Research Article **AJAR (2019), 4:72**

American Journal of Agricultural Research
(ISSN:2475-2002)

Nitrogen Nutrition, Yield, and Quality of Cotton under Varying Nitrogen Application Timings and Planting Dates

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ABSTRACT

Nitrogen (N) management may need to be different for cotton planted at different dates. The objective of this research was to determine the optimal N application timing for cotton under different planting dates. A field trial was conducted on the University of Tennessee West Tennessee Research and Education Center at Jackson, TN in 2011 and 2012 in a split plot randomized complete block design with four replicates. Three cotton planting dates of early planting, standard planting, and late planting and four N application timings of pre-plant, at-planting, early side-dress, and late side-dress were assigned to the whole plots and subplots, respectively. Although the interactions of planting date by N application timing, year by N application timing, and year by planting date were significant on leaf N at early bloom and late bloom; cotton plants received adequate N nutrition for optimal yield under different N application timings and varying planting dates in both years. No significant difference in lint yield was observed among the four N application timings regardless of planting date in 2011 that was wet in the early season but dry in the late season. In 2012 that was dry in the early season but wet in the late season, however, lint yield was higher with late side-dress of N than pre-plant at standard planting; the yield did not differ among the four N application timings at early planting or late planting. Higher fiber micronaire but lower fiber strength was obtained under early planting and standard planting than late planting. In 2011, the length and uniformity of fiber were not affected by the planting date. In 2012, however, the length and uniformity of fiber were greater at late planting than early planting and standard planting. The fiber length and fiber uniformity were greater with late side-dress of N than pre-plant and early side-dress of N. Overall, the effects of N application timing on cotton yield vary with planting date and year, which suggests that planting date and weather conditions need to be taken into account in deciding the N application timing.

Keywords: Nitrogen Application Timing · Planting Date · Leaf Nitrogen · Yield · Quality · Cotton

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How to cite this article:
Xinhua Yin and Guisu Zhou. Nitrogen Nutrition, Yield, and Quality of Cotton under Varying Nitrogen Application Timings and Planting Dates. American Journal of Agricultural Research, 2019,4:72.

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Introduction

Nitrogen fertilization is a key management practice in cotton production because it influences cotton yield, quality, and maturity (Hutmacher et al., 2004). Nitrogen application timing is an important part of an N management program. Nitrogen application timing needs to make N supply match up with the N uptake pattern of cotton during the growing season. The N uptake of cotton was low within the first 28 d, ranging from 0.18 to 0.29 kg N ha^{-1} d^{-1}, but increased to 2.9 to 4.3 kg N ha^{-1} d^{-1} during 49 to 71 d after planting (Boquet and Breitenbeck, 2000). Nitrogen uptake by cotton reaches to the maximum level during mid-bloom through boll set (Mullins and Burmester, 1990; Mitchell, 1996). According to this pattern, N fertilization might not be needed for cotton during the first month. Cotton N use efficiency was enhanced without preplant N application (Norton and Silvertooth, 1998). Ebelhar et al. (1996) observed a significant increase in cotton yield when N was applied as two equal splits, one at planting and the other at pinhead square stage in Mississippi. However, Howard et al. (2001) reported that split applications of N with a half applied at planting and the other half applied 6 weeks later, rarely increased cotton yield in Tennessee.

Planting date is an important management decision in cotton production in the Mid-south region of the United States. The influences of planting date on cotton yield varied due to differences in cotton varieties, pest infestations, and weather conditions among locations and years (Porter et al., 1996, Bauer et al., 1998). Planting early within the optimal planting window usually produced the highest cotton yield (Silvertooth et al., 1999). The optimal planting date for cotton yield was reported to be during April 20 and May 10 in Louisiana (Aguillard et al., 1980). Early planting was reported to reduce seed germination and slow down seedling establishment (Pettigrew and Johnson, 2005). Cooler soil temperatures and potential of increasing seedling diseases were responsible for poor stand establishment with early planting (Christiansen and Rowland, 1986; Pettigrew, 2002). On the other side, moderately late planting, 10 to 15 d after the optimal planting window, did not always cause cotton yield reduction (Slosser, 1993; Bauer et al., 1998).

The current N fertilizer recommendations for cotton in Tennessee are 67 to 90 kg N ha^{-1} for upland soils and 34 to 67 kg N ha^{-1} for bottom soils by the University of Tennessee (Savoy and Joines, 2009). The N application timing is recommended to be at planting for cotton. The side-dress of N fertilizer during the early growing season has not yet been adequately evaluated compared with at-planting or pre-plant application of N under the production and environmental conditions in Tennessee.

