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EFFECT OF NITROGEN ON GROWTH, YIELD AND FIBER QUALITY TRAITS OF COTTON GENOTYPES UNDER SEMI-ARID CONDITIONS

Running Title: *Nitrogen Application in Cotton Genotypes*

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Abstract

Nitrogen (N) management is of prime importance because it's play a dominant role in growth and development and consider a limiting factor of various cotton genotypes. Moreover, genotypes also differ on the basis of N mediated growth, yield and quality traits. An experiment was conducted to optimize N rates for varying cotton genotypes to improve growth, yield and fiber quality traits. Experiment was conducted at University of Agriculture Faisalabad, Pakistan. Experiment was laid out in Randomized Complete Block Design with factorial arrangements with combinations $N_1 \times C_1$, $N_1 \times C_2$, $N_1 \times C_3$, $N_2 \times C_1$, $N_2 \times C_2$, $N_2 \times C_3$, $N_3 \times C_1$, $N_3 \times C_2$, $N_3 \times C_3$ and replicated thrice. Comparatively, more total and opened bolls per plant, seed cotton yield per hectare, fiber length, fiber strength, fiber elongation were observed with 250 kg N ha^{-1} and fiber uniformity and ginning out turn with 200 kg ha^{-1}over control. While, genotypes FH-142 and MNH-886 depicted significant enhancement in yield and delay in senescence related attributes than FH-114 for most of instances. However, genotype MNH-886 in most of the cases and genotype FH-421 in some cases depicted more promising results than other genotypes on the basis of evaluated attributes. Conclusively, N application enhanced growth, yield related attributes and fiber quality traits. Comparatively more N triggered improvement in yield, fiber uniformity and fiber strength was observed for genotype MNH-886 but fiber length, fiber elongation and ginning out turn was observed for genotype FH-142.

Keywords

Boll opening, Boll weight, Seed index, Ginning out turn, Fiber length, Fiber strength, Fiber uniformity, Fiber elongation

Introduction

Cotton (*Gossypium hirustum* L.) is an important commercial crop in Pakistan, producing yarn and edible oil. Exports of lint and value-added cotton products account for 55% of Pakistan's foreign exchange profits. In addition, cotton provides raw materials for its textile. Cotton contributes 0.3% of the country's GDP and 1.4% of its agricultural value addition, along with oil producing industries (Govt. of Pakistan, 2023). In 2022-23, cotton was grown on 2144 thousand hectares, yielding 4.910 million bales. The cotton crop fell 41% to 8.329 million bales (Govt. of Pakistan, 2023).

It is critical to develop improved management strategies that will increase cotton output potential. Cotton is highly vulnerable to abiotic stressors. Cotton growth and development are heavily impacted by climatic factors and seasonal management methods such as variety selection, sowing date, sowing method, water need, seed treatment, and proper fertilizer administration, particularly nitrogen (Zhao *et al*., 2012).

Cotton growth and development are significantly affected by a lack of primary nutrients, particularly nitrogen. Nitrogen is widely regarded as the main limiting element affecting cotton growth, yield, and radiation use efficiency (Nicholos *et al*., 2004). Nitrogen application in cotton crops improves leaf area index and flowering when applied before flowering (Rutkowski and Lysiak, 2023). On the other hand, increasing nitrogen availability may tip the balance of vegetative and reproductive growth in favour of vegetative development, delaying crop maturity and lowering seed cotton output (Carranca *et al*., 2018). Higher nitrogen application rates promote vegetative development, which delays crop maturity and, eventually, reduces crop output (Carranca *et al*., 2018).

Cotton's two main fibre quality characteristics are its strength and length. They are associated with both cotton bale value and yarn quality (Ge *et al*., 2007). The performance of selected cotton cultivars for yield and fiber-related metrics, including CIM-1100, NIAB-448, NIAB-78, MNH-93, Karishma, and CIM-446 (Khan *et al*., 2007). All of these variants differed significantly across all traits. They found that the cultivar Karishma had a higher GOT% (36.47), boll weight per plant (4.7 g), staple length (29.57mm), and lint production (798.90 kg ha-1). The cultivar CIM-446 yielded a higher seed index (9.80). The yield performance of new cotton cultivars in terms of average boll weight, number of bolls plant^{-1}, plant height, seed cotton yield, fibre length, ginning out turn, number of sympodial branches plant^{-1}, and fibre fineness were significantly more than older varieties (Ehsan *et al*., 2008). The FH-115 produced a better yield because to the increased number of bolls per plant, sympodial branches, and higher ginning output.

