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GROWTH, YIELD AND EARLINESS RESPONSE OF COTTON TO ROW SPACING AND NITROGEN MANAGEMENT

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ABSTRACT

Agronomic practices may significantly influence earliness and yield in cotton (*Gossypium hirsutum* L.*)*. The present study was designed to evaluate the effect of row spacing and nitrogen on earliness and yield in cotton on a loam soil at Post Graduate Agricultural Research Station, University of Agriculture Faisalabad, during the year 2007 and 2008. Three row spacings of 60, 75 and 90 cm were established as the whole plots and four nitrogen fertilizer rates of 0, 60,120 and 180 kg N ha^{-1} were applied as the split plots. Both the factors significantly influenced plant height, main stem nodes, number of bolls per plant, boll weight and seed cotton yield per hectare. There were no significant differences between row spacings for earliness index but crop maturity hastened with lower N rates. The maximum seed cotton yield (2106 and 1936 kg ha^{-1} in 2007 and 2008, respectively) was recorded from 75 cm row spacing probably due to more number of bolls m^{-2}. Similarly, highest seed cotton yield (2197 and 2032 kg ha^{-1} in 2007 and 2008, respectively) was produced by applying 180 kg N ha^{-1} which was also statistically similar to 120 kg N ha^{-1} during both experimental years. For optimum seed cotton yield, cotton should be sown on 75 cm spaced rows with 120 kg ha^{-1} of nitrogen.

Key words: *Gossypium hirsutum*, nitrogen, row spacing, earliness and seed cotton yield.

INTRODUCTION

Cotton is a natural part of everyday life which serves the mankind from the cradle to the grave. Cotton plays a key role in socio-economic and political affairs of the world (Kairon *et al*., 2004). Its production, processing and trade generate revenue and sustain livelihoods in many countries. It is the world's leading source of natural textile fibre and fifth largest oilseeds crop which covers 40% of the global textile need (APTMA, 2012) and 3.3% of edible oil (FAS,2014), respectively. Pakistan is a fourth largest cotton producing country of the world while ranks third in consumption and is a leading yarn exporter (ICAC, 2012) with a production of 12.8 million bales from an area of 2.8 million hectares (Anonymous, 2014). However, Pakistan's seed cotton production per unit area owing to biological, physical, socio-economic, environmental and agronomic constraints is quite low. By adopting appropriate agronomic practices cotton yield per unit area can be improved. Management decisions like variety selection, planting date, plant density, and nitrogen management have a profound effect on the development and final outcome of the crop.

Cotton-wheat cropping system is being practiced on 2.8 million hectares which covers 33% wheat area of Pakistan (Anonymous, 2014). In cotton-wheat system the planting of wheat is delayed due to non-availability of land owing to delayed cotton maturity which in turn affects the wheat yield. Khan (2003) estimated that wheat sowing after 15th November may cause 42 kg ha^{-1} per day loss of wheat yield. Enhancing earliness without sacrificing yield has been the goal in most of the cotton breeding programmes, however early crop maturity can be manipulated by a range of management factors including, variety, nitrogen, plant density, sowing date, insect control, irrigation, and application of growth regulators (Shah *et al.*, 2005; Bang *et al.*, 2006). Early maturity helps to fit the crop in double cropping pattern as in cotton belt of Pakistan, enables cotton crop to develop during the periods of more favourable moisture conditions, escape losses from late season insect injuries, minimize use of chemical pesticides along with other inputs like irrigation water and fertilizer. However, the literature on response of local cotton cultivars to different management measures with objective to bring earliness is scarce.

