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SOILS AND PLANT NUTRITION

Yield and Petiole Nitrate Concentrations of Cotton Treated with Soil-Applied and Foliar-Applied Nitrogen

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INTERPRETIVE SUMMARY

Foliar N fertilization of cotton is a widely used production practice to augment soil-applied N fertilization programs. Early research indicated that the season-long N needs of cotton may not be met by soil N applications. These studies were used to generate sufficiency/deficiency petiole NO_3^--N levels. Producers have used petiole NO_3^--N analyses to determine the timing of foliar N applications based on the Cotton Nutrient Monitoring Program. Recent research has raised questions about the validity of foliar fertilization and petiole NO_3^--N analysis. Response of cotton to foliar fertilization was reported to be minimal and petiole NO_3^--N was reported to be a poor indicator of crop N status. The objective of this research was to determine the conditions when foliar N fertilization could produce an increase in yield. Further, petioles were analyzed for NO_3^--N to determine their suitability for evaluating crop N status.

Foliar N treatments were tested on a long-term, soil-applied N fertilization and irrigation study. Soil-applied N treatments that ranged from 0 to 168.0 kg N ha^{-1} were tested under dry land and furrow-irrigated conditions. Plots were divided in 1994 and half of each soil N plot was treated three times with 11.2 kg N ha^{-1} of 23% urea-N solution on 2-week intervals beginning at first flower.

Interactions between the soil N and foliar N treatments significantly influenced yields 1 year under irrigated conditions and 2 years under dry land conditions. Foliar N treatments (main effect only) were found to significantly increase lint yields of cotton across all soil-applied N treatments 2 years out of three under irrigated conditions. Foliar N (main effect only) was found to have no significant effect on yield 1 year under dry land conditions.

When soil N and foliar N treatments significantly interacted under irrigated conditions, yields increased with each increment of soil-applied N until a maximum was reached. Foliar N tended to increase yields more on cotton grown with lower soil-applied N rates. As the soil-applied N rates increased, the yield differences between foliar N-treated cotton and untreated cotton decreased. Yield trends in dry land cotton were similar, but large positive yield responses to foliar N were limited to cotton receiving very low soil N. Further, as the soil N rate was increased, there was a trend for negative yield responses in the dry land test. This was particularly true at the highest soil N rates.

Petiole NO_3^--N was found to vary directly with soil-applied N under both irrigated and dry land conditions during most sampling periods. Foliar N and the interaction of foliar N with soil N treatments were found to have little influence on petiole NO_3^--N. Petiole NO_3^--N was found to decline as the growing season progressed all 3 years as expected.

ABSTRACT

Nitrogen fertilization and N nutrient management are crucial components of economically successful cotton (*Gossypium hirsutum* L.) production. The efficacy of foliar N applications and the timing criteria for foliar N applications have been debated by cotton producers and scientists. The objective of this research was to use established soil-applied N experiments to evaluate foliar-applied N applications for increasing cotton yields in southeast Arkansas, and petiole NO_3^--N as an indicator of N status of the crop. A long-term, soil-applied N rates experiment was used in these studies. The test

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consisted of a furrow irrigated and a dry land block of plots. Soil-applied fertilization rates tested within each block ranged from 0 to 168 kg N ha^{-1} and N treatments were applied to the same plot each year of the study. The plots (eight rows; 9.14 m long and 7.72 m wide) were divided and half of each plot received three foliar N treatments (11.2 kg N ha^{-1} treatment^{-1}) on 2-week intervals beginning at first flower. Foliar N treatments most frequently increased lint yield when soil-applied N rates were low (0-67.2 kg N ha^{-1}). Lint yield increases due to foliar fertilization tended to be greater under irrigated production conditions than under dry land conditions. Yield decreases were sometimes found due to foliar-applied N when the rate of soil-applied N fertilizer was high (100.8-168.0 kg N ha^{-1}), although differences were not significant. Higher soil-applied N treatments resulted in higher petiole NO_3^--N throughout the growing seasons, although not all differences were significant. Foliar N treatments were found to significantly increase petiole NO_3^--N in 13 of 38 year-irrigation-sample date combinations. The interaction of foliar N and soil N fertilizer treatments was found to significantly influence petiole NO_3^--N in only one sampling date during 1 year of the study.