In addition, nitrogen is an essential component of many biological molecules. Its lack of availability has an impact on photosynthetic rate, crop growth rate, and crop source-sink associations (Dong *et al*., 2012). It also hinders the plant from producing bolls (fruit) or having square abscission (Gangaiah *et al*., 2013). Furthermore, the cotton genotype and nitrogen related effect revealed that Bt cotton had a quadratic nitrogen response, while non-Bt cotton had a linear nitrogen response (Ali *et al*., 2011). Applying the appropriate nitrogen dose (150 kg ha^{-1}) resulted in taller plants with higher boll number and weight (Nichols *et al*., 2004). Thus, the current study was done with the main purpose of to determine the nitrogen use efficiency for Bt-cotton cultivars under semi-arid conditions of Faisalabad.

1. Materials and methods:

2.1. Plant material:

Seed of genotypes FH-114, FH-142 and MNH-886 were collected from AARI, Faisalabad and Cotton Research Station Multan, Pakistan respectively for this study.

1.2. Experimental site:

The experiment was conducted at Agronomic research area in University of Agriculture, Faisalabad (UAF) 31.26 ^{o}N, 73.04 ^{o}E and at altitude of 184.4 meter.

1.3. Physiochemical traits of experimental site:

Soil samples were randomly collected from experimental plots with the help of soil auger. Samples were collected from the depths of 0-6 and 6-12 cm and analyzed to quantify different physiochemical attributes (ICARDA, 2013). Soil analysis was carried out in Environmental Sciences lab, Institute of soil and environmental science, UAF (Table 1).

1.4. Weather elements:

Weather data were collected from metrological observatory cell, Department of Crop Physiology, University of Agriculture; Faisalabad situated at latitude 31° north, longitude 73° east and at altitude of 184.4 meter are presented graphically (Figure 1). The experimental site was semiarid with annual mean rain fall of 375 mm.

1.5. Treatments:

The experiment was comprised of two variables a) cotton cultivars (FH-114, FH-142, MNH-886) and b) three nitrogen levels (150, 200, 250 kg ha^{-1}).

1.6. Experimental design:

The experiment was laid out in randomized complete block design (RCBD) with factorial treatment having three blocks.

1.7. Imposition of treatments:

Nitrogen (as per treatment) was applied at planting while one third at 30-35 days after sowing and remaining nitrogen was applied at flowering in different genotypes of cotton crop.

1.8. Statistical analysis:

Analysis of variance was employed to determine significance (F-test) of cotton genotypes and nitrogen doses. While, means of treatments were compared using LSD (Least Significant Difference) test (Steel *et al*., 1997).

1.9. Agronomic practices:

The crop was planted with manual dibbling having 75 cm apart ridges and plant to plant 30 cm distance. The seed rate during sowing was 10 kg ha^{-1}. Each plot size was 4.5 m × 3 m area. Fertilizer was applied at the rate of P: K @ 115: 95 kg ha^{-1} complete doses of the phosphorus and potash was applied at the time of planting of crop; whereas nitrogen was applied as per treatment in all experimental units. The crop was irrigated nine times according to requirement of the crop. Weed were controlled by using one post emergence broad spectrum herbicide (Roundup (Glyphosate) at 3000 mL ha^{-1}) using shield (90 days after sowing) as well as two manual hoeing i.e. squaring (35 days after planting) and at flowering (60 days after planting) while the sucking insects and boll worms were controlled with insecticides. All other agronomic practices were kept normal and uniform for all the treatments.

2.10. Observations recorded:

Total number of bolls were recorded through the opened and unopened bolls. Firstly total the opened and unopened bolls from first and second picking of selected plants and took the average. Average boll weight (g) was calculated by dividing the total seed cotton yield per plant by the number of opened bolls of the selected plants and then average was taken. Seed index (100-seed weight) was calculated by weighing the 100 seeds through electrical balance in grams from each of the selected plants and then average was taken. Seed cotton yield per hectare in kg was calculated from the seed cotton yield per plot.

