JOURNAL OF AGRICULTURE AND BASIC SCIENCES
ISSN Online: 2518-4210
http://www.jabsjournal.com/

*Full Length Research Article*

# Nitrogen Triggered Improvements in Growth, Net Assimilation, Allometric Traits and Yield of Bt. Cotton Genotypes

**Asif Imran, Syed Aftab Wajid, Abdul Shakoor*, Muhammad Shahid and Naveed Irshad**
Department of Agronomy, University of Agriculture, Faisalabad, Pakistan
*Corresponding author's Email: shakoor2914@gmail.com

## Abstract

Nitrogen (N) management and poor vegetative growth are chief deterrents to accomplish yield potential in cotton. Moreover, genotypes also differ on the basis of N mediated growth and leaf biomass accumulation. An experiment was conducted to optimize N rates for varying genotypes to improve leaf area, leaf area index, leaf area duration and net assimilation rate. Experiment was conducted at Agronomic Research Area, University of Agriculture Faisalabad, Pakistan during 2014. 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 3 times. Comparatively, more leaf area duration, net assimilation rate, boll maturation period, crop growth rate, plant height, total and opened bolls per plant and seed cotton yield per plant were observed with 250 kg N $ha^{-1}$ 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 depicted more promising results than other genotypes on the basis of evaluated attributes. Conclusively, N application enhanced growth, leaf biomass accumulation and yield related attributes. Comparatively more N triggered improvement in yield and allometric traits was observed for genotype MNH-886 than other cultivars.

**Keywords:** Biomass accumulation; boll opening; boll weight; chlorophyll; leaf area; leaf area index; photosynthetic organs; stay green

## Introduction

Cotton is grown around the globe as fiber, cash and oil seed crop (Ali, 2015). Cotton yield can be improved by good management practices such as maintaining fertilizer (nitrogen) levels (Ali *et al*., 2007). In some crops like cotton, excessive vegetative growth and delayed maturity occurs due to application of higher nitrogen levels than optimum, resulting reduction in seed cotton yield (Rinehardt *et al*., 2004). Nitrogen is an essential as well as macro nutrient that is required in larger amount than other nutrients that enhance cotton production (Dong *et al*., 2012). Cotton growth and development is highly sensitive to N deficiency as it contributes to plant photosynthetic organs (Wei *et al*., 2015). Photosynthetic rate increases with increase in the application of nitrogen (Wei *et al*., 2015). Therefore, deficiency of N includes poor chlorophyll contents, as well as adversely affected the leaf area, net photosynthetic rate of leaf and protein contents (Vanyine *et al*., 2012).

Nitrogen is important part of protein formation process (Habash *et al*., 2007). While, appropriate N management improves yield and yield components of cotton (Saleem *et al*., 2010). Moreover, N enhances yield and its components by 20%, leaf area index by 15%, 8% PAR and boosted 5% more CGR and total dry matter at suitable nitrogen level (Zhou *et al*., 2017). Likewise, 200 kg dose of nitrogen per hectare application depicted significantly higher plant height, number of sympodial branches per plant and number of nodes per stem than 50 kg dose of nitrogen per hectare (Dar and Anwar, 2005, Saleem *et al*., 2016).

Nitrogen deficiency aggravates ethylene biosynthesis which ultimately augments flower, square and boll drop. Therefore yield was restricted severely under N unavailability (He *et al*., 2016). While, successive inclined in yield was observed with enhancing N rate over the years (Fritschi *et al*., 2003).

Early sown cotton produces taller plants with higher number of bolls and seed cotton yield (Bange *et al*., 2008). Varietal comparison showed more opened bolls and unopened bolls per plant in cotton genotype FH-113. Among nitrogen levels with application of 175 kg N $ha^{-1}$ more opened as well as unopened bolls and total number of bolls per plant were recorded against the minimum with 115 kg N $ha^{-1}$ (Saleem *et al*., 2014). Various cultivars of cotton like CIM-707, CIM-443, CIM-506, CIM-446, TH-3/83, FH-901, Chnandi-95 and reshmi responded differently however; varieties CIM-446 and TH-3/83 depicted better response than other cultivar (Tahira *et al*., 2007).