A proper space between plants and row spacing is a key agronomic factor to optimize the crop profit (Zaxosa *et al*., 2012). The manipulation of plant density and crop geometry is a time tested agronomic technique to improve yield and profitability (Venugopalan *et al*., 2013). Establishing an appropriate plant stand is paramount to obtain high yields as lower plant density will be wastage of resources while high plant density limits individual plant growth (Brodrick *et al*., 2013). Plant density directly influences the radiation interception, moisture availability, wind movement and humidity (Heitholt *et al*., 1992) that in turn affects the canopy height, branching pattern, fruiting behavior, crop maturity and yield. Adequate plant density facilitates the efficient use of applied fertilizers and irrigation (Abbas, 2000). A decrease in row width resulted better light interception (Krieg, 1996) due to rapid canopy development and early canopy closure (Wright *et al.*, 2011) which helped in weed suppression (Marois *et al.*, 2004) and possible decrease in soil water evaporation (Snipes, 1996). The effect of plant density on earliness may be greater and of more economic importance than yield (Zaxosa *et al.*, 2012). Although previous studies have been conducted to investigate cotton growth and yield and earliness response to row spacing but results are often conflicting. Some researchers communicated that cotton seeded in 38 cm rows produced similar (Balkcom*et al.*, 2010) or higher yields than 97 to 102 cm wide rows (Wilson *et al.*, 2007; Reddy *et al.*, 2009). According to Boquet (2005) flat-planted narrow row cotton was lower yielding than wider rows planted on raised beds while Saleem *et al.* (2009) obtained highest yield with 75 cm row spacing compared to 60 and 90 cm row spacing. Rossi *et al.* (2004) reported that earliness has been attributed to narrow row spacing while Brodrick *et al.* (2010) found no differences in crop maturity between the row spacings. Clawson *et al.* (2006) suggested that yield potential of narrow row cotton may be influenced by environmental conditions and cultural practices.

The spirit of cotton crop management is to keep balance between vegetative and reproductive growth. The fertilizer use has played a crucial role in boosting the agricultural productivity. Nitrogen (N) is a key management component in cotton production which regulates photosynthesis and cotton development by stimulating the production of dry matter energy rich compounds but its management can reduce final yield and N use efficiency (Rutto *et al.*, 2013). Nitrogen influenced both vegetative and reproductive growth (Surya *et al.*, 2010) as its deficiency decreased yield by accelerating premature leaf senescence (Fageria and Baligar, 2005) and early cut-out (Read *et al.*, 2006), while, N in excess can delay crop maturity and promote boll shedding, diseases and insect damages **(**Howard *et al*., 2001; Oosterhuis, 2001). Diagnosing and correction of nitrogen deficiency is not difficult while excess of N is more difficult to detect and rectify, which necessitates applying N in appropriated doses to get maximum economical potential yield. Crop success depends on economically optimum levels of N fertilizers (Firbank, 2005). The cotton cultivars evolved in different agro climatic regions behave differentially to application of mineral fertilizers (Prasad, 2000). Hence there is a continuous need to find out the optimum nitrogen levels for local cotton cultivars in ever changing environment.

Thus the present study was designed to examine the effect of nitrogen and row spacing on cotton growth, yield and earliness.

MATERIALS AND METHODS

A field experiment was conducted at Post Graduate Agricultural Research Station, University of Agriculture Faisalabad, during the year 2007 and repeated in 2008 to investigate the effects of nitrogen and row spacing on yield and earliness in cotton. Each year before seed bed preparation, pre-soaking irrigation of 10 cm depth was applied. When the soil reached the proper moisture level, the fine seedbed was prepared by cultivating the land for 4 times with tractor mounted cultivator to a depth of 10-12 cm and three plankings. Land was leveled and laid out into ridges and furrows with tractor mounted ridger. The chemical analysis of the soil before implementation of the experiment was done during both the years. The soil of experimental site was loam having pH (8.0 and 7.9), electrical conductivity (0.78 and 0.87 dS m^{-1}**),** organic matter (0.79% and 0.72%), total N (0.040% and 0.036%), available phosphorus (6.2 and 5.9 ppm) and available potassium (127 and 122 ppm) during the years 2007and 2008, respectively. During 2007, the land was fallowed before sowing of crop while during 2008 previously grown crop was maize fodder.