Seed cotton weight of 100 g was processed in a roller ginning unit and computed ginning out turn using formula (Singh, 2004).

$$GOT\ (\%) = \frac{\text{Lint weight}}{\text{Seed weight}} \times 100$$

Fiber length, strength, uniformity and elongation are quantified by processing lint in high volume instruments (HVI) Module-920 of HVI-900A.

Characteristics	**Unit**	**Value**	
Depth of sample	Cm	0-6	6-12
Texture	-	Loam	
pH	-	8.00	8.00
Sand	%	33.78	33.78
Silt	%	34.12	34.12
Clay	%	32.23	32.23
EC	dSm^{-1}	1.05	0.96
Organic matter	%	0.35	0.77
Nitrogen (N)	%	0.058	0.053
Phosphorus (P)	ppm	3.2	2.9
Potassium (K)	ppm	180	180

Table. 1: Chemical analysis of soil before sowing of crop

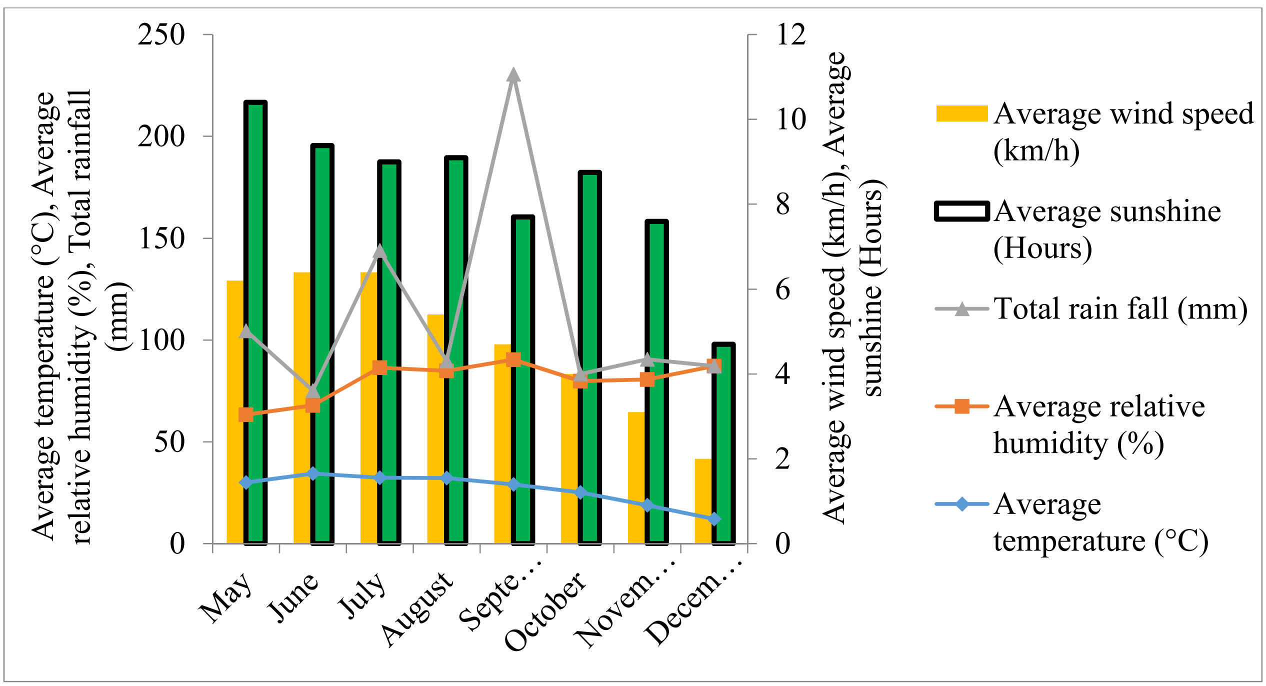

Fig. 1: Weather conditions during cotton growing period

3. Results:

3.1. Agronomic traits

Total number of bolls contribute the maximum share in seed cotton yield. The maximum bolls plant^{-1} was recorded (38) in FH-142 at 250 kg N ha^{-1}. While, the minimum number of bolls plant^{-1} were (28) recorded by cultivar FH-114 at 150 kg N ha^{-1}. Overall the highest number of bolls plant^{-1} was recorded in cultivar FH-142 and the lowest number of bolls plant^{-1} was observed in FH-114 showed in table (4.3.4). The maximum number of bolls plant^{-1} was observed at N_3 that was 250 kg N ha^{-1} (38) and the minimum number of bolls plant^{-1} was recorded at N_1 which was 150 kg N ha^{-1} (28) (Table 3).