Nitrogen is used by plants to manufacture proteins and nucleic acids that are used in almost all plant tissue (Tisdale et al., 1993). One of the most important proteins green plants produce is a component of chlorophyll, the compound that allows plants to photosynthesize. Without sufficient N cotton may become chlorotic and not photosynthesize enough to meet the demands of plant growth. Nitrogen-deficient plants typically have reduced leaf area and use water poorly. These conditions could reduce growth, increase fruit shedding, and decrease yield (Radin and Mauney, 1984).

Producers fertilize cotton with N to avoid yield loss due to N deficiency. Typically, large amounts of N fertilizer are split-applied, with about half the total amount applied before planting and the remainder applied before first bloom (Maples et al., 1990b). Soil testing for N and the subsequent fertilizer N recommendations may be inappropriate for cotton grown under all production conditions during all years. During years of high yield potential, recommended rates of early-season, fertilizer N may be insufficient for maximum yield, and during years of low yield potential, fertilizer N may be over-supplied (Miley, 1982). Arkansas recommendations are based on soil test results with additions and deductions from a base N rate of 112 kg N ha^{-1} based on soil NO_3^--N, soil texture, and cropping history (Chapman and Daniels, 1997).

Previous research has indicated that pre-plant and early sidedress N applications might not meet full-season crop demands. These studies indicated that either soil- or foliar-applied N after first flower may help meet crop N needs and increase yields (Maples and Baker, 1993; Maples et al., 1977). These studies and others were also used to develop critical deficiency and sufficiency values of petiole nitrate-N (NO_3^--N). The critical values were used as sufficiency/deficiency criteria for foliar N applications as the crop progressed during the growing season (Maples et al., 1990a) and incorporated into the Cotton Nutrient Monitoring Program, a producer service program available through the University of Arkansas (Maples et al., 1992). Foliar fertilization of cotton with 23% N (urea) solutions based on Cotton Nutrient Monitoring Program-generated recommendations is widely practiced by Arkansas cotton producers to meet late-season N requirements (Snyder, 1991).

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

Applications of foliar N were found to increase lint yield only when soil-applied N was inadequate for maximum yield (Parker et al., 1993). No significant differences in yield were observed when soil-applied N rates were 112 kg N ha^{-1} or greater regardless of the foliar N treatment. Parker et al. (1993) also observed that foliar-applied N did not significantly influence petiole NO_3^--N concentration at any sampling period. The effects of foliar urea-N applications and other foliar fertilizer products were tested on cotton fertilized with optimum rates of soil-applied N in the central Delta region of Mississippi (Heitholt, 1994). No foliar fertilizer material or technique was found to increase yield compared to the untreated control. Foliar N treatments were found to increase lint yields of cotton grown on water-logged clay soils in Australia as long as temperatures were warm and soil N was low (Hodgson and MacLeod, 1988).

Petiole NO_3^--N was found to be related to cultivar, but not to soil- and foliar-applied N rates in a study conducted in Mississippi (Jenkins et al., 1982). Cultivar was not found to be an important factor in petiole NO_3^--N concentration in a study conducted in Arkansas (McConnell et al., 1993). Sunderman et al. (1979) concluded that petiole NO_3^--N was a valid indicator of the N status of cotton only at first bloom. These results are similar to recent research conducted in Arkansas (Keisling, et al., 1995).

The objective of this study was to determine the N status of a cotton crop under which an increase in yield may be realized when foliar N is applied to cotton. Further, petiole NO_3^--N was evaluated as an indicator of N status of a developing cotton crop.

MATERIALS AND METHODS

Long-term studies of soil-applied N fertilization of cotton were used to determine the impact of foliar N treatments at the Southeast Branch Experiment Station near Rohwer, AR. The soil at Southeast Branch Experiment Station was an Hebert silt loam (fine-silty, mixed, thermic Aeric Ochraqualfs). The test was planted: 7 May 1993, 9 May 1994, and 2 May 1995. All production factors other than those tested were recommended standards for cotton grown in the Arkansas Delta region.