The experimental design was a four replicated split-plot with whole plots being row spacings of 60, 75 and 90 cm. The split plots were nitrogen fertilizer rates of 0, 60, 120, and 180 kg ha^{-1}. Plots were four rows (60, 75 and 90 cm centers) wide and 9 m long. Plot size of four rows (centered on 60, 75 or 90 cm) by 6 m was maintained for final yield and the rest of the plot was used for random sampling regarding the crop growth with 30 days interval. The variety used was MNH-786. The experiments were sown on May 16, 2007 and May 14, 2008, respectively, via manual planting on ridges by maintaining 30 cm plant to plant distance and variable row spacing with a satisfactory stand resulting. The furrows were irrigated and two seeds per hill were dibbled manually on the same day in the moist soil to a depth of 3 to 4 cm. The furrows were re-irrigated 72 hours after dibbling to ensure successful seed emergence followed by subsequent irrigations with varied interval for 7 to 21 days up till crop maturity depending upon the plant requirement, temperature and rainfall. Thinning was done at the four leaf stage to maintain one plant per hill. A uniform dose of phosphorus (60 kg ha^{-1}) in the form of TSP (Triple Super Phosphate) was applied at the time of sowing while urea was applied as per treatment. One third of the nitrogen was applied at the time of sowing and remaining 2/3 was applied in two equal splits; at squaring (40 DAS) and at peak flowering (70 DAS) stage. Insect pests were kept under the threshold level through chemical control. Two cotton pickings were done each year. First picking was done after 120 DAS and second at 155 DAS. All other agronomic practices were kept normal and uniform for all the treatments.

Standard procedures were followed to collect data at various growth stages of the crop. Ten plants were selected at random from each plot to record the number of days taken from planting to squaring, appearance of first flower, node number for the first (lowest) fruiting branch on the main axis above cotyledonary nodes, total number of nodes on main axis above cotyledonary nodes and plant height in cm from the soil surface to the terminal bud. Yield variables include average number of bolls (opened) per plant, average boll weight. Average boll weight was calculated by dividing the total plant seed cotton yield with respected number of bolls of the plant. Seed cotton yield per hectare (kg ha^{-1}) was computed from cotton yield per plot. Earliness index was defined as the ratio of first pick weight to total weight of seed cotton and measured with the help of following formula. This index is referred as maturity coefficient.

$$\text{Earliness index (\%)} = \frac{\text{Weight of seed cotton from first pick}}{\text{Total seed cotton weight from all picks}}$$

Weather data were recorded during the experiments and presented in Table 1. Daily heat units were calculated according to Jones and Wells (1998) and monthly cumulative heat units were also presented in Table 1.

$$\text{Heat Units (HU)} = \frac{\text{Tmax.} + \text{Tmin.}}{2} - 15.5\ ^{\circ}\text{C}$$

Where 15.5 ºC (60 ºF) was taken as developmental threshold temperature and a heat unit is the number of degrees by which the daily mean temperature exceeds this temperature. Accumulated heat units can be used to estimate the duration of crop development stages.

Table. 1 Weather conditions during conduct of experiment.

