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Plant spacing and nitrogen affects growth and yield of cotton

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Abstract
Selection of suitable agronomic practices like plant density and nitrogen management have a significant effect on overall crop growth and final output in terms of yield. An experiment with three plant spacing (21 cm, 27 cm, and 33 cm) and four nitrogen levels (0(control), 55, 110, and 165 kg ha^{-1}) were conducted in a randomized complete block design with split plot arrangement at Agronomy Research Farm of the University of Agriculture Peshawar during summer 2015. Results showed a significant effect ($P \leq 0.05$) of both plant spacing and nitrogen rates on number of monopodial and sympodial branches per plant, plant height, number of opened bolls per plant, main stem nodes per plant, and seed cotton yield per hectare. Taller plants were recorded with 21 cm plant spacing. Higher values for the rest of the studied traits were recorded with 33 cm plant spacing and in case of nitrogen maximum values were recorded with nitrogen applied at the rate of 165 kg ha^{-1}. For achieving higher cotton it is recommended to sow cotton crop with plant to plant distance of 33 cm along with application of N at the rate of 165 kg ha^{-1}.

Keywords: growth, yield, nitrogen, plant spacing and cotton

Introduction
Cotton has a significant role in the socioeconomic and political activities of the world (Kairon *et al*., 2004) [19]. Among oilseed crops it ranks 5th and covers 40% of the textile need globally (APTMA, 2012a) and 3.4% of the edible oil (FAS, 2014) [12]. Almost 36 million hectare land is under cotton cultivation globally which produce 25 million tones fiber annually (FAO, 2011) [11]. Pakistan ranks fourth regarding cotton production in the world and holds third position in its consumption (ICAC, 2012) [17]. The share of cotton in GDP is 1.5% and contributes 60% in the domestic edible oil consumption (Govt. of Pakistan, 2013) [14]. Cotton consumption of Pakistan rose to 14 million bales and the country has to import 2 million bales of cotton to meet the demand of textile industry (Anonymous, 2012) [2]. The country has to increase its cotton production to cope with the shortage of cotton to textile industries in the coming years. Appropriate agronomic practices like sowing dates, cultivar selection, plant density, fertilizer management, and timely irrigation has a significant effect on the overall performance and final output of the cotton. Although most of the environmental factors are uncontrollable but proper managemental decisions play a key role in maintaining fiber quality of the cotton (Zhao *et al*., 2012) [33].

Higher plant density limits individual plant growth while lower plant density is the wastage of resources therefore, optimum plant density is utmost important for achieving higher yield per unit area (Brodrick *et al*., 2013) [8]. Plant density affects light interception, moisture availability, nutrients uptake, humidity, weeds infestation (Heitholt *et al*., 1992) [15] and thus influence plant height, fruiting behavior, maturity and final yield. Location and number of fruiting structures (squares, blooms, and bolls) can be changed with plant density (Kerby *et al*., 1990) [21]. N doses at various stages significantly affect seed cotton weight per boll and seed cotton yield ha^{-1} (Saleem *et al*., 2010) [27]. More or less nitrogen (N) than the required amount reduces the final yield per unit area. Both vegetative and reproductive growth decreases with N deficiency (Gerik *et al*., 1994) [13] and when in excess endorses boll shedding, insect damages and diseases (Howard *et al*., 2001; Oosterhuis, 2001) [16, 24]. With optimum N the deleterious effect of future CO_2 on fiber quality can be corrected (Reddy *et al*., 2004) [26]. The present study aims to find the effect of N doses and plant density and their interactive effect on cotton growth and yield.

Materials and Methods
An experiment was conducted at Agronomy Research Farm of the University of Agriculture Peshawar during summer 2015. The experiment comprised of two factors i.e. factor I. included plant spacing and factor II. Included nitrogen.

The experiment was laid out in split plot arrangement of treatments in a randomized complete block design with four replicates. Plant spacing (21, 27, and 33 cm) were allotted to main plots while Nitrogen levels (0, 55, 110 and 165 kg ha^{-1}) to subplots. The subplot size was 4 m x 3.75 m having 5 rows equally spaced at 0.75 m from each other. The land was prepared by cultivator followed by a rotavator. Cotton cultivar CIM-496 was sown manually on ridges 75 cm apart from each other. Phosphorous in the form of triple super phosphate (TSP) was applied at the rate of 70 kg ha^{-1} during seedbed preparation. Nitrogen as a urea was applied in three equal splits i.e. at sowing, at 40 and 70 days after sowing. Other agronomic practices (thinning, insecticides, etc) were kept uniform for all treatments.

Procedure for recording data

Data regarding number of monopodial (vegetative) and sympodial (fruiting) branches per plant was recorded by selecting 8 plants randomly in each subplot. The monopodial and sympodial branches in these plants were counted and were averaged for a single plant data. Main stem of eight randomly selected plants were measured from base to the tip at the time of last picking and were averaged for recording plant height data. Eight plants were randomly selected and total number of nodes in their main stem was counted and was averaged for determining main stem nodes per plant. Total number of opened bolls of eight randomly selected tagged plants at first and second picking was counted and was averaged for calculating number of opened bolls per plant. Cotton obtained from all pickings in a plot were weighed and then converted into kg ha^{-1} for determining seed cotton yield per hectare.

