COTTON PLANT PHYSIOLOGICAL AND YIELD RESPONSES TO NITROGEN STATUS

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Abstract

A better understanding of the effect of soil nitrogen (N) level on cotton plant carbon metabolism is important in cotton research and production. Field studies were conducted at two locations of Clarkedale (Northeast Arkansas) and Fayetteville (Northwest Arkansas) in 2000 to investigate cotton plant physiological and yield responses to two levels of soil N fertilizer applications. The experiments consisted of two treatments of high N (HN) and low N (LN). The HN and LN treatments received a total of 100 and 50 (Clarkedale) or 100 and 40 (Fayetteville) lb. N/A, respectively. At Clarkedale, LN decreased plant height, leaf area index, plant dry matter accumulation, leaf chlorophyll concentration and leaf net photosynthetic rate during fruiting. As a result, the LN treatment had significantly lower boll numbers and lint yield than the HN treatment. Leaf nonstructural carbohydrate concentrations changed tremendously with growing season, but did not differ between the two N treatments at most measuring times. At Fayetteville, there were no statistical differences between HN and LN treatments in plant growth, lint yield and most physiological measurements. The inconsistent results in the two locations might be associated with soil fertility levels because the soil N fertility before planting at Fayetteville was much higher than at Clarkedale.

Introduction

The indeterminate growth habit of cotton (*Gossypium hirsutum* L.) plants makes them very responsive to changes in the environment and management. Both excess nitrogen (N) and N deficiency affect cotton growth and yield. Leaf photosynthesis and plant carbon metabolism are the cornerstones of crop growth and yield development. Therefore, investigating the effect of N deficiency on carbohydrate content of plant tissues will help us to understand the physiological mechanism of low N influencing cotton yield.

Many earlier studies have shown that N deficit is one of major factors influencing cotton plant growth and yield. Low N stress significantly decreased leaf area development, boll retention and lint yield (Jackson and Gerik, 1990; Miley and Oosterhuis, 1990; Gerik et al., 1994). But little is known about the response of nonstructural carbohydrate concentrations in different plant tissues to N deficit. A better understanding of the effect of N deficit on plant carbon metabolism of field-grown cotton is important because the accumulation and partitioning of photo-assimilate is fundamental for yield development. The objective of this study was to determine the effect of moderate N deficit on plant growth, leaf photosynthesis, concentrations of chlorophyll and nonstructural carbohydrates, and lint yield.

Materials and Methods

Plant Culture

Field experiments were conducted at the two locations of Clarkedale (Northeast Arkansas) and Fayetteville (Northwest Arkansas) in Arkansas. In Clarkedale, cotton cultivar Suregrow 747 was planted on 10 May 2000. The soil NO_3-N level was 9.2 lb./A in early spring. Preplant fertilizer was applied at a rate of 18-46-60 lb. N-P-K acre^{-1} for all plots. In Fayetteville, cotton (cv. Suregrow 215 BR) was planted on 24 May 2000. The soil NO_3-N level was 31.6 lb./A in early spring. Preplant fertilizer was applied at a rate of 40-18-33 lb. N-P-K acre^{-1}. In both locations, each plot consisted of four rows spaced 38-inch apart, and hand-thinned to 10 plants m^{-1} row when the seedlings had about three true leaves. The plot length was 50 feet (Clarkedale) or 16.5 feet (Fayetteville).

The two treatments were (1) high N (HL) and (2) low N (LN) at both locations. The HN treatment received a total amount of 100 lb. N acre^{-1} and the LN treatment received 50 lb. N acre^{-1}. Details of the rate and timing of N treatments are given in Table 1. Control of insects and weeds, and furrow irrigation were given as needed during the growing season in an attempt to minimize plant stress and optimize yield. The experiments were arranged in a randomized complete block design with six replications.

Measurements

During plant growth, the net photosynthetic rate, chlorophyll content and nonstructural carbohydrates concentrations of uppermost fully expanded main-stem leaves were determined using the methods of Zhao and Oosterhuis (2000). At the same time, the petiole NO_3- N concentrations of respective leaves were also determined. Plant height, main-stem nodes, leaf area index, the number of fruits, dry matter accumulation and dry matter partitioning were also recorded during fruiting.

At harvesting, seed cotton from two 1-m middle rows of each plot was picked by hand and the number of harvestable bolls recorded. Thereafter, the middle two rows of each plot were harvested by a mechanical picker in Clarkedale to obtain the seedcotton yield. The hand pick seedcotton was weighed and ginned to determine average boll weight, lint percentage, lint yield (seedcotton yield % lint percentage).