Month	Mean Temperature (ºC)			Relative Humidity		Total Rainfall (mm)	Sunshine Hours		Heat Units
	Max.	Min.	Differ	8 a.m.	5 p.m.		Mean	Total	
				2007					
May	39.7	23.8	15.9	46.5	31.8	15.2	10-05	312-35	503.65
June	39.2	25.9	13.3	60.9	45.7	30.4	9-06	275-45	512.45
July	36.6	25.4	11.2	72.2	60.0	159.4	8-20	258-10	479.60
August	37.6	25.5	12.1	72.9	55.1	27.0	7-59	247-35	498.00
September	35.3	23.2	12.0	71.1	54.7	38.9	7.55	237-20	412.65
October	33.7	14.8	18.9	66.6	36.0	-	9-05	281-25	271.30
November	28.0	11.1	16.9	83.0	55.0	-	6-12	186-15	122.05
				2008					
May	38.4	23.4	15.0	50.6	34.2	53.9	8-40	268-45	477.95
June	37.8	26.9	10.9	67.5	51.0	118.2	7-37	228-45	505.85
July	37.7	27.7	10.0	71.6	57.4	63.4	7-38	236-30	532.50
August	35.0	26.0	9.0	79.3	66.8	273.0	7-31	233-15	466.15
September	35.3	23.2	12.1	75.0	51.9	37.0	8-49	264-30	412.20
October	33.7	19.9	13.8	71.8	46.9	-	8-20	258-20	350.80
November	28.3	10.8	17.4	80.7	47.7	-	7-34	227-15	121.95

Data collected on all parameters were analyzed statistically by using Fisher's analysis of variance technique with the help of MSTATC programme (Anonymous, 1986), years were analyzed separately and differences among treatments' means were compared by using Fisher's protected least significant difference (LSD) test at 5 % probability level (Steel *et al*., 1997).

RESULTS

Growth Parameters: Plant height and main stem nodes were significantly affected by year as 6% more plant height and 4 % less main stem nodes recorded during 2008 than those observed during 2007. Row spacing and nitrogen rates significantly influenced plant height and main stem nodes during both years. The main stem nodes increased by decreasing plant density or increasing row width but plant height significantly increased with each reduction in row spacing. During 2007, 114, 109 and 103 cm plant height and 22.6, 25.2 and 26.5 main stem nodes observed for 60, 75 and 90 cm row spacings, respectively (Table 2). Almost similar trend was observed during 2008. Plant height significantly increased by each additional increment of N fertilizer (Table 2). Main stem nodes significantly increased with higher N rates, with the mean of the 180 kg ha^{-1} rate significantly greater than the means of the 0 and 60 kg N ha^{-1} rates in both years (Table 2). The row spacing by nitrogen interaction was not significant for any variable in either year (Table 2).

Earliness parameters: The appearance of first floral bud (square initiation) was significantly affected by row spacing and nitrogen levels in both years (Table 3). The year effect was significant as squaring starts with least days (29.3) during 2007 than 2008 where 31.1 days were recorded to initiate squaring. Square initiation started earlier by decreasing row width. During 2007, narrow rows (60 cm) took 29.0 days for square initiation as against maximum of 29.6 days with wider rows (90 cm). Both 60 & 90 cm row spacing were at par with medium row spacing (75 cm) during first year while 60 cm row spacing started square initiation significantly earlier than 75 and 90 cm row spacing during 2008. On contrary increase in nitrogen delayed squaring of the crop in both years, although during 2007 nitrogen did not influence significantly square initiation.

Number of days from planting to first flower appearance differed with different row spacings and nitrogen rates during both years. Though, row spacing differences were not significant in 2007, but flower initiation starts earlier by increasing plant density with narrow rows (Table 3). On contrary each increment of nitrogen delayed flowering of the crop in both years but results were non-significant in 2008. In 2007, nitrogen levels had significant effect on the appearance of first flower, 180 kg ha^{-1} and 120 kg ha^{-1} had statistically more number of days (49.7 and 49.5) from planting to appearance of first flower than 60 kg ha $^{-1}$ and 0 kg ha $^{-1}$ (49.2 and 48.9. The year effect was also significant as less mean days (49.3) were observed in 2007 for flower initiation than 2008 when flower appeared on 51.0 days. Row spacing by nitrogen interaction was not seen for days taken to appearance of first flower.