Both soil-applied N rates and irrigation methods have been tested at Southeast Branch Experiment Station since 1982. The experimental design within each irrigation block was a randomized complete block with five replicates. The individual plots were 7.72 m (eight rows) wide and 9.14 m long. All N treatments were tested under furrow-irrigated and dry land production conditions in side-by-side blocks. Fertilizer N treatments ranged from 0 to 134.4 kg N ha^{-1} in 33.6 kg N ha^{-1} increments from 1982 until 1988 and were split applied (half pre-plant, half first square). Since 1989, the N treatments have ranged from 0 to 168.0 kg N ha^{-1} in 33.6 kg N ha^{-1} increments (split-applied: half pre-plant, half at first square), but the three highest N treatments have also been split three ways (one-third pre-plant, one-third at first square, one-third at first flower). Additionally, the 168.0 kg N ha^{-1} treatment was also split 33.6 kg N ha^{-1} pre-plant, 67.2 kg ha^{-1} at first square and 67.2 kg N ha^{-1} at first flower. Each soil-applied N treatment plot was divided to accommodate foliar fertilization treatments. Residual soil NO_3^- was found to be minimal within the irrigated block regardless of the N fertilization rate (McConnell, et al., 1996). Substantial accumulation of residual soil NO_3^- in the dry land block was observed when N fertilization rates exceeded those needed for optimum production.

Testing of foliar N fertilization on the long-term plots was begun in 1993. Half of each soil-applied N treatment plot (four rows, 3.86 m wide and 9.14 m long) received additional foliar fertilization. The experimental design of the original randomized complete block test was modified to split plot with five replications to accommodate the foliar-applied N treatments. Three foliar treatments of 11.2 kg N ha^{-1} of 23% urea-N solutions were applied to the cotton on 2-week intervals beginning at first flower with a back pack spray system. The total foliar N received was either 0 or 33.6 kg N ha^{-1}.

The effects of the foliar- and soil-applied N were evaluated by weekly measurements of petiole NO_3^--N. The petiole NO_3^--N evaluations were begun near the week of first flower. Petioles were sampled from three replications, oven-dried, ground, and analyzed for NO_3^--N using methods described by Maples et al. (1992). Additional measurements included final plant height, node development, seed cotton yield, lint fraction, lint yield, and the fraction of the total lint yield picked in the first harvest. Only lint yield and petiole NO_3^--N are included in this report.

All data were analyzed with the Statistical Analysis System using analysis of variance. The *F*-tests were considered significant at the 0.05 level of probability. Fisher's least significant differences were also calculated at 0.05 level of probability for significantly different main effects and interaction means.

RESULTS AND DISCUSSION

Lint Yields

Although the foliar-applied N treatments within individual soil-applied N treatments did not significantly differ, interactions among soil- and

Table 1. Lint yield response of cotton grown with 10 soil-applied N fertilization rates and splits under two irrigation methods with an additional foliar 33.6 kg N ha^{-1} (Fol) and 0 kg N ha^{-1} (Untrt) at the Southeast Branch Experiment Station in 1993.

Soil N-rate				Irrigated			Dry land		
PP†	FS†	FF†	Total	Fol	Untrt	Mean	Fol	Untrt	Mean
---------------- kg N ha 1 -----------------				------------------------------------ kg lint ha 1 ----------------------------------					
84	84	0	168	1480	1485	1483	1127	1226	1177
56	56	56	168	1399	1507	1447	1156	1280	1219
33.6	67.2	67.2	168	1474	1558	1548	1194	1334	1257
67.2	67.2	0	134.4	1589	1505	1548	1072	1202	1145
44.8	44.8	44.8	134.4	1483	1500	1491	1218	1424	1320
50.4	50.4	0	100.8	1579	1398	1478	1109	1275	1193
33.6	33.6	33.6	100.8	1544	1542	1543	1133	1236	1185
33.6	33.6	0	67.2	1495	1342	1419	1042	1156	1105
16.8	16.8	0	33.6	1251	1150	1195	1128	1063	1095
0	0	0	0	1021	878	958	935	776	856
Mean				1429	1390		1114	1195	
‡LSD (0.05)				242			228		
§LSD (0.05)				393			374		

† PP, FS, and FF are preplant, first square and first flower, respectively.
‡ LSD (0.05) for comparing two soil-applied fertilization means within the same foliar fertilization (either foliar or untreated) in the same irrigation.
§ LSD (0.05) for comparing two soil-applied fertilization means in different foliar fertilization in the same irrigation.

