to grow into mature harvestable bolls. The ^{15}N data is still being analyzed. The results should permit direct measurement of the absorption from the foliar treatments and also identify the bolls to which the ^{15}N is translocated.

Results indicate that although foliar-N applications can be beneficial, interactions exist with the fertility status of the crop and the type of season experienced. Further research is required. This study will be continued.

ACKNOWLEDGMENTS

This project was supported by grants from the Altheimer Foundation and the Arkansas Science and Technology Authority.

LITERATURE CITED

1. Oosterhuis, D.M., J. Chipamaunga and G.C. Bate. 1983. Nitrogen uptake of field grown cotton. I. Distribution in plant components in relation to fertilization and yield. Experimental Agriculture 19:91-101.
2. Oosterhuis, D.M., B. Zhu and S.D. Wullschleger. 1989. The uptake of foliar-applied nitrogen in cotton. pp. 23-26. Proc. 1989 Cotton Research Meeting. Arkansas Agricultural Experiment Station, Special Report 138.
3. Zhu, B. and D.M. Oosterhuis. 1988. Absorption and translocation of foliar-applied urea in cotton. Agronomy Abstracts. p 120.

Table 1. Influence of late-season foliar nitrogen and soil N status on cotton lint yield.

		Yield by treatment and year			
	Foliar N	1988	1990		1991
Soil N	treatment	Altheimer	Altheimer	Marianna	Marianna
		(lb lint/acre)			
Low	Control	826 c[1]	398 a	1371 b	1379 a
	1 application[2]	963 b	437 a	1387 bc	1534 a
	2 applications	1093 a	513 a	1467 ac	1445 a
	3 applications	--[3]	491 a	1506 a	1280 a
High	Control	858 bc	466 a	--	1471 a
	1 application	919 b	443 a	--	1692 a
	2 applications	899 bc	411 a	--	1741 a
	3 applications	--	342 a	--	1615 a

[1] Values in a column followed by the same letter are not significantly different ($P < 0.05$).

[2] Foliar urea @ 10 lb N/acre applied at approximately weekly intervals.

[3] Treatment not included.

EFFECTS OF FOLIAR APPLICATION OF FIVE POTASSIUM FERTILIZERS ON COTTON YIELD AND QUALITY

W. N. Miley, D. M. Oosterhuis, W. H. Baker and J. Varvil

INTRODUCTION

In earlier research by Oosterhuis et al. (1990, 1991), foliar-applied KNO increased cotton yield and improved fiber strength and uniformity. Since there were no known published data on the effects of foliar applications of other potassium (K) sources on cotton, there was a need for research on the effects of other common K fertilizers compared with the effects of KNO_3.

MATERIALS AND METHODS

An experiment was conducted on Loring-Calloway silt loam at the University of Arkansas Cotton Branch Station, Marianna, Arkansas, in 1991. Soil tests (Mehlich 3 extractant) showed an average of 179 lb K/acre in the surface 6 in. and 176 lb in the 7- to 12-in. soil zone. Before planting, the experimental area was fertilized with 50-30-60 lb of N, P_2O_5 and K_2O per acre, respectively, as recommended by the Cooperative Extension Service. On 15 July, 35 lb N/acre as ammonium nitrate was applied on the soil surface by airplane. Based on deficient N as shown by petiole tests, 10 lb urea N was foliar-applied on 26 August and again on 3 September. Plants were furrow-irrigated five times from mid-July through August. Irrigation efficiency and plant root development were adversely affected by soil compaction and a sand stratum that was detected at the 12- to 18-in. zone extending diagonally across the second, third and fourth replication.

Salts of K used included sulfate, chloride, thiosulfate, carbonate and nitrate. Solutions of these K sources were prepared so as to apply the equivalent of 10 lb of KNO_3/acre in 10 gal of solution per acre (Table 1). Each solution containing a source other than KNO_3 was fortified with urea sufficient to apply 1.3 lb N/acre, the rate supplied by the KNO_3 treatment. A solution containing only urea was prepared to apply 1.3 lb N/acre, the rate supplied by the KNO_3 (Table 1). The solution for treatment 7 consisted of the standard rate of N and K plus magnesium sulfate to supply 2 lb S/acre, considering the S contents of treatments 3 and 4.

Treatments shown in Table 1 were applied bi-weekly at 2, 4, 6 and 8 weeks after the start of flowering. Petioles of the uppermost mature leaves were sampled immediately prior to each foliar treatment application. The petioles were washed under a stream of distilled water, oven-dried and analyzed for nitrate N, P, K and S according to the method described by Maples et al. (1977).

After chemical defoliation, 2 m of each of the center rows was hand-harvested and weighed, and average boll weight was determined. The remainder of the cotton in the plots was mechanically harvested, weighed and added to the hand-picked weights. The samples were ginned and analyzed for lint strength, fiber uniformity and micronaire.

RESULTS

None of the K foliar treatments significantly affected cotton yield or boll weight (Table 2). Unusual soil variation was thought to be a factor in the lack of significant results. Further research on a more uniform soil area is warranted. The lack of significant response in 1991 was probably also due to the warm extended season, which allowed the plants in the different treatments to scavenge for additional K and the younger upper-canopy bolls, which would not usually have had the K or the time to fully develop, to grow into mature harvestable bolls.

Only very minor and non-significant visual symptoms of foliar burn were observed following foliar application of any of the K fertilizers (data not shown). The occasional visual symptoms consisted of a few small spots on the leaf. This result was unexpected; however, treatments were applied at the recommended optimum times of early morning or late afternoon.

None of the treatments significantly affected nitrate N or K in petioles sampled at 4, 6 and 8 weeks of flowering (data not shown). Lint quality analyses were not available on the due date of this report.

SUMMARY

Foliar applications of potassium nitrate, potassium sulfate, potassium thiosulfate, potassium chloride, potassium carbonate and a combination of potassium nitrate and magnesium sulfate did not significantly affect cotton yield, boll size and petiole contents of nitrate N or K. Soil compaction and a sand stratum occurring across plots in three replications contributed to variations that possibly limited precision in measuring treatment effects.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support of the Cedar Chemical Company, Chilean Nitrate Corporation, Kerley Ag, Inc. and Na-Churs Plant Food Company.

LITERATURE CITED

1. Oosterhuis, D.M., S.D. Wullschleger, R.L. Maples and W.N. Miley. 1990. Foliar feeding of potassium nitrate in cotton. Better Crops With Plant Food, Potash and Phosphate Institute. Summer 1990, pp. 8-9.
2. Oosterhuis, D.M., R.G. Hurren and W.N. Miley. 1991. Foliar-fertilization with potassium nitrate, 1989-1990. Arkansas Soil Fertility Studies 1990. Arkansas Agricultural Experiment Station Research Series 411. pp. 93-95.
3. Maples, R.L., J.L. Keogh and W.E. Sabbe. 1977. Nitrate monitoring for cotton production in Loring-Calloway silt loam. Arkansas Agricultural Experiment Station Bulletin 825.

Table 1. Potassium sources and rates of nutrients per treatment in each of four applications.

Treatment no.	Potassium source and rate per application[1]	Nutrients per application N	K_2O	S[2]
		------------lb/acre-----------		
1	Check	1.3	0	0
2	K nitrate (KNO_3), 10 lb/acre	1.3	4.4	0
3	K sulfate (K_2SO_4), 8.8 lb/acre	1.3	4.4	1.6
4	K thiosulfate ($K_2S_2O_3$), 17.9 lb/acre	1.3	4.4	3.0
5	K chloride (KC1), 7.1 lb/acre	1.3	4.4	0
6	K carbonate (K_2CO_3), 14.7 lb/acre	1.3	4.4	0
7	K nitrate, 10 lb + Mg sulfate, 15.4 lb/acre	1.3	4.4	2.0

[1] Treatments 1, 3, 4, 5 and 6 also received 1.3 lb urea N/acre, the rate equivalent to that in 10 lb KNO_3/acre.

[2] The total lb/acre of foliar-applied nutrients amounted to 5.2 N for all treatments; 17.6 K_2O for all treatments except the check; and an additional 4.8, 12.0 and 8.0 S for treatments 3, 4 and 7, respectively.

Table 2. Effects of foliar applications of five potassium sources on cotton yield and boll weight.

Treatment no.	Potassium Source	Yield, lb lint per acre	Boll weight g/boll
3	K sulfate	1059 a[1]	4.64 a
7	K nitrate + Mg sulfate	1047 a	4.72 a
2	K nitrate	1036 a	4.81 a
4	K thiosulfate	1030 a	5.05 a
5	K chloride	989 a	4.84 a
1	Check	974 a	4.82 a
6	K carbonate	952 a	4.82 a

[1] Numbers within columns followed by the same letter are not significantly different ($P = 0.05$).

FOLIAR FERTILIZATION OF COTTON WITH POTASSIUM NITRATE, ARKANSAS 1989-1991

D.M. Oosterhuis, W.N. Miley, L.D. Janes, W.H. Baker, J.S. McConnell, P.W. Parker and M.B. Bryles

INTRODUCTION

The use of higher-yielding, faster-fruiting cotton (*Gossypium hirsutum* L.) cultivars has resulted in the appearance of fairly widespread potassium (K) deficiencies. These deficiencies can be corrected through preplant soil applications or partially corrected using midseason sidedress applications of potassium. Foliar applications of K may offer the opportunity of correcting these deficiencies more quickly and efficiently, especially late in the season when soil application of K may not be effective. Foliar applications have the advantage of allowing producers to add the necessary K, when tissue analysis indicates an impending shortage, thereby correcting the deficiency and preventing yield loss.

While there are many reports on research involving soil-applied K (e.g. Kerby and Adams, 1985), there are no definitive studies available on the usefulness of foliar-applied KNO_3. Preliminary research in 1989 in Arkansas (Oosterhuis et al., 1990) indicated that foliar applications of KNO_3 increased both yield and lint quality. With the national emphasis on lint quality, the effect of KNO_3 on lint quality may be of paramount importance. The objectives of the current research are to investigate the effect of foliar-applied KNO_3 compared to soil-applied KCl on cotton yield and fiber quality and to evaluate the potential of foliar-applied K for alleviating K deficiency in field-grown cotton.

PROCEDURES

Field trials were conducted from 1989 to 1991 at seven sites in Arkansas; the Main Experiment Station (MES), Fayetteville (1989 and 1990); the Cotton Branch Station (CBS), Marianna (1990 and 1991); the R.D. Jackson Farm (MSCO), Leachville (1991); the Northeast Research and Extension Center (NEREC), Keiser (1991); and the

Southeast Branch Experiment Station (SEBES), Rohwer (1991). Production practices were in keeping with those recommended by the Cooperative Extension Service. In 1989 a latin square design was used with four replications, and in 1990 and 1991 a randomized complete block design with five replications was used. In 1989 and 1990 four treatments were used: (1) a check with no added soil or foliar K, (2) soil-applied KCl preplant, (3) foliar-applied KNO_3 at 2, 4, 6 and 8 weeks after first flower and (4) preplant soil-applied KCl and foliar-applied KNO_3 at 2, 4, 6, 8 and 10 weeks after white flower appearance. The foliar rate was 10 lb KNO_3 /acre in 10 gal water/acre applied using a knapsack sprayer.

In 1991 five treatments were used: (1) a check with no added soil or foliar K, (2) low soil-applied KCl preplant (soil test recommendation) (3) high soil-applied KCl preplant (i.e. at twice soil recommendation) (4) low preplant soil-applied KCl and foliar-applied KNO_3 (4 X 10 lb KNO_3/acre) and (5) high preplant soil-applied KCl and foliar-applied KNO_3 (4 X 10 lb KNO_3/acre). In addition, 1.38 lb N/acre was added as foliar urea to treatments 2 and 3 each time the foliar KNO_3 was applied in treatments 4 and 5 so as to negate the possible effect of the N in KNO_3. The low and high soil rates were 30 and 60 lb K/acre, respectively, at CBS, NEREC and SEBES and 120 and 180 lb K/acre at MSCO.

Leaf, petiole and boll samples were taken at weekly intervals for nutrient analysis starting one week prior to first flower. Leaf area and total dry matter were recorded at peak flowering in mid-August. Lint quality (length, strength, fineness and maturity), boll number, boll weight and total lint yield were determined at final harvest. Two hundred bolls were tagged in each plot at 2, 4 and 6 weeks after flowering. Ten tagged bolls were sampled from each plot at two-week intervals and analyzed for the concentration of K in the seed, lint and capsule wall. Data were collected during the vegetative stage of growth concerning maximum possible rates of KNO_3 in relation to foliar burn. KNO_3 was sprayed in replicated rows of cotton at 0, 2.5, 5, 10, 15 and 20 lb KNO_3/acre in 10 gal water/acre using a backpack sprayer, and foliar burn symptoms were rated daily for a week after spraying.