In cotton production number of opened bolls per plant is an important yield component; more the number of opened bolls produced higher will be the seed cotton yield. The maximum number of opened boll plant^{-1} was (32.33) observed in FH-142 at 250 kg N ha^{-1}. The lowest number of opened boll plant^{-1} was noted in FH-114 at 150 kg N ha^{-1} (22.00). The effect of nitrogen levels and genotypes was non-significant for unopened bolls (Table 2). The interactive effect of both factors nitrogen levels and different genotypes was significant for total bolls and opened bolls but non-significant for unopened bolls per plant (Table 3).

The average boll weight is an important parameter which contributes materially towards final seed cotton in cotton crop. The interactive effect of nitrogen and genotypes was significant (Table 2). The crop which was treated with 200 kg N ha^{-1} contained maximum average boll weight (3.01 g) at 200 kg N ha^{-1} and the minimum average boll weight (2.42 g) at150 kg N ha^{-1}. Average boll weight was increase to about 20% (3.01 vs. 2.42 g). Average boll weight was (2.80 g) noted in cultivar FH-142. The average boll weight of cultivar MNH-886 and FH-142 had almost similar i.e. (2.80 g and 2.72 g) but the less average boll weight was recorded for FH-114 cultivar. The maximum average boll weight was recorded for cultivar FH-142 (2.80 g) under the nitrogen rate of 200 kg N ha^{-1} (Table 3).

The effect of cultivars on 100-seed cotton weight was observed significant (Table 2). Among the cultivars, the maximum 100-seed weight was (7.50 g) recorded in MNH-886 which was at par to the FH-142 (7.38) and minimum (6.51 g) in FH-114 (Table 3).

Seed cotton yield is a combined effect of individual yield components under particular environmental condition. Signification effect of cotton cultivars and nitrogen rates on seed cotton yield (Table 2). The effect of nitrogen rates on seed cotton yield was observed statistically significant. The maximum seed cotton yield was (3322.0 kg ha^{-1}) attainted in cotton at 200 kg N $ha^{-1}$and the minimum seed cotton was (2728.9 kg ha^{-1}) recorded by for 150 kg N ha^{-1}. Data indicated that maximum seed cotton (3369.0 kg ha^{-1}) was produced by FH-142 and the minimum seed cotton yield was (2655.7 kg ha^{-1}) attained by FH-114. Increase the seed cotton yield to about 21% (3369.0 vs. 2655.7 kg ha^{-1}) (Table 4).

3.2. Ginning out turn

The ultimate objective of cotton production is lint production; to increase the lint production, ginning out turn must be increased. Highest mean value of ginning out turn (45.01%) was recorded for 200 kg N ha^{-1} and the minimum ginning out turn (GOT) was noted (38.43%) at 150 kg N ha^{-1} which however, was statistically at par with that of 250 kg N ha^{-1} (40.81%). The effect of cotton cultivars on ginning out turn (GOT) was also significant (Table 2). The maximum ginning out turn (GOT) was observed in FH-142 (45.14%) and the minimum ginning out turn (GOT) was observed in MNH-886 (39.94%) which was at par with that of FH-114 (40.14%). Average ginning out turn (GOT) was increase to about 11% (45.141 vs. 39.94%) (Table 4).

3.3. Fiber quality parameters

Fiber quality traits such as length, strength, uniformity and elongation is significantly affected by nitrogen but it's not effected due to different genotypes (Table 2). The interactive effects of nitrogen and genotypes are non-significant. Maximum fiber length (26.36 mm) and strength (29.40 g/tex) and elongation (6.84%) was observed with nitrogen dose 250 kg ha^{-1} and minimum was recorded in 150 kg N ha^{-1}. In case of fiber uniformity maximum uniformity in fiber (50.32%) was recorded with 200 kg N ha^{-1} and minimum in 150 kg N ha^{-1} (Table 4).

