Research Article

Nitrogen Requirements of Promising Cotton Cultivars in Arid Climate of Multan

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Abstract | For assessing the adaptability of cotton cultivars (CIM-496 and NIAB-111) in Cotton-Wheat cropping system of Punjab under arid climate of Multan and response of different nitrogen (N) increments (50, 100, 150 and 200 kg N ha^{-1}) for efficient and effective resource (nitrogen) utilization. The study was conducted in Multan during cotton growing season in 2014. Cultivars as well as nitrogen increments significantly contributed to the related traits of cotton growth, seed cotton yield and yield attributes. Increasing N increments reveals a positive association with biomass accumulation (growth), yield and yield associated components. Among N increments, 200 kg ha^{-1} achieved more number of bolls per plant (31.00), average weight per boll (3.48 g) and ultimately lead to higher seed cotton yield (2.42 t ha^{-1}) as compared to other N rates (50, 100, 150 kg ha^{-1}). Significant differences were also observed in cultivars, CIM-496 produced higher seed cotton yield than other under arid climate of Multan in Cotton-Wheat Cropping system. Empirical model was developed on the basis of field observations to compute the seed cotton yield beyond the application of 200 kg N ha^{-1}. It is predicted that seed cotton yield increased with additional increment of nitrogen (>200 kg ha^{-1}) but it is not significant change in yield per unit increment as compared with previous ones.

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Introduction

Cotton, being a cash crop, plays an important role in the development of Pakistan's economy. It accounts for 1.5 and 7.1% in GDP and agriculture value addition, respectively. The textile industry of Pakistan earned a huge amount of foreign exchange (10.22 billion US$) during July to March of 2014-15. Cotton crop was planted on an area of 2961 thousand hectares during 2014-15 revealing a 5.5% increase as compared to area (2806 thousand hectares) of 2013-14. Similarly cotton production (13.983 million bales) was also 9.5% more as compared to last years (12.769 million bales) (GoP, 2014-15).

Nitrogen (N) plays an important role in cotton productivity (Ali et al., 2003) and its deficiency is one of the main yields limiting factor for cotton cultivars (Milroy and Bange, 2004; Nicholos et al., 2004). Over application of N can lead to excessive vegetative growth, delay in maturity and harvest, promotion of boll shedding, reduction of fiber quality and yield, and increased water pollution (Boquet and Breitenbeck, 2000). Zhao and Oosterhuis (2000) noted a reduction in leaf chlorophyll contents, photosynthetic rate and finally leaf area of cotton crop with N deficiency after vegetative growth. N deficiency promotes the fruit abscission and decrease crop productivity. Excessive N application also reduces crop performance (Howard et al., 2001). Studies show that older cultivars have much lower yield and also poor response to N fertilization than modern cultivars. Aslam et al. (2013) reported that cotton cultivar CIM-506 produced 2568 kg ha^{-1} of seed cotton with the application of 200 kg N ha^{-1}. Dar et al. (2004) noted that application of 200 kg N ha^{-1} to cotton cultivar CIM-499 enhanced seed cotton yield (2978 kg ha^{-1}) over all other nitrogen treatments (50, 100, 150 and 200 kg ha^{-1}). The selection of crop variety according to the prevailing climatic conditions is of primary importance (Hussain et al., 2007). Bange et al. (2003) concluded that yield losses of different cultivars were due to reduced boll number associated with less dry matter production. Cotton cultivars differed significantly for total dry matter (TDM) production (Bange et al., 2003) number of bolls per plant (Anwar et al., 2002; Rahman et al., 2016) susceptibility for bollworm (Lisheng, 2005) and economic yield (Hofs et al., 2006; Ehsaan et al., 2008, Wajid et al., 2014). The present study was conducted with the hypothesis that cotton cultivars differ in their response to different nitrogen fertilizer application. The objective of the study was to identify optimum nitrogen level and the best cultivar x nitrogen combination that would lead to maximum economic cotton yield in the cotton growing area of Cotton-Wheat cropping system of Punjab.