RESULTS AND DISCUSSION

Potassium deficiency symptoms occurred in all treatments at most sites but least of all in the soil-plus-foliar K treatment. The deficiency symptoms consisted of yellowish-white mottling of the older foliage that changes the leaf color to light yellowish green. Yellow spots appeared between the veins; then the center of these spots eventually died and numerous brown specks occurred at the leaf tips, around margins and between veins. Petiole nitrate analysis of upper-canopy leaves indicated that the combined application of soil and foliar K significantly enhanced plant K content compared to controls during both vegetative and reproductive development. No consistent differences in N, P and S nutrition were noted.

The initial soil K in 1989 was 358 lb K/acre; in 1990 it was 168 and 208 lb K/acre at MES and CBS, respectively; and in 1991 it was 243, 245, 488 and 194 lb K/acre at CBS, MSCO, NEREC and SEBES, respectively.

Visible symptoms of foliar burn were not observed following the application of up to 20 lb KNO_3/acre.

In 1989 and 1990 the application of foliar KNO_3 either alone or in combination with soil KCl had a beneficial effect on both boll dry weight and final seedcotton yield (Table 1). The greatest influence on average boll weight and yield was obtained from the combined soil and foliar K treatment, followed by foliar KNO_3, and then finally by soil-applied KCl alone. Lint yield in 1990 at CBS was significantly increased from 1410 lb/acre to 1642 lb/acre following the combined application of soil and foliar K. In 1991 foliar-K application had no significant effect on yield although the trends were similar to previous years. The lack of significant response in 1991 was probably due to the warm extended season, which allowed the younger upper-canopy bolls, which would not usually have had the K or the time to fully develop, to grow into mature harvestable bolls.

Soil- and foliar-applied KNO_3 also had a significant influence on fiber quality in 1989 and a similar trend in 1990. In 1989 both fiber uniformity and strength were increased in KNO_3-treated plants, whereas micronaire and length were unaffected. Application of KNO_3 either as foliar treatments or in combination with supplemental soil KCl effectively improved uniformity and strength. Surprisingly, soil application of KCl alone did not enhance any of the fiber quality components. The fiber quality data from 1991 are not yet available.

Foliar-plus-soil K increased fiber dry weight compared to the preplant soil application of K (Fig. 1). The K concentration and the K content of the fibers were also increased by the foliar-plus-soil K application (data not shown). The most rapid increase in fiber K occurred between 28 and 42 days after anthesis, with a maximum at 42 days. This period coincides with the time of secondary wall thickening. The K content of the seed continued to increase after day 42 after anthesis. The dry weight of the capsule wall peaked at 28 days and the K content at 42 days. The capsule wall contained the highest amount of K of the three components and may have acted in a storage capacity.

This research will be continued in 1992 with more emphasis on both basic and applied aspects.

CONCLUSIONS

In 1989 and 1990 yield and lint quality improvements resulted from cotton fertilized with both soil-applied and foliar-applied K, but especially for a combination of soil and foliar applications. In 1991, however, no significant effects of foliar-applied potassium on yield were recorded although the trends were similar to previous years. Fiber uniformity and strength increased with foliar applications of KNO_3 in 1989 and 1990. The quality data from 1991 is not yet available. These results suggest that where potential K deficiency exists, foliar fertilization with KNO_3 to supplement soil-applied K can have a significant effect on cotton yield and fiber quality.

ACKNOWLEDGMENTS

The author acknowledges the assistance of Robert Hurren, Merritt Holman, Bhaskar Bondada and Mike Withrow. The help of the Director and staff of the Cotton Branch Experiment Station, the Northeast Research and Extension Center and the Southeast Branch Experiment Station is also greatly appreciated. The study was supported by Cotton Incorporated, Cedar Chemicals and the Phosphate and Potash Institute.

LITERATURE CITED

1. Kerby, T.A. and F. Adams. 1985. Potassium nutrition of cotton. p. 843-860. *In* Potassium in agriculture. American Society of Agronomy, Madison, WI.
2. Oosterhuis, D.M., S.D. Wullschleger, R.L. Maples and W.N. Miley. 1990. Foliar-application of potassium nitrate in cotton. Better Crops, Summer 1990. p. 8-9.
3. Oosterhuis, D.M., R.G. Hurren, W.N. Miley and R.L. Maples. 1991. Foliar-fertilization of cotton with potassium nitrate. pp. 21-25. *In*: 1991 Proc. Cotton Res. Meeting, Univ. of Arkansas, Ark. Agri. Exp. Stn. Special Report 149.

Table 1. The influence of soil- and foliar-applied K on cotton yields at four sites in Arkansas, 1989 to 1991.

	1989	1990		1991			
Treatment	MES[1]	CBS	MES	NEREC	MSCO	CBS	SEBES
	lb lint/acre						
Control	541 c[2]	1410 c	745 c	877 a	931 b	1033 a	1338 a
Low soil K	553 bc	1540 b	754 bc	893 a	984 bc	1025 a	1353 a
High soil K	--[3]	--	--	863 a	1012 ac	1080 a	1330 a
Foliar KNO_3	563 ab	1540 b	810 ab	--	--	--	--
Low soil + foliar K	579 a	1642 a	815 a	911 a	1122 a	1093 a	1411 a
High soil + foliar K	--	--	--	906 a	1091 a	1055 a	1245 a

[1] MES = Main Experiment Station, Fayetteville, Arkansas; CBS = Cotton Branch Station, Marianna, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas; MSCO = R.D. Jackson Farm, Mississippi County, Arkansas; SEBES = Southeast Branch Experiment Station, Rohwer, Arkansas.

[2] Values within a column followed by the same letter are not significantly different ($P = 0.05$).

[3] Treatment not included.

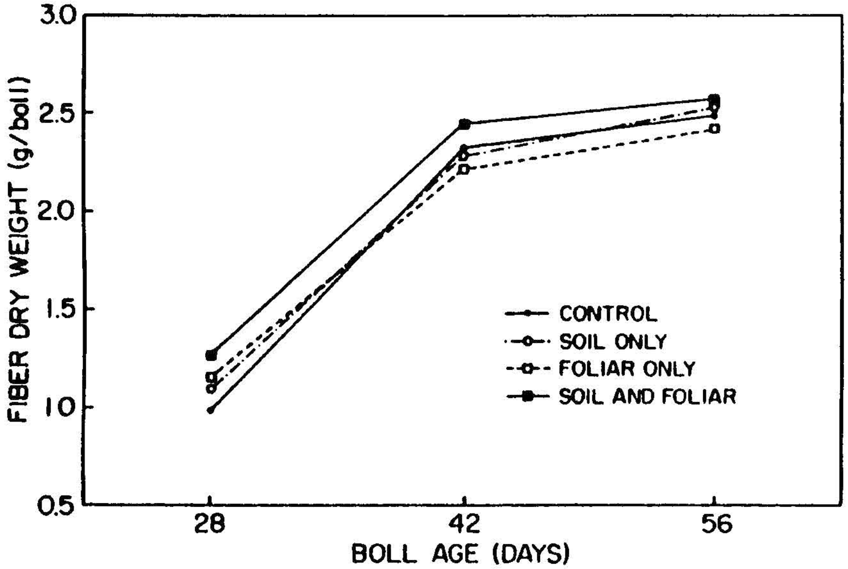

Fig. 1. The effect of soil- and foliar-applied KNO_3 on fiber dry weight during boll development.

EFFECT OF FOLIAR FERTILIZATION ON DROUGHTED COTTON SEEDLINGS.

E.M. Holman, D.M. Oosterhuis and R.G. Hurren

INTRODUCTION

The application of foliar nutrients to cotton (*Gossypium hirsutum* L.) to enhance boll development during flowering is an accepted and well-documented practice in Arkansas. Although much research has been conducted in this area, the benefits of applying foliar N and K to vegetative cotton have not been investigated. It is possible that foliar-applied N or K could partially offset the effect of water-deficit stress on early-season cotton growth by providing to the plants nutrients that would not otherwise be available from the soil due to the drying conditions. Therefore, this experiment was designed to examine the effects of foliar-applied N and K on the growth and drought tolerance of vegetative cotton.

PROCEDURE

A growth chamber study was conducted as a completely randomized design with four replications. The cultivar 'Stoneville 506' was grown in 72 2-L pots containing sand with one plant/pot under a 12-hour photoperiod and an average day/night temperature of 30/25 C. The plants were watered daily with 1:1 distilled water and a modified Hoaglands solution until 21 days after planting.

The plants were divided into six treatments, and at 21 days after planting watering was discontinued in three of the treatments, with the other three treatments remaining well watered (WW). Of the three water-deficit (WD) stressed treatments, one received a foliar-urea spray (5 lb N/acre with a 10-gal total spray volume) four days after cessation of watering. On the same day, the second WD treatment received a water spray at the same total volume per acre as the urea spray. The third WD treatment did not receive anything, which is equivalent to the current production practice. The three WW treatments were treated similarly with one receiving a urea spray, one a water spray and one no foliar spray.

Measurements of plant height, leaf area and shoot and root dry weight were taken on four plants/treatment at day 0, 4 and 8 of the stress period. Components of leaf water potential, diffusive resistance, transpiration and leaf extension growth were recorded at two-day intervals throughout the stress. This experiment was repeated to confirm the results, and the procedure was run again using a KNO_3 spray (10 lb K/acre with a 10-gal spray volume) in the place of the urea spray; however, growth analysis was not taken.

RESULTS AND DISCUSSION

Foliar N Study

By day 6 of the stress period, the leaf water potentials of the WD treatments had declined to an average of -16 bars compared to -12 bars for the WW treatments, but no significant differences were observed between the spray treatments within each water regime for leaf water, osmotic or pressure potential. The same trend was observed for diffusive resistance, transpiration and leaf extension with the only differences occurring between the averages of the WW and WD treatments. Plant height at day 8 was significantly greater in the WD-plus-urea and WD-plus-water treatments compared to the WD-only treatment by 6.3 and 5.6 cm, respectively (Table 1), suggesting that this difference was largely due to the water that was applied and not the urea. No differences in plant height were observed at any day between the WW treatments. Only slight differences were seen among any of the treatments for leaf area, shoot dry weight and root dry weight. Although there were no differences within water regimes for shoot and root dry weight, the average root/shoot ratio for the WD treatments at day 4 was 0.62 compared to an average of 0.36 for the WW treatments. This trend was also observed on day 8; however, at neither day was the urea spray significantly different from the other treatments within a water regime, indicating that the ratios were again due primarily to the water regime.

Foliar K Study

The WD treatment again had the dominant effect on all parameters measured, irrespective of the foliar-spray treatment applied. Foliar applications of KNO_3 showed no greater benefit on 3-week-old cotton plants than the water-spray treatment. However, within the WD treatments, both the K treatment and the water treatment were able to maintain the plants at diffusive resistances of 5.5 cm/s for three days after spraying as compared to the WD only treatment, which rose above 10 cm/s. Measurements of transpiration, leaf extension and components of water potential all showed the same trend with the only effect being the watering regime.

We conclude that although within the WD treatments both the water and N sprays caused a slight growth increase, N was of no more benefit to the plants than the water spray alone. Within the WD treatments, the K spray along with the water spray maintained a lower stomatal resistance than the WD-only treatment. However, as with the N treatment, the K itself did not improve plant drought resistance. Therefore, the potential benefit from such applications is not sufficient to warrant their use. Future research will address the effects of foliar fertilizer sprays on cotton seedlings during waterlogging and low temperatures.

ACKNOWLEDGMENTS

The authors gratefully acknowledge helpful discussions with Claude M. Bonner and Woody N. Miley.

Table 1. Foliar N study: Plant height, leaf area, shoot dry weight, root dry weight and root to shoot ratio (R/S) of well-watered (WW) and water-deficit (WD) vegetative cotton measured 8 days after the onset of stress.

	Shoot			Root	
Treatment	Height	Leaf area	Dry weight	Dry weight	R/S
	cm	cm^2	g	g	
Urea + WS	35.7[1]	240	2.96	0.97	0.33
Water + WS	35.0	200	2.49	1.33	0.53
Only WS	29.4	165	2.24	0.96	0.43
Urea + WW	38.5	288	2.86	0.67	0.23
Water + WW	33.5	276	2.47	0.70	0.28
Only WW	41.7	387	3.19	0.73	0.23
$LSD_{0.05}$	4.0	66	0.94	0.58	0.20

[1] Each value in the table is the mean of four observations.