Statistical Analysis

The recorded data were statistically analyzed according to analysis of variance techniques recommended for randomized complete block design with split plot arrangement. Least significant difference (LSD) was used at 5% level of significance ($P \leq 0.05$) upon significant F-test through the procedure described by Jan *et al*. (2009) [18].

Results and Discussion

Number of monopodial branches

Plant spacing (PS) and nitrogen (N) significantly ($P \leq 0.05$) affected monopodial branches per plant (Table 1). However, PS x N interaction was non-significant. Mean values indicated that more number (2) of monopodial branches were recorded with 33 cm plant spacing which was statistically not different with 27 cm plant spacing while less number (1.2) of monopodial branches were counted with 21 cm plant spacing. Increasing plant spacing resulted in more number of monopodial branches per plant. Less number of monopodial branches per plant for less plant spacing might be due to the more competition among plants for soil and environmental resources like nutrients, water, and light. Our findings are in line with Alfaqeih (2002) [1] who also reported an increasing trend in monopodial branches per plant with increasing plant spacing.

More number (2.1) of monopodial branches were recorded at higher level of N i.e. 165 kg ha^{-1} followed by 110 kg ha^{-1} N while less number (1.1) of monopodial branches were recorded in control i.e. 0 kg ha^{-1}. Nitrogen plays an accelerating role in the vegetative growth of the plant and monopodial branches showed a better response to higher nitrogen dose (Kumbhar *et al*., 2008) [22]. Karthikeyan and Jayakumar (2002) [20] reported higher number of monopodias at higher level of N.

Number of sympodial branches

Table 1. shows a significant ($P \leq 0.05$) variation in number of sympodial branches per plant for plant spacing and nitrogen. Highest sympodias (16.8) were recorded with 33 cm plant spacing followed by 27 cm plant spacing while lowest sympodias (16.1) were recorded with 21 cm plant spacing. With increasing plant spacing competition among plants for resources decreases and also space availability increases which resulted in more sympodias per plant. Alfaqeih (2002) [1] also reported the same results. Sympodias increased linearly with increasing N levels. Highest sympodias (17.9) were recorded at highest level of N i.e. 165 kg N ha^{-1} and then decreased with decreasing N with lowest sympodias (14.1) recorded in control. N enhances vegetative growth of the plant and hence when its rate increases vegetative growth also increases. More sypmodias produced with higher N application as reported by Mukand *et al*., (1989) [23]; Karthikeyan and Jayakumar (2002) [20]. The interaction of treatments i.e. plant spacing and nitrogen was found non significant.

Plant height

Means of the plant height was significantly ($P \leq 0.05$) affected by plant spacing and nitrogen (Table 1). Interaction of plant spacing and nitrogen remained non significant. Maximum plant height (118.3 cm) was recorded with 21 cm plant spacing followed by 27 cm plant spacing with minimum plant height (114.6 cm) recorded with 33 cm plant spacing. Higher plant density in case of less plant spacing enhances inter plant competition for nutrients and light which resulted in taller plants. Wang *et al*. (2011) [32] also reported taller plants at higher plant density i.e. less plant spacing. Plant height increased with increasing level of nitrogen and attained maximum height (121.3 cm) at highest level i.e. 165 kg N ha^{-1} and then height decreased accordingly with decreasing N levels with minimum height (111.4 cm) in control. Nitrogen stimulates plant growth and plays a key role in enhancing vegetative growth of a plant including its height. Plant height of cotton increased with increasing level of nitrogen (Kumbhar *et al*., 2008) [22].

Main stem nodes per plant

Plant spacing and nitrogen had a significant ($P \leq 0.05$) while their interaction had a non significant effect on stem nodes per plant (Table 1). With increase in plant spacing from 21cm to 33 cm nodes per plant also increased with maximum value (24.9) for 33 cm plant spacing against minimum (21.5) with 21 cm plant spacing. More competition among crop plants for light, water and nutrients under higher plant density suppressed node appearance. Higher plant density or low plant spacing results in less number of nodes per plant (Siebert *et al*. 2006) [30]. Maximum nodes (25.3) per plant were recorded for N applied at the rate of 165 kg ha^{-1} followed by N applied at the rate of 110 kg ha^{-1} which was statistically not different with N applied at the rate of 55 kg ha^{-1} with minimum value (20.4) in control. Nitrogen induces vegetative growth and thus results in more nodes per plant. Clawson *et al*. (2006) [9] also observed the same results of more main stem nodes per plant at higher level of N.

