COTTON NITROGEN UPTAKE AND NITROGEN USE EFFICIENCY IN TWO CROPPING SYSTEMS

Duli Zhao
USDA-ARS
Canal Point, FL
David Wright
Jim Marois
Cheryl Mackowaik
University of Florida, IFAS-NFREC
Quincy, FL

Abstract

An experiment was conducted in 2007 and 2008 at the University of Florida's North Florida Research and Education Center (NFREC), Quincy, FL to determine cotton (*Gossypium hirsutum* L.) plant growth, N uptake, yield, and fertilizer N use efficiency (NUE) in conventional (peanut-cotton-cotton) and sod-based (bahiagrass-bahiagrass-peanut-cotton) cropping systems. Two N rates for cotton in each rotation were 0 and 95 kg N ha^{-1} (0N and 95N). Lint yield of sod-based cotton was 13 to 22% higher than that of the conventional cotton. Averaged across rotations and years, cotton received the 95N had 20% higher lint yield than the 0N cotton. Although the sod-based cotton had higher N uptake and fertilizer N recovery than the conventional cotton, fertilizer NUE did not differ between the two cropping systems. Reduction in N application in sod-based peanut/cotton cropping system may improve cotton fertilizer NUE and increase profits.

Introduction

Nitrogen (N) management is one of the important practices in high-yielding cotton production systems (Gerik et al., 1998). Both N deficiency and excess N negatively affect plant growth, boll retention, lint yield, and fiber quality (Gerik et al., 1998). Insufficient N supply often reduces leaf area, leaf photosynthetic rate, and biomass production in cotton (Zhao and Oosterhuis, 2000), resulting in low lint yield and poor fiber quality (Heagle et al., 1999). However, lint yield of irrigated cotton does not always continue to increase as amount of N fertilizer is increased (Wood et al., 1992; Zhao et al., 2005). When N rate reaches a given amount, a further increase in N fertilizer may not improve and even limit lint yields if fruit abscission is increased due to poor light environment in the canopy. Excess use of N fertilizer increases not only production cost but also the potential for environmental problems, such as groundwater contamination by NO_3^- leaching.

Rotations of row crops with perennial grasses such as bahiagrass (sod-based rotation) in southeast USA can improve soil quality, reduce pest pressure, and increase crop yield and profitability compared to conventional cropping systems (Katsvairo et al., 2007). Little is known about cotton N uptake and fertilizer N use efficiency (NUE) in sod-based peanut-cotton rotations. We speculated that cotton plants in sod-based cropping systems may require less N fertilizer than the conventional cotton because of improved soil quality in the sod-based cropping systems, including soil nutrients and soil water holding capacity. Therefore, refining sod-based cotton N application should improve cotton yield and profits. The sod-based peanut-cotton rotation study has been established since 2000 for investigating long-term sustainability and profitability of two cropping systems. In this report, we only presented some data collected during the 2007 and 2008 growing seasons. The objectives of this study were to: (1) determine effect of N rate on cotton plant growth and yields and (2) estimate cotton plant N uptake, and fertilizer NUE in the conventional and sod based cropping rotations.

Materials and Methods

Experimental Background and Treatments

The sod based peanut-cotton rotation study was initiated in 2000 at the University of Florida's North Florida Research and Education Center in Quincy, FL (84°33' W, 30°36' N). The soil type at the experimental location is Dothan sandy loam (fine-loamy, kaolinitic, thermic Plinthic Kandiudult). Treatments included two cropping systems (sod-based and conventional peanut/cotton rotations) and two N rates (0 and 95 kg N ha^{-1}). The sod-based system was a 4-yr rotation with bahiagrass-bahiagrass-peanut-cotton and the conventional system was a 3-yr rotation with peanut-cotton-cotton. Both systems were used conservation tillage (strip-till for summer crops) with winter oat cover crop following the summer crops. Based on the Florida cotton N fertilizer recommendation, all plots received a total of 95 kg N ha^{-1} (28 kg at planting and 67 kg at the first square) from 2000 to 2004. Nitrogen treatments were started from 2005 and two N rates were 61 and 95 kg N ha^{-1}. Because there was no yield difference between the two N rates in 2005, from 2006 to 2008 two N rates were reset 0 and 95 kg ha^{-1}, respectively.

