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EFFECT OF PLANT GEOMETRY UNDER HDPS ON CROP PHENOLOGY AND YIELD CONTRIBUTING CHARACTERS IN COTTON

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ABSTRACT

A field experiment entitled "Effect of plant geometry under high density planting system (HDPS) on crop phenology and yield contributing characters in cotton" was carried out in field of Cotton Research Unit, Dr. PDKV, Akola, during *kharif* season of 2016 on clayey soil. The cotton crop was sown 26 June 2015. The experiment was laid out in split plot design with three replications. There were twelve treatment combinations comprising of four different varieties viz., AKH-1301, AKH-1302, AKH-081and SURAJ with three plant spacings viz., 45 x 10 cm^2, 60 x10 cm^2 and 60 x 15 cm^2, the different varieties were allotted to main plot and plant spacings were accommodated in sub plots. Significant variation for varieties and spacing was observed for all the traits studied. Interaction effects were significant for few traits only. All the crop phonological characters like days to emergence, days to first square appearance, days to first flower appearance, days to first boll bursting, days to 50% boll bursting and yield and yield related characters like number of bolls harvested plant^{-1}, boll wt.(g), seed cotton weight plant^{-1} (g), cotton stalk yield (kg plot^{-1}), cotton stalk yield (kg plot^{-1}), biological yield (kg plot^{-1}) and biological yield (kg ha^{-1}) and B : C ratio were significantly enhanced by variety AKH-1301. The number of harvested bolls plant^{-1} and seed cotton weight plant^{-1} was significantly higher in spacing of 60 x 15 cm^2 over spacings of 45 x 10 cm^2 and 60 x 10 cm^2. The seed cotton yield ha^{-1} was higher in plant spacing of 60 x 10 cm^2 due to more plant population unit^{-1} area than spacing of 60 x 15 cm^2. It is summarized from this study that variety AKH-081 responded well to higher plant spacing of 45 x 10 cm^2 and spacing of 60 x 10 cm^2 recorded maximum seed cotton yield of 2356 kg ha^{-1} and 2210 kg ha^{-1} respectively.

(Key word: Plant geometry, HDPS, phenology, yield)

INTRODUCTION

Cotton is the most important fiber crop of Indian farming community and plays an important role in agrarian and rural economy of India. Due to fact that cotton is the backbone of textile industry, the stiff global competition in the production and consumption of cotton. Cotton fiber combined with the technological revolution in the spinning and yarn manufacturing sectors has reprioritized the importance of fiber quality parameters (Venugopal *et al*., 2001).

World cotton production is estimated at 100.22 million bales of 480 lb in 2015-16 (USDA, March, 2016) which is 16 % lesser than the previous year 2014-15 and cotton area decreased to the tune of 3.22 million ha compared to 2014-15. India continued to maintain the largest area under cotton followed by China with 35.29% and 24% of world cotton area and production, respectively. India also sustained the position of being the second largest consumer and exporter of cotton and is expected to export 5.5 million bales and expected to consume 23 million bales in 2015-16.

The difference in cotton production between China and India is changed down this year. Significant drop in the cotton production in China amounts to 8.57% from 35 million bales last year to 32 million bales this year due to decrease in slight area and productivity. The same scenario is observed in the United States this year with drop in production to 23.84% compared to previous year due to significant decrease in cotton area and productivity. China is expected to hold around 57 million bales as reserve this year which is 50% of expected world cotton production in 2015-16. India is the largest cotton growing country in the world with area under cotton around 34% followed by China. China and India are the major cotton consuming country in the world (around 46% of world cotton production). As regards export, USA and India exports 28% and 20% of the world cotton export.

In Vidarbha, cotton is grown as a rainfed crop. As such about 89.1% cultivable land is under rainfed farming and rainfed cotton production has direct bearing on the agrarian economy of the region. Therefore, it is necessary to develope the number of straight varieties suitable for

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rainfed condition on farmers field. The low productivity is mainly due to maximum area under rainfed condition and erratic distribution of rainfall and also pest and disease problems.