IRRIGATION METHODS AND NITROGEN FERTILIZATION RATES IN COTTON PRODUCTION

J.S. McConnell, W.H. Baker, B.S. Frizzell and J.J. Varvil

INTRODUCTION

Management of nitrogen (N) and irrigation are two of the most important aspects of cotton (*Gossypium hirsutum*, L.) production. Under-fertilization of a developing cotton crop will reduce growth and fruiting and thereby limit yield. Over-fertilization of cotton with N may induce rank growth and reduce fruit set. Both conditions may result in delayed maturity and reduced yield.

Adequate soil moisture is also necessary for cotton to achieve optimum yields. Cotton subjected to substantial drought stress will not grow or fruit properly and will suffer diminished yields. The roots of the cotton are the only plant part able to absorb air. If the soil becomes too wet and oxygen is excluded from the soil for even a few days, the plants will undergo oxygen stress and begin to shed small and moderately sized bolls as well as squares.

The primary objective of these studies is to evaluate N rates and split applications under several irrigation methods on intensively managed cotton.

PROCEDURES

The effects of five irrigation methods and 10 N rates and split applications were investigated to determine their influence on the yield and development of cotton. This study was conducted at the Southeast Branch Experiment Station near Rohwer, Arkansas, on an Hebert silt loam (Aeric Ochraqualfs) and was begun in 1988. The five irrigation methods are described in Table 1. Six different N rates (0, 30, 60, 90, 120 and 150 lb urea-N/acre) were split with half the N applied preplant (PP) and half applied when the crop reached the first square (FS) stage. The three highest N rates were also split three ways with one third of the total applied PP, one third at FS and one third at the first bloom (FB) stage. The 150-lb N/acre treatment was also split 30, 60 and 60 lb N/acre at PP, FS and FF, respectively. The experimental design was a split block with 10 replications. The main blocks were irrigation methods. Data were analyzed using the Statistical Analysis System (SAS) at the 0.05 level of probability.

RESULTS

Significant lint yield responses ($P = 0.05$) to the irrigation methods were found in 1988 and 1990 of the study (Table 2). An unusually wet growing season in 1989 precluded the need for irrigation. These results indicate that irrigated cotton yields were superior to dry-land cotton yields. Optimum yields were obtained with center pivot irrigation in 1988 and furrow irrigation in 1990. Long-term irrigation studies have shown irrigation method to be less important to cotton lint yield than irrigation usage under similar experimental conditions (McConnell et al., 1988). Although percent first harvest (PFH) was found to be significantly different due to irrigation methods, the means were tightly grouped both years of the study. Final plant heights (Ht) were generally tallest under center pivot irrigation and shortest under dry-land conditions.

Lint yield means were influenced by the N fertilization treatments within each irrigation block both years, except the Moderate Frequency Center Pivot method in 1988 and 1990 (Table 3). Lack of response of cotton to N fertilizer in the initial years of an experiment is not surprising. Other research has shown that several cropping years may be necessary to produce significant yield differences (Maples et al., 1977). The other four irrigation blocks exhibited similar yield trends in response to the N application. Generally, lint yield was found to increase with increasing N fertilization. Exceptions were found for the 150-lb N/acre treatment (75 lb N/acre PP and 75 lb N/acre FS), which was found to decrease lint yield in some irrigation blocks, and the High Frequency Center Pivot block in 1990. The N treatment that usually resulted in the greatest lint yield was a three-way split application of either 150 or 120 lb N/acre. The yields of the High Frequency block in 1990 were influenced by verticillium wilt. The disease was more virulent in the plots receiving higher N rates, thereby reducing yields with increasing N.

LITERATURE CITED

1. Maples, R., J.G. Keogh and W.E. Sabbe. 1977. Nitrate monitoring for cotton production in Loring-Calloway silt loam. Univ. of Ark. Agric. Exp. Sta. Bull. 825.

2. McConnell, J.S., B.S. Frizzell, R.L. Maples and G.A. Mitchell. 1988. Relationships of irrigation methods and nitrogen fertilization rates in cotton production. Univ. of Ark. Agric. Exp. Sta. Rep. Ser. 310.

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

Irrigation methods	Duration	Tensiometer threshold	Tensiometer depth	Water applied
		cbar	in.	in.
High Frequency	Planting to P.B.[1]	35	6	0.75
Center Pivot	P.B. to Aug. 15	35	6	1.00
Mod. Frequency	Planting to			
Center Pivot	Aug. 15	55	6	1.00
Low Frequency	First Irrigation	55	12	1.00
Center Pivot	Until Aug. 15	55	6	1.50
Furrow Flow	Until Aug. 15	55	12	Not Precise
Dry land	Not Irrigated	--	--	---

[1] P.B. = Peak Bloom

Table 2. Lint yield, percent first harvest (PFH) and final plant height (Ht) responses of cotton to five irrigation methods in 1988 and 1990.

	1988			1990		
Method	Yield	PFH	Ht	Yield	PFH	Ht
	lb/acre	%	in.	lb/acre	%	in.
High Frequency Center Pivot	1567ab	95.7a	42a	1118c	90.6b	44a
Moderate Frequency Center Pivot	1410bc	90.4d	41ab	1461ab	88.8b	45a
Low Frequency Center Pivot	1620a	92.7bc	37c	1442b	90.1b	43a
Furrow Flow	1370c	91.2cd	40b	1511a	93.7a	40b
Dry Land	1271c	93.5b	33d	915d	94.2a	22c
LSD (.05)	159	1.8	3	67	2.1	3

Table 3. Lint yield response of cotton to 10 nitrogen (N) fertilization rates and splits under five irrigation methods in 1988, 1989 and 1990.

N Rate							
PP[1]	FS	FF	LF[2]	MF[2]	HF[2]	FI[2]	DL[2]
lb N/acre			lb lint/acre				
1988							
75	75	0	1906 a	1730	1524 ab	1571 ab	1378 a-c
50	50	50	1730 ab	1395	1631 ab	1627 a	1409 ab
30	60	60	1588 bc	1549	1682 a	1508 ab	1319 a-c
60	60	0	1776 ab	1439	1567 ab	1417 bc	1273 bc
40	40	40	1763 ab	1360	1683 a	1467 bc	1449 a
45	45	0	1738 ab	1153	1600 ab	1479 ab	1293 a-c
30	30	30	1756 ab	1470	1693 a	1549 ab	1400 ab
30	30	0	1632 a-c	1358	1533 ab	1288 c	1215 cd
15	15	0	1328 cd	1409	1464 bc	976 d	1048 d
0	0	0	1069 d	1235	1295 c	739 e	838 e
LSD(.05)			314	NS	188	190	175
1989							
75	75	0	1115 ab	903 a-c	959 ab	1080 a-c	1294 ab
50	50	50	1067 ab	938 ab	992 ab	1066 a-c	1321 a
30	60	60	1214 a	869 a-c	942 ab	1154 a	1170 cd
60	60	0	1182 a	1069 a	976 ab	1111 ab	1227 a-c
40	40	40	1177 a	1045 ab	1071 a	998 cd	1250 a-c
45	45	0	1175 a	979 ab	855 b	1143 ab	1214 a-c
30	30	30	1170 a	842 b-d	1045 a	1173 a	1187 bc
30	30	0	993 bc	1045 ab	919 ab	1035 b-d	1058 d
15	15	0	917 c	700 cd	843 b	929 d	861 e
0	0	0	747 d	616 d	625 c	629 e	497 f
LSD(.05)			148	228	154	108	115
1990							
75	75	0	1474 a	1479	1018 d	1601 a	1002 a
50	50	50	1464 a	1539	1022 cd	1517 ab	1033 a
30	60	60	1542 a	1344	1011 d	1563 a	955 ab
60	60	0	1396 a	1522	1091 b-d	1531 ab	825 b
40	40	40	1525 a	1468	1191 a-c	1663 a	1000 a
45	45	0	1491 a	1582	1112 a-d	1596 a	957 ab
30	30	30	1421 a	1487	1155 a-d	1663 a	995 ab
30	30	0	1515 a	1392	1234 ab	1636 a	911 ab
15	15	0	1440 a	1571	1265 a	1374 b	867 b
0	0	0	1169 b	1238	1106 a-d	995 c	663 c
LSD(.05)			184	NS	172	185	133

[1] Preplant (PP), first square (FS) and first flower (FF).

[2] Low frequency (LF), moderate frequency (MF), high frequency (HF), furrow irrigated (FI), dry land (DL).

RESPONSES OF THREE COTTON CULTIVARS TO NITROGEN FERTILIZATION IN SOUTHEAST ARKANSAS

J.S. McConnell, W. H. Baker, B. S. Frizzell and J. J. Varvil

INTRODUCTION

Cotton (*Gossypium hirsutum*, L.) cultivars have been shown to vary in yield potential, earliness, disease resistance, insect resistance, fiber properties and many other characteristics (Niles and Feaster, 1984). Proper nitrogen (N) fertilization of cotton is of primary importance in achieving optimum lint yield. Maples and Frizzell (1985) demonstrated that certain cultivars ('Rex 713', 'Stoneville 213' and 'Deltapine 61') responded differently to preplant (N) fertilization rates from 0 to 150 lb N/acre. Generally, they concluded that the later-maturing cultivars required more N to maximize lint yield. The objective of this study was to observe the response of three modern cultivars, including an Acala type, to five N fertilizer rates.

PROCEDURES

The responses of three cotton cultivars to five N rates was investigated at the Southeast Branch Experiment Station near Rohwer, Arkansas. This study was conducted on an Hebert silt loam (Aeric Ochraqualfs) under furrow-irrigated, optimum-management conditions. The experimental design is split-plot with N rate as the main plot.

Three cotton cultivars were used to represent different maturity groups. 'Deltapine 90' (DPL 90) is a late-maturing Acala type; 'Stoneville 453' (ST 453) is a moderate-maturing cultivar; and 'Arkot 518'. (A 518) is one of the earliest-maturing cultivars commercially available. All three cultivars exhibit characteristics that make them advantageous to cotton producers in the Mississippi River Delta region. The DPL 90 has superior fiber properties, especially fiber strength. The ST 453 has a very high yield potential. The early-maturing A 518 allows a shorter time for production inputs and thus a more timely harvest.

Commercially available urea (46-0-0) was the N source employed in this study. The rates of N applied as treatments were 0, 50, 100, 150 and 200 lb N/acre. The N fertilizer was split between preplant (PP), first square (FS) and first flower (FF) applications in 50-lb N/acre increments.

Data collected from this study included yield, lint turn-out, percent first harvest (PFH), petiole NO_3^--N, uppermost white flower counts and final plant height (Ht). Data were analyzed using the Statistical Analysis System (SAS) at the 0.05 level of probability.

RESULTS

Significant main effects were observed for PFH of the cultivars, and for yield, PFH and Ht of the N rates in 1989 (Table 1). Significant main effects observed in 1990 were Ht of cultivars and yield and Ht of the N treatments. The interaction effects of cultivar and N rate were not significant ($P = 0.05$) in the 1989 growing season with respect to yield, PFH or Ht. The interaction of cultivars with N rates significantly affected PFH in 1990 (Table 2).

The response of the cultivars was generally limited both years of the study. The A 518 cultivar had a significantly higher PFH than either the ST 453 or DPL 90 cultivars in 1989. The greater PFH is indicative of the earliness of A 518 compared to the other two cultivars. ST 453 and DPL 90 were not significantly different in PFH. Significant differences in Ht were observed in 1990. DPL 90 was found to be the tallest, A 518 intermediate in Ht, and ST 453 the shortest.

Greatest differences occurred as a function of the fertilization levels. Yield was greater for the 100-, 150- and 200-lb N/acre treatments than for the 0- and 50-lb N/acre treatments. Cotton that received only PP or no N yielded significantly less lint in 1989 than the cotton that received an FS or FF application. The 50-lb N/acre treatment produced lint yields that were not significantly less than the higher N treatments in 1990. The Ht also increased with increasing N. The PFH generally decreased as N was increased. This indicated that the additional N produced a greater but less-mature top crop.

The interaction means of cultivars and N rates were not significantly different except PFH in 1990. The trends observed in PFH and Ht for the cultivar-N rate interaction were similar to the overall N rate effect. The trends in the yield data indicated that the cultivars may respond differently to N fertilization but that the response will probably differ between growing seasons.

LITERATURE CITED

1. Maples, R., and M. Frizzell. 1985. Effects of varying rates of nitrogen on three cotton cultivars. Univ. of Ark. Agric. Exp. Sta. Bull. 882.
2. Niles, G.A., and C.V. Feaster. 1984. Breeding. *In:* R.J. Kohel and C.F. Lewis (eds.). Cotton. American Society of Agronomy, Inc. Madison, WI.

Table 1. Seed cotton yield, percent first harvest (PFH) and final plant height (Ht) responses of 'Arkot 518', 'Stoneville 453' and 'Deltapine 90' to five nitrogen rates in 1989.