Table 2. Lint yield response of cotton grown with 10 soil-applied N fertilization rates and splits under two irrigation methods with an additional foliar 33.6 kg N ha^{-1} (Fol) and 0 kg N ha^{-1} (Untrt) at the Southeast Branch Experiment Station in 1994.

Soil N-rate				Irrigated			Dry land		
PP†	FS†	FF†	Total	Fol	Untrt	Mean	Fol	Untrt	Mean
---------------- kg N ha 1 ----------------				----------------------------------- kg lint ha 1 -----------------------------------					
84	84	0	168	1829	1812	1821	1587	1487	1537
56	56	56	168	1790	1828	1810	1635	1681	1659
33.6	67.2	67.2	168	1977	1840	1908	1594	1695	1644
67.2	67.2	0	134.4	1826	1794	1810	1467	1490	1478
44.8	44.8	44.8	134.4	1886	1902	1894	1701	1746	1724
50.4	50.4	0	100.8	1812	1671	1742	1511	1522	1516
33.6	33.6	33.6	100.8	1866	1735	1801	1595	1547	1571
33.6	33.6	0	67.2	1764	1660	1712	1505	1373	1428
16.8	16.8	0	33.6	1583	1361	1472	1365	1215	1290
0	0	0	0	1215	978	1096	1017	933	974
Mean				1755	1659		1497	1469	
‡LSD (0.05)				NS			NS		
§LSD (0.05)				NS			NS		
¶LSD (0.05)						106			143
#LSD (0.05)				45			NS		

† PP, FS, and FF are preplant, first square, and first flower, respectively.
‡ LSD (0.05) for comparing two soil-applied fertilization means within the same foliar fertilization (either foliar or untreated) in the same irrigation.
§ LSD (0.05) for comparing two soil-applied fertilization means in different foliar fertilization in the same irrigation.
¶ LSD (0.05) for comparing mean soil N rate main effects.
 # LSD (0.05) for comparing mean foliar N main effects.

Table 3. Lint yield response of cotton grown with 10 soil-applied N fertilization rates and splits under two irrigation methods with an additional foliar 33.6 kg N ha^{-1} (Fol) and 0 kg N ha^{-1} (Untrt) at the Southeast Branch Experiment Station in 1995.

Soil N rate				Irrigated			Dry land		
PP†	FS†	FF†	Total	Fol	Untrt	Mean	Fol	Untrt	Mean
---------------- kg N ha 1 -----------------				--- kg lint ha 1 --					
84	84	0	168	1596	1560	1578	965	1068	1017
56	56	56	168	1481	1538	1509	1028	1164	1096
33.6	67.2	67.2	168	1606	1532	1569	962	1088	1025
67.2	67.2	0	134.4	1590	1540	1566	936	983	960
44.8	44.8	44.8	134.4	1596	1522	1560	996	1156	1085
50.4	50.4	0	100.8	1378	1383	1381	1001	1058	1030
33.6	33.6	33.6	100.8	1487	1434	1460	997	1061	1029
33.6	33.6	0	67.2	1353	1230	1291	993	954	974
16.8	16.8	0	33.6	1249	1098	1172	921	875	898
0	0	0	0	954	788	871	777	586	682
Mean				1429	1364		958	999	
‡LSD (0.05)				NS			269		
§LSD (0.05)				NS			216		
¶LSD (0.05)						142			
#LSD (0.05)				31					

† PP, FS, and FF are preplant, first square, and first flower, respectively.
‡ LSD (0.05) for comparing two soil-applied fertilization means within the same foliar fertilization (either foliar or untreated) in the same irrigation.
§ LSD (0.05) for comparing two soil-applied fertilization means in different foliar fertilization in the same irrigation.
¶ LSD (0.05) for comparing mean soil N rate main effects.
 # LSD (0.05) for comparing mean foliar N main effects.

foliar-applied treatments were significant in both irrigation blocks in 1993 and the dry land block in 1995. Consistent trends were observed in the lint yield means of both the irrigated and dry land cotton. Significant differences in lint yield due to the soil-applied N treatments and foliar-applied N treatments main effects were observed.