There is need to increase the production of cotton for improving financial status of farmer's and to increase national economy by increasing productivity of cotton by increasing the area under production and plant population ha^{-1} also. Hence, study of genotypes under high density planting is important for new cotton genotypes. Such studies has not been done on plant geometry. Now a days plant geometry plays an important role in HDPS to increase yield level of cotton.

In Vidarbha, cotton is grown predominantly as a rainfed crop. Major causes of low productivity in Vidarbha are erratic rainfall, soil moisture stress, delayed sowing, drought condition during flowering and boll development stages. (critical stages) Among the various agronomic manipulation practices to increase the cotton yield sowing time, ideal plant density, optimum dose of fertilizer, moisture conservation etc. play a key role in enhancing the productivity of cotton. Optimum spacing is an important factor for increasing the plant stand $hectare^{-1}$ as well as yield $unit^{-1}$ area. There is a positive relationship between plant population and seed cotton yield. The most appropriate spacing enable plant to take best advantage of growth condition as it is ultimately connected with root development as well as shoots growth. Optimum plant stand play very crucial role in improving the production potential of cotton and to help to overcome the low production of cotton under rainfed condition of Vidarbha. To enhance the productivity under high density planting in rainfed agriculture, adoption of soil moisture conservation practices are very essential for adequate supply of moisture at critical stages.

Keeping in mind the struggle between plants for getting more plant nutrients and moisture, it is essential to find out the appropriate combination between variety and spacing to achieve the maximum yield under rainfed condition. Hence, this study on "Effect of plant geometry under HDPS on crop phenology and yield contributing characters in cotton" was conducted.

MATERIALS AND METHODS

The field experiment was conducted on field of cotton research unit Dr. PDKV Akola during 2015-16 in *kharif* season. The topography of the field was fairly uniform and leveled. The soil was medium black cotton belongs to *Vertisols.* The experiment was laid out in split plot design with three replications. The experiment consisted of twelve treatment combinations comprising of four varieties (AKH-1301, AKH-1302, AKH-081 and Suraj) as main plot and three spacing (45 X10 cm^2 - 2,22,222 plants ha^{-1}, 60 X 10 cm^2 - 1,66,666 plants ha^{-1}, 60 X 15 cm^2 -1,11,111 plants ha^{-1}). The gross and net plot sizes were 3.6 m x 3 m and 2.4 m x 2.4 m respectively. The quantity of fertilizers to be applied was calculated on gross plot basis. The fertilizers were given as per the recommendation i.e. 100% (60 : 30 :30 NPK kg ha^{-1}). The crop was fertilized with nitrogen, phosphorus and potassium. Full dose of nitrogen (N), phosphorus (P_2O_5) and potash (K_2O) was given to all the plots after one month of sowing. Appropriate and timely plant protection measures and interculture operations were undertaken as per need to protect the crop from sucking and other pests and control of bacterial blight disease throughout the growth period of cotton. Biometric observations on crop phenology and yield contributing characters like days to emergence, days to first square appearance, days to first flower appearance, days to first boll bursting, days to 50% boll bursting, number of bolls harvested $plant^{-1}$, boll wt.(g), seed cotton weight $plant^{-1}$ (g), cotton stalk yield (kg $plot^{-1}$), cotton stalk yield (kg $plot^{-1}$), biological yield (kg $plot^{-1}$) and biological yield (kg ha^{-1}) were recorded.

The experimental data collected during the course of investigation were statistically analyzed with split plot design programme on computer by adopting standard statistical techniques of analysis of variance (Gomez and Gomez, 1984). Wherever, the results were significant, critical differences at $P = 0.05$ levels were calculated for comparison of treatment means. Data on interaction effects are presented wherever found significant.

RESULTS AND DISCUSSION

Data regarding characters related to crop phenology and yield contributing characters are given in table 1.

1) Crop phenology characters

Days required to emergence : On average days to emergence was noticed after 5.50 days. The effect of different varieties, plant geometry and their interactions were not found significant in respect to days to emergence.