Number of opened bolls per plant

With increase in plant spacing number of bolls per plant also increased (Table 1.). More number (22.5) of bolls per plant were recorded with 33 cm plant spacing followed by 27 cm plant spacing with minimum bolls (14.7) per plant recorded for 21 cm plant spacing. As plant spacing increased inter plant competition reduces, availability of space and nutrients increases, sympodial branches also increases which led to more bolls per plant. Siddiqui *et al*. (2007) [29] showed that number of bolls per plant decreases with increase in plant density i.e. less plant spacing. With each increment in N number of bolls per plant increased and more bolls (22.2) per plant were recorded for N applied at the rate of 165 kg ha^{-1} followed by 110 kg ha^{-1} with the minimum bolls (15) per plant recorded in control i.e. 0 kg N ha^{-1}. N has a key role in leaf area production and assimilates synthesis (Ayissaa and Kebedeb, 2011) [3] and also contributes in mobilization and accumulation of photosynthates to newly develop bolls (Sawan *et al*., 2006) [28]. Thus, it fulfilled the photosynthates demand of fruiting organs which resulted in more number of bolls per plant. Ayissaa and Kebedeb, (2011) [3] also reported more bolls per plant with increasing level of nitrogen.

Seed cotton yield per hectare

Different plant spacing and nitrogen showed a significant ($P \leq 0.05$) variation in seed cotton yield per hectare. Maximum cotton yield (1891.7 kg) per hectare were recorded with 33 cm plant spacing followed by 27 cm plant to plant spacing with minimum yield (1650 kg) per hectare for 21 cm plant spacing. An optimum plant stand is utmost important for harvesting soil and environmental resources in an efficient way towards higher crop yield (Sparlangue *et al*., 2007) [31]. Under more plant density i.e. less plant spacing over population and more competition among crop plants for light, nutrients, and water decreases the yield. Boquet (2005) [5] also observed less bolls per plant and boll weight under higher plant density which finally result in lower crop yield. Nitrogen applied at highest level i.e. 165 kg ha^{-1} produced maximum cotton yield (1977.8 kg) per hectare and then yield decreased with decrease in nitrogen and minimum yield (1533.3 kg) per hectare was recorded in control plots. N stimulates new growth (Borowski, 2001) [6] improves nutrient uptake (Breitenbeck and Boquet, 1993) [7], avoid abscission of bolls and squares (Sawan *et al*., 2006) [28]. Our findings are in parallel with those of Saleem *et al*. (2010) [27] who also recorded higher cotton yield at higher level of N. Clawson *et al*. (2008) [10] found an increasing trend with increasing nitrogen rates, suggesting that as N increases yield increases with no level of N was extreme while (Prasad and Siddique, 2004; Bell *et al*., 2003) [25, 4] reported a decline in yield above an optimum N level. Soil type, environmental factors (rain, solar radiation, crop duration) and managemental techniques determine optimum level of nitrogen.

Conclusion

From the experimental results it can be concluded that sowing cotton having plant to plant distance of 33 cm along with the application of N at the rate of 165 kg ha-1 resulted in higher seed cotton yield.

Table 1: Number of monopodial and sympodial branches plant^{-1}, plant height (cm), main stem nodes plant^{-1}, bolls plant^{-1} and seed cotton yield (kg ha^{-1}) of cotton as affected by plant spacing (cm) and nitrogen levels (kg ha^{-1}).

	No. of Monopodial branches plant^{-1}	No. of sympodial branches plant^{-1}	Plant height (cm)	Main stem nodes plant^{-1}	No. of bolls plant^{-1}	Seed cotton yield (kg ha^{-1})
Plant spacing(PS)						
PS 1= 21 cm	1.2b	16.1b	118.3a	21.5c	15c	1650c
PS 2= 27 cm	1.7a	16.3ab	116.8b	22.9b	19b	1792b
PS 3= 33 cm	2a	16.8a	114.6c	24.9a	23a	1892a
LSD	0.44	0.5	1.5	1.0	0.6	82.35
Nitrogen (N)						
N1= 0 kg ha^{-1}	1.1c	14.1d	111.4d	20.4d	15d	1533d
N2= 55 kg ha^{-1}	1.4bc	16.2c	115.0c	22.8c	18c	1733c
N3= 110 kg ha^{-1}	1.8ab	17.4b	118.3b	23.9b	19b	1867b
N4= 165 kg ha^{-1}	2.1a	17.9a	121.3a	25.3a	22a	1978a
LSD	0.40	0.37	1.81	1.2	0.65	103.08
Interaction (PS x N)						
PS1N1	1.0	14.0	114.0	19.3	11	1400
PS1N2	1.0	16.0	117.0	21.7	14	1567
PS1N3	1.3	16.7	120.0	22.7	16	1800
PS1N4	1.3	17.7	122.0	22.3	18	1833
PS2N1	1.0	14.0	112.0	20.0	15	1500
PS2N2	1.7	16.0	115.0	22.3	18	1733
PS2N3	2.0	17.3	118.0	24.0	19	1933
PS2N4	2.0	18.0	122.0	25.3	22	2000
PS3N1	1.3	14.3	108.3	22.0	18	1700
PS3N2	1.7	16.7	113.0	24.3	22	1900
PS3N3	2.0	18.3	117.0	25.0	23	1867
PS3N4	3.0	18.0	120.0	28.3	27	2100
LSD	NS	NS	NS	NS	NS	NS

Means sharing same letter(s) for a parameter in a column are statistically similar at 5% level of significance. ns= non-significant

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