Materials and Methods

An experiment was conducted to study the influence of various N rates on growth and yield of cotton cultivars at the Central Cotton Research Institute, Multan during cotton growing season in 2014. The treatments that include cotton cultivars (CIM-496 and NIAB-111) and nitrogen rates (50, 100, 150 and 200 kg ha^{-1}) were randomly allocated to the main and sub plots, respectively utilizing randomized complete block design (RCBD) with split plot arrangement. Used cultivars have potential to survive better in arid climatic conditions than others. Performance of these cultivars were found reasonable good under semi-arid to arid climate so these cultivars were selected for this study. Each subplot has a length and width of 10 m and 3 m, respectively. The seeds of tested verities were sown on May 16, 2014 utilizing hand drill and maintained 75 cm row spacing while plant spacing was maintained at 25 cm by thinning (20 days after sowing). Phosphorus (Diammonium phosphate) and potassium (potassium sulphate) were applied at the rate of 60 and 50 kg ha^{-1} in all the plots. Complete amount of phosphorus and 1/3rd nitrogen (Urea) was applied at seeding, 1/3rd N at flowering and remaining 1/3rd at boll formation. The crop was irrigated 9 times at different stages (monopodial branches, squaring, flowering, boll formation and boll opening initiation phases) and insecticides (actara 25WP @ 24 g, mospilan 20SP @ 125 mg, polo 500SC @ 250 ml, karate 2.5EC @ 400 ml and talstar 10EC @ 250 ml) were used to control the sucking insects and bollworms. Final yield was determined from a net plot size of 1.5 m × 6.0 m and rest area of the plot was utilized to collect sample for crop growth. Randomly three plants from each plot were harvested with an interval of 30 days. After recoding weight of all samples, these samples were placed in an oven for total dry matter (TDM) calculation. Leaf area index (LAI) (Leaf area / Land area) and Leaf area duration (LAD) = $[(LAI_1 + LAI_2) /2 \times \{(T_2 - T_1)\}]$ were calculated as proposed by Hunt (1978). At maturity, an area of 1.5 m x 6 m which had 48 plants was harvested for final yield and various yield components. Sigma Plot was used to develop empirical model for the prediction of seed cotton yield on the basis of nitrogen application in the field.

Weather: Mean monthly weather data for the crop growth period is presented in Table 1. The maximum average air temperature was recorded in the month of June (34.7°C) and minimum average temperature was recorded in the month of November (19.7°C). The average relative humidity increased from May to December (maximum 87.3%). The maximum average rainfall was recorded in the month of July (134.3 mm) while no rainfall was occurred in the months of June, August, October and November. The total rainfall throughout the cotton growing season was 155.3 mm.

Table 1: *Meteorological data for cropping season 2014.*

Month	Max.Temp. (°C)	Min. Temp. (°C)	Mean Temp. (°C)	Relative humidity (%)	Rainfall (mm)
May	36.8	23.7	30.2	49.2	12.5
June	40.7	28.7	34.7	55.0	0.0
July	36.4	28.6	32.5	78.6	134.3
August	34.9	28.3	31.6	78.4	0.0
September	34.0	25.0	29.5	82.1	8.5
October	32.5	18.0	25.3	79.4	0.0
November	27.1	12.3	19.7	87.3	0.0
Total	-	-	-	-	155.3