Days to first square appear : In general days to first square appear were attended 47 days after emergence. It was observed that the variety AKH-1301 (V_1) significantly required more days to first square appear than AKH-081 (V_3) and SURAJ (V_4) but at par with AKH-1302 (V_2). Similarly variety AKH-1302 (V_2) significantly required higher days to first square appear than AKH-081 (V_3) and SURAJ (V_4) but variety SURAJ (V_4) was found at par with AKH-081 (V_3) in respect of days required to first square appear. The effect plant geometry was found to be not significant in respect of days to first square appear.Interaction effect among different varieties and plant geometries (V x S) was not significant in respect to days to first square appear.

Days to first flower appear : On an average days to first flower appear was noticed after 53.50 days. It was observed that the variety AKH-1302(V_2) significantly required more days to first flower appear than varieties AKH-081(V_3) and SURAJ (V_4) but at par with varieties AKH-1301(V_1). Similarly variety AKH-1301(V_1) significantly required higher days to first flower appear than AKH-081

(V_3) but at par with variety SURAJ (V_4) but variety SURAJ (V_4) was found at par with variety AKH-081 (V_3) in respect of days required to first flower appear. Days to first flower appear was significantly influenced by different treatments of plant geometry. It was recorded that first flower appear was delayed significantly under wider plant population of (1,11,111 plants ha^{-1}) (60 x15 cm^2-). Closer plant population of 2,22,222 plant ha^{-1} (45 x10cm^2) required significantly less days to first flower appear followed by 1,66,666 plant ha^{-1} (60 x10 cm^2). Days to first flower appear was significantly delayed under wider plant population, due to lower plant population unit^{-1} area. Interaction effect among different varieties and plant geometries (V x S) was not found significant in respect to days to first flower appear.

Days to first boll bursting : On an average days to first boll bursting was noticed after 89.50 days. It was observed that the variety SURAJ (V_4) significantly required more days to first boll bursting than AKH-081(V_3) but remained at par with varieties AKH-1301(V_1) and AKH-1302 (V_2). Similarly variety AKH-1302(V_2) significantly required higher days to first boll bursting than variety AKH-081 (V_3) but found at par with variety AKH-1301(V_1). Days to first boll bursting was significantly influenced by different treatments of plant geometry. It was recorded that first boll bursting was delayed significantly under wider plant population of 1,11,111 plant ha^{-1} (60 x15 cm^2-). Closer plant population of 2,22,222 plant ha^{-1} (45 x 10 cm^2) required significantly less days to first boll bursting followed by plant population of 1,66,666 plant ha^{-1} (60 x10 cm^2). Days to first boll bursting was significantly delayed under wider plant population It might be due to no competition for light, space, nutrients and moisture. None of the interaction was found to be significant.

Days to 50% boll bursting : In general days to 50% boll bursting was attended 112 days after emergence. It was observed that the variety SURAJ (V_4) significantly required more days to first boll bursting than variety AKH-081(V_3) but remained at par with variety AKH-1301(V_1) and AKH-1302 (V_2). Similarly variety AKH-1302 (V_2) significantly required higher days to first boll bursting than variety AKH-081 (V_3) but was found at par with variety AKH-1301(V_1). Days to 50% boll bursting was significantly influenced by different treatments of plant geometry. It was recorded that 50% boll bursting was delayed significantly under wider plant population of 1,11,111 plant ha^{-1} (60 x15 cm^2-). Closer plant population of 2,22,222 plant ha^{-1} (45 x10cm^2) required significantly less days to 50% boll bursting followed by 1,66,666 plant ha^{-1} (60 x10 cm^2). Days to 50% boll bursting was significantly delayed under wider plant population, might be due to lower competition for nutrients, light, space etc. Interaction effect among different varieties and plant geometry (V x S) was not significant in respect to days to 50% boll bursting.