Irrigated cotton generally responded to foliar fertilization with increased yield when soil N was restricted to pre-plant and first square application totaling 134.4 kg N ha^{-1} or less in 1993 (Table 1). No increase in yield due to foliar fertilization was observed in conjunction with the 168.0 kg N ha^{-1} soil-applied treatments or when the cotton received soil-applied N at first flower. Greatest yielding N treatments in the furrow irrigated block were 100.8 kg N ha^{-1} (50.4 kg pre-plant N ha^{-1}, 50.4 kg first square N ha^{-1}, and 0 kg first flower N ha^{-1}) and 134.4 kg N ha^{-1} (67.2 kg pre-plant N ha^{-1}, 67.2 kg first square N ha^{-1}, and 0 kg first flower N ha^{-1}) treated with the additional 33.6 kg foliar N ha^{-1}.

Dry land cotton at Southeast Branch Experiment Station responded to foliar fertilization treatments with increased yield when soil N rates were low in 1993 (Table 1). Dry land cotton that received 0 and 33.6 kg N ha^{-1} as a soil-applied treatment yielded 159 and 65 kg lint ha^{-1} more, respectively, when additional N was applied to the foliage. Soil-applied N rates of 100.8, 134.4, and 168.0 kg N ha^{-1} did not significantly increase cotton yields compared to 67.2 kg N ha^{-1}. Further, foliar-applied N on cotton fertilized with 67.2 kg N ha^{-1} or more apparently decreased yields, although the differences were not significant. The five greatest yielding treatments in the dry land experiment received no foliar N.

Lint yields during the 1994 growing season were generally greater than in 1993, probably due to better growing conditions. Foliar N treatment by soil N treatment interactions did not significantly influence lint yield in either the irrigated or dry land test in 1994 (Table 2). Only main effects soil- and foliar-applied N treatments produced significant differences in yield. Foliar N significantly increased yields of irrigated cotton in 1994. Greatest increases in lint yield were observed with the two lowest soil-applied N-rates (0 and 33.6 kg N ha^{-1}), similar to the 1993 results. Foliar N treatments did not

Table 4. Petiole NO_3^--N responses of irrigated and dry land cotton grown with three selected soil-applied N fertilization rates (0, 100.8, and 168.0 kg N ha^{-1}) with and without an additional foliar-applied 33.6 kg N ha^{-1} (Fol N) in 1993.

Soil N rate					Date†						
PP‡	FS‡	FF‡	Total	Fol N	1-Jul	8-Jul	14-Jul	22-Jul	30-Jul	5 Aug.	12 Aug.
-------------- kg N ha 1 --------------					---------------------------------- mg NO3 -N kg 1--						
							Irrigated				
56	56	56	168	33.6	18 765§	6 771§	10 100§	7 074§,#	12 242§	6 771§,¶	949§
56	56	56	168	0	19 339	5 898	10 378	4 175	10 663	5 898	1 039
50.4	50.4	0	100.8	33.6	14 652	5 281	6 789	3 009	2 211	5 281	581
50.4	50.4	0	100.8	0	11 747	5 480	7 210	1 190	516	5 480	578
0	0	0	0	33.6	3 440	968	1 440	410	348	968	287
0	0	0	0	0	8 491	2 014	1 546	2 055	4 455	2 014	287
Mean				33.6	12 998	4 490	7 359	4 484	4 573	2 326	698
Mean				0	15 620	5 237	7 174	3 884	4 309	1 595	548
LSD (0.05)					NS	NS	NS	------	NS	461	NS
							Dry land				
56	56	56	168	33.6	10 367§	4 842§	7 015§	10 395§,¶	9 738§,¶	5 971§,¶	4 187§,¶
56	56	56	168	0	12 856	6 668	9 155	10 616	9 687	5 271	3 802
50.4	50.4	0	100.8	33.6	9 831	5 050	5 504	7 963	6 167	3 847	2 301
50.4	50.4	0	0	0	8 994	3 575	5 547	6 740	4 406	1 850	1 375
0	0	0	0	33.6	2 695	1 870	2 948	2 253	2 868	1 562	2 096
0	0	0	0	0	3 424	2 082	1 930	2 474	2 043	1 371	1 272
Mean				33.6	8 545	4 193	6 311	9 810	7 369	4 544	3 520
Mean				0	8 265	4 519	6 384	7 778	6 372	3 639	2 809
LSD (0.05)					NS	NS	NS	898	802	393	437