Source: *Central Cotton Research Institute, Multan*

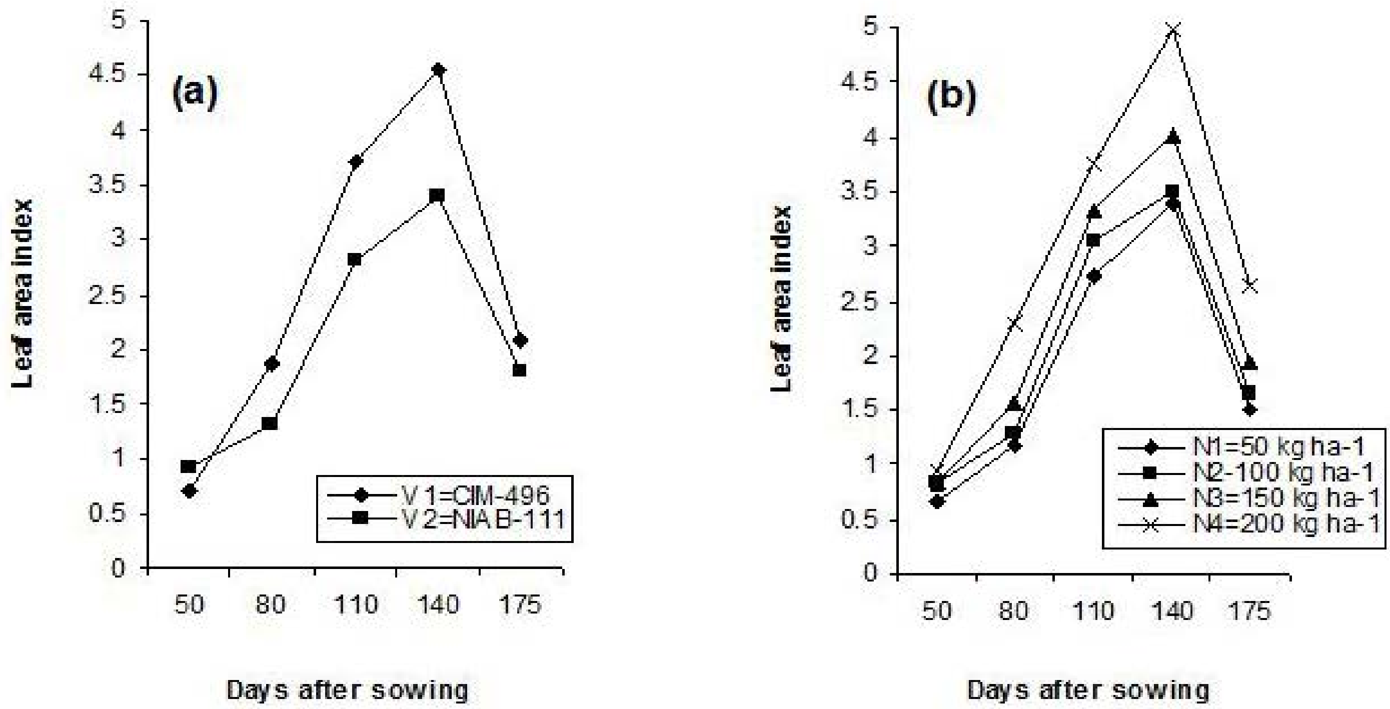

Figure 1: *Effect of vartiety (a) and nitrogen (b) raets pm LAI.*

Results and Discussion

Leaf area index

LAI has prime significance in increasing the crop yield (Awais et al., 2013). Development of canopy during the growing season in response to cultivars and nitrogen applications (Figure 1 a and b). LAI increased rapidly, in all the treatments, up to 140 days after sowing (DAS) and then decreased gradually with the passage of time due to leaf senescence. Cultivar CIM-496 developed its canopy at much faster rate as compared to the other cultivar (NIAB-111). At final harvest CIM-496 gained more LAI (2.08) than NIAB-111 (1.80). Wajid et al. (2010) reported that cultivar NIAB-111 produced more LAI (3.5) as compared to CIM-496 (3.2) which did not confirm the findings of our study. Among the nitrogen levels, 200 kg N ha^{-1} produced maximum LAI (4.98) at 140 DAS. Decline in LAI was more obvious at lower N rates than high N rates due to senescence of leaves during the early growth season. Higher nitrogen levels increased LAI due to increase in leaf expansion. Leaf greenness was increased; radiation absorption was improved while reflectance was decreased at higher use of nitrogen. Nitrogen application boosted the photosynthetic rate, leaf expansion and leaf persistency. As leaf area directly relates to the rate as well as duration of leaf expansion, so LAI finds to be sensitive to N availability to crop plants. Wajid et al. (2010) reported that less LAI (2.8) was observed at 80 kg N ha^{-1} and value of 3.9 was attained from the application of 185 kg N ha^{-1}.

Total dry matter

Nitrogen application improves crop development and growth (Kumbhar et al., 2008; Awais et al., 2015).