N Rate			Arkot 518			Stoneville 453		
PP	FS	FF	Yield	PFH	Ht	Yield	PFH	Ht
lb N/acre			lb/acre	%	in.	lb/acre	%	in.
50	50	100	2756	84.7	37.2	2925	79.9	38.9
50	50	50	2178	84.4	36.2	2629	80.1	37.5
50	50	0	2671	87.2	41.0	2585	82.0	36.3
50	0	0	2161	88.9	32.9	2141	85.3	29.8
0	0	0	1691	87.8	27.5	1779	83.8	28.5
$LSD_{0.05}$			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Avg of N rates			2292	86.6a	35.0	2384	82.4b	33.8
$LSD_{0.05}$			N.S.	1.66	N.S.			

N Rate			Deltapine 90			Avg of Cultivars		
PP	FS	FF	Yield	PFH	Ht	Yield	PFH	Ht
lb N/acre			lb/acre	%	in.	lb/acre	%	in.
50	50	100	2430	81.9	38.7	2701 a	82.0 a	38.3 a
50	50	50	2664	80.8	38.6	2493 ab	81.8 a	37.5 ab
50	50	0	2826	85.1	38.6	2694 a	84.7 ab	38.6 a
50	0	0	2623	86.1	37.8	2319 b	86.6 b	33.5 b
0	0	0	1467	85.1	25.8	1656 c	85.4 b	27.3 c
$LSD_{0.05}$			N.S.	N.S.	N.S.	306.2	3.41	4.68
Avg of N rates			2424	83.7b	36.2			

Table 2. Seed cotton yield, percent first harvest (PFH) and final plant height (Ht) responses of 'Arkot 518,' 'Stoneville 453' and 'Deltapine 90' to five nitrogen rates in 1990.

N Rate			Arkot 518			Stoneville 453		
PP	FS	FF	Yield	PFH	Ht	Yield	PFH	Ht
lb N/acre			lb/acre	%	in.	lb/acre	%	in.
50	50	100	2549	92.3	44.0	2570	91.1	40.5
50	50	50	2234	93.0	45.0	2543	90.7	39.5
50	50	0	2320	90.0	41.5	2715	91.7	34.3
50	0	0	2384	92.5	38.5	2186	93.5	30.4
0	0	0	2010	91.7	27.7	2024	91.7	24.4
$LSD_{0.05}$			N.S.	3.35	N.S.	N.S.	3.35	N.S.
Avg of N rates			2298	92.0	39.3b	2408	91.7	33.9c
$LSD_{0.05}$			N.S.	-	2.18			

N Rate			Deltapine 90			Mean of Cultivars		
PP	FS	FF	Yield	PFH	Ht	Yield	PFH	Ht
lb N/acre			lb/acre	%	in.	lb/acre	%	in.
50	50	100	2443	90.2	48.3	2521 a	91.2	44.3 a
50	50	50	2749	87.9	52.4	2509 a	90.5	45.6 a
50	50	0	2487	91.1	45.3	2536 a	91.1	40.3 b
50	0	0	2491	91.8	38.3	2354 ab	92.6	35.7 c
0	0	0	2093	89.8	25.8	2042 b	91.1	27.2 d
$LSD_{0.05}$			N.S.	3.35	N.S.	322.6	-	3.78
Avg of N rates			2453	90.1	42.8a			

EFFECT OF NITROGEN RATE ON FOUR COTTON CULTIVARS GROWN ON A SANDY SOIL 1990-1991

H.J. Mascagni, Jr., W.H. Baker, R.L. Maples, W.E. Sabbe and P.W. Parker

INTRODUCTION

In order to balance nitrogen (N) inputs with cotton yield capability, it is necessary to know how well each cultivar can respond to N inputs and its tolerance to higher-than-average rates of N. This study was designed to 1) measure yield response of four cultivars to varying rates of N and 2) develop soil and plant diagnostic criteria to improve the accuracy of N fertilizer recommendations for a sandy soil.

PROCEDURE

A field experiment was conducted in 1990 and 1991 on a Routon-Dundee-Crevasse complex on a farmer's field (David Wildy farm) near Manila, Arkansas. The soil in the experimental area was primarily a Dundee sandy loam (fine silty, mixed, thermic, Aeric Ochraqualfs).

The experimental design was a randomized complete block with a split plot arrangement of treatments. There were five replications. Nitrogen treatments were the main plots and cultivars the split plots. The experiments were repeated on the same plots each year.

The N treatments consisted of five soil N rates and a soil N rate plus a supplemental N rate (total of six treatments). Five N rates (0, 50, 100, 150 and 200 lb N/acre) as urea were applied broadcast on the soil. Fifty pounds of N was applied preplant for all treatments except the control. An additional 50 lb N/acre was applied on the 100-, 150- and 200-lb N/acre plots at pin-head squaring, and the remainder of the 150- and 200-lb N/acre rate was applied at full squaring. Also included in this study was a treatment in which 100 lb N/acre was applied on the soil as described above, and supplemental N was applied, soil and/or foliar, whenever NO_3-N content in the petioles was deficient as determined by the University of Arkansas' petiole nitrate monitoring program. For foliar-N treatments, 9 to 10 lb N/acre was applied using liquid urea (23% N). The initial preplant N was incorporated by discing, and all subsequently applied N was cultivated in or watered in soon after application. The cultivars 'Deltapine 20', 'Deltapine 50', 'Stoneville 453' and 'Stoneville 506' were planted 8 May in 1990 and 7 May in 1991.

Petiole samples were taken weekly for eight weeks starting one week prior to flowering. Samples were taken from the fourth petiole from the top of the plant. Soil samples were collected from the check plots at the initiation of the test and prior to the application of N treatments in 1991. Samples were collected at 6-in. increments down to a depth of 24 in.

Recommended cultural practices were followed by the farmer during this study. A boll-opener was not applied. The cotton was irrigated using a center-pivot irrigation system. Yield was determined on each plot and is reported as seedcotton yield.

RESULTS

Soil test data from no-N control plots for 1990 and 1991 at four depths are reported in Table 1. Total NO_3-N in the top 24 in. was 17 lb-NO_3-N/acre in 1990 and 23 lb-NO_3-N/acre in 1991. Organic matter content was 1.0% or greater down to the 24-in. soil depth.

In 1990, there was a significant N rate X cultivar interaction for total seedcotton yield (Table 2). Yield for two of the cultivars, Deltapine 50 and Stoneville 506, did not respond to the application of N. However, yield for Deltapine 20 and Stoneville 453 was increased by applied N with yield not significantly increasing above the 50 lb N/acre rate. At the higher N rates (150 and 200 lb N/acre), yield tended to decrease for all the cultivars with a significant yield reduction for Deltapine 50 and Stoneville 506. Yield decreased at both the 150- and 200-lb N/acre rates for Deltapine 50 and at the 200-lb N/acre rate for Stoneville 506. The 100-lb N/acre soil rate plus supplemental N did not increase yield greater than the 100-lb N/acre soil rate for any of the cultivars (Table 2). Supplemental N was foliarly applied three times on Deltapine 20, Deltapine 50 and Stoneville 506 and two times on Stoneville 453.

The N rate and cultivar main effects were significant and the N rate X cultivar interaction was not significant for total seedcotton yield in 1991 (Table 3). Although yield was much higher in 1991 than in 1990, yield on the no-N control plots was 2612 lb/acre in 1991 compared to 2929 lb/acre in 1990. Across cultivars, yield did not increase with soil-applied rates greater than 100 lb N/acre. Yield declined with the two high N rates, 150 and 200 lb N/acre. Similar to 1990, the 100-lb N/acre soil rate plus supplemental N was no better than the 100-lb N/acre soil-applied rate. Total N for the supplemental N treatment ranged from 140 lb N/acre for Stoneville 453 and Stoneville 506 to 169 lb N/acre for Deltapine 50. The Stoneville 453 cultivar had the highest yield among the four cultivars.

Nitrate-N content of the petioles at each sampling period was increased by applied N each year (Tables 4 and 5). In 1991, petiole NO_3-N for the 100-lb N/acre soil rate plus supplemental N was higher than for the 100-lb N/acre soil rate from the fourth through eighth sampling periods. In general, the Stoneville 453 cultivar had the highest NO_3-N content among the four cultivars.

This study confirms the present N recommendation of 80 to 90 lb N/acre for a sandy soil, preferably split between preplant and a sidedress application (Chapman, 1991). This specific recommendation is based on soils with soil calcium levels less than 4500 lb/acre, soils with a history of rank growth, soil NO_3-N less than 25 (top 36 in. of soil) and a high yield potential (irrigation). On this sandy soil, high N rates (i.e. 150 lb N/acre or higher) resulted in rank growth and subsequent yield reductions. The lack of a yield response to the supplemental N applications based on petiole analysis suggests that the present NO_3-N critical level in the petiole may be too high.

LITERATURE CITED

1. Chapman, S.L. (ed.). 1991. Soil test recommendations guide. Cooperative Extension Service, Agricultural Experiment Station, University of Arkansas Division of Agriculture, Fayetteville, AR.

Table 1. Soil test data from no-nitrogen control plots at four soil depths at Manila, Arkansas, for two years.

Soil Depth	pH	OM	NO_3-N	Ca
in.		%	---- lb/acre ----	
		1990		
0-6	6.8	2.6	7	3405
6-12	7.0	2.1	4	4100
12-18	7.1	1.6	3	4534
18-24	7.2	1.0	3	4452
		1991		
0-6	6.7	1.7	6	3540
6-12	6.7	1.7	7	4055
12-18	6.8	1.2	6	4571
18-24	7.0	1.1	4	4989

Table 2. Effect of nitrogen (N) on seedcotton yield for four cultivars at Manila, Arkansas, in 1990.

Cultivar[1]	N rate[2]	1st pick	2nd pick	Total	% 1st pick
	-----------	-----------	lb/acre	-----------	%
DPL 20	0	2733	110	2843	96.1
	50	3002	125	3128	96.0
	100	2975	286	3261	91.3
	100 (P)	2937	378	3314	88.7
	150	2493	514	3007	82.9
	200	2293	548	2841	80.6
DPL 50	0	2969	190	3159	94.1
	50	3200	183	3383	94.6
	100	2863	421	3284	87.3
	100 (P)	2869	510	3379	85.0
	150	2036	605	2641	77.1
	200	2271	618	2888	78.8
Stv. 453	0	2603	107	2710	96.1
	50	3050	211	3261	93.6
	100	2859	336	3195	89.9
	100 (P)	2843	406	3249	87.5
	150	2461	629	3090	79.6
	200	2320	533	2853	81.3
Stv. 506	0	2849	154	3003	94.9
	50	2908	202	3110	93.8
	100	2660	396	3056	87.1
	100 (P)	2585	531	3116	83.2
	150	2426	680	3106	78.0
	200	2117	617	2733	77.4
		N MEANS			
	0	2788	140	2929	95.3
	50	3040	180	3220	94.5
	100	2838	356	3194	89.0
	100 (P)	2808	456	3265	86.1
	150	2354	607	2961	79.4
	200	2250	579	2829	79.5
		CULTIVAR MEANS			
DPL 20		2739	327	3066	89.3
DPL 50		2696	421	3117	86.1
Stv. 453		2689	370	3060	88.0
Stv. 506		2591	430	3021	85.7
$LSD_{(.05)}$:					
N		130	93	161	2.6
Cultivar		90	37	N.S.	1.1
N x Cultivar		221	N.S.[3]	243	N.S.

[1] DPL = Deltapine. Stv. = Stoneville.

[2] 100(P) = 100 lb N/acre soil applied plus supplemental N as recommended by petiole analysis. Foliar N was applied three times on Deltapine 20, Deltapine 50 and Stoneville 506 (total of 30 lb N/acre of supplemental N) and two times on Stoneville 453 (total of 20 lb N/acre of supplemental N).

[3] N.S. = non-significant.

Table 3. Effect of nitrogen (N) on seedcotton yield for four cultivars at Manila, Arkansas, in 1991.