Nitrogen fertilizer is one of the largest costs in cotton production, and has severe potential negative effects on the environment. Because of rising N price and increased environmental concern, N fertilization needs to be managed more efficiently for increased N use efficiency, improved cotton productivity and profitability, and healthier environment. Because planting date influences cotton growth pattern and rate, it may also affect cotton N uptake. Thus, the objectives of this study were to determine the effects of N application timing, planting date, and their interaction on N nutrition, growth, yield, and lint quality of cotton. This article only reports the responses of N nutrition and lint yield and quality to N application timings and planting dates.

Materials and Methods

Field Trial Implementation

A field trial was conducted on upland soil at the University of Tennessee West Tennessee Research & Education Center at Jackson, TN in 2011 and 2012. The soil was classified as Lexington silt loam in 2011 and Dexter loam in 2012. Three cotton planting dates of early planting, standard planting, and late planting and four N application timings of pre-plant, at-planting, early side-dress, and late side-dress were assigned to the whole plots and subplots, respectively, under a split plot randomized complete block design with four replicates in each year. Cotton was planted on April 29, May 6, and June 2 for the early planting date, standard planting date, and late planting, respectively, in 2011 and on April 20, May 9, and June 1 for the early planting date, standard planting, and late planting, respectively, in 2012. Application timings of N fertilizer for each planting date are presented in Table 1. Cotton was planted in 97-cm rows under no-tillage and managed with the recommended management practices except the N application timing and planting date treatments for cotton in the region during both years.

Sampling and Measurements

A composite soil sample with ten probes of 2.5-cm diameter was collected at the 0-15 cm depth using a hand soil probe prior to initiation of the treatments for each year. After soil samples were air dried, ground to pass through a 2-mm sieve, and thoroughly mixed, they were analyzed at the Brookside Laboratories Inc. (New Bremen, OH) for pH, organic matter, NO_3^--N, NH_4^+-N, P, K Ca, Mg, and micronutrients with the Mehlich 3 as the extractant (Mehlich, 1984).

A composite leaf sample was collected from the most newly fully developed leaves from the two center rows of each subplot at the early bloom and late bloom stages for analyzing tissue N concentration. Leaf samples were dried to a constant weight in a forced-air oven at 65°C, and ground in a Wiley mill (Arthur K. Thomas Co. Philadelphia) to pass through a 1-mm screen. Total N concentrations in these samples were determined using the dry combustion method with a Leco TruSpec C and N Analyzer (Leco, St. Joseph, MI).

Cotton was harvested from the two center rows of each subplot using a small cotton picker on September 29 in 2011 and October 31 in 2012. Seedcotton was weighed, and a subsample was collected for ginning. Each subsample was ginned on a 10-saw laboratory gin to determine gin turnout and obtain a lint sample for each subplot. Fiber micronaire, strength, length, and uniformity of the lint samples were determined at the USDA Memphis Classification Laboratory.

Statistical Analysis

Analysis of variance for each measurement was conducted by combining the two-year data together under a split split-plot randomized complete block design with the ANOVA procedure of SAS statistical software for Windows V9 (4) (SAS Institute, Cary, NC). The years, planting dates, and N application timings were treated as fixed factors, and were treated as whole plots, subplots, and sub subplots, respectively, in the statistical model. The replicates were treated as a random factor. Treatment means were separated with the Fisher's protected least significant difference (LSD). Probability levels less than 0.05 were considered significant for all analyses.

Results and Discussion

Weather conditions, particularly the rainfall, varied between the two growing seasons (Table 2). Average air temperature was lower in May but higher in June of 2011 than 2012. Monthly rainfall was substantially higher during April through June but lower from July to October in 2011 than 2012 and the 30-yr averages. Overall, the 2011 growing season was wet in the early season but dry in the late season, while the 2012 year was dry in the early season but wet in the late season.

Initial Soil Fertility

The major soil properties in 0-15 cm prior to treatment initiation for each year are presented below. The two fields had soil pH 6.7 and 6.5, organic matter 15.5 and 16.2 g kg^{-1}, inorganic soil N (NO_3^--N + NH_4^+-N) 26.5 and 10.9 mg kg^{-1}, and estimated soil N release 57 and 58 kg

Table 1. Nitrogen application timing (month/date) under different planting dates in 2011 and 2012.

Year	N application timing	Early planting	Standard planting	Late planting
2011	Pre-plant	04/25	04/25	04/25
	At-planting	05/04	05/04	06/03
	Early side-dress	06/03	06/10	06/20
	Late side-dress	06/15	06/22	07/11
2012	Pre-plant	04/03	04/03	04/03
	At-planting	04/20	05/09	06/01
	Early side-dress	05/22	06/01	06/21
	Late side-dress	06/11	06/18	07/11

Table 2. Monthly average temperatures and monthly total rainfall in 20111 and 2012 and the 30-year averages.

