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Nitrates in Petioles of Three Cottons[1]

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ABSTRACT

Three cotton strains, *Gossypium hirsutum* L., were grown with two N levels, 56 (soil applied) and 86 kg N/ha (56 kg/ha soil applied plus 30 kg/ha foliar applied). Foliar applications were based on results from petiole nitrate monitoring. The primary objective was to determine if petiole nitrates and phosphorus levels were affected by cotton strains. We chose three cottons which we knew were different in leaf area and rate of fruiting.

Significant differences among 'Stoneville 213,' Stoneville 817 frego, and Stoneville 7A nectariless, okra leaf were found for levels of petiole nitrates and P when monitored for 11 weeks during the growing season. No significant differences in levels of petiole nitrates or P were found between two levels of N. There was a significant cotton strain by week interaction for petiole nitrates but not P.

Petiole nitrates ranged from 310 to 16,000 ppm during the season. There was a significant increase in lint yields at the second harvest in foliar-fed plots and an increase of 47 kg lint/ha in total yield. However, total lint yields were not significantly different between the two levels of N or among the three strains. Yields ranged from 981 to 1,010 kg lint/ha for the three strains. Strains did not respond differently to the two N levels. Foliar feeding did not affect boll size or lint percent. These data illustrate some of the inherent difficulties associated with the use of petiole nitrate monitoring as a useful tool for assessing N application.

Additional index words: Gossypium hirsutum L., Nitrogen, Phosphorus, Okra leaf cotton.

NITROGEN management has a greater potential for increasing or decreasing cotton, *Gossypium hirsutum* L., yields than that of any other primary fertilizer nutrient. For optimum yields, cotton should have the correct amount of N in all phases of growth and fruit development. Plant tissue analysis, specifically petiole nitrate analysis, has been researched as a means of supplying optimum amounts of N to cotton (MacKenzie et al., 1963; Miley and Maples, undated).

In a 7-year study MacKenzie et al. (1963) showed consistently that the concentration of nitrates in cotton petioles was related directly to the amount of N applied and to the N status of the crop. Nitrogen rate had a larger effect on nitrate content of petioles than soil moisture or cotton cultivar. Under the conditions of their tests at Brawley, Calif., petiole levels of nitrate N of 16,000, 8,000, and 2,000 ppm during the early, mid, and late-bloom stages of growth were considered adequate levels for high production. These rates are within the ranges considered adequate for Arkansas conditions (Miley and Maples, undated).

MacKenzie et al. (1963) showed significant differences in petiole nitrate content among cultivars 'Acala 4-42,' 'Deltapine 15,' and the strain R15. They suggested these differences were related to the differences in growth rate and N uptake capabilities of the cottons. We decided to research this in our study by including three cottons which we knew would have different fruiting rates and leaf areas, and would thus be at different physiological stages (fruit sink strengths) at certain times during the growing season.

We grew three cottons with 56 kg/ha soil-applied N both with and without an additional 30 kg N/ha applied as a foliar spray based upon results from petiole nitrate monitoring. Our objectives were 1) to monitor petiole nitrates and P levels and determine if they were affected by cotton strains, and 2) to determine the relationships of cottons, petiole nitrates, and P with lint yield and yield components of lint percent and boll size.

MATERIALS AND METHODS

The study was conducted at the Plant Science Research Center at Mississippi State, Miss. The soil type was Leeper silty clay loam, a vertic haplaquept. The experimental design was a split plot, with four replications. Rows were 96 cm wide. Whole plots were N levels; split-plots were cotton strains. Split plots were 40 rows wide by 11.6 m long. Each split-plot was divided into two sampling areas of 20 rows each. This experiment consisted of 24 plots (of 2 sampling areas each) and occupied approximately 1.4 ha.

The two N levels were 56 (soil applied) and 86 kg N/ha (56 kg soil applied plus 30 kg foliar applied). The soil-applied N was a split application with 18 kg N/ha from commercial 8-24-24 applied prior to planting and 38 kg N from commercial ammonium nitrate applied as a sidedress 1 month after emergence. Foliar N was supplied as feed grade urea in a water solution and was applied four times during the season upon recommendations based on petiole nitrate monitoring. The three cottons were 'Stoneville 213' (ST213), Stoneville 7A nectariless, okra leaf (ST7ANO), and Stoneville 817 frego bract (ST817 fg). These cottons have different rates of fruit formation and differ in earliness of maturity of open bolls. Okra leaf has a reduced leaf area and fruits considerably faster than normal leaf (Andries et al., 1969).

