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AGRONOMY AND SOILS

Effect of Foliar Applied Nitrogen to Cotton with Artificial Terminal and Node Removal

Michael T. Plumblee*, Darrin M. Dodds, L. Jason Krutz, Angus L. Catchot, J. Trenton Irby, and Johnie N. Jenkins

ABSTRACT

Management decisions are needed for producers who experience hail or wildlife damage to cotton when replanting is not an option. This research was conducted to determine if applications of foliar nitrogen (N) fertilizer had an effect on cotton growth, lint yield, lint turnout, or fiber quality to cotton that had eight nodes of growth, including the apical meristem, removed at pinhead square or first bloom. The effects of foliar N (no foliar N, foliar N applied at the time of damage, one week after damage, two weeks after damage, at the time of damage + one week after damage, at the time of damage + two weeks after damage, one week after + two weeks after damage, and at the time of damage + one week after + two weeks after damage) were evaluated on Phytogen 499 WRF planted in Mississippi in 2016 and 2017.

The interaction of foliar N application timing and the time damage occurred did not affect cotton height at harvest, lint turnout, lint yield, or fiber quality. Cotton growth stage when damage occurred affected cotton height at harvest, lint turnout, lint yield, micronaire, strength, and fiber elongation. Timing of foliar N affected lint turnout, micronaire, and fiber strength. No differences in lint yield were observed following any foliar N application timing; however, a 28 to 37% lint yield reduction was observed in damaged cotton compared to the untreated. These data indicate that application of foliar N to damaged cotton did not increase cotton height, lint yield, lint turnout, or fiber quality compared to undamaged cotton; therefore, use of foliar N to bolster growth and yield of damaged cotton is not recommended.

Cotton (*Gossypium hirsutum* L.) is a major crop grown in the southern U.S. and across the Mid-South region (Arkansas, Louisiana, Mississippi, Missouri, and Tennessee). From 2011 to 2015, approximately 4.6 million hectares (11.4 million acres) of cotton were planted per year across the U.S., with approximately 14% of production taking place in the Mid-South (NASS, 2016). In Mississippi, cotton produced $370 million in revenue annually from 2011 to 2015 (NASS, 2015). Cotton is a high input cost crop when compared to other crops grown in rotation with cotton. Commercially available seed, seed treatments, and technology costs typically exceed $247 per hectare (MSU, 2019). In addition, it is not uncommon to spray five to seven times for control of *Lygus lineolaris* (Palisot de Beauvois) as well as an additional application for *Helicoverpa zea* (Boddie) in Mississippi, which combined with other costs, forces growers to maximize yields and return on investment (MSU, 2016). Environmental factors, such as rainfall, are unpredictable and typically lead to variations in productivity from year to year (Wang, 2011). Crop damage from hailstorms and wildlife cause an estimated $5.5 billion in crop and property damages annually in the U.S. (Conover, 2002; NSSL, 2015). When crop failures due to hail or wildlife damage are experienced, the option to replant is not always viable depending on the time of year when the damage occurs. Therefore, the decision to terminate the crop or continue to manage the existing crop must be made. After damage has occurred, management practices to alleviate plant stress, promote plant growth, and reduce delays in maturity might be warranted. The typical producer response to damaged cotton is to apply additional fertilizer nitrogen (N) in an

M.T. Plumblee*, Clemson University, Edisto Research and Education Center, Blackville, SC 29817; D.M. Dodds, L.J. Krutz, and J.T. Irby, Mississippi State University, Plant and Soil Sciences, Mississippi State, MS 39762; A.L. Catchot, Mississippi State University, Biochemistry, Molecular Biology, Entomology, and Plant Pathology, Mississippi State, MS 39762; and J.N. Jenkins, United States Department of Agriculture, Agriculture Research Service, Mississippi State, MS 39762.
*Corresponding author: mplumbl@clemson.edu

effort to overcome adverse environmental effects (Peacock and Hawkins, 1974). Applications of additional fertilizer N can lead to excessive vegetative growth in cotton as well as increase production costs and ultimately reduce profit. Applications of foliar fertilizer N recently have become more popular due to the increased need for efficient nutrient utilization that is observed with early maturing, high-yielding cotton varieties that are currently grown (Oosterhuis and Weir, 2010).

Previous research evaluating applications of foliar fertilizer N in cotton have shown benefit to meeting N demand in high boll load scenarios, where foliar fertilizer N is used to supplement soil-applied N fertilizer during reproductive growth (Oosterhuis and Bondada, 2001; Oosterhuis et al., 1989). However, applications of foliar fertilizer N have not consistently increased lint yields in scenarios where insufficient soil N was applied (Anderson and Walmsley, 1984; McConnell et al., 1998; Oosterhuis and Bondada, 2001; Roberts et al., 2006). Research conducted by McConnell et al. (1998) concluded that lack of yield response from applications of foliar fertilizer N might be due to N rate applied to the soil as well as foliar fertilizer N applications made to cotton that does not have critically deficient N levels.