Node number for first fruiting branch and earliness index did not differ significantly among row spacing in both the years. Numerically, wider row spacing showed highest value of node number for first fruiting branch (7.8 in 2007 and 8.2 in 2008) and lowest value of earliness index (55.3 in 2007 and 54.1 in 2008) compared to 75 and 60 cm row spacing. However, N rates significantly influenced crop maturity as node number for first fruiting branch increased and earliness index decreased with each increase in nitrogen. The highest value for node number of first fruiting branch was recorded at 180 kg N ha^{-1} which was statistically at par with 120 kg N ha^{-1} while the lowest value recorded at 0 kg N ha^{-1} which was statistically at par with 60 kg N ha^{-1}. The differences between 120 kg N ha^{-1} and 60 kg N ha^{-1} were also non significant for this character. Statistically highest earliness index (58.39% in 2007 and 56.61% in 2008) was recorded where no nitrogen was applied whereas minimum earliness index (54.64% in 2007 and 53.65% in 2008) was recorded at 180 kg N ha^{-1}. The year effect was significant as mean value of node number for first fruiting branch was lower in 2007 (7.67) as compared to 2008 (7.92) while earliness index was more in 2007 (56.44) as compared to 2008 (55.10). The interaction between row spacing and nitrogen for earliness parameters was absent in either year (Table 3).

Table-2. Effect of row spacing and nitrogen rates on growth parameters in cotton.

		Plant height (cm)		Main stem nodes per plant	
Treatments		**2007**	**2008**	**2007**	**2008**
Row Spacing (cm)					
S_1=60		114 a	121 a	22.6 b	22.1 b
S_2=75		109 b	117 a	25.2 a	24.1 a
S_3=90		103 c	111 b	26.5 a	24.7 a
	LSD (0.05)	4.09	4.49	1.50	1.35
Nitrogen (kg ha^{-1})					
N_1=0		94 d	99 d	22.1 c	20.7 c
N_2=60		105 c	112 c	24.3 b	22.9 b
N_3=120		116 b	124 b	26.2 a	25.1 a
N_4=180		120 a	131 a	26.5 a	25.8 a
	LSD (0.05)	3.49	4.29	0.96	1.17
Year Means		109 b	116 a	24.8 a	23.7 b
	LSD (0.05)	0.66		0.51	
Interactions					
S x N		**NS**	**NS**	**NS**	**NS**

Means sharing different letters differ significantly at p≤0.05
NS: Non significant

Yield Parameters: Number of opened bolls per plant, average boll weight and seed cotton yield per hectare were significantly influenced by row spacing or plant density and nitrogen rates. Cotton planted in 90 cm wide rows produced more bolls per plant in both years (Table 4). As plant density increased by decreasing row spacing, number of opened bolls per plant decreased with 25.6, 22.5 and 16.4 bolls per plant in 2007 and 23.6, 21.0 and

14.7 bolls per plant in 2008 for 90, 75 and 60 cm row spacings, respectively. However, cotton planted in 75 cm row spacing produced more bolls m^{-2} in both years, though row spacing differences in bolls m^{-2} were not significant in 2007. Average boll weight was decreased by reduction in row spacing. During both years differences between row spacing means for boll weight were significant except 75 and 90 cm row spacing. Cotton grown in 75 cm row spacing produced highest seed cotton yield (2106 kg ha^{-1} in 2007 and 1936 kg ha^{-1} in 2008) and lowest seed cotton yield (1773 kg ha^{-1} in 2007 and 1701 kg ha^{-1} in 2008) was obtained from 60 cm narrow row spacing. Seed cotton yields, bolls per plant, average boll weight, and bolls m^{-2} increased significantly from 0 to 120 kg N ha^{-1}, afterward no significant increase realized. In both years, the row spacing by nitrogen interaction was not significant for yield parameters.