The growth and yield performance of five cotton varieties performed differently. The cultivar FH-115 showed best result and gave maximum yield by producing maximum number of sympodial branches, more number of bolls per plant and greater ginning out turn (Fahad *et al*., 2008). Different cultivars of cotton manifest varying capability to uptake N (Wajid *et al*., 2010). Hence, boll weight and other yield components vary among genotypes. Likewise, cultivars also differ on the basis of leaf area, leaf area duration and index. Consequently, dry matter accumulation and yield also differ among genotypes (Bange *et al*., 2003). Some cultivars were reducing their leaf area index (LAI) due to not proper development of crop canopy (Bange *et al*., 2003). Although, appropriate nitrogen management improves yield components in all genotypes (McConnell *et al*., 2000) but boll weight was enhanced with increasing N application (Sawan *et al*., 2006).

Various cultivars have different yield potential under different environments (Wajid *et al*., 2010). Growth habit such as morphological and maturity characteristics of tall and medium cultivars are different (Dzotsi *et al*., 2010). The different cotton cultivars respond differently at various agro-management practices such as sowing time, plant population and fertilizer especially nitrogen management (Khan *et al*., 2006).

Conclusively, appropriate N enhances leaf area, leaf duration, and leaf area index of cotton genotypes. Hence, improvement in green photosynthetic area improves yield components. Moreover, quantifying N application for varying cultivars contribute towards enhanced N use efficiency. Hence experiment was conducted with objectives (i) Quantify N for varying genotypes to improve dry matter accumulation of photosynthetic organs of cotton genotypes. (ii) Explore the N mediated improvements in dry matter accumulation of different genotypes and their impact on yield components.

## Materials and methods

An experiment was conducted to assess the nitrogen use efficiency on growth and yield of Bt. cotton at Agronomic Research Area, University of Agriculture, Faisalabad, during Kharif 2014. Randomized Complete Block Design (RCBD) with factorial arrangements having 3 replications was applied. Net plot size was 6 m × 3 m and seed was placed manually at 30 cm distance on one side of 75 cm apart ridges. The experiment was comprised of two factors such as nitrogen levels and cotton varieties. There were four lines maintained in each plot. The experimental treatments comprised three nitrogen rates viz. $N_1$ (150 kg ha$^{-1}$), $N_2$ (200 kg ha$^{-1}$) and $N_3$ (250 kg ha$^{-1}$) and three varieties of Bt. cotton viz. FH-114, FH-142 and MNH-886. Seedbed was prepared to fine tilth. Then 75 cm apart ridges were made by tractor mounted ridger. The crop was sown on May 27, 2014 using 20 kg seed ha$^{-1}$. Full dose of phosphorus (115 kg ha$^{-1}$) and potassium (95 kg ha$^{-1}$) and one third dose of nitrogen (as per treatment) was applied at sowing while one third at 30 days after sowing and remaining nitrogen was applied at flowering (60 DAS). The source of nitrogen urea was used in the trial. To control weeds, a herbicide {Dual Gold (S Metachlore) at 2000 ml ha$^{-1}$} was sprayed 23 hours after sowing followed by two hoeings (first 25 days after sowing and second 50 days after sowing), and then a post emergence broad spectrum herbicide (Roundup (Glyphosate) at 3000 mL ha$^{-1}$ ) was sprayed using shield (90 days after sowing). Insects were controlled by spraying proper insecticides (Imidachloprid at the rate of 625 ml ha$^{-1}$) at proper time (first 70 days after sowing and second 90 days after sowing). All other husbandry practices were kept uniform for entire experiment. Ten true representative plants were randomly tagged in each plot and following parameters were documented.

**Crop growth rate (CGR) (g m$^{-2}$ d$^{-1}$):** Crop growth rate (CGR) was calculated as proposed by Hunt (1978).

$$CGR = W_2\text{-}W_1 / (T_2\text{-}T_1)$$

$W_1$ and $W_2$ are the total dry weights after sowing of 30 days and 50 days of interval and times $T_1$ and $T_2$, respectively at squaring stage. Mean CGR was calculated by averaging all CGRs.

**Leaf area duration (LAD):** Leaf area duration was estimated according to Hunt (1978).

$$LAD = LAI_1 + LAI_2 \times (t_2 - t_1) / 2$$

Where,

$LAI_1$ = leaf area index at time $t_1$

$LAI_2$ = leaf area index at time $t_2$

**Net assimilation rate (NAR) (g m$^{-2}$ d$^{-1}$):** Net assimilation rate (NAR) is the ratio of total dry weight to leaf area duration and was estimated by using the formula of Hunt (1978).

$$NAR = TDM / LAD$$

TDM and LAD are the total dry matter and leaf area duration at final harvest.