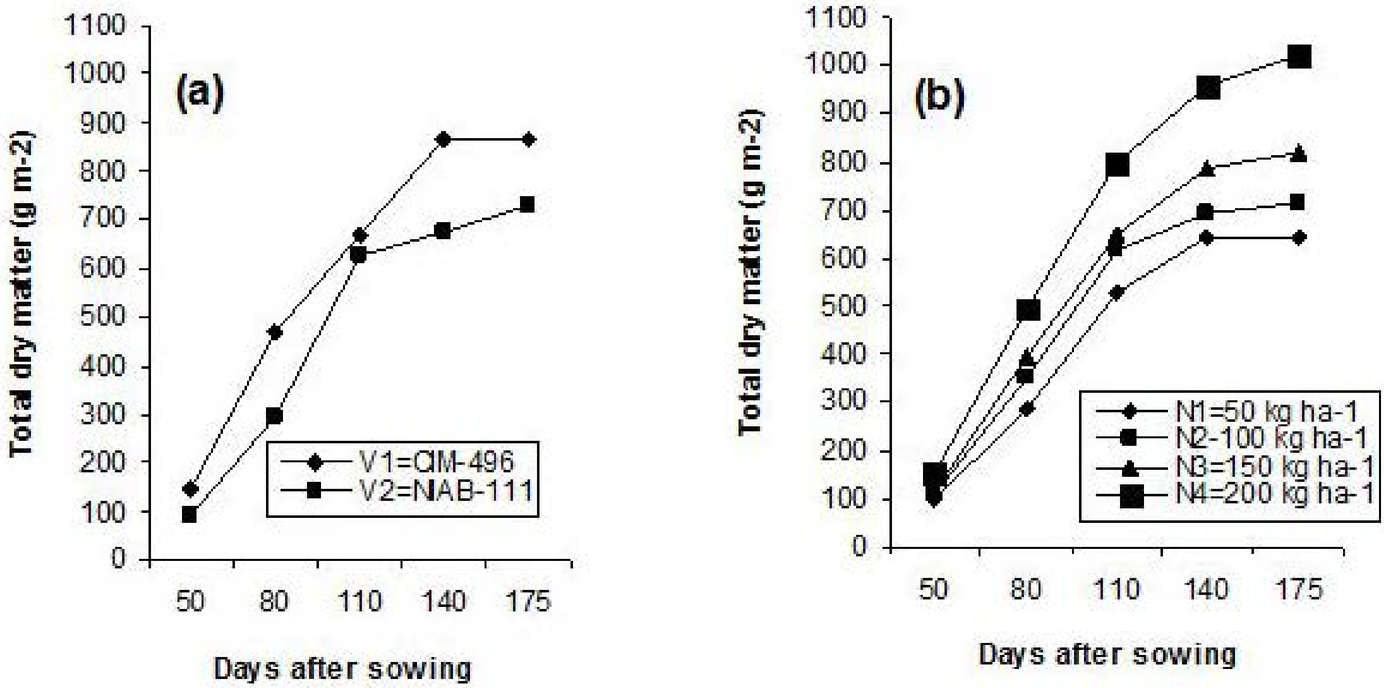

Figure 2: *Effect of variety (a) and nitrogen (b) rates on TDM assimilation.*

Table 2: *Performance of two cotton cultivars under different rates of nitrogen.*

Treatments	LAD (Days)	Plant height (cm)	Sympodia per plant	Bolls per plant	Weight per boll (g)	Seed cotton yield (t ha^{-1})
Cultivars						
CIM-496	223.37 a	134.61 a	22.00 a	30.42 a	3.49 a	2.17
NIAB-111	170.75 b	118.37 b	19.60 b	25.17 b	3.02 b	1.96
LSD	44.65	11.92	1.07	4.90	0.11	0.34
Significance	*	*	*	*	**	NS
N levels						
50 kg ha^{-1}	164.9 c	121.17 c	19.23 d	24.83 d	3.04 d	1.71 c
100 kg ha^{-1}	175.6 bc	125.80 b	20.31 c	26.50 c	3.17 c	1.96 b
150 kg ha^{-1}	199.4 b	127.22 b	21.33 b	28.83 b	3.34 b	2.15 b
200 kg ha^{-1}	248.4 a	131.78 a	22.34 a	31.00 a	3.48 a	2.42 a
LSD	26.13	2.86	0.54	1.17	0.12	0.23
Significance	**	**	**	**	**	**
Interaction	NS	NS	*	NS	NS	NS
Mean	197.06	126.49	20.80	27.79	3.26	2.06

Means sharing different letters in a column differ significantly from each other at $p \leq 0.05$; ***, **:** *significantly and highly significant respectively;* **NS:** *Non-Significant.*

The response of TDM to cultivars and nitrogen doses at different harvests during the growth season of the crop is indicated in Figure 2 a and b. TDM continued to increase linearly and gradually throughout the growth period of crop up to maturity. Five harvests for TDM were recorded with an interval of 30 days starting from 50 days after sowing (DAS) to maturity. Among varieties CIM-496 produced more TDM (868.49 g m^{-2}) than NIAB-111 (731.77 g m^{-2}). In case of nitrogen levels, 200 kg N ha^{-1} produced maximum TDM (1025.50 g m^{-2}) followed by 150 kg N ha^{-1} which produced TDM of 818.00 g m^{-2}. And lowest TDM (645.60 g m^{-2}) was produced by the 50 kg N ha^{-1} treatment. Nitrogen takes part in the production of energy rich compound, adenosine triphosphate, (ATP) that control photosynthesis and ultimately assimilate crop biomass (Sawan et al., 2009). Wajid et al. (2010) concluded that each increment of nitrogen application had a positive effect on TDM and it ranged between 874-1308 g m^{-2}.