Cultivar[1]	N rate[2]	1st pick	2nd pick	Total	% 1st pick
	------------	------------ lb/acre	------------	------------	%
DPL 20	0	2433	101	2534	96.0
	50	3138	235	3373	92.7
	100	3614	269	3883	93.2
	100 (P)	3247	416	3663	88.5
	150	3215	382	3597	89.3
	200	2918	430	3348	87.1
DPL 50	0	2713	119	2833	95.8
	50	3242	179	3422	94.8
	100	3400	337	3737	90.9
	100 (P)	3450	469	3919	88.0
	150	2956	585	3541	83.0
	200	2929	537	3466	84.3
Stv. 453	0	2391	89	2480	96.4
	50	3439	140	3579	96.1
	100	3725	211	3936	94.7
	100 (P)	3877	314	4192	92.5
	150	3664	429	4093	89.3
	200	3043	504	3547	85.5
Stv. 506	0	2495	101	2597	96.1
	50	2997	134	3131	95.7
	100	3822	304	4126	92.8
	100 (P)	3475	320	3794	91.4
	150	3178	443	3620	87.8
	200	2720	599	3319	81.9
		N MEANS			
	0	2509	103	2612	96.1
	50	3215	174	3389	94.8
	100	3631	279	3910	93.0
	100 (P)	3512	380	3892	90.1
	150	3257	461	3718	87.3
	200	2902	518	3420	84.7
		CULTIVAR MEANS			
DPL 20		3094	306	3400	91.1
DPL 50		3115	371	3486	89.5
Stv. 453		3357	281	3638	92.4
Stv. 506		3113	328	3441	90.6
LSD$_{(.05)}$:					
N		246	68	257	2.0
Cultivar		143	37	136	1.2
N x Cultivar		N.S.[3]	90	N.S.	2.9

---

[1] DPL = Deltapine. Stv. = Stoneville.

[2] 100(P) = 100 lb N/acre soil applied plus supplemental N as recommended by petiole analysis. Supplemental N was 30 lb N/acre soil applied and four foliar applications for DPL 50 (total of 69 lb N/acre of supplemental N); 30 lb N/acre soil and two foliar applications for DPL 20 (total of 50 lb N/acre of supplemental N); and 30 lb N/acre soil and one foliar application for Stv. 453 and Stv. 506 (total of 40 lb N/acre of supplemental N).

[3] N.S. = non-significant.

Table 4. Effect of nitrogen (N) on petiole NO_3-N at eight sampling periods for four cultivars at Manila, Arkansas, in 1990.

Cultivar[1]	N rate[2]	Week of sampling[3] 1	2	3	4	5	6	7	8
	lb/acre	ppm NO_3-N							
DPL 20	0	7602	5418	2528	1372	260	571	592	250
	50	10272	10066	5068	3462	2860	667	948	717
	100	15092	12991	12776	8482	3941	1837	1021	429
	100 (P)	14279	14292	11674	7891	2429	1194	1239	719
	150	14273	15162	14810	13250	6852	4359	3078	890
	200	14477	14131	14841	14981	8935	6495	4224	2261
DPL 50	0	6619	7009	3446	1388	394	774	1013	443
	50	10114	9640	5357	3273	953	522	487	493
	100	14794	13449	12669	8992	2532	1470	1762	466
	100 (P)	15033	15045	12319	10310	3310	1935	1458	943
	150	14743	14255	14618	13645	8156	6528	3814	2585
	200	14202	15795	15634	15352	8706	8546	5839	3083
Stv. 453	0	8730	7194	3367	2761	857	1433	521	383
	50	13162	12121	8762	3719	1681	1077	1023	342
	100	17590	15330	13864	8924	3313	1916	1525	829
	100 (P)	17556	15988	14011	9436	3895	2174	2096	392
	150	16274	15872	15943	14603	8286	3644	3847	2143
	200	16841	17370	14181	17286	11602	9675	6688	4050
Stv. 506	0	8794	6865	3156	2099	547	718	622	206
	50	11590	10446	6146	3901	1207	1042	981	892
	100	15061	14030	13141	10045	3122	2957	1197	931
	100 (P)	16132	15782	13087	10440	2994	1716	1427	1532
	150	14751	14787	14970	14916	6273	4259	2134	704
	200	14165	14434	15074	16232	9237	8372	5231	2664

continued

Table 4. Continued

Cultivar[1]	N rate[2]	Week of sampling[3] 1	2	3	4	5	6	7	8
	lb/acre	ppm NO_3-N							
					N MEANS				
	0	7937	6621	3124	1905	515	874	687	321
	50	11284	10568	6333	3589	1675	827	860	611
	100	15634	13950	13112	9111	3227	2045	1376	664
	100 (P)	15750	15277	12773	9519	3157	1755	1555	897
	150	15010	15019	15086	14104	7392	4698	3218	1583
	200	14922	15432	14933	15963	9620	8272	5496	3015
					CULTIVAR MEANS				
DPL 20		12666	12010	10283	8240	4213	2520	1850	879
DPL 50		12584	12532	10674	8827	4009	3296	2396	1336
Stv. 453		15025	13979	11688	9455	4939	3320	2617	1357
Stv. 506		13416	12724	10929	9606	3897	3177	1932	1155
$LSD_{(.05)}$:									
N		1509	1248	1091	1820	1405	976	1040	836
Cultivar		824	676	839	751	N.S.	N.S.	428	N.S.
N x Cultivar		N.S.[4]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

[1] DPL = Deltapine. Stv. = Stoneville.

[2] 100(P) = 100 lb N/acre soil applied plus supplemental N as recommended by petiole analysis. Foliar N was applied three times on Deltapine 20, Deltapine 50 and Stoneville 506 and two times on Stoneville 453.

[3] Petiole sampling started July 5.

[4] N.S. = non-significant.

Table 5. Effect of nitrogen (N) on petiole NO_3-N at eight sampling periods for four cultivars at Manila, Arkansas, in 1991.

Cultivar[1]	N rate[2]	Week of sampling[3]							
		1	2	3	4	5	6	7	8
		ppm NO_3-N							
DPL 20	0	2221	760	630	511	276	305	144	84
	50	5904	2380	1951	1401	637	584	264	452
	100	12249	5116	6870	3315	897	788	189	72
	100 (P)	11741	4336	6739	6595	4025	1454	721	383
	150	11117	5337	9359	7236	4752	4466	831	550
	200	11482	5272	10416	10248	8150	6175	2433	1173
DPL 50	0	2073	758	771	1169	212	295	159	210
	50	5563	2970	985	1243	538	407	234	226
	100	10448	4754	8153	4299	2027	1487	565	106
	100 (P)	11657	5307	6661	7590	4560	1844	768	474
	150	12624	5286	10760	9060	6446	4910	2085	1002
	200	12624	6104	11395	11288	9677	7863	3539	1860
Stv. 453	0	3274	1135	1715	1367	350	1165	249	92
	50	7182	3235	3289	1719	960	602	261	126
	100	13416	6777	10075	4230	2333	743	420	107
	100 (P)	13171	7061	8517	4571	2056	5120	1924	261
	150	13694	7327	11384	9848	7007	4021	1720	253
	200	13562	7851	12178	11305	10710	7123	4846	2068
Stv. 506	0	2741	413	685	542	194	622	158	312
	50	7336	3115	2812	1877	995	1122	368	267
	100	12359	5985	7895	4640	2850	1572	520	279
	100 (P)	11560	5277	6721	6655	3941	1661	597	316
	150	12049	4609	10262	7989	6888	3420	1401	358
	200	12028	6229	11079	9843	10151	8256	3665	1756

continued

Table 5. Continued

Cultivar[1]	N rate[2]	Week of sampling[3]							
		1	2	3	4	5	6	7	8
		ppm NO_3-N							
		N MEANS							
	0	2577	767	950	897	257	595	177	175
	50	6497	2925	2259	1560	783	679	282	268
	100	12118	5658	8248	4121	2027	1147	423	141
	100 (P)	12032	5495	7160	6353	3645	2520	1003	358
	150	12371	5640	10441	8533	6273	4204	1509	541
	200	12424	6371	11266	10671	9672	7355	3621	1712
		CULTIVAR MEANS							
DPL 20		9119	3867	5994	4884	3221	2295	764	452
DPL 50		9165	4196	6454	5775	3910	2801	1225	646
Stv. 453		10716	5565	7860	5507	3903	3129	1570	484
Stv. 506		9679	4204	6575	5258	4170	2850	1118	507
LSD(0.05):									
N		761	1261	911	1161	1054	1042	639	404
Cultivar		507	533	477	526	594	N.S.	227	N.S.
N X Cultivar		N.S.[4]	N.S.	N.S.	1289	N.S.	N.S.	557	414

---

[1] DPL = Deltapine, Stv. = Stoneville.

[2] 100(P) = 100 lb N/acre soil applied plus supplemental N as recommended by petiole analysis. Supplemental N was 30 lb N/acre soil applied and four foliar applications for DPL 50 (total of 69 lb N/acre); 30 lb N/acre soil and two foliar applications for DPL 20 (total of 50 lb N/acre); and 30 lb N/acre soil and one foliar application for Stv. 453 and 506 (total of 40 lb N/acre).

[3] Petiole sampling started June 26.

[4] N.S. = non-significant.

EFFECT OF SULFUR FERTILIZATION ON COTTON YIELD ON SANDY SOILS 1990-1991

H.J. Mascagni, Jr., W.H. Baker, W.E. Sabbe and P.W. Parker

INTRODUCTION

Sulfur (S) deficiencies have been recognized in Arkansas on the cool-season crops, wheat (Wells et al., 1986) and spinach (Wells et al., 1989). Deficiencies would not be expected on a warm-season, deep-rooted crop such as cotton. However, there is some recent evidence that S deficiencies in cotton may occur in certain years on certain soil types (Mascagni et al., 1990). As with the cool-season crops, a S deficiency in cotton would be most expected on sandy soils, particularly soils with deep sandy profiles. Therefore, experiments were designed to evaluate the response of cotton to S applications on sandy soils.

PROCEDURES

Experiments were conducted to evaluate cotton response to S applications in the Manila/Leachville, Arkansas, area at three locations in 1990 and two locations in 1991. Locations and soil test data are presented in Table 1. The Brown location was dropped in 1991. The soil at each location was mapped as a Routon-Dundee-Crevasse complex.

The experimental design was a randomized complete block with twelve replications at each location. The experiments were repeated in the same plots each year. Three S treatments evaluated included 1) a control, 2) 20 lb SO_4-S/acre applied on the soil and 3) a foliar S treatment applied if and when S deficiency symptoms appeared. Treatment two was broadcast by hand using ammonium sulfate as the S source. Nitrogen was balanced in treatments one and three using ammonium nitrate. In 1990 at the Wildy and Brown locations, S was applied preplant. At the Hawkins location, the soil-applied S treatment was applied after the cotton had emerged (2-leaf growth stage). In 1991, the soil-applied S was applied at plant emergence (15 May).

Since S deficiency symptoms appeared only at the Hawkins location in 1990, this is the only location foliar S was applied. In 1991, slight S deficiency symptoms appeared at each location. Magnesium sulfate (epsom salts), the S source for the foliar treatment, was applied at a rate of 4 lb SO_4-S/acre.

Petiole samples in the control and soil-applied S plots were taken weekly for eight weeks starting one week prior to flowering. Samples were taken from the fourth petiole from the top of the plant. Soil samples from the top 6 in. were taken from check plots prior to treatment applications in 1990 and also taken each year at 6-in. increments down to the 24-in. soil depth approximately one month after soil treatments were applied. Petiole and soil analyses were conducted at the Marianna Soil Test Lab.

Cotton was planted at each location 10 May and 7 May in 1990 and 1991, respectively. The cultivar was 'Deltapine 50'. Recommended cultural practices were followed by the farmer at each location. Each location was irrigated using a center-pivot irrigation system. Yield was determined on each plot and is reported as seedcotton yield. At the Wildy and Brown locations, cotton was picked twice by machine. Cotton was picked by hand at the Hawkins location after all the bolls had opened.

RESULTS

Excessive spring and winter rainfall (Table 2), especially in 1991, was conducive to the development of S deficiency in cotton. Slight S deficiency symptoms appeared at the Hawkins farm in 1990 and at the Wildy and Hawkins farms in 1991. Accordingly, foliar S was applied 17 August at the Hawkins farm in 1990; 8 and 20 August at the Wildy farm in 1991; and 11 and 22 July and 7 and 20 August at the Hawkins farm in 1991. Applications of S, soil or foliar, did not significantly increase seedcotton yield at any location in either year of the study (Tables 3 and 4).

The SO_4-S content of petioles for the control and soil-applied S treatment is shown in Tables 5 and 6. Generally, the SO_4-S content of the petioles increased throughout the growing season with applied S. The NO_3-N/SO_4-S ratio in the petioles decreased as the growing season progressed (Tables 7 and 8). At the Hawkins farm in 1991, the NO_3-N/SO_4-S ratio on the no-S control plots ranged from 17.6 to 30.0 through the fifth sampling period (Table 8).

Soil-applied S increased the SO_4-S level in the soil only at the Wildy and Hawkins farms in 1990 (Table 9). Sulfate-S on the control plots at the Hawkins farm in 1991 (30.2 lb-SO_4-S/acre; Table 10) was much higher than in 1990 (19.8 lb-SO_4-S/acre; Table 9).