Prior to planting, each split plot was sampled for residual nitrate N at 0 to 15, 15 to 46, and 46 to 76 cm depths. Mean levels of residual nitrate N were 6.0, 6.8, and 5.3 kg/ha at the three depths, respectively. Soil pH was 8.26. The S, Mg, K, and B were also brought up to adequate levels. In order to accomplish this, we applied 224 kg/ha of commercial grade 8-24-24, 224 kg/ha of Sul-Po-Mag[3] (18% MgO, 22% K_2O, 22% S), and 4 kg/ha of borax (0.44 kg B/ha).

Cotton was planted 17 May and petiole nitrate monitoring was initiated at the fifth node (V5) stage (Elsner et al., 1977). Each week from 7 July through 1 September, 15 petioles were taken in each plot by selecting the youngest fully developed leaf on each of 15 plants. These samples were sent to the University of Arkansas' Eastern Arkansas Soil Testing Laboratory at Marianna, Ark., for analyses of petiole nitrates and P using their standard procedures. Based upon their recommendations foliar

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[3]Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

Table 1. Mean square values for variables from analysis of variance.

Source†	Petiole‡ NO_3	Petiole‡ P	No. sqs/ha	Percent lint	Boll size	kg lint/ha‡ 1st pick	2nd pick	Total
R	59.94	7.86	1.72	0.58	0.68*	0.597	0.066**	0.311
N	39.93	4.75	2.78	0.00	0.00	0.025	0.131**	0.270
Error a	534.69	17.46	47.96	0.64	0.06	1.526	0.006	1.348
C	1,223.39**	24.41*	107.13**	7.48**	4.46**	0.204	0.043**	0.046
N×S	2.48	3.67	5.01	2.48	0.05	0.011	0.013	0.047
Error b	29.39	3.55	3.82	0.99	0.12	0.158	0.008	0.117
W§	13,211.51**	179.43**	312.76**					
N×W	16.62	4.26	2.65					
S×W	141.05	4.69	12.13**					
N×C×W	11.76	3.30	1.20					
Error c	30.81	4.59	2.81					
Subsample error	22.95	3.62	1.88	2.22	0.030	0.202	0.018	0.141

*,** Significantly different at the 0.05 and 0.01 levels, respectively, by F test.
† R—replications, N—nitrogen levels, C—cottons, W—weeks.
‡ Means squares × 10^{-5}. Error a = N × R; Error b = C × R plus N × C × R; Error c = R × W plus R × W × N plus R × C × W plus R × N × C × W.
§ df for weeks = 10 for petiole NO_3 and P and 7 for no. sqs/ha.

applications of urea were made at 5.0, 7.5, 10.1, and 7.5 kg N/ha on 26 July and 3, 15, and 23 August to the plots in the high N treatment.

Weekly fruiting records were kept by counting all fruiting forms on 0.91 m of row each week from one of the four center rows with the exception of the last 2 weeks when only bolls were counted.

All pest insects were adequately controlled by applying insecticides every 10 days. Field scouting records verified the adequacy of insect control. Fifty boll samples for determining boll size and lint percent were harvested prior to the first harvest. The four center rows in each plot were mechanically harvested on 20 September and again 5 weeks later.

RESULTS AND DISCUSSION

Mean squares from the analyses of variance are shown in Table 1. The fruiting response of the three cottons is shown in Table 2. Each reached peak square production at the same time; however, ST7ANO had considerably more squares than ST213 or ST817 fg. The fewest fruit were on ST817 fg. The three cottons thus should have had different sink strengths during the season for carbohydrates and N.

Petiole nitrate monitoring began at the fifth node, V5, stage of growth. Based upon results from petiole nitrate monitoring, urea was applied four times during the season to supply an additional 30 kg N/ha to the high N plots. The foliar-fed plots were noticeably greener.