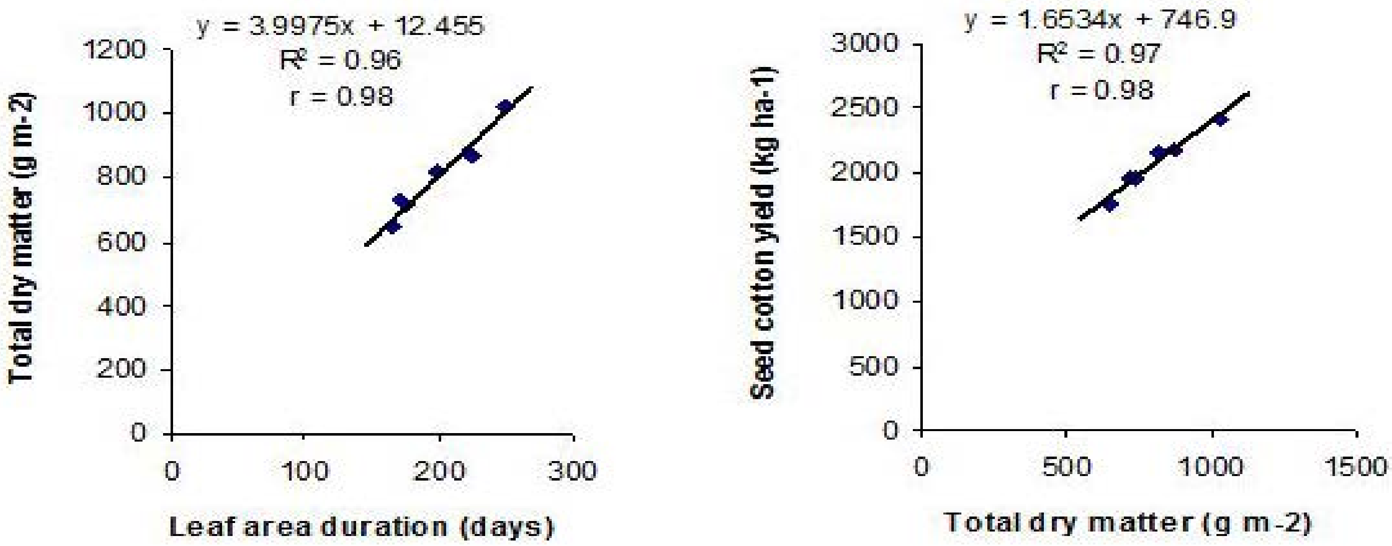

Figure 3: *Relationship between LAD and TDM and seed cotton yield.*

Leaf area duration

Data indicates that CIM-496 remains green for longer period (223 days) as compared to NIAB-111 (170 days). Data showed that each increment of nitrogen enhanced the capacity of leaves to remain photosynthetically active (Table 2). At higher rates of N (200 kg ha^{-1}) leaf tissues remained green for more days (248.40 days) as compared to lower rate of nitrogen. Leaf area duration has positive association with total dry matter (R2 = 0.96) while TDM has also positive relationship with seed cotton yield (Figure 3). An increase in leaf area duration of cotton cultivars in response to different rates of nitrogen was also reported by Wajid et al. (2010).

Plant height

Data reveal that two varieties responded differently in attaining plant height. It was noted that variety CIM-496 attained higher plant height (134.61 cm) as compared to NIAB-111 (118.37 cm). Taller plants in case of CIM-496 may be due to better genetic potential and efficiency for N uptake. Plant height depends on N application in cotton (Rochester et al., 2001). Copur (2006) also reported considerable differences in plant height of different cultivars. Each increment of nitrogen application had significant effect on plant height and it ranged from 121 to 132 cm. The tallest plants (131.78 cm) were observed with the 200 kg N ha^{-1} application. The increase in plant height due to increasing levels of nitrogen application could be due to increased cell division and cell elongation. Our results are supported by earlier findings that plant height was significantly affected by the genetic make up (Wankhade et al., 2002; Jatt et al., 2007), cultivars (Anwar et al., 2002) and nitrogen application rate (Rochester et al., 2001).

Sympodial branches

Higher amount of sympodial branches in a plant is an indication of higher potential of cotton crop for high production of seed cotton because these are considered the boll bearing branches (Hussain et al., 2007). Cotton variety CIM-496 produced more number of sympodial branches per plant (22.0) as compared to NIAB-111 (19.60). These significant differences may be due to high sink capacity and potency for withdrawing the food materials in case of variety CIM-496. Khan et al. (2007) also reported that sympodial branches per plant may vary among different cotton cultivars. Nitrogen levels significantly increased sympodial branches per plant. Maximum number of sympodial branches per plant (22.34) was observed with the application of 200 kg N ha^{-1}. The interaction between cultivars and nitrogen levels was also significant as indicated in Table 2. The cultivar CIM-496 at nitrogen level of 200 kg N ha^{-1} gave the largest number of sympodial branches per plant (23.97) and was statistically different from all other combinations, while the variety NIAB-111 at nitrogen level of 50 kg N ha^{-1} produced the least number of sympodial branches per plant. Nitrogen boosted vegetative growth of crop plants. The sympodial branches, being a component of vegetative growth, indicated a positive response to each N increment. A gradual increase in sympodial branches with the subsequent increases in the nitrogen application rates was also reported by Kumbhar et al. (2008).