	Temperature (ºC)			Rainfall (mm)		
Month	2011	2012	1973-2012	2011	2012	1973-2012
January	1.9	6.5	3.0	63	93	109
February	6.9	7.3	5.2	93	67	103
March	11.0	16.7	10.7	146	119	135
April	17.3	16.8	15.6	282	36	127
May	19.8	22.8	20.2	212	38	141
June	26.4	24.3	24.5	156	96	124
July	28.2	28.2	26.6	95	123	117
August	26.7	26.2	26.0	42	92	80
September	21.3	22.3	22.1	84	152	98
October	14.5	14.8	15.7	28	136	96
November	11.2	8.5	10.3	244	53	130
December	5.9	8.4	4.9	204	118	134

Table 3. Effects of year by planting date interaction on leaf N concentration (g kg^{-1}) at early bloom and late bloom.

Year	Planting date	Early bloom	Late bloom
2011	Early planting	33.1a	30.8b
	Standard planting	30.5b	33.5a
	Late planting	29.5b	31.4ab
2012	Early planting	34.8b	42.6b
	Standard planting	44.4a	36.8c
	Late planting	35.5b	45.1a

ha^{-1} for 2011 and 2012, respectively.

Effects of N Application Timing and Planting Date on Leaf N Concentration

The sensitivity of cotton leaf N nutrition to N application was greater at early bloom than at any other growth and developmental stages (Bell et al., 2003; Fritschi et al., 2004). This phenomenon indicates monitoring of leaf N nutrition status at early bloom is particularly helpful in deciding whether supplemental N application is needed.

The effects of planting date on leaf N concentration were affected by year at both early bloom and late bloom growth stages (Table 3). At early bloom, early planting resulted in higher leaf N concentration than standard planting and late planting in 2011, while standard planting had higher N level than the other two planting dates in 2012. By late bloom, leaf N concentration was higher with standard planting than early planting in 2011, and late planting caused higher leaf N level than the other two planting dates in 2012.

There was a significant interaction of planting date by N application timing on leaf N concentration at both early bloom and late bloom (Table 4). At early bloom, leaf N was higher with at-planting and early side-dress than pre-plant at the early planting date, but was higher with late side-dress than the other three N application timings when cotton was planted late. There was no difference in leaf N among the four N application timings under the standard planting date. At late bloom, at-planting N application resulted in higher leaf N than pre-plant when cotton was planted early. At the standard planting of cotton, the two side-dress applications of N had higher leaf N than at-planting N application. When cotton was planted late, late side-dress of N had higher leaf N level than the other three N application timings.

The interaction of year by N application timing was significant on leaf N at both early bloom and late bloom (Table 5). In 2011, late side-dress of N had higher leaf N at early bloom and late bloom than the other N application timings. In 2012, at-planting and early side-dress resulted in higher leaf N than late side-dress at early bloom; leaf N was lower with pre-plant than the other N application timings at late bloom.

Campbell and Plank (2011) recommended that the sufficiency ranges of leaf N concentration be 30 to 45 g kg^{-1} during both early bloom and late bloom for cotton grown in the southern United States. According to these criteria, leaf N concentrations at early bloom and late bloom were all within or close to the sufficiency range in this study (Tables 3, 4, & 5), indicating that

Table 4. Effects of planting date by N application timing interaction on leaf N concentration (g kg^{-1}) at early bloom and late bloom.

Planting date	N application timing	Early bloom	Late bloom
Early planting	Pre-plant	32.5b	35.6b
	At-planting	35.1a	38.1a
	Early side-dress	34.6a	36.7ab
	Late side-dress	33.7ab	36.5ab
Standard planting	Pre-plant	32.4a	36.8b
	At-planting	32.6a	38.0ab
	Early side-dress	33.1a	39.0a
	Late side-dress	32.1a	39.1a
Late planting	Pre-plant	36.5b	32.6c
	At-planting	36.4b	34.9b
	Early side-dress	36.6b	35.5b
	Late side-dress	40.1a	37.6a

[a] Values in a column within a planting date followed by the same letter are not significantly different at the 0.05 probability level.

Table 5. Effects of year by N application timing interaction on leaf N concentration (g kg^{-1}) at early bloom and late bloom.