† Dates of foliar N applications were 15 July, 30 July, and 12 Aug. 1993. Date of first flower was 8 July 1993.
‡ PP, FS, and FF are preplant, first square, and first flower, respectively.
§ Significant differences in the petiole NO_3^--N means of the soil-applied N treatments.
¶ Significant differences in the petiole NO_3^--N means of the foliar-applied N treatments.
 # Significant differences in the petiole NO_3^--N interaction means of the foliar and soil-applied N treatments.

significantly affect the dry land lint yields in 1994.

Soil-applied N-treatments significantly influenced lint yield means in both the irrigated and dry land cotton during 1994 (Table 2). Greatest irrigated yields were found with the 168.0 kg soil-applied N ha^{-1} that was split 33.6, 67.2, and 67.2 kg N ha^{-1} pre-plant, first square, and first flower, respectively. No soil-applied N-treatment was found to increase yield significantly more than the 134.4 kg N ha^{-1} treatments. Yield response trends of dry land cotton to soil-applied N were similar to irrigated cotton. Lint yields were maximized with 134.4 kg N ha^{-1} split three ways.

Lint yields in 1995 tended to be intermediate compared to 1993 and 1994 yields (Table 3). Increasing soil-applied N up to 134.4 kg N ha^{-1} and foliar fertilization significantly increased lint yields in the irrigated block, but the interaction of soil- and foliar-applied N treatments was not significant. Trends of greatest increases in yield with foliar N in cotton that received low soil-applied N were observed. This is similar to the results from the first 2 years.

A significant interaction effect on yield was found between soil-applied N treatments and foliar N treatments in the dry land test (Table 3). Positive yield responses to foliar fertilization were found in the cotton grown in the three lowest soil-applied N treatments. Greatest yield increase with foliar N was found in the plots that received no soil-applied N. Negative yield responses to foliar N treatments, although not significantly different, were observed when soil-applied N-rates were 67.2 kg N ha^{-1} or greater. Negative yield response to foliar N were similar to those observed by Parker et al. (1993).

Petiole Nitrate-Nitrogen

Primary differences in petiole NO_3^--N concentrations in 1994 were due to soil-applied N

Table 5. Petiole NO_3^--N responses of irrigated and dry land cotton grown with three selected soil-applied N fertilization rates (0, 100.8, and 168.0 kg N ha^{-1}) with and without an additional foliar-applied 33.6 kg N ha^{-1} (Fol N) in 1994.

Soil N rate					Date†					
PP‡	**FS‡**	**FF‡**	**Total**	**Fol N**	**7-Jul**	**14-Jul**	**21-Jul**	**28-Jul**	**4 Aug.**	**11 Aug.**
------------- kg N ha 1 -------------					-------------------------------- mg NO3 -N kg 1 -----------------------------------					
					Irrigated					
56	56	56	168	33.6	10 166§	10 715§	11 072§,¶	13 901§,¶	8 104§	2 912§
56	56	56	168	0	7 387	8 231	7 978	13 201	8 116	3 201
50.4	50.4	0	100.8	33.6	4 639	6 193	3 643	1 460	227	101
50.4	50.4	0	100.8	0	3 768	5 266	2 564	478	63	106
0	0	0	0	33.6	148	50	236	108	58	123
0	0	0	0	0	335	59	285	154	58	106
Mean				33.6	5 112	6 266	5 322	5 867	2 813	867
Mean				0	5 118	5 102	4 152	5 053	2 219	746
LSD (0.05)					NS	NS	1014	797	NS	NS
					Dry land					
56	56	56	168	33.6	7 739§	5 448§	13 658§	13 335§	9 319§	4 470§
56	56	56	168	0	8 005	6 942	12 790	13 175	11 396	5 161
50.4	50.4	0	100.8	33.6	6 394	3 184	10 034	9 093	5 528	1 956
50.4	50.4	0	100.8	0	4 924	2 580	8 395	8 418	2 599	597
0	0	0	0	33.6	148	61	284	395	251	197
0	0	0	0	0	148	61	192	296	155	188
Mean				33.6	4 844	3 835	9 225	8 750	6 165	2 585
Mean				0	4 930	3 643	8 512	8 909	6 153	2 373
LSD (0.05)					NS	NS	NS	NS	NS	NS