Bahiagrass in the sod-based cropping system was cut one (first year) or three (second year) times during the growing season and hay yield of forage was estimated for system economic analysis purpose. The second year bahiagrass was killed in late October of each year with Rundup Weather Max for the coming year peanut. In late March of each year, about 3 weeks prior to cotton planting, oat cover crop was killed with Rundup and plot rows were strip-tilled using a Brown Ro-till implement (Brown Manufacturing Co., Ozark, AL) and oat residues were remained in field. Cotton (cultivar DP 555 BG/RR) was planted on 23 April 2007 and 1 May 2008 with a Monosem pneumatic planter (ATI Inc., Lenexa, KS). Rows were orientated west to east with a row spacing of 0.91 m and about 18 seeds per meter row. Two levels of 0N and 95N (i.e., 0 and 95 kg N ha^{-1}) were composed in each cropping system. For the 95N treatment, N (28 kg N ha^{-1}), P (56 kg P ha^{-1}), and K (84 kg K ha^{-1}) from a combination fertilizer (5-10-15) were band applied adjacent to each row at planting and an addition of 68 kg N ha^{-1} was sidedressed with ammonia nitrite at first square stage. For the 0N treatment, the equal amount of P and K was band adjacent to each row at planting time by using commercial AIP (0-46-0) and Muriate of potash (0-0-60), but no any N was used during growing season. Irrigation was applied using a lateral move irrigation system if needed based on the lowest leaf water potential (-1.5 MPa) of uppermost fully expanded mainstem leaves, measured with a plant water status console (Soil Moisture Inc., CA) between 1300 and 1400 h EDT during squaring and fruiting. Plant growth regulator PIX was applied at first square (FS), first flower (FF), and three weeks after FF stages. Details of bahiagrass and peanut and other cotton crop management practices, including disease and insect control, herbicide application, and chemical defoliation, were employed according to standard University of Florida crop production recommendations (Ferrell et al., 2006).

Measurements

Plants from 1-m row in each plot were cut from soil surface five times at 27, 42, 72, 93, and 120 days after planting (DAP) in 2007 and 30, 42, 69, 96, and 132 DAP in 2008. Plants were immediately transported to a laboratory and separated into leaves, stems, and fruit. Leaf area was measured with a leaf area meter. Tissue samples were dried in a forced draft oven at 60°C for 72 hours and weighed. Leaf area index (LAI) was estimated based on leaf area of the destructively harvesting plants. Dry tissues were ground to determine total N concentration in a commercially analytical laboratory (Waters Agricultural Laboratories, Inc., Camilla, GA).

Four middle rows (no any destructive sampling in these rows) in each plot were harvested with a spindle picker (International Harvester model 1822; Case Corp., Racine, WI) 2 weeks after defoliation. Seedcotton yield was recorded. Two seedcotton subsamples (1000 g each) in each plot were ginned to determine lint %. Lint yield was calculated based on seedcotton yield and lint %.

Cotton shoot N uptake, fertilizer N recovery, and fertilizer NUE were estimated using the following equations:

$$\textit{Shoot N uptake (kg N ha}^{-1}\textit{)} = \Sigma \textit{ (tissue biomass} \times \textit{tissue N concentration),}$$
$$\textit{Fertilizer recovery (\%) = (N uptake of the 95N treatment - N uptake of the 0N treatment)/95} \times \textit{100, and}$$
$$\textit{Fertilizer NUE (kg lint/ kg N) = (lint yield of the 95N treatment – lint yield of the 0N treatment)/95.}$$

Experimental Design and Data Analysis

The experiment was arranged in split-block design with 3 replicates. Cropping system was the main plot and fertilizer N rate was sub-plot. The sub-plot size was 21 m long and 9.1 m wide with 10 rows of cotton in each sub-plot. All data were analyzed for variances and Fisher LSD test using the GLM procedures of SAS statistics package (SAS Inc., 2002).

Results

Leaf area Index (LAI)

Leaf area index increased rapidly starting from squaring stage (40 DAP) and reached maximum between peak flowering (80 DAP) and boll development (100 DAP). Both cropping system and N application rate affected LAI significantly during flowering and fruiting (Fig. 1). At 95 DAP, the 0N cotton had a 37% less LAI than the 95N cotton, averaged across cropping systems and years; and sod-based cotton had 20 and 15%, respectively, greater LAI than the conventional first- and second-year cotton averaged across the N rates and years.

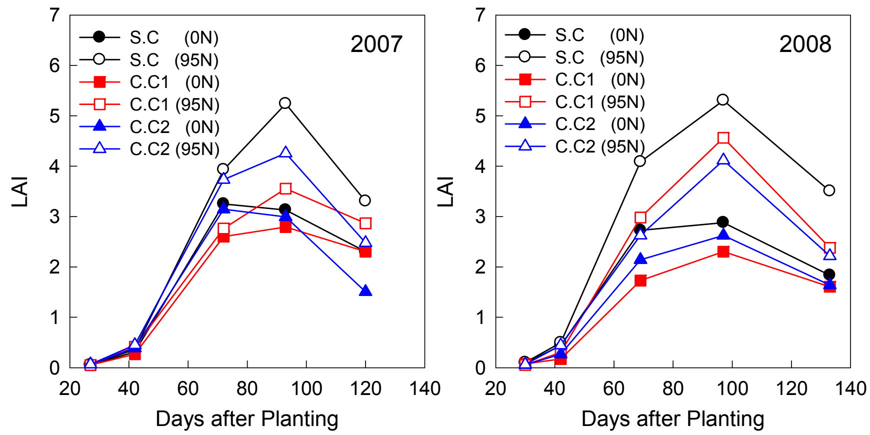

Figure 1. Leaf area index (LAI) as affected by N rate and cropping system. The 'S.C', 'C.C1', and 'C.C2' represent sod-based, conventional first-year, and conventional second-year cottons, respectively.