Year	N application timing	Early bloom	Late bloom
2011	Pre-plant	29.2c	30.5b
	At-planting	30.5bc	31.3b
	Early side-dress	30.9b	32.0b
	Late side-dress	33.6a	33.7a
2012	Pre-plant	38.4ab	39.4b
	At-planting	38.9a	42.7a
	Early side-dress	38.6a	42.1a
	Late side-dress	37.1b	41.8a

[a] Values in a column within a year followed by the same letter are not significantly different at the 0.05 probability level.

Table 6. Effects of year by planting date by N application timing interaction on lint yield (kg ha^{-1}).

Planting date	N application timing	2011	2012
Early planting	Pre-plant	1318.7a	1324.4a
	At-planting	1261.4a	1348.1a
	Early side-dress	1115.4a	1324.2a
	Late side-dress	1185.1a	1313.3a
Standard planting	Pre-plant	1173.2a	1450.6b
	At-planting	1200.2a	1639.1ab
	Early side-dress	1050.7a	1519.8ab
	Late side-dress	1082.4a	1823.3a
Late planting	Pre-plant	746.5a	1217.9a
	At-planting	753.1a	1144.6a
	Early side-dress	716.5a	1019.0a
	Late side-dress	708.4a	1018.0a

[a] Values in a column within a planting date followed by the same letter are not significantly different at the 0.05 probability level.

Table 7. Effects of planting date on fiber micronaire and fiber length.

Planting date	Micronaire	Strength
Early planting	4.53a	29.1b
Standard planting	4.55a	29.0b
Late planting	4.03b	30.1a

[a] Values in a column followed by the same letter are not significantly different at the 0.05 probability level.

Table 8. Effects of year by planting date interaction on fiber length and fiber uniformity.

Year	Planting date	Fiber length	Fiber uniformity
			%
2011	Early planting	1.11a	81.9a
	Standard planting	1.09a	81.4a
	Late planting	1.11a	81.3a
2012	Early planting	1.08b	80.0b
	Standard planting	1.08b	80.4b
	Late planting	1.13a	81.8a

[a] Values in a column within a year followed by the same letter are not significantly different at the 0.05 probability level.

Table 9. Effects of N application timing on fiber length and fiber uniformity.

N application timing	Fiber length	Fiber uniformity
Pre-plant	1.09b	80.9b
At-planting	1.10ab	81.3ab
Early side-dress	1.09b	80.8b
Late side-dress	1.11a	81.6a

[a] Values in a column followed by the same letter are not significantly different at the 0.05 probability level.

cotton plants obtained adequate N nutrition for optimum yield under different N application timings, different planting dates, and different years.

Effects of N Application Timing and Planting Date on Lint Yield

The interaction of year by planting date by N application timing was significant on lint yield in this study (Table 6). There was no significant difference in lint yield among the four N application timings regardless of planting date in 2011. In 2012, however, late side-dress resulted in higher lint yield than pre-plant at standard planting; no difference was observed among the four N application timings at early planting or late planting.

Effects of N Application Timing and Planting Date on Fiber Quality

The fiber micronarie and fiber strength of lint were both influenced by the planting date averaged over the N application timings and years (Table 7). Specifically, early planting and standard planting resulted higher fiber micronaire, but lower fiber strength than late planting. Meanwhile, there was a significant interaction of year by planting date on fiber length and fiber uniformity (Table 8). In 2011, the length and uniformity of fiber were similar among the three planting dates. In 2012, however, late planting resulted in greater length and uniformity of fiber than early planting and standard planting. Both length and uniformity of fiber were affected by N application timing averaged over the planting dates and years (Table 9). Late side-dress of N resulted in greater fiber length and fiber uniformity than pre-plant and early side-dress of N.

Conclusions

Although the interactions of planting date by N application timing, year by N application timing, and year by planting date were significant on leaf N at early bloom and late bloom; cotton plants received adequate N nutrition for optimal yield under different N application timings and varying planting dates in both years. No significant difference in lint yield was observed among the four N application timings regardless of planting date in 2011 that was wet in the early season but dry in the late season. In 2012 that was dry in the early season but wet in the late season, however, lint yield was higher with late side-dress of N than pre-plant at standard planting; the yield did not differ among the four N application timings at early planting or late planting. Higher fiber micronaire but lower fiber strength were obtained under early planting and standard planting than late planting. In 2011, the length and uniformity of fiber were not affected by the planting date. In 2012, however, the length and uniformity of fiber late planting were greater at late planting than early planting and standard planting. The fiber length and fiber uniformity were greater with late side-dress of N than pre-plant and early side-dress of N. Overall, the effects of N application timing on cotton yield vary with planting date and year, which suggests that planting date and weather conditions need to be taken into account in deciding the N application timing.

Acknowledgments

This project was supported by the University of Tennessee. Technical assistance was provided by Robert Sharp and others.

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