† Dates of foliar N applications were 18 July, 28 July, and 12 Aug. 1994. Date of first flower was 7 July 1994.
‡ PP, FS, and FF are preplant, first square, and first flower, respectively.
§ Significant differences in the petiole NO_3^--N means of the soil-applied N treatments.
¶ Significant differences in the petiole NO_3^--N means of the foliar-applied N treatments.

fertilizer (Table 4). Petiole NO_3^--N concentrations of cotton fertilized with 168.0, 100.8, and 0 kg N ha^{-1} differed inconsistently with additional foliar N fertilization. Irrigated cotton that received no soil-applied N had greater petiole NO_3^--N levels without foliar N. The reason for the low petiole NO_3^--N concentration in cotton that received no soil N but did receive foliar N is unknown. Main effect foliar-applied N treatments indicated significantly more petiole NO_3^--N in cotton that received foliar-applied N only once in the irrigated block in and four times in the dry land block in 1993. Petiole NO_3^--N concentrations tended to decline irregularly as the growing season progressed. Declining petiole NO_3^--N values were expected as the cotton plants matured and more N was translocated into the bolls (Maples et al., 1992).

Primary differences in petiole NO_3^--N concentrations were due to the soil-applied N fertilizer at Southeast Branch Experiment Station in 1994 (Table 5), similar to the results observed in 1993. The interaction of soil-applied N treatments with foliar N treatments did not significantly affect petiole NO_3^--N content of the cotton at any sampling date under either irrigated or dry land conditions. Further, the foliar treatments significantly affected petiole NO_3^--N in only two sampling dates under irrigated conditions.

Samples taken near first flower had very high petiole NO_3^--N concentrations, but still varied with the soil-applied N treatments (Table 4). The trend of irrigated cotton that received no soil-applied N having greater petiole NO_3^--N levels without foliar N was not observed in 1994. Main effect foliar-applied N treatments did not significantly affect petiole NO_3^--N in dry land cotton and only twice in the irrigated block. Petiole NO_3^--N concentrations tended to decline irregularly as the growing season progressed similar to 1993.

Petiole NO_3^--N concentrations in 1995 generally followed the same patterns observed during the previous 2 years (Table 6). Petiole NO_3^--N were

Table 6. Petiole NO_3^--N responses of irrigated and dry land cotton grown with three selected soil-applied N fertilization rates (0, 100.8, and 168.0 kg N ha^{-1}) with and without an additional foliar-applied 33.6 kg N ha^{-1} (Fol N) in 1995.

Soil N rate					Date†					
PP‡	FS‡	FF‡	Total	Fol N	13-Jul	20-Jul	27-Jul	2 Aug.	10 Aug.	17 Aug.
------------ kg N ha 1 ------------					--------------------------------- mg NO3 -N kg 1 -----------------------------------					
					Irrigated					
56	56	56	168	33.6	13 206§	7 453§,¶	10 269§,¶	4 338§	2 399§	623§
56	56	56	168.9	0	13 024	5 647	8 743	4 220	552	211
50.4	50.4	0	100.8	33.6	7 848	1 380	522	321	122	66
50.4	50.4	0	100.8	0	8 109	810	500	565	16	20
0	0	0	0	33.6	1 159	447	20	591	64	20
0	0	0	0	0	3 364	14	20	90	9	14
Mean				33.6	8 514	3 174	3922	1613	426	176
Mean				0	7 987	2 411	2936	1171	389	99
LSD (0.05)					NS	560	947	NS	NS	NS
					Dry land					
56	56	56	168	33.6	15 187§	6172§	8945§,¶	5181§,¶	2941§,¶	2175§,¶
56	56	56	168	0	16 034	7 043	10750	3 904	3 230	2 032
50.4	50.4	0	100.8	33.6	10 450	3 139	5 117	2 226	1 554	1 166
50.4	50.4	0	100.8	0	11 190	2 810	3 932	1 027	543	355
0	0	0	0	33.6	4 816	3 203	911	650	1 029	617
0	0	0	0	0	2 768	3 184	2 052	1 914	1 118	1 444
Mean				33.6	10 854	4 970	7 637	3 880	2 732	1 907
Mean				0	10 582	5 010	6 515	3 169	1 837	1 432
LSD (0.05)					NS	NS	978	548	492	426