Bolls per plant

More number of bolls per plant ultimately produced higher seed cotton yield. Variety CIM-496 produced more bolls (30.42) per plant than NIAB-111, which

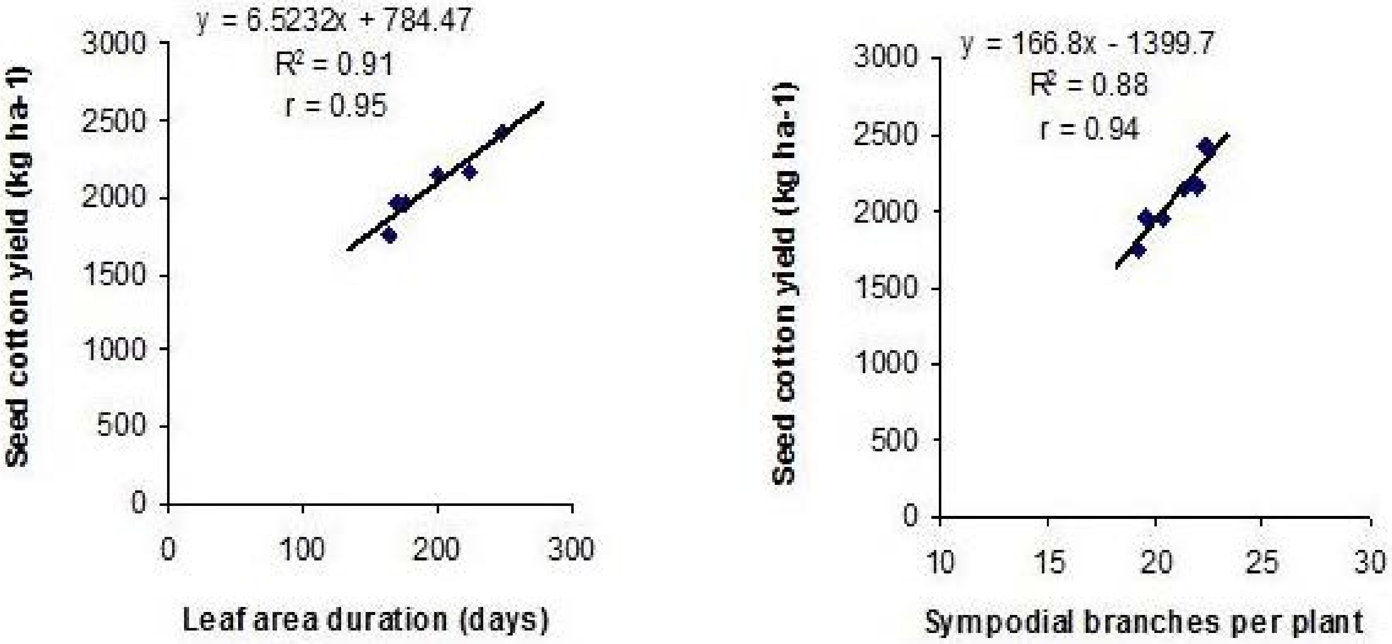

Figure 4: *Relationship of leaf area duration (LAD) and sympodial branches per plant with seed cotton yield (kg ha^{-1}).*

expressed 25.17 bolls per plant. The difference in number of bolls per plant among verities was due to difference in number of sympodial branches per plant and number of flowers formed. Similar results were revealed from the study of Rahman et al. (2016) for different cotton cultivars shows that genetic potential does matter and contribute differently to number of bolls and ultimately to cotton yield. Difference in number of bolls per plant among different cotton cultivars was also reported by Khan et al. (2007). Maximum number of bolls per plant was produced by higher nitrogen application (Seilsepour and Rashidi, 2011). The same was recorded in our study, however interaction between cultivar and nitrogen was found to have non significant effect on number of bolls per plant. The highest boll number (31.00) was recorded with 200 kg ha^{-1} N rate which was statistically different from all other nitrogen rates. The minimum boll number (24.83) was recorded with 50 kg N ha^{-1}. The similar results were also reported by several researchers (Ali and El-Sayed, 2001; Kumbhar et al., 2008; Rashidi and Gholami 2011).

Average weight per boll

Both size and weight of seed cotton per boll are directly related to the final yield. Cotton cultivars indicate diverse potential for producing light or heavy weight bolls (Hofs et al., 2006). In case of average boll weight cultivar CIM-496 gave heavy bolls (3.49 g) than the cultivar NIAB-111, which gained 3.02 g weight per boll. Hofs et al. (2006) also described the differences in boll weight among different varieties of cotton. Boll weight increased by increasing application of nitrogen to cotton crop (Rashidi and Gholami, 2011). As far as the results for the effect of nitrogen rates on bolls weight are concerned, more weight per boll (3.48 g) was recorded with the application of 200 kg N ha^{-1} followed by 150 kg N ha^{-1}. Nitrogen enhanced the photosynthetic rate, so more photosynthates were produced and stored in different plant parts (Evans, 1989). So, nitrogen positively contributed to growth of cotton plant that finally led to higher boll weight. Minimum boll weight (3.04 g) was produced by the 50 kg N ha^{-1} treatment. Numerous studies have shown the positive effect of nitrogen application on boll weight (Sawan et al., 2006; Saleem et al., 2010; Seilsepour and Rashidi, 2011).