2) Yield contributing characters

Number of bolls harvested plant^{-1} : The effect of different varieties were found to be not significant in respect of number of picked bolls plant^{-1}. Plant density significantly influenced the number of bolls picked plant^{-1}. Plant spacing of 60 x 15 cm^2 recorded significantly more number of harvested bolls plant^{-1} than spacings of 45 x 10 cm^2 and 60 x 10 cm^2. Similarly plant spacing of 60 x 10 cm^2 recorded significantly more number of harvested bolls plant^{-1} than spacing of 45 x 10 cm^2. The boll number plant^{-1} decreased in closer spacing due to greater plant competition. However, the increase in number of plants unit^{-1} area at closer spacing compensate for this decline. Similar to this findings Manjappa *et al.* (1996) and Nehra *et al*. (2004) also observed significant influence of plant density on the number of bolls picked plant^{-1} in cotton. Paslawar *et al.* (2015) also reported that number of bolls were increased with decreased plant densities in cotton. The treatment combination (V_4S_3) of variety SURAJ with spacing of 60 x15 cm^2 produced significantly higher number of picked bolls plant^{-1} but found at par with treatment combinations V_1S_3 (Variety AKH-1301 with spacing of 60 x 15 cm^2), V_2S_3 (Variety AKH-1302 with spacing of 60 x 15 cm^2) and V_3S_2 (Variety AKH-081 with spacing of 60 x 10 cm^2).

Boll weight : It was observed from the data that the variety AKH-1301(V_1) significantly gave more boll weight than variety AKH-081(V_3)) but remained at par with varieties AKH-1302 (V_2) and SURAJ (V_4). Similarly variety SURAJ (V_4) recorded significantly more boll weight than variety AKH-081(V_3) but found at par with variety AKH-1301(V_1). Significant influence of varietal difference on boll weight in cotton was also reported by Pothiraj *et al*. (1994). The data reported in table indicate that the difference due to various plant spacing in respect of boll weight was significantly influenced. A wider plant spacing of 60 x 15 cm^2 produced more boll weight (2.98g) over the closer plant spacing of 45 x 10 cm^2 and 60 x 10 cm^2. The variation in boll weight in plant spacing was due to fact that the better aeration and adequate interaction of light and lesser competition of nutrients at wider spacing, which resulted in synthesis of higher photosynthates and thereby helped to produced higher boll weight. The significant variability of boll weight due to spacing has been established by Nehra *et al*. (2004) in cotton. Paslawar *et al.* (2015) also reported that boll weight were increased with decreased plant densities in cotton. Interaction effect among different varieties and plant geometry (V x S) was not found significant in respect to boll weight.

Seed cotton weight plant^{-1} (g) : On an average seed cotton weight plant^{-1} (g) was obtained in two pickings. Different plant varieties significantly influenced the seed cotton weight plant^{-1}. It was observed that the variety AKH-081(V_3) gave significantly more seed cotton weight plant^{-1} than varieties AKH-1301(V_1), AKH-1302(V_2) and SURAJ (V_4). Similarly variety SURAJ (V_2) significantly recorded more seed cotton weight plant^{-1} than variety AKH-1301 (V_1) but remained at par with variety AKH-1302(V_2). The significant variability of seed cotton weight plant^{-1} has been established by Narkhede *et al*. (2000). Treatment differences due to plant spacing were observed to be significant. Wider plant spacing of 60 x15 cm^2 recorded significantly higher seed cotton weight plant^{-1} as compared to plant spacing of 45 x10 cm^2 and 60 x10 cm^2. Wider plant spacing of 60 x15 cm^2 produced 17.23 g of seed cotton weight plant^{-1}.This might be due to more availability of photosynthates under wider spacing to individual plant, which led to overall improvement in growth attributes and its positive effect on number of bolls plant^{-1} and it produced maximum seed cotton weight plant^{-1} as compared to closer planting geometry. The above results are in conformity with the findings of Chavan *et al.* (2011). They also observed significant reduction in yield plant^{-1} with increase in plant density. Interaction effect was significantly influenced for seed cotton weight plant^{-1}. The treatment combination V_4S_3 of variety SURAJ with spacing of 60 x15 cm^2 produced significantly higher seed cotton weight plant^{-1} but remained at par with treatment combinations V_2S_3 (varietyAKH-1302 with spacing 60 x 15 cm^2) and V_3S_3 (varietyAKH-081 with spacing 60 x15 cm^2).