Table 2. Fruiting rate of three cottons over 10 weeks.†

Week	Fruit per ha ST7ANO	ST817 fg	ST213
7 July	128,600	61,400	75,800
19 July	362,500	230,000	297,000
26 July	330,900	220,200	248,600
1 Aug.	284,200	211,100	220,500
9 Aug.	257,500	203,600	198,800
16 Aug.	172,900	197,600	167,300
23 Aug.	110,400	87,800	105,100
1 Sept.	110,900	103,900	105,800

† The F test for strain by week interaction was significant. The L.S.D. 0.05 level is 36,800.

There was no significant difference between the concentration of either nitrates or P in petioles of plants from the two levels of N; i.e., foliar application of 30 kg N/ha did not result in a significant increase in petiole nitrates (Table 1). However, more nitrates, but not more P, were generally found in petioles of foliar-fed plots. There was, however, a significant difference among the three cottons for petiole nitrates and P (Tables 1 and 3). Sunderman et al. (1979) did not find a consistent effect of cotton cultivar on nitrate levels. We, however, used different cottons than they used. On the average, we found that ST7ANO had the highest level of petiole nitrates and ST213 the lowest. ST817 fg had significantly lower levels of P than the other two strains. There was a significant strain by week interaction for petiole nitrates but not P

Table 3. Weekly petiole nitrates and phosphorus in three cottons.†

Week	Petiole nitrates ppm ST7ANO	ST817 fg	ST213	$\bar{x}$	Petiole phosphorus ppm ST7ANO	ST817 fg	ST213	$\bar{x}$
23 June	18,600	15,500	13,250	15,783	3,304	3,110	3,407	3,274
30 June	12,950	11,285	10,100	11,445	2,475	2,172	2,523	2,390
7 July	8,300	6,700	5,200	5,733	2,350	1,878	2,335	2,188
19 July	8,200	5,250	4,550	6,000	2,389	2,388	2,858	2,545
28 July	3,300	2,002	1,450	2,251	1,933	1,719	1,796	1,816
2 Aug.	1,050	675	675	800	1,489	1,317	1,409	1,405
8 Aug.	506	375	338	406	1,294	1,196	1,158	1,216
17 Aug.	1,463	1,444	1,369	1,425	1,607	1,553	2,374	1,845
23 Aug.	1,088	619	600	769	1,822	1,815	1,874	1,837
1 Sept.	338	319	300	319	1,668	1,795	1,751	1,738
8 Sept.	450	338	338	375	1,274	1,249	1,293	1,272
$\bar{x}$	5,113	4,046	3,470	--	1,964	1,836	2,071	--

† L.S.D. 0.05 was 1,216 and 469 for the petiole nitrates and phosphorus, respectively, for the cottons by week interactions. L.S.D. 0.05 was 398 and 138 for the petiole nitrates and phosphorus, respectively, for cottons. L.S.D. 0.05 was 702 and 271 for the petiole nitrates and phosphorus, respectively, for weeks.

(Table 3). Petiole nitrates on 23, 30 June and 7 July for all three strains were significantly different. These three dates were before any foliar applications of urea were made. This indicated a significant difference among the three cottons. On 19 and 28 July, nitrate levels of ST213 and ST817 fg were not significantly different from each other but were significantly lower than in ST7ANO. Thereafter, the level of nitrates in the three strains was not significantly different during the remainder of the season. ST7ANO generally had the highest level of petiole P and ST817 fg the lowest level. The lower level in ST817 fg may be related to its slow rate of fruiting (Table 3). Petiole nitrates averaged over all three strains varied from 319 to 15,783 ppm during the season. This agrees with Miley and Maples, updated; MacKenzie et al., 1963; and Sunderman et al., 1979. Petiole P varied from 1,272 to 3,274 ppm during the season. Early in the season both were high and declined with plant age (Table 3). This is as expected (Miley and Maples, undated).

Petiole nitrates were consistently higher in the ST7ANO strain. The smaller leaf areas of ST7ANO (Andries et al., 1969) resulted in a smaller storage volume for N reserves which may account for the higher accumulation of nitrates in the petioles. On the other hand, this strain fruited at a fast rate which could have resulted in a stronger sink strength. Thus, if the nitrates in the petiole reflect the amount being transported to the sinks, we would expect ST7ANO to be higher in petiole nitrates than the other two strains.