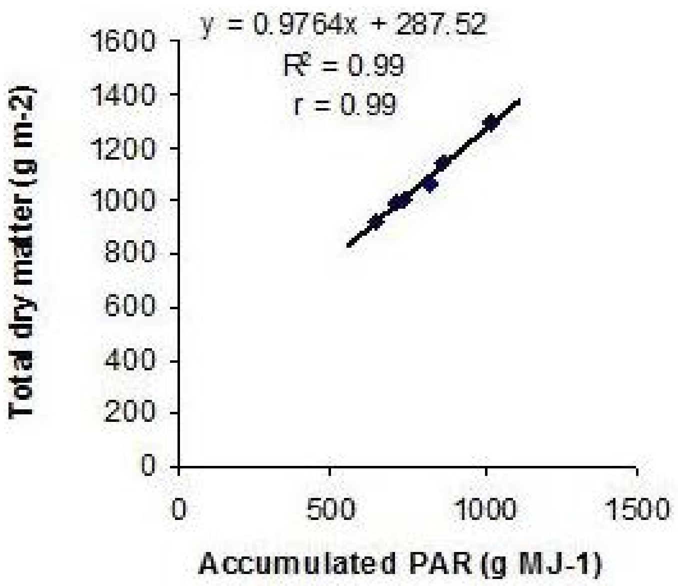

Figure 5: *Relationship between accumulated PAR and total dry matter (TDM).*

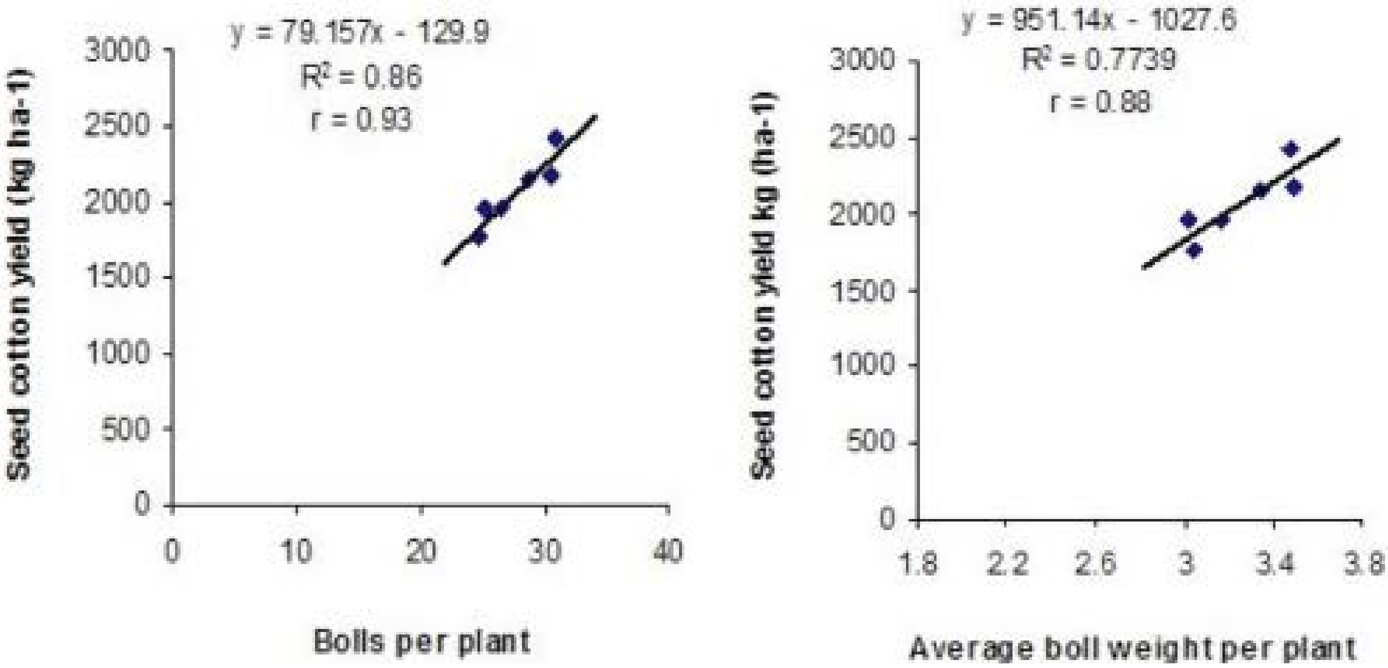

Figure 6: *Relationship of number of bolls per plant and average boll weight (g) with seed cotton yield (kg ha^{-1}).*