Table-3. Effect of row spacing and nitrogen rates on earliness parameters in cotton

	Days to square initiation		**Days to flower initiation**		**First fruiting branch node number**		**Earliness index**	
Treatments	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
Row Spacing (cm)								
S_1=60	29.0 b	30.5 b	49.1	50.1 b	**7.5**	**7.7**	**57.5**	**56.1**
S_2=75	29.3 ab	31.2 a	49.3	51.1 ab	**7.7**	**7.9**	**56.5**	**55.1**
S_3=90	29.6 a	31.6 a	49.5	51.7 a	**7.8**	**8.2**	**55.3**	**54.1**
LSD (0.05)	0.37	0.45	NS	1.62	**NS**	**NS**	**NS**	**NS**
Nitrogen (kg ha^{-1})								
N_1=0	28.9	30.6 c	48.9 b	50.4	**7.4 c**	**7.5 c**	**58.39 a**	**56.61 a**
N_2=60	29.1	30.9 bc	49.2 bc	50.8	**7.6 bc**	**7.8 bc**	**56.98 ab**	**55.48 ab**
N_3=120	29.4	31.2 ab	49.5 ab	51.2	**7.8 ab**	**8.1 ab**	**55.75 bc**	**54.67 ab**
N_4=180	29.7	31.6 a	49.7 a	51.5	**7.9 a**	**8.3 a**	**54.64 c**	**53.65 b**
LSD (0.05)	Ns	0.63	0.50	NS	**0.29**	**0.29**	**2.0**	**2.1**
Year Means	29.3	31.1	49.3 b	51.0 a	**7.67 b**	**7.92 a**	**56.44 a**	**55.10 b**
LSD (0.05)	**0.29**		**0.29**		**0.23**		**0.9**	
Interactions								
S x N	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Means sharing different letters differ significantly at $p \leq 0.05$
NS: Non significant

Table-4. Effect of row spacing and nitrogen rates on yield variables in cotton.

	Bolls per plant		**Bolls per m^{-2}**		**Boll weight (g)**		**Seed cotton yield (kg ha^{-1})**	
Treatments	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
Row Spacing (cm)								
S_1=60	16.4 c	14.7 c	91.0	81.5 c	2.92 b	2.82 b	1773 c	1701 b
S_2=75	22.5 b	21.0 b	100.1	93.4 a	3.09 a	2.95 a	2106 a	1936 a
S_3=90	25.6 a	23.6 a	94.6	87.3 b	3.04 a	2.97 a	1965 b	1827 a
LSD (0.05)	2.11	1.35	NS	5.7	0.09	0.05	110.4	119.8
Nitrogen (kg ha^{-1})								
N_1=0	18.2 c	17.0 c	81 c	75 c	2.85 c	2.80 c	1551 c	1496 c
N_2=60	20.8 b	19.1 b	92 b	85 b	3.00 b	2.88 b	1867 b	1751 b
N_3=120	23.2 a	21.1 a	103 a	94 a	3.13 a	2.97 a	2179 a	2006 a
N_4=180	23.8 a	21.9 a	105 a	96 a	3.09 a	3.01 a	2194 a	2032 a
LSD (0.05)	1.66	1.16	7.19	4.84	0.06	0.05	136.7	147.8
Year Means	21.5 a	19.8 b	95.2 a	87.4 b	3.0 a	2.9 b	1948 a	1822 b
LSD (0.05)	**1.01**		**3.72**		**0.05**		**95.29**	
Interactions								
S x N	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Means sharing different letters differ significantly at $p \leq 0.05$
NS: Non significant