Although previous research evaluating foliar fertilizer N applications in cotton has been conducted, limited research on foliar fertilizer N applications made during vegetative growth stages and to damaged cotton in the Mid-South is available. Therefore, the objectives of this research were to determine if applications of foliar fertilizer N or foliar N fertilizer application timing had an effect on cotton growth, lint turnout, lint yield, or fiber quality when applied to artificially damaged cotton.

MATERIALS AND METHODS

Research was conducted at the R.R. Foil Plant Science Research Center near Starkville, MS (33.474670°N, 88.788238°W) on a Leeper silty clay loam (fine, smectitic, nonacid, thermic Vertic Epiaquepts) and at the Black Belt Experiment Station near Brooksville, MS (33.257110°N, 88.559723°W) on a Brooksville silty clay (fine, smectitic, thermic Aquic Hapluderts) in 2016 and 2017. Phytogen 499 WRF (Dow AgroSciences, Indianapolis, IN) cotton was seeded at 111,150 seed/ha and a depth of 2.5 cm (Table 1). Furrow-irrigated plots consisted of two 96-cm rows that were 9.1 m in length in 2016 and 12.2 m in length in 2017. Simulated damage was imposed by mechanically removing eight main stem nodes from the cotton plant beginning at the apical meristem and proceeding downward. All plant material including leaves, branches, and the mainstem were removed. Node removal was carried out using scissors and applied at different timings, which included pinhead square and first bloom. Removal of eight nodes of growth at pinhead square resulted in only cotyledon leaves remaining on the plant. Removal of eight nodes of growth at first bloom resulted in four to five nodes of growth above the cotyledon leaves remaining on the plant. Unpublished data has suggested that removing eight nodes of growth at pinhead square and first bloom had the greatest effect on lint yield compared to the removal of two and four nodes at four-leaf or two, four, or six nodes at pinhead, first bloom, and first bloom + 4 wk growth stages. After plants were damaged by clipping mainstem nodes at pinhead square and first bloom, the apical meristem was removed and total number of mainstem nodes remained the same for the remainder of the growing season. After damage occurred, two vegetative branches arose from the point where the mainstem was clipped. These branches then produced sympodial branches where bolls developed. After node removal, foliar N fertilizer was applied at different timings including: immediately after damage occurred; 1 wk after damage; 2 wk after damage; at the time damage occurred + 1 wk after; at the time damage occurred + 2 wk after; 1 wk + 2 wk after damage occurred; and at the time damage occurred + 1 wk + 2 wk after. Plots where cotton was damaged but no foliar N fertilizer was applied were included as well as an undamaged check that received no foliar N fertilizer for comparison purposes. Treatments were arranged within a randomized complete block design with three replications in 2016 and four replications in 2017. All foliar applied N fertilizer treatments were applied with a CO_2-powered backpack sprayer calibrated to deliver a spray volume of 187 L/ha at a pressure of approximately 317 kPa at a speed of 4.8 km/h using a two-row boom equipped with AI 11002VS nozzles (TeeJet, Springfield, IL). Controlled-Release Nitrogen (CoRoN®, Helena Holding Co. Collierville, TN) (25-0-0) was applied at 2.8 kg N/ha at each application timing. All applications were made at or near sunset per label instructions to reduce risk for crop injury.

Insect control, fertility, weed control, and harvest aids were applied based on Mississippi State University Extension recommendations (Bond et al., 2018; Catchot et al., 2017; Dodds et al., 2017). All treatments were sampled and controlled for insect pests such as *Frankliniella fusca* (Hinds) and *Lygus lineolaris* throughout the growing season. All plots were maintained weed free throughout the season with POST applications of glyphosate and S-metolachlor prior to damage occurring. Harvest aids consisting of Thidiazuron (0.105 kg ai ha^{-1}), S,S,S-Tributyl phosphorotrithioate (0.315 kg ai ha^{-1}), and Ethephon (1.261 kg ai ha^{-1}) were applied when the untreated check reached 60% open boll. Data collection consisted of cotton height, lint turnout, lint yield, and fiber quality. Cotton was harvested using a spindle picker modified for small plot research (Table 1). All treatments were harvested on the same day at each location and year regardless of damage treatment. Lint turnout was determined by hand harvesting a 25-boll sample that was ginned on a 10-saw laboratory cotton gin (Continental Eagle Corp., Prattville, AL). Seed and lint were weighed, and lint turnout was calculated by dividing the weight of lint by the total weight of seed plus lint. Fiber quality was determined by a High Volume Instrument (HVI®) at the Fiber and Biopolymer Research Institute, Lubbock, TX. Statistical analyses were conducted using PROC GLIMMIX procedure in SAS v.9.4 (SAS Institute, Cary, NC). Data were analyzed using analysis of variance (ANOVA) and differences among least square means were determined by using multiple pairwise t-tests at the 0.05 level of significance. Random effects consisted of location and year. No significant differences in location were observed ($p = 0.0582$) therefore, data were combined across locations. Fixed effects consisted of foliar N fertilizer application timing, cotton growth stage at the time of damage, and foliar N fertilizer application timing by growth stage.