The sand content of the soils varied among locations. Soil calcium (Ca) content gives some indication of the soil texture. In general, as the Ca content of the soil decreases, the sand content increases. Using this criterion, the sand content of the soils at the three locations ranked in the following order: Hawkins > Wildy > Brown (Table 11). The soil at the Hawkins location was predominantly a Routon sandy loam (Typic Ochraqualfs), soil texture becoming less sandy with depth (Table 11).

A sulfur response occurred in 1989 immediately adjacent to the Hawkins location on a Crevasse loamy sand (Typic Udipsamments) (Mascagni et al., 1990). The Crevasse is characterized by a very deep sandy profile. On this soil, SO_4-S is more likely to leach through the soil profile, and a S deficiency is more likely than on a soil such as a Routon.

In summary, even though conditions were conducive to the development of S deficiency, cotton yield was not significantly increased in either year by the application of S on these sandy soils. Although additional research may be merited, this study suggests that the probability of a cotton response to applied S on the more typical cotton soils, i.e. Routon and Dundee, is low. These soils are characterized by relatively shallow sandy horizons. On the other hand, a S response may be more likely in certain years on soils with very deep sand profiles, i.e. Crevasse.

LITERATURE CITED

1. Mascagni, H.J., M.E. Terhune, R.L. Maples and W.N. Miley. 1990. Influence of sulfur on cotton yields. University of Arkansas Cooperative Extension Service Fact Sheet 2058.
2. Wells, B.R., R.K. Bacon, W.E. Sabbe and R.L. Sutton. 1986. Response of sulfur deficient wheat to sulfur fertilization. Journal of Fertilizer Issues 3(2):72-74.
3. Wells, B.R., T.E. Morelock and D.R. Motes. 1989. Response of 'Fall Green' spinach to sulfur. Arkansas Farm Research 38(5):8.

Table 1. Soil test data in the top 6 in. of soil at three locations in Manila/Leachville, Arkansas, at the initiation of the test in 1990.

Location	pH	OM	P	K
		%	---------lb/acre---------	
Wildy Farm	6.4	1.9	111	262
Hawkins Farm	5.3	0.8	92	396
Brown Farm	5.8	2.5	176	425

Table 2. Rainfall in 1989/90 and 1990/91 and long-term average.[1]

Month	1989/90	1990/91	Average[2]
	------------------------------	in.	------------------------------
October	1.6	9.2	2.8
November	1.7	2.9	4.8
December	1.4	13.9	4.8
January	4.6	4.2	3.1
February	7.3	5.4	3.2
March	7.3	2.9	4.7
April	6.1	11.8	4.9
May	4.9	7.2	5.7
June	4.4	4.0	3.4
July	2.0	1.9	3.8
August	1.3	3.0	3.0
September	3.1	3.0	3.9

[1] Rainfall data from Northeast Research and Extension Center, Keiser, Arkansas.

[2] Average of 26 years.

Table 3. Effect of fertilizer sulfur (S) on seedcotton yield at three locations in Manila/Leachville, Arkansas, area in 1990.

Sulfur treatment[1]	1st pick	2nd pick	Total yield
lb-SO_4-S/acre	----------lb seedcotton/acre----------		
		Wildy Farm	
0	2566	280	2846
20	2589	280	2870
Foliar	-	-	-
Level of significance	N.S.[2]	N.S.	N.S.
		Hawkins Farm[3]	
0			3121
20			3150
Foliar			3217
Level of significance			N.S.
		Brown Farm	
0	2751	292	3043
20	2738	260	2998
Foliar	-	-	-
Level of significance	N.S.	N.S.	N.S.

[1] S-foliar treatment was applied only once (17 August) at the Hawkins farm.

[2] N.S. = non-significant.

[3] Harvested once after all bolls were open.

Table 4. Effect of fertilizer sulfur (S) on seedcotton yield at two locations in Manila/Leachville, Arkansas, area in 1991.

Sulfur treatment[1]	1st pick	2nd pick	Total yield
lb-SO_4-S/acre	----------lb seedcotton/acre----------		
		Wildy Farm	
0	3594	293	3887
20	3625	299	3924
Foliar	3407	354	3761
Level of significance	N.S.[2]	N.S.	N.S.
		Hawkins Farm[3]	
0			3812
20			3881
Foliar			3934
Level of significance			N.S.

[1] S-foliar treatment was applied 8 and 20 August at the Wildy farm and 11 and 22 July and 7 and 20 August at the Hawkins farm.

[2] N.S. = non-significant.

[3] Harvested once after all bolls were open.

Table 5. Effect of fertilizer sulfur (S) on petiole SO_4-S at eight sampling periods at three locations in Manila/Leachville, Arkansas, area in 1990.

Sulfur treatment	Week of sampling[1]							
	1	2	3	4	5	6	7	8
lb SO_4-S/acre	----------ppm SO_4-S----------							
				Wildy Farm				
0	1120	1551	1917	2135	1906	1768	850	1747
20	1472	1805	2033	2359	2210	1991	1063	1798
Level of significance[2]	**	**	N.S.	**	**	**	**	N.S.
				Hawkins Farm				
0	667	847	1208	1163	1099	1091	1515	858
20	968	1207	1609	1532	1475	1341	1602	1017
Level of significance	**	**	**	**	**	N.S.	N.S.	**
				Brown Farm				
0	1281	1943	1937	2100	2210	2129	1597	1923
20	1530	2366	2353	2457	2483	2436	1760	2038
Level of significance	**	**	**	**	*	**	**	N.S.

[1] Petiole sampling started 5 July at each location.

[2] *, ** Significance at the 0.05 and 0.01 probability levels, respectively. N.S. = non-significant.

Table 6. Effect of fertilizer sulfur (S) on petiole SO_4-S at eight sampling periods at two locations in Manila/Leachville, Arkansas, area in 1991.

Sulfur treatment	Week of sampling[1]							
	1	2	3	4	5	6	7	8
lb SO_4-S/acre	ppm SO_4-S							
	Wildy Farm							
0	830	646	992	1156	1453	2143	1748	1858
20	1341	1019	1357	1354	1742	2449	2027	2134
Level of significance[2]	**	**	*	*	**	**	**	**
	Hawkins Farm							
0	670	355	531	673	485	731	579	528
20	1107	776	964	935	801	1042	865	744
Level of significance	**	**	**	**	**	**	**	**

[1] Petiole sampling started 26 June at each location.

[2] *, ** Significance at the 0.05 and 0.01 probability levels, respectively.

Table 7. Effect of fertilizer sulfur (S) on petiole NO_3-N/SO_4-S ratio at eight sampling periods at three locations in Manila/Leachville, Arkansas, area in 1990.

Sulfur treatment	Week of sampling[1]							
	1	2	3	4	5	6	7	8
lb SO_4-S/acre	NO_3-N/SO_4-S							
	Wildy Farm							
0	13.4	8.9	5.2	5.4	3.5	2.3	1.3	0.4
20	10.5	7.8	4.4	5.1	3.2	2.0	0.9	0.5
Level of significance[2]	**	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	Hawkins Farm							
0	38.9	20.2	11.6	13.8	11.6	10.1	4.2	3.4
20	26.9	14.1	8.3	10.0	8.1	8.9	3.6	2.9
Level of significance	**	**	**	**	*	N.S.	N.S.	N.S.
	Brown Farm							
0	11.9	6.4	3.4	1.2	0.8	0.6	0.6	0.3
20	10.1	5.2	2.5	0.9	0.7	0.6	0.5	0.2
Level of significance	**	*	*	N.S.	N.S.	N.S.	N.S.	N.S.

[1] Petiole sampling started 5 July at each location.

[2] *, ** Significance at the 0.05 and 0.01 probability levels, respectively. N.S. = non-significant.

Table 8. Effect of fertilizer sulfur (S) on petiole NO_3-N/SO_4-S ratio at eight sampling periods at two locations in Manila/ Leachville, Arkansas, area in 1991.

Sulfur treatment	Week of sampling[1] 1	2	3	4	5	6	7	8
lb SO_4-S/acre	NO_3-N/SO_4-S							
			Wildy Farm					
0	18.7	11.0	8.9	7.8	5.2	1.8	0.8	0.7
20	10.1	6.0	6.6	5.9	4.2	1.5	0.6	0.6
Level of significance[2]	**	**	*	N.S.	N.S.	N.S.	N.S.	N.S.
			Hawkins Farm					
0	18.2	30.0	17.6	19.7	19.5	10.6	7.6	3.4
20	8.4	7.6	7.1	13.3	10.2	5.9	5.4	2.0
Level of significance	**	**	**	**	**	**	N.S.	N.S.

[1] Petiole sampling started 26 June at each location.

[2] *, ** Significance at the 0.05 and 0.01 probability levels, respectively. N.S. = non-significant.

Table 9. Effect of soil-applied fertilizer sulfur (S)[1] on soil SO_4-S at four depths at three locations in Manila/Leachville, Arkansas, area in 1990[2].

	Wildy Farm		Hawkins Farm		Brown Farm	
Soil depth	No S	S	No S	S	No S	S
in.	lb SO_4-S/acre					
0-6	27.5	36.2	19.8	33.1	25.5	30.6
6-12	28.5	29.2	16.1	19.2	29.4	25.6
12-18	29.1	34.2	14.8	17.4	25.4	27.6
18-24	30.7	38.3	13.6	14.5	26.4	28.5
$\bar{x}$	29.0	34.5	16.1	21.1	26.7	28.1
$LSD_{(.05)}$:						
S	2.0		1.7		N.S.	
Depth	N.S.[3]		2.9		N.S.	
S x Depth	N.S.		4.1		N.S.	

[1] 20 lb SO_4-S/acre.

[2] Sampled 1, 26 and 1 June at the Wildy, Hawkins and Brown locations, respectively. Sulfur applied on the soil 9, 30 and 9 May at the Wildy, Hawkins and Brown locations, respectively.

[3] N.S. = non-significant.

Table 10. Effect of soil-applied fertilizer sulfur (S)[1] on soil SO_4-S at four depths at two locations in Manila/Leachville, Arkansas, area in 1991[2].

	Wildy Farm		Hawkins Farm	
Soil depth	No S	S	No S	S
in.	---lb SO_4-S/acre---			
0-6	26.7	26.7	30.2	33.4
6-12	25.8	26.1	24.7	26.3
12-18	28.4	25.3	27.3	25.0
18-24	32.8	35.9	26.3	26.3
$\bar{x}$	28.4	28.5	27.1	27.8
$LSD_{(.05)}$:				
S	N.S.[3]		N.S.	
Depth	4.7		N.S.	
S x Depth	N.S.		N.S.	

[1] 20 lb SO_4-S/acre.

[2] Sampled 24 June and 20 June at the Wildy and Hawkins farms, respectively. Sulfur applied on the soil 15 May at each location.

[3] N.S. = non-significant.

Table 11. Soil calcium (Ca) content at four soil depths at three locations in Manila/Leachville, Arkansas, area in 1990.

	Location		
Soil depth	Wildy Farm	Hawkins Farm	Brown Farm
in.	---lb/acre---		
0-6	2065	995	3389
6-12	2040	1415	4192
12-18	2240	1434	4009
18-24	1971	1612	4400

COTTON RESPONSE TO DEEP POTASH FERTILIZATION

T.C. Keisling

INTRODUCTION

Recently, Mississippi Experiment Station scientists have reported substantial yield increases to potash fertilizer placed in a vertical band 2 in. wide located between 6 and 15 in. deep. The objective of this study was to test whether or not similar cotton yield responses occurred for Arkansas soil and climatic conditions.

PROCEDURE

Experiment 1

The study was established on the McGinnis farm in south central Lee County, Arkansas, on a Loring-Calloway-Henry (fine-silty, mixed, thermic Typic Fragiudalf; fine-silty, mixed, thermic Glassaquic Fragiudalf; coarse-silty, mixed, thermic Typic Fragiaqualf, resp.) soil complex. This site was diagnosed as having a K deficiency in the 1989 growing season. The average soil test is given in Table 1. Treatments as designated in Table 2 were applied in a Latin Square design on six 38-in. rows 60 ft long.

In 1990 fertilizer was surface applied uniformly as 120-180-0 on 7 May 1990 with surface potash applied on 27 April 1990. All in-the-row subsoiling and deep fertilizer application was done using the same implement on 11 May 1990 after the beds had been established. Cotton, cultivar DPL50, was planted on 17 May 1990. In-season nitrogen management followed the Arkansas CNM system. Irrigation was scheduled according to the Arkansas irrigation scheduler computer program. Insect scouting and spraying was also according to Arkansas recommendations. Boron was applied as 0.1 lb/acre foliar on a weekly schedule. Cotton was harvested as a once-over picking operation with a mechanical picker on 31 October 1990.