DISCUSSION

The main stem nodes and their appearance rate as well as plant height are simple indicators to assess cotton development for management purposes (Kerby and Hake, 1996). The availability of horizontal space for individual plant in narrow rows reduced due to which intense inter plant competition for nutrient and light suppressed node appearance and plants grew taller in respect of vertical space. Wang *et al*. (2011) also endorsed that inter-plant competition for nutrients and light produced taller plants at higher plant density. Shorter plants are preferred in narrow row cotton to avoid late maturity (Clawson *et al*., 2006). In agreement with other studies (Nichols *et al*., 2004; Clawson *et al*., 2006; Siebert *et al*., 2006), reduction of main stem nodes was observed with narrow rows high plant density production system. Similar to Fritschi *et al*. (2003) and Clawson *et al*. (2006), our results indicated final plant height and main stem nodes increased with each additional increment of fertilizer N because nitrogen stimulates growth. Marois *et al*. (2004) opined that plant height had more influence on canopy microclimate than did plant density or fertilizer N application. Moreover, the negative impacts on plant health from narrow rows or high N cotton may be minimized through careful management of plant height, especially by keeping plants lower than 1 meter. An increase in plant height may also be associated with more square and boll abscission due to insect damage and over shading of lower leaves. More plant height during 2008 than 2007 might be due to low May June temperatures and more rains and more humidity.

The appearance of first floral bud (square) is considered as an important trait to assess earliness in cotton (Poehlman, 1987); however, early recognition of first square is difficult. Number of days from planting to first floral bud initiation (squaring) were significantly decreased by narrow row spacing in either year (Table 4) might be due to increased inter-plant competition. These results substantiated the findings of Bednarz *et al*. (2000) and Mygdakos *et al*. (2004), who reported that the earliness (early squaring or flowering) increased when row spacing decreased. Squaring was delayed by increasing N rates. Our results are similar with the previous findings, that increased nitrogen level promoted vegetative growth and delayed maturity (Brown, 2002). Appearance of first flower is easily recognizable and more reliable to assess earliness in cotton compared to square initiation (Saleem *et al*., 2009). Number of days from planting to appearance of first flower was decreased by decreasing row spacing. This might be due to increased inter-plant competition for nutrients and light etc. These results are in line with Jost and Cothren (2001), who reported that cotton grown on narrow rows matured earlier than on conventional (wider) rows. Like wise squaring, flower initiation also delayed with each increase of nitrogen. Cotton growth and development relates with the amount of heat to which the plant is exposed (Clay *et al*., 2006). During 2007 square and flower initiation started earlier than 2008; this might be due to high temperature and more accumulation of heat units in the months of May and June. Node number for the first fruiting branch (sympodia) is considered as most reliable and practical morphological trait to measure earliness in cotton (Iqbal *et al*., 2003). In our study first fruiting branch node number was not affected by row spacing (Table 4) because this parameter mainly depends on genotype and night temperatures (Ali *et al.,* 2003). Nichols *et al*., (2004) also found no impact of row spacing on lowest fruiting branch node number. However, numerically lower node number for first fruiting branch was noted in 60 cm narrow rows which were quite in line with the findings of Saleem *et al*. (2009) who also recorded lowest fruiting branch on the main axis with 60 cm narrow rows compared to 75 and 90 cm rows. First fruiting branch node number increased with each addition of nitrogen, nitrogen favored vegetative growth. During 2008 higher first fruiting branch node number than 2007 might be due to more rains and low temperatures in the months of May and June.

Earliness index (percent first-pick) is most frequently used to estimate earliness in cotton (Bourland *et al*., 2001). In the present study, earliness index (EI) was not significantly affected by row spacing in either year. Although lower boll retention was measured in narrow rows but these bolls did not mature earlier than wider rows (Brodrick *et al.*, 2010). However, EI decreased by increasing row spacing though the magnitude of the difference was very minute. This may be due to intense competition between plants for soil and water resources which led to earlier flowering and boll formation and ultimately ratio of harvestable bolls in first picking increased that contributed to improve earliness index. Similar reports have also been communicated by Oad *et al*. (2002) and Saleem *et al*. (2009) who narrated that the use of narrow-rows or high plant-density is conducive for earliness in cotton mainly because of shortening of the growing season. Earliness index decreased as fertilizer N increased because nitrogen delayed maturity. Similar to our results, Tang *et al*. (2003) and Reddy *et al*. (2004) also found higher percentage of opened bolls for cotton receiving no nitrogen compared to which nitrogen was applied.