**Boll maturation period (days):** Boll maturation period was calculated by deducting the days taken to flowering from the days taken to boll splition from the sowing of the crop.

**Plant height (cm):** Plant height at harvest of selected plants was measured with the help of meter rod at the time of second picking and average calculated.

**Total number of bolls per plant:** Total number of bolls per plant was recorded by counting the number of opened bolls per plant and number of unopened bolls per plant at the time of second picking and took the average of the selected plants.

Total bolls per plant = Opened bolls per plant + Unopened bolls per plant

**Number of opened bolls per plant:** Opened bolls per plant were counted at first and second picking of guarded plants.

**Boll weight (g):** It was obtained by dividing seed cotton yield per plant with respective number of opened bolls per plant.

**Seed index (g):** Seed index 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 plant (g):** Seed cotton yield per plant was calculated by weighing the seed cotton yield from the selected plants of each plot of all the picks in grams by electrical balance and then the average of the selected plants was taken.

## Results and discussion

### Boll maturation period (days)

The interactive effect of nitrogen and varieties was statistically non-significant. Varying N altered boll maturation period significantly while cultivars depicted a non-significant impact on boll maturation period (Table 1). The maximum boll maturation period (56 days) was recorded at $N_3$ (250 kg N $ha^{-1}$) and the minimum boll maturation period (54 days) was noted at $N_1$ (150 kg N $ha^{-1}$) which was at par to the 200 kg N $ha^{-1}$ (55 days) (Table 2). Enhancing N might have enhanced area of photosynthetic organs. Moreover, increasing N might improve stay green trait which ultimately delayed maturation (earliness decreased/maturity delayed). Furthermore, improved stay green trait might have delayed senescence also. Hence, bolls took more time to reach maturity. Moreover, higher N might have caused more dry matter accumulation which improved light utilization efficiency and photosynthetic organs kept performing activities for longer duration of time (Ning *et al*., 2013).

Nitrogen application has been reported to improved canopy, dry matter accumulation and photosynthetic area of plant (Gu *et al*., 2017). Moreover, growth was highly associated with N application (Marschner, 1986). While N enhanced stay green trait, and also reduced senescence (Main *et al*., 2011). Our results are supported with the early findings that increase the dose of nitrogen the crop stay green period is longer that may increase the length of boll maturation period so more number of bolls will be mature that increase the seed cotton yield (Saleem *et al*., 2009).

### Plant height (cm)

The interactive effect of nitrogen and cultivars was non-significant for plant height (Table 1). Nitrogen application significantly enhanced plant height of cotton over control (Table 1). The maximum plant height (92.22 cm) was with 250 kg nitrogen per hectare application and minimum (86.22 cm) was observed with the application of 150 kg nitrogen per hectare that was statistically similar (86.22 cm) with the 200 kg nitrogen per hectare. Height of different cultivars was also significant. The cultivar MNH-886 produced more plant height (94.22 cm vs. 87.22 cm) than FH-142 (Table 3).

Dissimilar cultivars varied significantly on basis of plant height (Copur, 2006). Various cultivar of cotton responded differentially to chemical fertilizers in different ecological zone for plant height (Prasad, 2000; Tomar *et al*., 2000). Our results are supported by the earlier finding that plant height significantly affected by the genetic makeup, environmental conditions of that area (Wankhade *et al*., 2002), different cultivars (Anwar *et al*., 2002) and different levels of nitrogen (Rocheater *et al*., 2001).

### Crop growth rate (CGR) g $m^{-2}$ $day^{-1}$

The interactive effect of both factors nitrogen levels and different cultivars was significant. Nitrogen rates and different cotton cultivars considerably enhanced the mean crop growth rate (CGR) (Table 1). Cultivar FH-142 showed higher CGR (13.6 g $m^{-2}$ $day^{-1}$) which was equivalent with 12.4 g $m^{-2}$ $day^{-1}$ by using nitrogen dose at 200 kg per hectare. While, lesser CGR was perceived in cultivar MNH-886 (Table 3). Nitrogen application significantly enhanced mean crop growth rate and the response was linear during crop growth (Wajid *at el*., 2014). Cultivar FH-142 depicted higher CGR (13.6 g $m^{-2}$ $day^{-1}$) than other cultivars. While lesser CGR was observed in MNH-886.