In 1991, the experiment was repeated on the same site with variations as noted herein. The whole site was fertilized by the farmer at

60-30-90 lb/acre N-P_20_5-K_20. Surface and subsoil treatments were applied 28 March 1991 except for Rep 8, which was applied on 13 May 1991. Owing to unusual amounts of spring rain, the field was disced on 11 May 1991 to kill vegetation and rebedded on 12 May 1991. Cotton was planted on 13 May 1991. Harvest was once over on 14 November 1991.

Experiment 2

This experiment was established in 1991 adjacent to experiment 1. Two treatments were made, i.e. 90 lb/acre of potash soil applied in early March followed by either four applications of potassium nitrate at 10 lb/acre of material or 180 lb/acre of potash broadcast and disced in together with another 180 lb/acre of potash applied deep on 13 May 1991. Experimental design was randomized complete block with four blocks. All other cultural practices followed those used in Experiment 1.

RESULTS

Experiment 1

Yield and quality results of 1990 are somewhat variable due to the wet spring and poor cotton stand. The results are sufficient to show substantial yield increases (Table 2) of about 300 lb/acre of lint. Best yields were obtained when some potash was applied. In-the-row subsoiling did not have a measurable effect on lint yield. Lint quality data are shown in Table 3. Generally, additions of potash improved fiber quality. In 1991, there were no measurable yield differences (Table 2), and quality data are not yet available. Potash being inadvertently applied to the whole area masked the responses obtained previously.

Plant data taken at the end of the 1990 and 1991 season (Table 4) showed no differences resulting from the various treatments. In 1990, each plant produced about six pre-fruiting nodes and 14 fruiting nodes with 20 total nodes. Mature plants were about 42 in. tall. Boll set had approximately 52% of bolls in first sympodial position with 29% in the second. There was a total of 15 bolls/plant. In 1991, each plant produced about eight pre-fruiting nodes and 12 fruiting nodes with 20 total nodes. The mature plants were 34 in. tall. Boll set was about 52% at first sympodial position and 21% at second. There was a total of 12 bolls/plant.

The 1990 tissue analyses for leaf blades are not yet available, but those for petioles are shown in Table 5. Of particular interest is the fact that K content decreased about 0.5%/week from period 2 to period 6. Data from week 7 were lost, but it appears from the remaining data that from period 6 through 8 there is a very dramatic decrease in the K content of the petioles. Regression analysis indicates that at period 8 there is a reduction of 190 lb of lint/% reduction in petiole K content. This result is highly significant and needs to be checked thoroughly with earlier periods.

The 1991 tissue analysis for leaf blades is given in Tables 6 and 7. Statistical analyses have not been completed on the leaf blade data. Petiole analysis are given in Table 8. A response in petiole K content was obtained from the fertilizer treatments.

Experiment 2

Yield, stand, boll weight and percent lint for 1991 are presented in Table 9. Primary plant characteristics are shown in Table 4. The soil-applied potash resulted in two more bolls per plant than did the foliar applications. Otherwise the plants' structures were similar.

DISCUSSION

Several reports have indicated that severe potash deficiency results in yield loss primarily through reduction in boll size. Fertility studies with deep placement of potash on fields with potash deficiencies that are severe enough to limit lint yields to less than 800 lb/acre do not address the production situation in which lint yields are in excess of 800 lb/acre. Very few producers of irrigated cotton have lint yields as low as 800 lb/acre or they would be bankrupt. Therefore, we are interested in yield responses obtained from potash additions when the check is yielding at least 800 lb/acre or more. Overlaying Experiment 1 with 90 lb/acre of potash resulted in check lint yields close to 1100 lb/acre. In 1990 under severe K stresses, any addition of potash resulted in dramatic yield responses contrasted to little or no response to any method of additional of K in 1991.

Dr. Gordon Tupper in Mississippi has reported yield increases from deep-placed potash when the check cotton lint yields are over 1000 lb/acre. He visually observed his response to be due to an increased top crop. Experiment 2 was instigated to check whether or not an extremely large rate of soil-applied potash could be equivalent to normal soil recommendations supplemental with foliar potassium applications. The 450 lb/acre of soil-applied potash (180 lb/acre deep) resulted in an increase in fruit set primarily with a top crop. This result agrees with Dr. Tupper's observations. The lint yield increase of 167 lb/acre was not statistically significant but was practically significant. Essentially, this yield increase results from deep application cost plus material cost, which are $6.50 and $39.60 ($0.11/lb of potash), respectively, for a total of $46.10. With lint selling for about $0.62/lb, a 167 lb/acre increase gives a return of ~~$103.54 or profi~~t of $57.44.

Since most irrigated cotton fields are already producing 800 lb/acre of lint or even higher yields, the extra expense of deep placement will be justified if it increases yields above that obtained by surface applications alone. The experiment should be redesigned to check deep placement at very high rates versus (1) ordinary high surface rates and (2) the high surface plus foliar. In addition, sufficient replications need to be made to pick up practically significant treatment effects.

ACKNOWLEDGMENTS

This research was made possible through funds provided by PPI and through the Arkansas Fertilizer Tonnage Fee. We wish to thank Mr. Bob McGinnis for allowing us to do this research on his farm and providing equipment necessary for the completion of these tests.

Table 1. Average soil test at beginning of experiment by Mehlich III.

Depth	pH	OM	NO_3-N	P	K	Ca	Na	Mg	Fe	Mn	Cu	Zn	S
(cm)		%	----------	----------	----------	----------	----------	lb/acre	----------	----------	----------	----------	----------
0-15	6.2	1.0	11	54	152	1758	131	403	217	252	3.0	2.1	19
15-30	6.2	0.6	5	52	108	1718	131	463	195	201	2.6	2.2	33
30-45	5.5	0.5	6	53	116	1387	146	525	232	100	2.5	1.3	56
45-60	5.2	0.4	5	46	126	1279	159	635	242	59	2.4	1.5	51
60-75	5.1	0.4	4	43	146	1407	184	850	251	37	2.5	1.4	38
75-90	5.0	0.3	4	42	170	1612	209	1112	258	39	2.6	1.8	30

Table 2. Experimental treatments, lint yield and petiole potassium content for the 1990 growing season for Experiment 1.

Trtmt	Surface Applied	Placed Deep	Sub Soiled	Lint Yield 1990	Lint Yield 1991
	---- lb K_2O/acre ----			-------- lb/acre -------	
1	0	0	No	502 bc[1]	1149 a
2	90	0	No	661 a	1191 a
3	180	0	No	777 a	1188 a
4	0	0	Yes	643 ab	1088 a
5	90	0	Yes	719 a	1165 a
6	0	90	Yes	444 c	1114 a
7	0	180	Yes	661 a	1108 a
8	90	90	Yes	771 a	1147 a

[1] Numbers in same column followed by same letter are not significantly different at 0.1 level according to Duncan's New Multiple Range Test.

Table 3. Fiber quality characteristics as influenced by treatment.

Trtmt	MIC	I50	I025	E1	FT
1	3.575 b[1]	0.5125 b	1.10375 b	8.375 a	20.8 a
2	3.750 ab	0.5258 ab	1.12667 ab	7.833 bc	21.4 a
3	3.880 ab	0.5320 ab	1.11100 ab	8.050 ab	21.1 a
4	3.740 ab	0.5270 ab	1.11300 ab	7.600 c	20.8 a
5	3.975 a	0.5375 a	1.12750 a	7.875 bc	21.6 a
6	3.783 ab	0.5233 ab	1.10500 ab	7.833 bc	20.6 a
7	3.820 ab	0.5380 a	1.24000 ab	7.800 bc	20.9 a
8	3.700 ab	0.5330 ab	1.12800 a	8.000 ac	20.9 a

[1] Numbers in same column followed by same letter are not significantly different at 5% level according to F test.

Table 4. Plant characteristics at end of the season.

Trtmt	First Symp. Node	Number of Sympodia	Plant Height (in.)	Bolls in Position One (%)	Bolls in Position Two (%)	Total Bolls per Plant
1990						
1	6.0	13.0	40.2	56	26	14
2	5.9	13.6	40.7	49	31	14
3	6.0	14.9	45.1	49	28	18
4	6.0	13.8	45.0	50	28	18
5	6.3	13.6	41.2	46	30	16
6	5.8	14.0	42.8	57	25	15
7	6.2	13.9	42.2	59	29	14
8	6.8	13.4	40.8	53	31	13
Mean	6.1	13.7	42.1	52	29	15.1
1991						
1	8.2	9.6	33.7	44	20	13
2	7.0	9.7	28.3	55	21	12
3	8.1	11.4	45.4	48	24	14
4	8.3	9.7	33.9	54	24	11
5	8.1	11.3	36.6	52	18	13
6	7.9	9.7	30.8	62	21	10
7	7.8	11.0	33.8	50	21	15
8	7.4	9.9	31.8	54	22	11
Mean	7.9	12.2	34.3	52	21	12.4
Experiment 2						
Soil	8.8	9.0	35.1	51	18	12 a[1]
Foliar	8.2	9.0	33.3	48	30	10 b

[1] Numbers in same column followed by same letter are not significantly different at 5% level according to F test.

Table 5. The 1990 petiole potassium content.

Trtmt	CNM Period 1	2	3	4	5	6	7	8
	%K							
1	4.1 d	4.8 d	3.6 d	3.4 e	2.7 d	1.8 e	----	0.5 d
2	5.4 ab	6.3 a	4.5 ab	5.2 b	4.3 ab	3.6 a	----	1.6 ab
3	5.4 ab	6.4 a	4.3 bc	4.7 c	3.9 bc	3.3 ab	----	1.1 bd
4	4.6 cd	5.6 bc	3.7 d	3.9 d	2.8 d	2.3 de	----	0.6 cd
5	5.1 ac	5.8 b	4.7 a	4.7 c	3.8 bc	3.0 bc	----	1.0 bd
6	4.6 c	5.4 c	3.6 d	4.1 d	3.4 c	2.5 cd	----	1.3 bc
7	5.0 bc	5.9 b	4.1 c	4.8 bc	3.9 bc	3.5 ab	----	1.3 b
8	5.7 a	6.3 a	4.8 a	5.7 a	4.7 a	3.8 a	----	2.1 a
	Average Petiole N Content (ppm)							
	17050	20487	12050	9550	6058	3125	----	863
	Average Petiole P Content (ppm)							
	2278	3409	2593	2884	2391	2041	----	1086
	Average Petiole S Content (ppm)							
	1393	3651	2014	2345	1732	1682	----	1329

Table 6. Leaf blade analysis for various elements for deep placement potash on cotton for 1991.

Element	CNM Period 1	2	3	4	5	6	7	8	9	10
% Ca	4.05	2.82	2.09	2.23	2.48	2.70	2.84	8.42	---	5.02
% Na	0.05	0.03	0.04	0.06	0.05	0.07	0.10	0.10	---	0.10
% Mg	0.71	0.56	0.51	0.61	0.60	0.66	0.69	0.73	---	0.84
ppm P	5247	4877	3276	3473	4512	4693	4787	4134	---	4823
ppm Fe	290	128	175	716	802	1056	1387	840	---	1027
ppm Mn	197	229	212	241	316	371	335	224	---	365
ppm Cu	10.2	9.2	8.0	10.1	10.1	15.6	7.7	5.6	---	11.9
ppm Zn	56	204	86	69	68	116	52	80	---	58
ppm S	0.53	0.41	0.37	0.41	0.56	0.68	0.80	0.78	---	1.10

Table 7. Leaf blade analysis for deep placement potash on cotton for 1991.

	CNM Period									
Trtmt	1	2	3	4	5	6	7	8	9	10
	%K									
1	1.96	1.29	0.85	0.99	1.06	1.15	1.21	0.93	---	0.83
2	1.89	1.48	1.00	0.99	1.06	1.25	1.19	1.01	---	0.99
3	2.06	1.60	1.08	1.17	1.13	1.13	1.15	0.98	---	1.12
4	1.78	1.34	0.96	0.98	1.03	1.11	1.12	0.91	---	0.80
5	1.88	1.35	1.01	1.01	1.03	1.28	1.24	0.98	---	0.97
6	2.03	1.43	1.03	1.13	1.15	1.20	1.21	0.95	---	1.00
7	1.90	1.30	0.91	1.11	1.05	1.10	1.19	0.98	---	0.95
8	1.91	1.39	1.00	1.01	1.05	1.21	1.18	1.02	---	1.06

Table 8. The 1991 petiole tissue content.