Cotton plant produced more bolls per plant in wider rows because of substantial space available for growth, more photosynthetic efficiency, frequent availability of water and nutrients, less humidity for efficient control of insect pest attack and boll saving from rottening, which resulted in increase in fruiting points, fruiting period, fruit retention and ultimately greater bolls per plant and seed cotton yield per plant. Similar responses of cotton to plant density or row spacing have also been found by other researchers (Clawson *et al*., 2006; Sawan *et al*., 2008; Rajakumar and Gurumurthy, 2008). The number of bolls per plant is a function of boll production and retention which mainly depends on leaf area development and its photosynthetic efficiency. Nitrogen is a key factor in leaf area development and assimilates production (Ayissaa and Kebedeb, 2011) and also stimulates the mobilization and accumulation of metabolites (assimilates) in newly developed bolls (Sawan *et al*., 2006). Hence, it fulfilled the assimilate demand of fruiting organs which in turn increased number of bolls per plant. Many researchers observed increase in bolls per plant by increasing N level (Kumbhar *et al*., 2008; Ayissaa and Kebedeb, 2011).

Reductions in row spacing decreased boll weight due to intense competition for nutrients, water and light at higher plant density (Ogola *et al*., 2006). However, Bednarz *et al*. (2000) accredited decreased boll set and weight due to combined effect of excessive LAI, reduced PPFD (photosynthetic photon flux density) efficiency, and reduced mean NAR at higher plant population. Moreover, plant density can alter fruit location which impacts boll size (Clawson, 2003). Boll weight increased significantly by increasing N probably due to enhanced photosynthetic activity, as N is an essential component of chlorophyll (Oosterhuis and Bondada, 2001), stimulates mineral uptake (Ciampitti *et al*., 2013) photosynthate assimilation and accumulation in developing bolls (Sawan *et al*., 2006).

The crop canopy influenced production efficiencies and profitable yields, which can be manipulated by row spacing and population adjustment (Silvertooth, 1999). An appropriate plant stand may help in harnessing all the renewable and non renewable resources in a more and efficient manner towards higher crop yields (Sparlangue *et al.,* 2007). In present study, the highest seed cotton yield per hectare was produced by 75 cm row spacing regardless of fertilizer N because of more number of bolls m^{-2}. Moreover, row spacing was primarily dictated by equipment for cultivation (Wilson, Jr., 2006) and ridges are difficult to build and maintain in row widths of less than 75 cm. Ozpinar and Isik, (2004) also established that the highest yields associated with 76 cm row spacing in a semiarid Mediterranean environment in Turkey. Increase in seed cotton yield may be attributed to the fact that nitrogen controlled new growth (Borowski, 2001), stimulated nutrient uptake (Ciampitti and Vyn, 2013), and prevented abscission of squares and bolls (Sawan *et al*., 2006). Our results are in line to those of the Saleem *et al*. (2010) who obtained optimum seed cotton yield at 120 kg N ha^{-1}. Clawson *et al*. (2006, 2008) found that each incremental increase in N rate (0,50,101,151 kg ha^{-1}) resulted in a significant increase in lint yield, suggesting that no rate of N was excessive, while Prasad and Siddique (2004) observed decrease in yield above an optimum level. The optimal rate of nitrogen for cotton depends on various factors including soil type, environment (rain, sunlight, and season length), and management techniques.

The significant difference in both years regarding seed cotton yield and yield parameters was related to environmental conditions as lower May June temperatures and more rains were observed in 2008 than in 2007 (Table 1).

Conclusion: It may be concluded from this study that early plant competition in narrow row high plant density systems limited yield potential and negated early maturity benefits because of increased plant height. The retention of early fruiting structures is also important to manage early crop maturity. Moreover, increasing early inputs did not alleviate the competition stress between plants which is most likely a result of more complex physiological processes (e.g. competition for space and light). Optimum application of fertilizer N also contributes towards more managed maturity with good crop harvest.

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