### Leaf area duration (LAD) (days)

The interactive effect leaf area duration was non-significant Nitrogen as well as genotypes differed significantly for LAD (Table 1). The cultivar FH-142 had manifested longer LAD (484.77 days) at 250 kg N $ha^{-1}$ while, shorter LAD was recorded in FH-114 (278.23 days) at 150 kg N $ha^{-1}$. The N level significantly enhanced LAD and the response was mostly linear (Table 2). These results are in agreement with the finding of Arshad (2006) that LAD of cotton crop varied significantly with different cultivars. Our results are similar with the early findings that nitrogen levels and different cultivars perform differently for leaf area duration (Hunt, 1978).

### Net assimilation rate (NAR) (g $m^{-2}$ $day^{-1}$)

Net assimilation rate (NAR) was affected by various cotton cultivars but different levels of nitrogen application had non-significant effect (Table 1). While, similar trend in both genotypes at all N rates resulted in a non-significant interaction. The maximum NAR (3.95 $gm^{-2}$ $day^{-1}$) was recorded in FH-114 against the minimum in MNH-886 NAR (2.93 $gm^{-2}day^{-1}$) that was at par with FH-142 (3.02 $gm^{-2}$ $day^{-1}$) (Table 2). Hunt (1978) found average values of NAR at about 5-6 g $m^{-2}$ $day^{-1}$ for a range of species.

**Number of opened bolls per plant**

Dissimilar performance of genotypes at varying N levels consequenced into significant (N × C) effect (Table 1). Considering the nitrogen rate 150 kg $ha^{-1}$, maximum number of opened bolls per plant was produced by cultivar FH-142 (31.33) that was at par with MNH-886 (31.33) followed by FH-114 (22.00). At the rate of 200 kg $ha^{-1}$ nitrogen, cultivar FH-114 resulted in significantly maximum number of opened bolls per plant. Cultivar FH-142 and MNH-886 was at par with N rate of 200 kg $ha^{-1}$. Significantly minimum number of opened bolls per plant was recorded in cultivar FH-114. At 250 kg $ha^{-1}$ N, significantly greater number of opened bolls per plant was depicted by cultivar FH-142 that was at par with cultivars MNH-886 and FH-114. Whereas, significantly lowest number of opened bolls per plant was recorded in cultivar FH-114 (Table 3).

It might be due to translocation of accumulated dry matter in leaves of cotton. The lowest number of opened boll per plant was noted in FH-114 at 150 kg N $ha^{-1}$ (22.00) (Table 3). Wajid *et al.* (2010) found higher number of matured bolls was present in the highest N level treatment than the lowest one. Number of opened bolls per plant was significantly affected by increasing nitrogen levels (Swan *et al*., 2006) and cultivars (Copur, 2006). Our results are similar with earlier findings that higher boll retention was observed in different cultivars such as Bollard II cotton cultivars (Wilson *et al*., 2004).

**Total number of bolls per plant**

The interactive effects of nitrogen levels and cultivars were significant for total number of bolls per plant (Table 1). The maximum bolls per plant (38) was recorded in FH-142 at 250 kg N $ha^{-1}$. While, the minimum number of bolls per plant (28) was recorded for cultivar FH-114 at 150 kg N $ha^{-1}$ (Table 3). Baraich *at el.* (2012) nitrogen significantly effects on number of bolls at different cultivars. The substantial alterations between cultivars for number of bolls per plant had also been described by Copur (2006) observed difference in genetic potential of the cultivars due to differ at the number of bolls per plant. Number of bolls increased with increase in nitrogen levels (Ali and El-Sayed, 2001) and early stage of cotton N deficiency caused the ethylene production that may be the reason of flowers and bolls in cotton (Lege *et al*., 1997).

**Average boll weight (g)**

The average boll weight was statistically enhanced with N application over control (Table 1). The maximum average boll weight (2.2 g) was observed at 200 kg N $ha^{-1}$ (3.06 g) and the minimum average boll weight (2.42 g) was recorded at 150 kg N $ha^{-1}$ (Table 3). The average boll weight is an important parameter which contributes materially towards final seed cotton in cotton crop.