	CNM Period									
Trtmt	1	2	3	4	5	6	7	8	9	10
	%K									
1	7.11	5.62	3.75	4.40	4.71	4.01	5.00	4.14	---	2.00
2	7.47	6.08	4.30	4.31	4.65	4.58	4.05	4.10	---	2.21
3	8.02	6.58	4.87	5.61	5.11	4.48	4.40	4.10	---	2.71
4	7.08	5.67	3.87	4.70	4.35	3.97	3.60	3.88	---	1.67
5	7.54	5.84	4.22	4.31	4.48	4.91	4.58	4.12	---	2.21
6	7.98	6.35	4.46	5.25	5.41	5.31	4.47	3.78	---	2.37
7	7.64	5.71	4.34	5.32	4.74	4.54	4.70	4.41	---	2.38
8	7.46	6.18	4.67	4.85	4.54	4.40	4.52	4.35	---	2.45
	Average Petiole Content									
	N									
	19505	9930	3786	5393	4105	1913	1872	1914	---	638
	P									
	2266	2139	1750	1521	2148	2025	2248	2367	---	1628
	S									
	1178	1126	881	993	1000	1411	1235	1458	---	1253

Table 9. Yield, stand and boll characteristics of cotton at harvest time.

Treat	Lint Yield	Stand	Boll Weight	Lint
	lb/acre	Plants/acre	g/boll	%
Soil	1255	39639	1.45	.39
Foliar	1088	36032	1.10	.39
Prob > F	0.16	.38	.19	.80
CV(%)	11	13	23	3

RESPONSE OF COTTON GROWN ON COMPACTED SOILS TO PHOSPHORUS AND POTASSIUM FERTILIZATION AND DEEP TILLAGE

J.S. McConnell, W.H. Baker, B.S. Frizzell and J.J. Varvil

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) grown in the Mississippi River Delta is subject to yield reduction due to soil compaction. The intensive tillage used by producers and the coarse texture of most cotton soils allow rapid formation of tillage pans or compacted zones beneath the soil surface (Harris, 1971; Voorhees and Lindstrom, 1984). Tillage pans inhibit root growth, thereby preventing the plant from exploring the soil for nutrients. Potassium (K) and phosphorus (P) are primary plant nutrients with limited soil mobility. The restricted soil movement of P and K may make the nutrients less available in compacted soils than in soils in which root growth is uninhibited.

These studies were begun in 1990 to evaluate the growth and development of cotton grown on a soil with a tillage pan. The response of cotton to P and K fertilization and to subsoil tillage was observed.

PROCEDURE

The study site was located in 1990 on the John Staudinger Farm near Winchester, Arkansas, in a field cropped to continuous cotton. The soil at the study location is an Hebert silt loam (Aeric Ochraqualfs). Soil samples were taken to a depth of 24 in. in the early spring. Whole core soil samples were taken and tested in 1-in. segments for bulk density. Soil chemical properties were determined from samples taken in increments of 0-2, 2-4, 4-6, 6-12, 12-18 and 18-24 in.

The P and K fertilizer rates tested were recommended by soil analysis (30 lb P_2O_5/acre and 60 lb K_2O/acre); the recommended rates plus 50% (45 lb P_2O_5/acre and 90 lb K_2O/acre); and twice the recommended rates (60 lb P_2O_5/acre and 120 lb K_2O/acre). Fertilizer materials used were commercially available potash (0-0-60) and phosphate

(0-46-0). Fertilizer treatments were applied in the early spring and incorporated by discing.

Additionally, the effects of early spring subsoil (SS) tillage every year and once every three years were compared to non-SS tilled controls. In-row SS tillage was performed after the site was disced and beds were formed. A subsoiler with parabolic shanks was used to disrupt the soil and the tillage pan to an approximate depth of 15 in. and the beds then reformed.

The impact of the treatments on cotton plant development was assessed by stand, seedling nutrient content, petiole analyses, nodes above white flower (NAWF), plant height, yield, lint fraction and fiber quality. All data were analyzed using the Statistical Analysis System (SAS) at the 0.05 level of probability.

RESULTS AND DISCUSSION

Bulk density analysis of the soil profile indicated the presence of a tillage pan approximately 6 to 14 in. deep that was disrupted by SS tillage. The NO_3^--N and organic matter content of the soil were low in the surface and subsoil, but such conditions are typical in fields cropped to continuous cotton. The surface soil pH was near optimum for plant growth at 6.4. The levels of P and K were moderate, although P was near the high range.

The growth and development of the cotton seedlings was first evaluated using tissue tests. Cotton seedlings sampled at the two true leaf stage indicated that the uptake of N was unaffected by the treatments but that P and K content of the seedlings were significantly different due to the P and K fertilizer treatments (Table 1). Greatest levels of P and K were found in seedlings grown in plots that had been SS tilled and received 150% the recommended rate of P and K fertilizer. Second highest concentrations of P and K were found in the seedlings that were treated with 200% of the recommended rates of P and K but were not SS tilled. The 200% rate of P and K combined with SS tillage seemed to depress uptake. The reason for this effect is not clear.

NAWF counts and petiole nutrient contents were not significantly different at any sampling period during the growing season. NAWF counts and petiole nutrient contents decreased with time as the crop approached maturity. Plant heights were measured in each plot on 7 August, 6 September and 29 October to determine the effects of the treatments on mid- and late-season plant growth. No significant differences in mean plant height were detected between the treatments

(Table 2) even though greater plant height is commonly observed when compacted soils are deep-tilled (McConnell et al, 1989).

The mean lint yields were significantly affected by the SS tillage and P and K treatments (Table 2). Most dramatic yield increases were associated with treatments that included SS tillage. The lowest-yielding treatments were non-SS tilled and received either the recommended rate of P and K or 150% of the recommended rates. The optimum treatment for the 1990 growing season was SS tilled with 150% of the recommended P and K. This treatment apparently allowed adequate root growth and sufficient P and K for proper nutrition.

Seed cotton samples were taken from each plot and ginned on a laboratory cotton gin to determine the lint fraction and to allow evaluation of fiber properties. The length, strength, micronaire and uniformity were not significantly affected by the treatments (Table 3), although two trends were observed: fiber strength tended to be greater with elevated P and K fertilizer rates, and micronaire was greater with high P and K in conjunction with SS tillage.

These studies have been in progress one year and should be continued a minimum of two more years before final conclusions are drawn.

LITERATURE CITED

1. Harris, W.L. 1971. The soil compaction process. *In* K.K. Barnes, W.M. Carleton, H.M. Taylor, R.I. Throckmorton and G.E. Vanden Berg (eds.). Compaction of agricultural soils. ASAE, St. Joseph, MI.
2. McConnell, J.S., B.S. Frizzell and M.H. Wilkerson. 1989. Effects of soil compaction and subsoil tillage of two alfisols on the growth and yield of cotton. J. Prod. Agric. 2:140-146.
3. Voorhees, W.B., and M.J. Lindstrom. 1984. Long-term effects of tillage method on soil tilth independent of wheel traffic compaction. Soil Sci. Soc. Am. J. 50:428-433.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Dr. Bob Thompson and PPI/FAR for the financial support received for these studies. The authors further express their appreciation to Mr. John Staudinger for allowing these studies to be conducted on his farm.

Table 1. Concentration of N, P and K in the above-ground portion of cotton seedlings (two true leaf) as influenced by subsoil (SS) tillage and P and K fertilization.

Treatment		Nutrient		
Tillage	P and K	N	P	K
		-%-	-ppm-	-%-
SS	200%	3.27	2827 bc	2.48 bc
SS	150%	3.71	3637 a	2.93 a
None	200%	3.74	3309 a	2.86 a
None	150%	3.12	2525 c	2.48 bc
SS	100%	3.50	3245 ab	2.81 ab
SS once	100%	3.21	2840 bc	2.44 c
None	100%	3.13	2619 c	2.47 c
$LSD_{0.05}$		NS	421.9	0.339
CV(%)		12.25	9.47	8.26

Table 2. Plant height and yield response of cotton to subsoil (SS) tillage and P and K fertilization.

Treatment		Plant Height			
Tillage	P and K	7 Aug	6 Sep	29 Oct	Yield
		-----cm-----			lb lint/acre
SS	200%	99	108	101	1340 bcd
SS	150%	104	113	104	1493 ab
None	200%	106	105	101	1274 cd
None	150%	111	109	110	1197 d
SS	100%	103	105	100	1448 abc
SS Once	100%	101	102	102	1577 a
None	100%	98	105	98	1327 bcd
$LSD_{0.05}$		NS	NS	NS	215.5
CV(%)		9.03	5.43	8.00	10.26

Table 3. Length, uniformity, micronaire and strength responses of cotton fiber to subsoil (SS) tillage and P and K fertilization.

Treatment					
Tillage	P and K	Length	Uniformity	Micronaire	Strength
		in.	%		g/in.
SS	200%	1.10	82.3	4.63	23.0
SS	150%	1.11	82.3	4.70	22.0
None	200%	1.10	82.8	4.40	22.8
None	150%	1.10	81.8	4.45	22.8
SS	100%	1.10	81.0	4.55	21.3
SS Once	100%	1.10	81.5	4.43	22.3
None	100%	1.10	80.5	4.00	24.0
$LSD_{0.05}$		NS	NS	NS	NS
CV(%)		1.33	1.66	9.50	5.60

INFLUENCE OF LIME AND BORON ON COTTON YIELD ON A SANDY SOIL

H.J. Mascagni, Jr., W.H. Baker, W.E. Sabbe and P.W. Parker

INTRODUCTION

Boron (B) is one of the essential micronutrients needed by the cotton plant for growth and fruiting. Boron deficiencies in Arkansas have occurred primarily on the silt loam soils of the Loessial Hills in northeast Arkansas and the Loessial Plains in both northeast and southeast Arkansas (Miley and Woodall, 1982). These deficiencies often occur on recently limed fields. Little information is available on the sandy-textured soils of the Mississippi River Delta. Therefore, experiments were conducted for two years to evaluate the response of cotton to applied B at two soil pH levels.

PROCEDURES

Experiments were conducted in 1990 and 1991 to evaluate cotton yield response to B and lime applications on the Marvin Brown farm near Leachville, Arkansas. The field was mapped as a Routon-Dundee-Crevasse complex with the Dundee sandy loam (Aeric Ochraqualfs) the dominant soil in the experimental area. Initial soil test data is presented in Table 1.

The experimental design was a randomized complete block with eight replications. The treatments consisted of 1) a control, 2) 2 lb B/acre, 3) lime at 2 tons/acre, and 4) lime at 2 tons/acre plus 2 lb B/acre. Boron at a rate of 2 lb B/acre was broadcast in solution immediately after planting. Solubor, 20% B, was the B source. Lime (calcitic) was applied at 2 tons/acre on 12 March 1990. The lime was broadcast by hand and disced in. The experiments were repeated on the same plots each year.

Deltapine 50 was planted about 10 May each year. Cultural practices were under the direction of the farmer. The cotton was irrigated using a center-pivot irrigation system. Seedcotton yields were obtained from one mechanical pick in 1990 and two in 1991.

RESULTS

Total seedcotton yield was not significantly increased either year by the lime and/or B treatments (Tables 2 and 3). However, in 1991 yield for the first and second picks and total yield was highest for the lime plus B treatment (Table 3). Since lime was not applied until March 1990, the soil pH was not increased appreciably until the 1991 growing season (5.7 on the no-lime plots versus 6.5 on the lime plots).

LITERATURE CITED

1. Miley, W.N. and W.E. Woodall. 1982. Boron for cotton in Arkansas. University of Arkansas Cooperative Extension Service Leaflet 349.

Table 1. Soil test data for the Dundee sandy loam at the initiation of the boron test in 1990.

pH	Organic matter	P	K	Ca	Mg
	%	----------	lb/acre	----------	
5.7	1.6	157	254	2263	360

Table 2. Influence of boron and lime on total seedcotton yield in 1990.

Treatment	Yield
	lb/acre
Control	3031
Boron	2933
Lime[1]	2845
Lime + Boron	3099
LSD(0.05)	N.S.[2]

[1] Lime rate was 2 tons/acre applied 12 March 1990. Soil pH at harvest was 5.7 and 6.1 on the no-lime and lime plots, respectively.

[2] N.S. = non-significant.

Table 3. Influence of boron and lime on seedcotton yield in 1991.

Treatment	1st pick	2nd pick	Total	Percent 1st pick
	-----lb/acre-----			%
Control	3369	152	3521	96.5
Boron	3256	132	3388	96.1
Lime[1]	3386	149	3535	95.2
Lime + Boron	3630	174	3804	97.7
LSD(0.05)	N.S.[2]	N.S.	N.S.	N.S.

[1] Lime rate was 2 tons/acre applied 12 March 1990. Soil pH at planting in 1991 was approximately 5.7 and 6.5 on the no-lime and lime plots, respectively.

[2] N.S. = non-significant.