Results and Discussion

Petiole NO_3-N Content

Petiole NO_3-N concentration decreased rapidly with increasing plant age from squaring (Fig. 1). Soil N application significantly affected petiole NO_3-N content. From the FF stage the LN treatment had lower petiole NO_3-N than the HN treatment at the both locations. Even though there was a statistical difference in petiole NO_3-N content between two N treatments at the FF stage and 2 weeks after FF in Fayetteville, the petiole NO_3-N concentrations of the LN treatment were still in an adequate recommended range. This was mainly associated with a high soil N fertility.

Leaf Chlorophyll and Photosynthetic Rate

At Clarkedale, there was no difference in leaf chlorophyll concentration at the FF stage between the two N treatments. However, the LN treatment had a significantly lower chlorophyll content than the HN treatment three and six weeks after FF (Fig. 2A). At Fayetteville, the chlorophyll level did not differ between the HN and LN treatments until five weeks after the FF stage (Fig. 2B). The N treatments did not affect the ratio of chlorophyll a/b. The response of leaf net photosynthetic rate to N treatments was similar to that of leaf chlorophyll concentration (Fig. 3). Therefore, decreased leaf photosynthetic rate from the LN might be associated with lower chlorophyll content.

Leaf Nonstructural Carbohydrates

Starch was a dominant nonstructural carbohydrate in cotton leaves (Table 2 and Fig. 4). Leaf starch concentration decreased and the level of soluble sugars (glucose, fructose and sucrose) increased as plants aged. Leaf nonstructural carbohydrates did not differ between the two N treatments at most measuring times.

Plant Growth and Dry Matter Accumulation

In Clarkedale, the LN treated plants had significantly lower plant height, LAI, and dry matter (DM) accumulation at three weeks after FF (Table 3). In this study, the LN treatment did not affect the partitioning of dry matter

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among plant tissues because the percentages of total DM in the different organs were the same between the two N treatments. In Fayetteville, no differences were observed between the HN and LN treatments in plant growth and DM accumulation (data not shown).

Lint Yield and Yield Components

The LN treatment had a 9% lower lint yield compared to the HN treatment in Clarkedale (Table 4). Decreased lint yield from the LN was mainly caused by a decreased boll number because the LN treatment did not affect average boll weight and lint percentage. In Fayetteville, there were no differences in lint yield and yield components between the two N treatments (Table 4). The different results between the two locations might be related to soil N fertility before planting because the base soil N level in Fayetteville (31.6 lb. NO_3-N/A) was much higher than in Clarkedale (9.2 lb. NO_3-N/A).

Conclusions

Petiole NO_3-N concentration decreased rapidly with progressing plant age and was very sensitive to soil N level. Insufficient N supply during cotton reproductive growth depressed leaf area, leaf net photosynthetic rate, and leaf chlorophyll content. Leaf soluble sugars increased and starch decreased with growth stages. Soil N level did not affect leaf nonstructural carbohydrate concentration in our studies. Nitrogen deficit decreased plant height, leaf area index and dry matter accumulation, but did not change the dry matter partitioning. Insufficient N supply reduced lint yield. Decreased yield from the low N was closely related to decreased boll number, rather than average boll weight and lint percentage. Optimum management of soil and plant N will improve plant carbon metabolism and enhance lint yield.

References

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Table 1. The rate and timing of nitrogen application for high nitrogen (HN) and low nitrogen (LN) treatments at two locations in 2000.

	Clarkedale		Fayetteville	
Time	HN	LN	HN	LN
	--------------- (lb. N/A) -----------------			
Preplanting	18	18	40	40
2nd true leaf	30	30	0	0
Pinhead square	50	0	60	0
Total	98	48	100	40

Table 2. Effects of Nitrogen application on leaf nonstructural carbohydrate concentration of field-grown cotton at Clarkedale.

Treatment	Glucose	Fructose	Sucrose	Starch
	-------------------- ($g\ m^{-2}$ leaf area) --------------------			
3 weeks after FF				
HN	0.593*	0.183	1.285**	11.35
LN	0.478	0.176	1.110	11.72
6 weeks after FF				
HN	0.354	0.290	1.363	3.252
LN	0.359	0.263	1.364	2.844

* and ** Differences between N treatments are significant at P < 0.05 and 0.01 levels, respectively.