Table 1. Planting and harvest dates for Starkville and Brooksville, MS, 2016-2017

	------- Starkville -------		------ Brooksville ------	
	–2016–	–2017–	–2016–	–2017–
Planting Date	**07 May**	**07 May**	**10 May**	**08 May**
Harvest Date	**24 October**	**10 November**	**11 October**	**31 October**

RESULTS AND DISCUSSION

The interaction of growth stage at the time of damage and foliar N fertilizer application timing did not influence cotton height, lint turnout, lint yield, or fiber quality (Table 2). Growth stage at the time of damage influenced cotton height at harvest, lint turnout, lint yield, micronaire, fiber strength, and fiber elongation when pooled across locations and years (Table 2). Cotton height at harvest was reduced by 7% where plants were damaged at pinhead square compared to first bloom (Table 3). Cotton that was undamaged was 6 and 13% shorter than cotton damaged at pinhead square and first bloom, respectively (Table 3). Cotton that was undamaged averaged 18 nodes per plant (data not shown). Lint turnout was greater where cotton was damaged at pinhead square compared to first bloom. Cotton that was undamaged had 3.2 to 7.1% greater turnout than cotton that had eight nodes of growth removed at pinhead square or first bloom (Table 3). Cotton damaged at first bloom produced 47% less lint yield compared to cotton damaged at pinhead square (Table 3). Lint yield, where cotton was damaged at pinhead square and first bloom, was reduced 57 and 77%, respectively, compared to cotton that was undamaged (Table 3). Reduced lint yield could be attributed to the reduced number of days remaining in the growing season following the time at which cotton was damaged. Similar findings from Smith and Varvil (1981) reported that the time at which damage occurs within the growing season reflects a point in the development of the crop; therefore, the amount of time remaining in the growing season can greatly influence observed outcomes. Additionally, Smith and Varvil (1981) found that when the same severity of damage occurred in older plants, a decrease in recoverability was observed, which agrees with this research. Similar to lint yield, a 7% reduction in micronaire was observed where plants were damaged at first bloom compared to pinhead square (Table 3). In addition, micronaire from damaged cotton was reduced by 6 to 17% compared to undamaged cotton (Table 3). Smith and Varvil (1981) also observed a decrease in micronaire where simulated hail damage occurred. Although, micronaire was reduced in their research and this study, micronaire did not fall below the minimum premium range. Differences in fiber strength and fiber elongation were also evident depending on the time damage occurred. Fiber strength was lower in undamaged cotton compared to both damaged cotton treatments. Furthermore, fiber elongation was lower in undamaged cotton and cotton that had been damaged at pinhead square compared to cotton damaged at first bloom (Table 3.). Research conducted by Kerns et al. (2016) observed that fiber quality might have declined due to delays in maturity in cotton that experienced pre-bloom square loss. Similar delays in maturity were observed in this study, where damaged cotton had delayed maturity compared to undamaged cotton.

Foliar N fertilizer application timing affected lint turnout, lint yield, micronaire, and fiber strength when pooled across locations and years (Table 2). No differences in lint yield or turnout due to foliar N fertilizer application or lack thereof were observed where cotton had been damaged (Table 4). However, turnout was reduced 7 to 10% due to damage, and lint yield reductions between 63 and 72% were observed from damaged cotton, regardless of fertilizer N application, compared to cotton in which no damage occurred and no foliar N fertilizer was applied (Table 4). Foliar N fertilizer application to damaged cotton had no effect on micronaire values except where foliar N fertilizer was applied 1 wk after damage occurred and 1 wk after damaged occurred + 1 wk (Table 4). Furthermore, when compared to the undamaged check, all damaged cotton, except where foliar N fertilizer was applied 1 wk after damage, resulted in 12 to 19% reduction in micronaire (Table 4). Reduced micronaire scores where cotton was damaged could be due to damaged plants having delayed maturity, and though defoliation was delayed as late as possible, lint fibers might have been immature at the time harvest aids were applied, when the untreated plots reached 60% open boll. Fiber strength was the only fiber quality parameter affected by removal of eight nodes of growth at pinhead square or first bloom. Nitrogen fertilizer applied to the foliage of damaged cotton had no effect on fiber strength. However, all damaged cotton, regardless of foliar N fertilizer application or lack thereof, had between 3 and 6% greater fiber strength compared to undamaged cotton that did not receive a foliar N fertilizer application (Table 4). Based on the findings from Peacock and Hawkins (1974), secondary wall thickness within the boll heavily influences fiber strength. Though day length and temperature influence secondary wall formation, the delay in maturity experienced by damaged cotton in this research did not appear to adversely affect fiber strength as fiber strength was improved.