3) Yield studies

Seed cotton yield plot $^{-1}$ (kg) : Seed cotton yield plot^{-1} was 1.18 kg. It was observed that the variety AKH-081(V_3) recorded significantly more seed cotton yield plot^{-1} (1.24 kg) than variety AKH-1301(V_1), AKH-1302(V_2) and SURAJ (V_4). Similarly variety SURAJ (V_4) was found at par with varieties AKH-1301(V_1) and AKH-1302(V_2) in respect of seed cotton yield plot^{-1}. Differences due to various plant spacing on the seed cotton yield plot^{-1} were significant. A plant spacing of 45 x 10 cm^2 and 60 x 10 cm^2 recorded significantly higher seed cotton yield plot^{-1} (1.19 kg) and (1.26 kg) respectively than spacing of 60 x 15 cm^2 (1.08 kg). The increase in seed cotton yield plot^{-1} in closer spacing might be due to higher plant population. Such beneficial results were also observed by Narayana *et al.* (2008), Reddy *et al.*(2008) Mohapatra and Nanda (2011) and Paslawar *et al,*(2015), who also reported increased seed cotton yield plot^{-1} in closer spacing . Interaction was found significantly influenced seed cotton yield plot^{-1}. The treatment combination of V_3S_1 ie., variety AKH-081 with spacing 45 x 10 cm^2 produced significantly higher seed cotton yield (1.36 kg) plot^{-1} than all other treatment combinations. The lowest yield was recorded in treatment combination V_1S_3 (variety AKH-1301 with spacing 60 x 15 cm^2).

Seed cotton yield ha^{-1} (kg) : On an average seed cotton yield plot^{-1} was 2040 kg. It was observed that the variety AKH-081(V_3) recorded significantly more seed cotton yield ha^{-1} (2155 kg) than all other varieties. Similarly variety AKH-1302 (V_2) remained at par with varieties AKH-1301(V_1) and SURAJ (V_4) in respect of seed cotton yield ha^{-1}. Significant influence of varieties on seed cotton yield ha^{-1} was reported by Venugopalan *et al.* (2011). Differences due to various plant spacing on the final yield performance in terms of seed cotton yield ha^{-1} were significant. A closer spacing of 45 x 10 cm^2 and 60 x10 cm^2 recorded significantly higher seed cotton yield of 2058 kg ha^{-1} and 2190 kg ha^{-1} respectively than wider plant spacing of 60 x 15 cm^2 (1871 kg ha^{-1}). The closer density of 2,22,222 plant ha^{-1} and 1,66,666 plant ha^{-1} recorded more seed cotton yield kg ha^{-1} ie. 10% and 17% respectively over control plant density (1,11,111 plant ha^{-1}). The increase in seed cotton yield in closer spacing was due to significantly higher plant population unit^{-1} area. But here plant population of 1,66,666 plant ha^{-1} recorded more yield than 2,22,222 plant ha^{-1}, because number of picked bolls plant^{-1} (3.20 plant^{-1}) was lower than plant population of 1,66,666 plant ha^{-1} (4.97 plant^{-1}). It is also due to difference in boll weight i.e. 2.66 g boll^{-1} in 45 x10 cm^2 spacing and 2.82 g boll^{-1} in 61 x10 cm^2 spacing. The increase in seed cotton yield in closer spacing was due to significantly higher plant population unit^{-1} area. In comparison to closer spacing wider spacing recorded more number of picked bolls and yield plant^{-1} but higher plant population, which compensated the yield plant^{-1} even though there were lesser number of picked bolls and yield plant^{-1}. Lower plant population is the major cause for its lower seed cotton yield. Similar to this finding Sharma (2004), Raut *et al.* (2005), Reddy *et al.*(2008) and Mohapatra and Nanda (2011) also reported increased yield in closer spacing in cotton. Paslawar *et al.* (2015) also reported highest seed cotton yield (3108 kg ha^{-1}) with high density (2.22 lakh ha^{-1}) in cotton. Interaction effect (V x S) was found statistically and significantly influenced seed cotton yield ha^{-1}. The treatment combination of (V_3S_1) variety AKH-081 with spacing 45 x10 cm^2 produced significantly higher seed cotton yield (2356 kg ha^{-1}) than all other treatment combinations. The lowest yield of 1791 kg ha^{-1} was recorded in treatment combination V_1S_3 (AKH-1301 with spacing 60 x 15 cm^2).