The average boll weight of cultivars MNH-886 and FH-142 was almost similar (2.80 g and 2.72 g). Still, the lower average boll weight was recorded for FH-114 cultivar under the nitrogen rate of 200 kg N $ha^{-1}$ (Table 3). The interaction between N levels and C was significant under 150 kg N $ha^{-1}$ maximum average boll weight (2.45 g) was recorded in cultivar FH-114 which was statistically similar with MNH-886 and FH-142. In case of 200 kg $ha^{-1}$ N treatments differed significantly in average boll weight with highest values recorded in cultivar FH-142 which is statistically similar with cultivar MNH-886. Minimum average boll weight (2.73 g) was recorded in cultivar MNH-886. At 250 kg N $ha^{-1}$ maximum boll weight (2.77 g) was recorded in cultivar FH-142 that was statistically similar with MNH-886. Whereas, significantly minimum boll weight was recorded in cultivar FH-114 (Table 3). Hofs *et al.* (2006) reported that different genetic potential of cotton cultivars for boll weight and nitrogen application levels (Ram *et al*., 2001). Positive relation was also exit between the average boll weight and seed cotton yield (Kaynak, 1995).

**Seed index (g)**

The interaction between nitrogen levels and cultivars was non-significant. Seed index was non-significantly affected by different levels of nitrogen while, the effect of cultivars on seed index was significant (Table 1). Among the cultivars, the maximum seed index was observed (7.72 g) in MNH-886 and the minimum was noted (6.00 g) in FH-114 (Table 2). Arshad *et al.* (2007) the effect of nitrogen rates and cultivar was found to be non-significant.

**Seed cotton yield per plant (g)**

Different N rates and genotypes varied significantly for seed cotton yield per hectare (Table 1). The more seed cotton yield per plant was recorded (81.67 g) at 200 kg N $ha^{-1}$ while, lesser seed cotton yield (56.21 g) was noted at 150 kg N $ha^{-1}$. Regarding cultivars, cultivar, FH-142 produced more seed cotton yield (76.49 g) per plant, while the cultivars FH-114 and MNH-886 resulted relatively in lower seed cotton yields of 65.88 and 71.61 g per plant, respectively (Table 2). The interactive effect between different nitrogen rates and cultivars was non-significant. According to Prasad (2000) cotton varieties established in various ecological zones, worked differentially to chemical fertilizers. Tomar *et al*. (2000) also described hereditarily variations in different climates created in response to different fertilizer levels. Seed cotton yield per plant (g) increased with increasing N levels and cultivars also differed with respect to seed cotton yield per plant (Ehsan *et al*., 2008).

## Conclusion

Yield, biomass accumulation, growth rate and yield 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 than FH-142 and FH-114.

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**Table 1. Mean sum of square for nitrogen and cultivars on growth and yield related traits of cotton**
Where: * = Significant, ** = Highly significant, NS = Non-significant

| Parameters | Source of variations | | | |
|---|---|---|---|---|
| | **Nitrogen rate (N)** | **Cultivar (C)** | **N × C** | **Error** |
| Crop growth rate | 24.4691** | 40.4702** | 4.7683* | 1.5121 |
| Leaf area duration | 4724.5** | 42050.4** | 2247.3$^{NS}$ | 864.7 |
| Net assimilation rate | 0.278$^{NS}$ | 2.836** | 0.381$^{NS}$ | 0.180 |
| Boll maturation | 14.9259* | 5.8148$^{NS}$ | 1.1481$^{NS}$ | 1.8009 |
| Plant height | 81.333** | 180.333** | 1.833$^{NS}$ | 10.236 |
| Total bolls per plant | 15.4444** | 28.7778** | 28.2222** | 1.2778 |
| Number of opened bolls | 10.111$^{NS}$ | 30.333** | 40.611** | 4.791 |
| Boll weight | 0.8685** | 0.2581** | 0.0919* | 0.0268 |
| Seed index | 0.4647$^{NS}$ | 2.6418* | 0.3999$^{NS}$ | 0.3195 |
| Seed cotton yield per plant | 573.802** | 254.162** | 35.847$^{NS}$ | 37.241 |