4. Discussion:

The primary factors which affect the cotton fiber quality are cultivar and nutrient (Nitrogen) and secondary factors are different agronomic practices such as planting time, seed rate, method of irrigation and environmental conditions (Subhan *et al*., 2001). Nitrogen is known as a key limiting nutrient, used in the production of cotton in dry land (Kienzler *at el*., 2010). In many crops such as cotton, nitrogen promotes excessive vegetative growth and delayed maturation resulting in low yield (Rinehardt *et al*., 2004). In different concentrations of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1} respectively), it was noted that by increasing the nitrogen up to 80 kg ha^{-1} increased seed cotton yield in the United States (Dar and Anwar, 2005).

Maximum height, numbers of sympodial branches per plant, number of nodes per stem were noted in 200 kg ha^{-1} nitrogen per hectare and lowest in 50 kg ha^{-1} (Dar and Anwar, 2005). It is also reported that cotton yield varies among different cultivars (Wajid *et al*., 2010). In different cultivars decreased yield is due to reduction in boll weight and numbers associated with less dry matter production (Bange *et al*., 2003).

Nitrogen levels (0, 67,134 and 201 kg ha^{-1} respectively) significantly increase the growth, development and cotton yield. He reported that by increasing the N rates also increase the number of bolls m^{-1}, number of bolls $plant^{-1}$, plant height and lint yield. They also stated that with every one kg of nitrogen ha^{-1}applied to cotton, lint yield increased by 1.74 kg ha^{-1} (Wang *et al*., 2004). Significantly higher number of matured bolls was present in the highest N level treatment than the lowest one (Wajid *et al*., 2010).

Nitrogen has linear correlation with seed cotton yield (Ali *et al*., 2004). These results are also supported by Badr (2003) and Copur (2006) determined the yield and yield components of (*Gossypium hirsutum*) cultivars and observed significant differences. Soomro *et al.* (2005) also studied the seed cotton yield in upland cotton cultivars and found that cultivars showed significant differences. Afiah and Ghoneim (2000) also mentioned that seed cotton yield was positively correlated lint yield.

High lint yield was changed by the change of varieties (Wang *et al*., 2004). Nitrogen did show significant effect on GOT (%) (Saleem *et al*., 2010). According to these findings, seed cotton yield could be increased by using optimum doses of nutrients particularly of nitrogen (Marsh *et al*., 2000).

Fiber strength and length of cotton are the two major fiber qualities parameters. They link with both lend value of cotton bale and yarn quality (Ge *et al*., 2007). Khan *et al.* (2007) performed a field trial to evaluate the performance of selected cotton cultivars for yield and fiber related parameters likewise CIM-1100, NIAB-448, NIAB-78, MNH-93, Karishma and CIM-446. All these varieties differed significantly for all traits. They concluded that the cultivar Karishma produced greater GOT% (36.47), boll weight per plant (4.7 g), staple length (29.57 mm) and lint yield (798.90 kg ha^{-1}). The cultivar CIM-446 produced greater seed index (9.80).

Fiber length did not decrease with increased nitrogen levels (Alew *et al*., 2007). Fiber length increased by high levels of nitrogen (Tewolde and Fernandez, 2003). Nitrogen doses but did not increase to the economic importance (Sawan *et al*., 2006). Fiber strength is influenced by both genetics and environmental conditions (Bednarz *et al*., 2005).

Conclusion

Growth rate, yield and quality traits were improved significantly with the application of 250 kg N ha^{-1}. While, 250 kg N ha^{-1} was closely followed by 200 kg N ha^{-1} on basis of evaluated parameters. Whereas, more promising response of recorded attributes was conserved in genotype MNH-886 and in some traits FH-142 than FH-114.

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Table 2: Mean sum of square for nitrogen and genotypes on yield and fiber quality related traits of cotton