Aboveground Biomass

Aboveground biomass increased slowly and was not different during seedling growth (before squaring) and then increased linearly from first square to first boll opening (Fig. 2). Both cropping system and N application affected shoot biomass. Sod-based cotton accumulated more biomass than the conventional cotton at the same N rate in mid and late growing season. At the first boll opening stage, cotton growing in sod-based cropping system with 95 kg N ha^{-1} had 33 to 110% greater biomass than other treatments (Fig. 2).

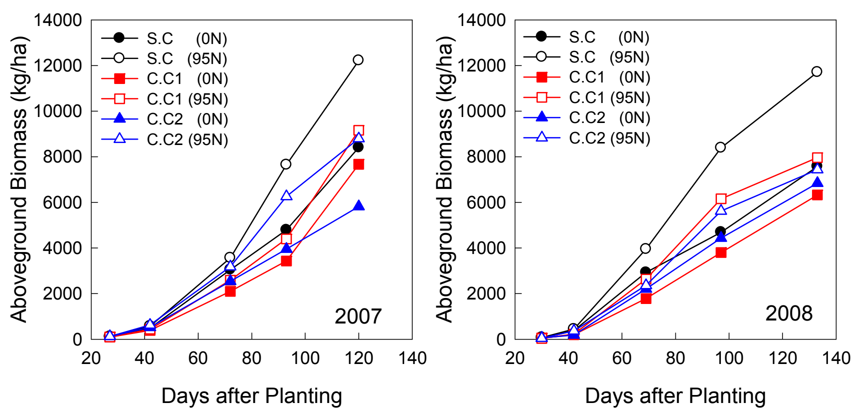

Figure 2. Cotton aboveground biomass as affected by cropping system and N fertilizer application in 2007 and 2008. The 'S.C', 'C.C1', and 'C.C2' represent the sod-based, the first-year conventional, and the second-year conventional cottons, respectively.

Plant N Uptake

Plant N uptake patterns were similar to biomass accumulation, but the peak N uptake occurred between 60 and 100 DAP and the differences among treatments were much greater than that of biomass (Fig. 3). Nitrogen application and cropping system greatly affected plant N uptake in mid and late growing season. Sod-based cotton accumulated more N than the conventional cotton for both the 0N and 95N treatments.

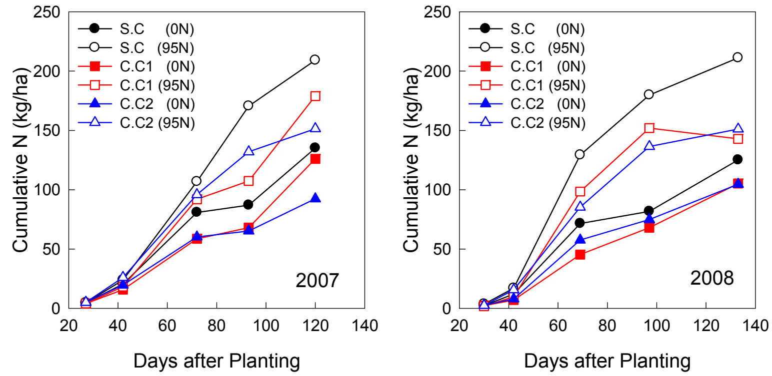

Figure 3. Plant N uptake during growth as affected by cropping system and N application. The 'S.C', 'C.C1', and 'C.C2' are the sod-based cotton, the first-year conventional cotton, and the second-year conventional cotton, respectively.

Lint Yield

Cropping system and N rate significantly affected lint yields ($P < 0.01$). Interactions among year, system and N rate were not significant. Among the treatments, sod-based cotton with 95N had the greatest and the second-year conventional cotton with 0N had the lowest lint yields ($P < 0.05$, Fig. 4). Averaged across the N treatments, sod-based cotton had a 13% higher lint yield than the first-year conventional cotton and 22% greater yield than the second-year conventional cotton. Lint yields of the 0N and 95N treated cotton were 1324 and 1590 kg ha^{-1}, respectively averaged across years and rotations (Fig. 4).