† Dates of foliar N applications were 10 July, 21 July, and 13 Aug. 1995. Date of first flower was 3 July 1995.
‡ PP, FS, and FF are preplant, first square, and first flower, respectively.
§ Significant differences in the petiole NO_3^--N means of the soil-applied N treatments.
¶ Significant differences in the petiole NO_3^--N means of the foliar-applied N treatments.

found to be high in the earlier sampling periods near first flower and declined as the season progressed. Soil-applied N was found to have the greatest influence on petiole NO_3^--N. Foliar-applied N was found to significantly increase petiole NO_3^--N on two dates in the irrigated test and on five dates in the dry land test. The interaction effects of soil- with foliar-applied N were not significant at any sampling date. Main effect foliar-applied N treatments indicated significantly more petiole NO_3^--N in cotton that received foliar-applied N in only two sampling dates in the irrigated block in and four times in the dry land block in 1995. The irregular decline in petiole NO_3^--N concentrations as the growing season progressed was again observed in 1995.

CONCLUSIONS

The interaction of foliar N with soil-applied N-treatments significantly affected lint yields of cotton under both irrigated and dry land conditions in 1993, and under dry land conditions in 1995. Although significant differences between foliar-applied N treatments within the same soil-applied N were not observed, trends in the data indicated differential response to the foliar N. Irrigated cotton yields tended to increase with additional foliar N on plots that received up to 134.4 kg N ha^{-1} soil-applied N as long as the soil N treatment did not include a first flower application. Dry land cotton yields were increased by foliar N treatments only when soil N-rates were either 0 or 33.6 kg N ha^{-1}.

Only main effects means were significantly different in 1994 and the irrigated block in 1995. No soil-applied treatment resulted in significantly greater yields than 100.8 kg N ha^{-1} applied in a three-way split under dry land conditions in 1994 and 1995. The three-way split of 168 kg N ha^{-1} produced slightly greater lint yields than 100.8 kg N ha^{-1} under irrigated conditions in 1994. Foliar-applied N treatments significantly increased yields in the irrigated cotton by 5.8% and 4.8% in 1994 and 1995, respectively. Dry land cotton yields were not significantly affected by foliar-applied N in 1994.

Yield responses to foliar N tended to differ between years and between irrigated and dry land cotton production conditions. The reason for the differences in yield response to foliar N is not clear. Generally, foliar-applied N applications resulted in increased yield when soil-applied N was less than optimum.

Petiole NO_3^--N concentrations of cotton was influenced almost exclusively by soil-applied N-rates. Petiole NO_3^--N generally increased with increasing soil N fertilizer and declined irregularly as the growing season progressed. Foliar N treatments were found to significantly increase petiole NO_3^--N on 13 of 38 date-irrigation-year combinations. The interaction of soil N and foliar N treatments significantly affect petiole NO_3^--N on only one sampling date in 3 years.

Petiole NO_3^--N concentrations were found to be a good indicator of soil-applied N with greater concentrations found in cotton receiving greater N fertilization. Foliar-applied N was found to have erratic effect on petiole NO_3^--N concentrations. Frequently, cotton receiving foliar-applied N treatments did not exhibit significantly different petiole NO_3^--N concentrations from untreated cotton. Petiole NO_3^--N concentration was found to be a poor indicator of foliar-applied N fertilization.

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