Parameters	Source of variation			
	Nitrogen rate (N)	**Cultivar (C)**	**N × C**	**Error**
Seed index	0.4647^{NS}	2.6418*	0.3999^{NS}	0.3195
Unopened bolls	8.111^{NS}	1.444^{NS}	2.722^{NS}	45.527
Total bolls per plant	15.4444**	28.7778**	28.2222**	1.2778
Opened bolls	10.111^{NS}	30.333**	40.611**	4.791
Average boll weight	0.8685**	0.2581**	0.0919*	0.0268
Ginning out turn	135.212**	77.438*	6.658^{NS}	17.445
Seed cotton yield per hectare	791659**	1147453**	10446^{NS}	48858
Fiber length	34.5559*	0.3659^{NS}	0.1476^{NS}	1.9069
Fiber strength	3.7448*	0.4814^{NS}	0.5298^{NS}	1.0638
Fiber uniformity	56.9381**	60.3604^{NS}	8.3659^{NS}	4.3200
Fiber elongation	4.0281**	0.0737^{NS}	0.2214^{NS}	0.0737

Where:

* = Significant, NS = Non-significant

Table 3: Effect of nitrogen levels on yield related parameters of cotton genotypes

Treatments	SI	UOB	TB	OB	ABW
Nitrogen rates (kg N ha^{-1})					
150 (N_1)	7.36	5.00	33.22 C	28.22	2.42 B
200 (N_2)	7.13	6.89	35.00 B	28.11	3.01 A
250 (N_3)	6.90	5.78	35.78 A	30.00	2.56 A
LSD (≤ 0.05)	NS	NS	1.129	NS	0.163
Cultivars					
FH-114 (C_1)	6.51 B	6.22	33.22 B	27.00 B	2.47 B
FH-142 (C_2)	7.38 A	6.00	36.67 A	30.67 A	2.80 A
MNH-886 (C_3)	7.50 A	5.44	34.11 B	28.67 B	2.72 A
LSD (≤ 0.05)	0.564	NS	1.129	2.187	0.163
Interaction					
N_1 (150 kg N ha^{-1})					
$N_1 \times C_1$	7.03	6.00	28.00 d	22.00 d	2.45 cde
$N_1 \times C_2$	7.67	6.67	37.00 a	31.33 ab	2.39 e
$N_1 \times C_3$	7.29	3.33	34.67 c	31.33 ab	2.41 de
N_2 (200 kg N ha^{-1})					
$N_2 \times C_1$	7.67	7.33	36.67 ab	30.00 ab	2.73 bc
$N_2 \times C_2$	7.48	6.67	35.00 bc	28.33 bc	3.24 a
$N_2 \times C_3$	7.40	6.67	33.33 c	26.00 c	3.06 a
N_3 (250 kg N ha^{-1})					
$N_3 \times C_1$	6.03	6.00	35.00 bc	29.00 abc	2.24 e
$N_3 \times C_2$	6.99	5.67	38.00 a	32.33 a	2.77 b
$N_3 \times C_3$	7.72	5.67	34.33 c	28.67 abc	2.68 bcd
LSD (≤ 0.05) for interaction	**NS**	**NS**	**1.956**	**3.789**	**0.383**

Means not sharing a letter in common within a row differ significantly at 5% probability.
NS = Non-significant, SI = Seed index (g), UOB = Unopened bolls, TB = Total bolls per plant
OB = Opened bolls per plant, ABW = Average boll weight (g)

Table 4: Effect of nitrogen levels on yield and fiber quality traits of cotton genotypes

Treatments	GOT	SCY	FL	FS	FU	FE
Nitrogen rates (kg N ha^{-1})						
150 (N_1)	38.43 B	62.84 C	22.53 B	28.16 B	45.46 B	5.56 C
200 (N_2)	46.01 A	78.70 A	25.15 A	29.11 AB	50.32 A	6.51 B
250 (N_3)	40.81 B	72.44 C	26.36 A	29.40 A	46.76 B	6.84 A
LSD (≤ 0.05)	4.173	6.098	1.380	1.030	2.077	0.271
Cultivars						
FH-114	40.14 B	65.88 B	24.90	29.07	46.64	6.34
FH-142	45.14 A	76.49 A	24.66	28.63	47.57	6.37
MNH-886	39.94 B	71.61 AB	24.50	28.96	48.32	6.20
LSD (≤ 0.05)	4.173	6.098	NS	NS	NS	NS
LSD (≤ 0.05) for interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Means not sharing a common letter within a column differ significantly at 5% probability level.
NS = Non-significant, GOT = Ginning out turn (%), SCY = Seed cotton yield per hectare (kg ha^{-1}), FL = Fiber length (mm), FS = Fiber strength (g/tex), FU = Fiber uniformity (%), FE = Fiber elongation (%)

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