Cotton stalk yield plot^{-1} (kg) : The average cotton stalk yield plot^{-1} was 3.05 kg. Cotton stalk yield plot^{-1} found to be significant with different varieties. It was observed that the variety AKH-1301(V_1) gave significantly more cotton stalk yield plot^{-1} (3.09kg) than variety AKH-081 (V_3) but at par with varieties AKH-1302(V_2) and SURAJ (V_4). Similarly variety SURAJ (V_4) recorded significantly more cotton stalk yield as compared to variety AKH-081(V_3) but at par with variety AKH-1302(V_2) in respect of seed cotton yield plot^{-1}. Differences due to various plant spacing on the cotton stalk yield plot^{-1} were significant. A plant spacing of 45 x 10 cm^2 recorded significantly higher cotton stalk yield plot^{-1} (3.95 kg) over spacing of 60 x10 cm^2 (2.96 kg) and 60 x15 cm^2 (2.23 kg). The increase in cotton stalk yield plot^{-1} in closer spacing might be due to significantly higher plant population. Interaction effect (V x S) was statistically and significantly influenced cotton stalk yield plot^{-1}. The treatment combination (V_1S_1) of variety AKH-1301 with spacing of 45x10 cm^2 produced significantly higher cotton stalk yield plot^{-1} (4.04 kg) than all other treatment combinations except V_4S_1 (Variety SURAJ with spacing 45 x 10 cm^2. The lowest stalk yield of 2.21 kg plot^{-1} was recorded in treatment combination of V_2S_3 (AKH-1302 with spacing 60 x 15 cm^2).

Cotton stalk yield ha^{-1} (kg) : On an average cotton stalk yield plot^{-1} was 5290 kg. It was observed that the variety AKH-1301 noted significantly more cotton stalk yield ha^{-1} (5367kg) than variety AKH-081 but found at par with other varieties. Significant differences in cotton stalk yield were observed among various plant geometry of 45 x10 cm^2 and showed significantly superior to spacing of 60 x10 cm^2

followed by wider plant spacing of 60 x15 cm^2. Higher cotton stalk yield (6860 kg ha^{-1}) was produced under closer plant spacing of 45 x 10 cm^2 which was significantly increased near by 21.50% and 77% over plant spacing of 60 x 10 cm^2 and 60 x 15 cm^2 respectively. It was mainly due to higher plant spacing of 45 x 10 cm^2 than other plant spacings. In accordance to this result, Chavan *et al*. (2011), Reddy *et al.*(2008) and Mohapatra and Nanda (2011) also reported higher cotton stalk yield under closer plant spacing. Interaction effect (V x S) was significantly influenced cotton stalk yield ha^{-1}. The treatment combination (V_1S_1) of variety AKH-1301 with spacing of 45x10 cm^2 produced significantly higher cotton stalk yield (7011 kg ha^{-1}) than all other treatment combinations. The lowest yield of 3826 kg ha^{-1} was recorded in treatment combination of V_2S_3 (AKH-1302 with spacing 60 x 15 cm^2).

Biological yield $plot^{-1}$ (kg) : On an average biological yield $plot^{-1}$ was 4.22 kg. Biological yield $plot^{-1}$ was found to be non significant with different varieties. Plant geometry of 45 x 10 cm^2 recorded significantly higher biological yield (5.14 kg $plot^{-1}$) as compared to plant geometry of 60 x 10 cm^2 and 60 x 15 cm^2 which recorded biological yield of 4.23 kg $plot^{-1}$ and 3.60 kg $plot^{-1}$ respectively. Planting geometry of 60 x 10 cm^2 also showed significantly higher biological yield over spacing 60 x 15 cm^2. The treatment combination (V_3S_1) of variety AKH-081 with spacing of 45 x 10 cm^2 produced significantly higher biological yield $plot^{-1}$ (5.23 kg ha^{-1}) than all other treatment combinations except V_1S_1 (AKH-1301 with spacing of 45 x 10 cm^2). The lowest biological yield of 3.26 kg ha^{-1} was recorded in treatment combination V_1S_3 (AKH-1301with spacing of 60 x 15 cm^2).