Table 2. Analysis of variance probability values for damage timing (growth stage), foliar N fertilizer application timing, and interaction of foliar N fertilizer application timing by growth stage for plant growth parameters, lint turnout, lint yield, and fiber quality

	Cotton Height at Harvest	Lint Turnout	Lint Yield	Micronaire	Fiber Length	Fiber Uniformity	Fiber Strength	Fiber Elongation
	p-values[z]							
Growth Stage (GS)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.6855**	**0.2639**	**0.0005**	**0.0322**
Foliar N Application Timing	**0.4569**	**<0.0001**	**<0.0001**	**0.0002**	**0.9798**	**0.8339**	**0.0079**	**0.7178**
Foliar N Application Timing*GS	**0.9818**	**0.5935**	**0.7183**	**0.2713**	**0.7898**	**0.9233**	**0.6473**	**0.7623**

[z] **Data was pooled across year and location.**

Table 3. Damage timing (growth stage) effects on plant height (cm), lint turnout (%), lint yield (kg/ha), micronaire (mic), fiber length (mm), fiber uniformity (%), fiber strength (grams/tex), and fiber elongation (%)

Damage Timing[z]	Cotton Height –cm–	Lint Turnout –%–	Lint Yield –kg/ha–	Micronaire –mic–	Fiber Length –mm–	Fiber Uniformity –%–	Fiber Strength -grams/tex-	Fiber Elongation –%–
No Damage	**91 c**	**43.86 a**	**1262 a**	**4.8 a**	**28.7 a**	**83.7 a**	**32.0 b**	**7.2 b**
Pinhead Square	**97 b**	**40.60 b**	**545 b**	**4.3 b**	**28.7 a**	**83.9 a**	**33.3 a**	**7.3 b**
First Bloom	**104 a**	**39.74 c**	**289 c**	**4.0 c**	**28.7 a**	**83.6 a**	**33.6 a**	**7.5 a**

[z] **Data pooled over location, year, and foliar N application timing. Means within a column followed by same lowercase letter are not significantly different according to pairwise t-tests at $p = 0.05$.**

Table 4. Foliar N fertilizer application timing effect on plant height (cm), lint turnout (%), lint yield (kg/ha), micronaire (mic), fiber length (mm), fiber uniformity (%), fiber strength (grams/tex), and fiber elongation (%)

Foliar N Application Timing[z]	Cotton Height –cm–	Lint Turnout –%–	Lint Yield –kg/ha–	Micronaire –mic–	Fiber Length –mm–	Fiber Uniformity –%–	Fiber Strength -grams/tex-	Fiber Elongation –%–
No Damage/No N	91 a	43.85 a	1262 a	4.7 a	28.7 a	83.6 a	31.9 b	7.2 a
No Nitrogen	102 a	40.29 b	427 b	4.0 bc	29.0 a	83.5 a	33.7 a	7.4 a
At Clipping	99 a	39.96 b	420 b	4.1 bc	28.7 a	83.8 a	33.5 a	7.4 a
1 Week After Clipping	102 a	40.47 b	462 b	4.3 ab	28.7 a	83.8 a	33.1 a	7.5 a
2 Weeks After Clipping	102 a	40.34 b	434 b	4.0 bc	29.0 a	83.8 a	33.4 a	7.3 a
At Clipping + 1 Week After Clipping	100 a	39.46 b	352 b	3.8 c	29.0 a	83.6 a	33.0 a	7.3 a
At Clipping + 2 Weeks After Clipping	102 a	40.69 b	429 b	4.0 bc	28.7 a	83.6 a	32.9 ab	7.4 a
1 Week After Clipping + 2 Weeks After Clipping	98 a	40.29 b	367 b	4.1 bc	28.7 a	83.8 a	33.5 a	7.4 a
At Clipping + 1 Week After Clipping + 2 Weeks After Clipping	99 a	39.83 b	443 b	4.1 bc	28.5 a	83.2 a	34.0 a	7.4 a

[z] **Data pooled over location, year, and damage timing (growth stage). Means within a column followed by same lowercase letter are not significantly different according to pairwise t-tests at $p = 0.05$.**

CONCLUSION

Foliar N fertilizer, regardless of timing or number of applications, applied to physically damaged cotton did not increase plant height, lint turnout, lint yield, or fiber quality. Overall, if damage in the form of mainstem node loss occurs in cotton, management strategies other than the use of foliar applied N fertilizer should be evaluated for positive responses in plant growth, lint yield, and fiber quality.

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