Table 3. Effect of soil nitrogen level on plant growth and dry matter accumulation at Clarkedale

Treatment	Plant height	Main-stem nodes	Bolls	Leaf area index
	(cm)	(no. $plant^{-1}$)	(no. m^{-2} land)	
HN	111*	18.8	120*	3.21*
LN	99	17.6	99	2.74
	Leaf DW	Stem DW	Fruit DW	Total DW
	----------------------- ($g\ m^{-2}$ land area) -----------------------			
HN	164.6*	325.2*	159.4*	649.4*
LN	137.4	258.4	130.0	525.8

* Differences between N treatments are significant at P < 0.05.

Table 4. Effects of Nitrogen deficit on lint yield and yield components of field-grown cotton.

Treatment	Lint yield	Bolls	Boll weight	Lint percentage
	($kg\ ha^{-1}$)	(no./ m^2)	($g\ boll^{-1}$)	(%)
Clarkedale				
HN	1348*	88.8*	4.18	41.7
LN	1230	75.3	4.21	41.3
Fayetteville				
HN	1172	65.0	4.69	39.0
LN	1152	58.4	4.99	39.5

* Differences between treatments are significant at P < 0.05

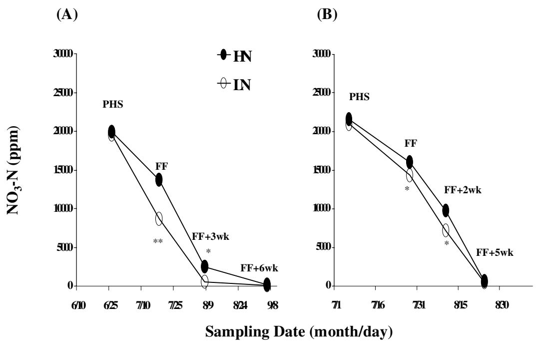

Figure 1. Changes in petiole NO_3 -N content with growth stage as affected by soil N status at (A) Clarkedale and (B) Fayetteville. *and ** indicate that differences between two N treatments are significant at P< 0.05 and P< 0.01, respectively.

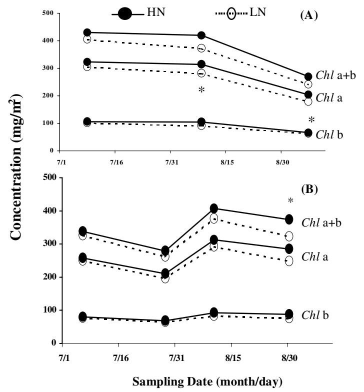

Figure 2. Changes in the chlorophyll content during growth at two locations of (A) Clarkedale and (B) Fayetteville as affected by soil N levels. * indicates that the difference in *chl. a* and total chlorophyll content is significant at P< 0.05 between two N treatments.

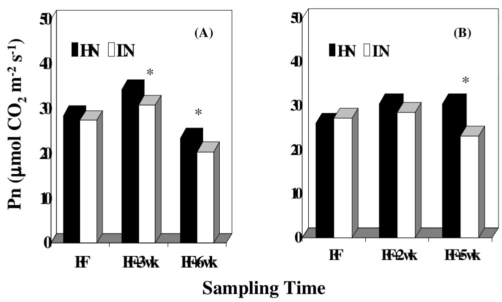

Figure 3. Effect of Soil N level on leaf net photosynthetic rate (pn) at two locations of (A) Clarkedale and (B) Fayetteville as affected by soil N levels. * indicates that the difference between treatments is significant at P< 0.05.

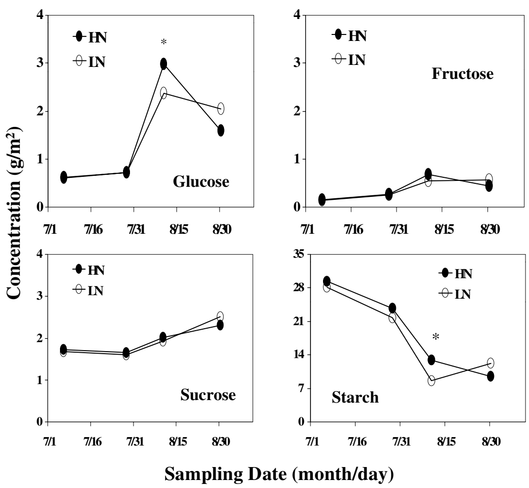

Figure 4. Changes in the leaf nonstructural carbohydrate concentrations as affected by siol nitrogen levels at Fayetteville. * indicates that the difference between two N treatments is significant at P< 0.05.