**Table 2. Effect of nitrogen levels on growth and yield related traits of cotton cultivars**

| **Treatments** | **LAD** | **NAR** | **BM** | **SI** | **SCY** |
|---|---|---|---|---|---|
| **Nitrogen rates (kg N ha$^{-1}$)** | | | | | |
| 150 ($N_1$) | 385.08 B | 3.18 | 54 B | 7.36 | 62.84 C |
| 200 ($N_2$) | 379.47 B | 3.43 | 55 B | 7.13 | 72.44 C |
| 250 ($N_3$) | 421.66 A | 3.29 | 56 A | 6.90 | 78.70 A |
| LSD (≤ 0.05) | 29.386 | NS | 1.341 | NS | 6.098 |
| **Cultivars** | | | | | |
| FH-114 | 318.09 B | 2.93 B | 54 | 6.51 B | 65.88 B |
| FH-142 | 447.80 A | 3.02 B | 54 | 7.38 A | 76.49 A |
| MNH-886 | 420.32 A | 3.95 A | 56 | 7.50 A | 71.61 AB |
| LSD (≤ 0.05) | 29.386 | 0.424 | NS | 0.564 | 6.098 |
| LSD (≤ 0.05) for interaction | NS | NS | NS | NS | NS |

Means not sharing a common letter within a column differ significantly at 5% probability level.
NS = Non-significant, LAD = Leaf area duration (days), NAR = Net assimilation rate (g m$^{-2}$ day$^{-1}$), BM = Boll maturation period (days), SI = Seed Index (g), SCY = Seed cotton yield per plant (g)

**Table 3. Effect of nitrogen levels on crop growth rate and yield related parameters of cotton cultivars**

| Treatments | CGR | PH | TB | OB | BW |
|---|---|---|---|---|---|
| **Nitrogen rates (kg N ha$^{-1}$)** | | | | | |
| 150 ($N_1$) | 8.0 B | 86.22 B | 33.22 C | 28.22 | 2.42 B |
| 200 ($N_2$) | 11.1 A | 88.89 B | 35.00 B | 28.11 | 3.01 A |
| 250 ($N_3$) | 10.7 A | 92.22 A | 35.78 A | 30.00 | 2.56 A |
| LSD ($\leq$ 0.05) | 1.228 | 3.197 | 1.129 | NS | 0.163 |
| **Cultivars** | | | | | |
| FH-114 ($C_1$) | 10.3 A | 87.22 B | 33.22 B | 27.00 B | 2.47 B |
| FH-142 ($C_2$) | 11.8 A | 85.89 B | 36.67 A | 30.67 A | 2.80 A |
| MNH-886 ($C_3$) | 7.6 B | 94.22 A | 34.11 B | 28.67 B | 2.72 A |
| LSD ($\leq$ 0.05) | 1.228 | 3.197 | 1.129 | 2.187 | 0.163 |
| **Interaction** | | | | | |
| **$N_1$ (150 kg N ha$^{-1}$)** | | | | | |
| **$N_1 \times C_1$** | 8.7 de | 83.67 | 28.00 d | 22.00 d | 2.45 cde |
| **$N_1 \times C_2$** | 9.4 d | 84.00 | 37.00 a | 31.33 ab | 2.39 e |
| **$N_1 \times C_3$** | 5.8 f | 91.00 | 34.67 c | 31.33 ab | 2.41 de |
| **$N_2$ (200 kg N ha$^{-1}$)** | | | | | |
| **$N_2 \times C_1$** | 10.5 bcd | 87.33 | 36.67 ab | 30.00 ab | 2.73 bc |
| **$N_2 \times C_2$** | 12.4 ab | 85.00 | 35.00 bc | 28.33 bc | 3.24 a |
| **$N_2 \times C_3$** | 10.1 cd | 94.33 | 33.33 c | 26.00 c | 3.06 a |
| **$N_3$ (250 kg N ha$^{-1}$)** | | | | | |
| **$N_3 \times C_1$** | 11.6 abc | 90.67 | 35.00 bc | 29.00 abc | 2.24 e |
| **$N_3 \times C_2$** | 13.1 a | 88.67 | 38.00 a | 32.33 a | 2.77 b |
| **$N_3 \times C_3$** | 7.0 ef | 97.33 | 34.33 c | 28.67 abc | 2.68 bcd |
| LSD ($\leq$ 0.05) | 2.128 | 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, CGR = Crop growth rate (g m$^{-2}$ day$^{-1}$), PH = Plant height (cm), TB = Total bolls per plant
OB = Opened bolls per plant, BW = Boll weight (g)