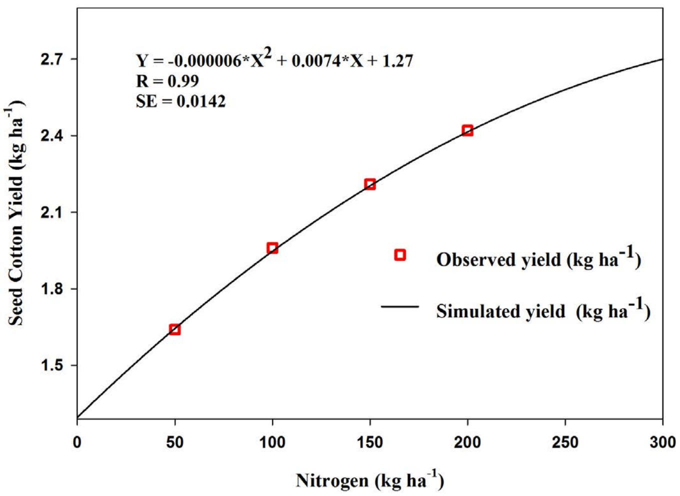

Figure 7: *Empirical model for seed cotton yield forecasting on the basis of nitrogen application in arid climatic conditions of Punjab.*

Seed cotton yield (t ha^{-1})

The cultivars showed significant differences for cotton productivity (Ehsan et al., 2008), which is the interaction of entire yield components (Khan et al., 2007). Seed cotton yield was found significantly different between cultivars (Table 2). Cultivar CIM-496 produced more seed cotton yield (2.17 t ha^{-1}) as compared to cultivar NIAB-111 (1.96 t ha^{-1}). Cultivars vary significantly in seed cotton yield (Copur, 2006; Hofs et al., 2006), this may be due to differences in fruiting branches, productive bolls and seed cotton weight per boll. Seed cotton yield boosted gradually with each N fertilizer increment. The considerable higher seed cotton yield (2.42 t ha^{-1}) was achieved from the treatment where 200 kg N ha^{-1} was applied. Application of 200 kg N ha^{-1} enhanced yield by 29% over low dose of N (50 kg ha^{-1}). Leaf area duration (days) and fruit bearing branches (sympodial) have direct and positive association with seed cotton yield with reasonably well high values of coefficient of regression 0.91 and 0.88, respectively (Figure 4). Nitrogen promoted biomass by accumulating more photosynthetically active radiation (PAR) on larger canopy promoted by higher nitrogen application compared with lower noes while positive and strong association was found between PAR and total dry mater with R^2 of 0.99 (Figure 5). Number of bolls and boll weight have also positive relationship with seed cotton yield as reasonable good association was found with reasonably good values of coefficient of regression, 0.86 and 0.77, respectively (Figure 6). Empirical model was developed on the basis of observed findings of seed cotton yield in relation with nitrogen application, higher coefficient of regression (0.99) and lower standard error (0.0142) was found for this model (Figure 7). This model was used for the prediction of seed cotton yield with the application of nitrogen beyond 200 kg N ha^{-1}, it is forecasted that seed cotton yield increased but with lower increase in yield for each unit addition in nitrogen beyond 200 kg N ha^{-1} (Figure 7). Nitrogen application promoted photosynthetic rate, assimilates production and accumulation that ultimately boosted final seed cotton yield (Kumbhar et al., 2008). Role of N fertilize in improving seed cotton yield was also reported by previous studies (Felix et al., 2003; Wajid et al., 2010; Rashidi and Gholami, 2011).

Conclusions

From the above discussion it was indicated that variety CIM-496 produced higher plant height, more number of sympodial branches per plant, higher boll weight, maximum number of bolls per plant and maximum seed cotton yield. Among nitrogen increments, nitrogen application of 200 kg ha^{-1} was best for attaining maximum seed cotton yield under Multan climatic conditions in Cotton-Wheat cropping system of Punjab.

Authors Contribution

Aftab Wajid and Ashfaq Ahmad designed the experiment and supervised all work. M. Awais, M. Habib ur Rahman, Muhammad Naveed Arshad, M. Irfan and Umair Gull collect the data and analyzed. Usman Bashir, M. Awais, M. Aown Sammar Raza write the article while it was improved by Muhammad Irfan and M. Habib ur Rahman. It was corresponded by Dr. M. Habib ur Rahman.

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