Petiole nitrates comprise the supply component of the pool of soluble N compounds in cotton plants. Most of the N is located in the leaves. Healthy plants maintain an equilibrium of the various components of this pool. Thus, when demand for dry matter production exceeds N uptake, the soluble compounds are partially depleted and reductase activity speeds up in leaf blades to maintain equilibrium, resulting in lower nitrates in the petioles. Nitrates are the most sensitive variable of this system and are the easiest to measure quantitatively.

There was a trend toward higher levels of petiole nitrates in the foliar-fed plots, which may be an indirect effect. The N in the urea supplied by foliar feeding was a substitute for the nitrate N in the plant. Foliar-fed plants, by using the N in the urea during rapid fruit development, could have caused a reduction in the utilization of nitrate N which in turn lead to the increase in petiole nitrates that we observed.

Lint yields, boll size, and lint percentages for the six treatments are shown in Tables 4, 5, and 6. The plots receiving foliar N had significantly more lint at the second harvest but first and final yields were not significantly affected by the foliar-applied N.

There were no significant differences in total lint yield among the three strains. The interactions were not statistically significant. Sunderman et al. (1979) with different levels of nitrogen found only a few significant relationships between lint yield and petiole nitrate N levels. They, however, concluded that plant tissue analysis appeared to be a useful diagnostic tool for assessing the N level of cotton in the southern Great Plains but indicated that appropriate correlations were not available to use it at present. In our study the foliar-fed plots showed no response in yields at first picking but yields at second picking were increased. Foliar-fed plots of ST817 fg and ST213 yielded more, although not significantly more, whereas less differences were shown between N levels with ST7ANO. ST7ANO was the earliest strain followed by ST213 with ST817 fg being the latest. Mean yields were 980, 1,008, and 1,010 kg/ha for ST7ANO, ST817 fg, and ST213 (Table 6).

Boll size and lint percent were not affected by foliar-applied N in any of the strains. The three strains were different in lint percentage and in boll size. Bolls from ST7ANO were significantly smaller than those of the other two strains.

We could see visible differences in green color of leaves between the two levels of N, and an increase in number of late fruit where foliar N was applied, but we did not measure any major significant effects on plant growth and development, or total lint yields that could be associated with the two N levels. We did, however, produce 47 kg

Table 4. Yield data for three cottons and two nitrogen levels.†

Strain N levels	Boll size	Lint	kg lint/ha First harvest	Second harvest	Total harvest
	g	%			
ST7ANO					
– Foliar N	5.68	38.9	926	48	974
+ Foliar N	5.69	38.3	922	64	986
ST817 fg					
– Foliar N	6.74	37.2	839	129	969
+ Foliar N	6.63	38.1	868	180	1,048
ST213					
– Foliar N	6.42	39.1	869	115	984
+ Foliar N	6.53	38.8	887	148	1,035
L.S.D. 0.05	0.37	1.1	137	30	118

† None of the F tests for N by cotton interactions were significant for any of the yield components.

Table 5. Effect of two levels of N on yield components averaged over three cottons.

Nitrogen level	Boll size	Lint	kg lint/ha First harvest	Second harvest	Total harvest
	g	%			
– Foliar N	6.28	38.4	878	98	976
+ Foliar N	6.29	38.4	893	131	1,023
L.S.D. 0.05	0.22	0.7	359	23	337

Table 6. Yield data for three cottons averaged over two N levels.

Strains	Boll size	Lint	kg/ha First harvest	Second harvest	Total harvest
	g	%			
ST7ANO	5.69	38.6	924	56	980
ST817 fg	6.68	37.6	853	155	1,088
ST213	6.48	39.0	878	132	1,010
L.S.D. 0.05	0.26	0.8	99	21	83

lint/ha more on the foliar-fed plots, but this was not statistically significant at the 0.05 level. This is, however, consistent with data from Arkansas and is about the yield increase expected from 30 ka/ha additional N (Lancaster unpublished data).[4]

It is difficult to successfully apply more than 30 kg/ha of N by foliar feeding based upon petiole nitrate monitoring, yet it is difficult to measure a statistical difference with 47 kg lint/ha in experimental plots. This illustrates some of the inherent difficulties associated with the use of petiole nitrate monitoring as a useful tool for assessing N application. The significant difference between petiole nitrate levels among the strains but no significant difference in lint yields due to strains also indicates difficulties in assessing this relationship and the use of petiole nitrate monitoring.

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