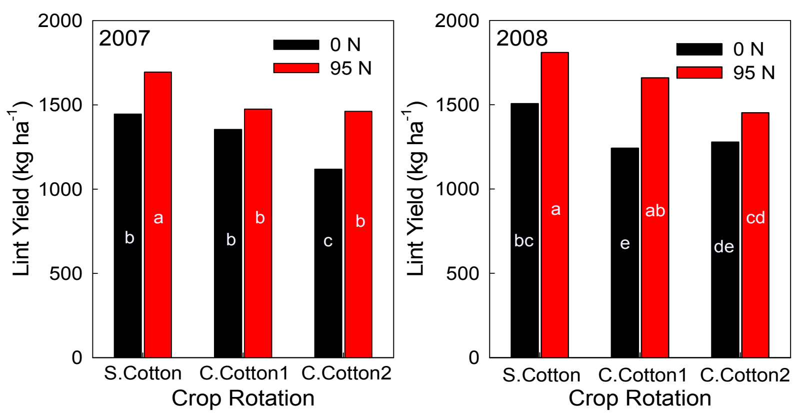

Figure 4. Lint yield of the sod-based cotton (S.Cotton), conventional first-year cotton (C.Cotton1), conventional second-year cotton (C.Cotton2) as affected by N rate At Quincy, FL in 2007 and 2008. Means followed the same letter within a year are not significantly different ($P > 0.05$) across the six treatments.

Fertilizer N uptake, fertilizer N recovery, and NUE

Sod-based cotton had much greater fertilizer N uptake and recovery than conventional cotton (Table 1). However, there was no difference in fertilizer NUE between the two cropping systems. Based on measurements of plant growth and N accumulation in our study, the optimum N rate of sod-based cotton should be lower than 95 kg N ha-1 because of high soil N availability. Therefore, reducing N application in sod-based rotation may increase cotton NUE and improve profits.

Summary

Cropping system and N fertilizer rate affected cotton plant growth, physiology, and lint yield. Sod-based cotton had greater LAI, shoot biomass, and plant N accumulation than conventional cotton. Compared to conventional cotton, lint yields of sod-based cotton increased by 17 to 20% for the 0N treatment and 15 to 16% for the 95N treatment.

Sod-based rotation increased fertilizer N uptake and recovery of cotton plants, but did not improve fertilizer NUE because of higher soil N availability in the sod-based rotation. Therefore, refining amount of N fertilizer application in sod-based cropping systems in southeast USA may improve lint yield and NUE, reduce input costs, and increase profits.

Table 1. Fertilizer N uptake, recovery, and use efficiency (NUE) of sod-based and conventional cottons in 2007 and 2008.

Year	System	N uptake	N recovery	NUE
		(kg N ha^{-1})	(%)	(kg lint kg^{-1} N)
2007	Sod-based	73.9	77.8	2.62
	Conventional	56.0	58.9	2.45
2008	Sod-based	86.1	90.5	3.19
	Conventional	42.1	44.3	3.11

Acknowledgements

This research was supported in part by cooperative research agreements with Cotton Inc. and USDA-ARS. We thank Brian Kidd and all other support staff at the Research Center for their excellent field work and technical assistance.

References

Ferrell, J.A., G.E. MacDonald, and B. J. Brecke. 2006. Weed management in cotton. [Online] Available at http://edis.ifas.ufl.edu/WG003. (accessed 14 Oct. 2006; verified 20 Dec. 2007).University of Florida IFAS. Gainesville, FL.

Gerik, T.J., D.M. Oosterhuis, and H.A. Torbert. 1998. Managing cotton nitrogen supply. Advn. Agron. 64:15–147.

Heagle, A.S., J.E. Miller, F.L. Booker, and W.A. Pursley. 1999. Ozone stress, carbon dioxide enrichment, and nitrogen fertility interactions in cotton. Crop Sci. 39:731–741.

Katsvairo, T.W., D.L. Wright, J.J. Marois, D.L. Hartzog, J.R. Rich, and P. Wiatrak. 2007. Cotton roots, earthworms and infiltration characteristics in sod/livestock peanut/cotton cropping systems. Agron. J. 99:390–398.

SAS Institute. 2002. The SAS system for Windows. Version 9.00. SAS Inst., Cary, NC.

Wood, C.W., P.W. Tracy, D.W. Reeves, and K.L. Edmisten. 1992. Determination of cotton nitrogen status with a hand-held chlorophyll meter. J. Plant Nutr. 15:1435–1448.

Zhao, D., and D.M. Oosterhuis. 2000. Nitrogen application effect on leaf photosynthesis, nonstructural carbohydrate concentrations and yield of field-grown cotton. pp. 69–71. *In* D.M. Oosterhuis (ed.) Proc. 2000 Arkansas Cotton Res., AAES Special Report 198.

Zhao, D., K.R. Reddy, V.G. Kakani, J.J. Read, and S. Koti. 2005. Selection of optimum reflectance ratios for estimating leaf nitrogen and chlorophyll concentrations of field-grown cotton. Agron. J. 97:89–98.