Biological yield ha^{-1} (kg) : On an average biological yield plot 3.26 kg ha^{-1} was 7730 kg. Biological yield ha^{-1} found to be non significant with different varieties. Plant geometry of 45 x 10 cm^2 recorded significantly higher biological yield (8919kg ha^{-1}) as compared to plant geometry of 60 x 10 cm^2 and 60 x 30 cm^2 which recorded biological yield of 7336 kg ha^{-1} and 5737 kg ha^{-1} respectively. Planting geometry of 60 x 10 cm^2 also showed significantly higher biological yield over spacing 60 x 15cm^2. Closer plant geometry of 45 x 10 cm^2 produced nearly 21.50% and 55% more biological yield over the remaining of plant geometry respectively. Significant improvement in biological yield under closer plant geometry of 45 x 10 cm^2 was due to higher seed cotton yield and stalk yield by accommodating more plant population than that of 60 x 10 cm^2 and 60 x 15 cm^2 which recorded less seed cotton yield and stalk yield due to less number of plant population. Similar to this result Chavan *et al.* (2011), Reddy *et al.*(2008) Mohapatra and Nanda (2011) and Paslawar *et al.* (2015) also reported that closer spacing resulted in increased yield in cotton. Interaction effect (V x S) was found statistically significant. The treatment combination (V_3S_1) of variety AKH-081 with spacing of 45 x 10 cm^2 produced significantly higher biological yield ha^{-1} (9076 kg ha^{-1}) than all other treatment combinations except V_1S_1 (AKH-1301 with spacing 45 x 10 cm^2). The lowest biological yield of 5667 kg ha^{-1} was recorded in treatment combination of V_1S_3 (AKH-1301 with spacing 60 x 15 cm^2).

4) Benefit : cost ratio

Mean benefit : cost ratio was 3.00. It was observed that the variety AKH-081(V_3) gave significantly more benefit : cost ratio (3.15) than all other varieties. Plant geometry of 60 x 10 cm^2 recorded higher benefit : cost ratio than spacings of 45 x 10 cm^2 and 60 x 15 cm^2 spacing. In accordance to this result Chavan *et al.* (2011) ,Wankhede *et al*. (2003), Reddy *et al.*(2008) and Mohapatra and Nanda (2011) also observed significant influence of variety and spacing on benefit :cost ratio in cotton. Paslawar *et al.* (2015) also reported highest B: C ratio of 3.17 in 45 x 10 cm^2 spacing.

Seed cotton yield was recorded significantly higher in variety AKH-081 than AKH-1301, AKH-1302 and SURAJ. The seed cotton yield $plant^{-1}$ was significantly higher in AKH-081 variety. The variety AKH-081 recorded higher benefit : cost ratio than other varieties ie. AKH-1301, AKH-1302 and SURAJ. The duration of 50% flowering, first boll bursting and 50% boll bursting was significantly influenced by different varieties. The variety AKH-081 was found to earlier in respect of flowering and boll bursting. Delay in first boll bursting and 50% bolls bursting was noticed in variety SURAJ. The Gross monetary ratio, net monetary returns and B : C ratio were significantly higher in variety AKH-081 than varieties AKH-1301, AKH1302 and SURAJ.

Higher seed cotton yield were recorded significantly higher in plant spacing of 60 x10 cm^2 but cotton stalk yield and biological yield significantly higher in spacing of 45 x10 cm^2. The number of harvested boll $plant^{-1}$ and seed cotton weight $plant^{-1}$ were significantly higher in plant spacing of 60 x15 cm^2 over spacing of 45 x10 cm^2 and 60 x10 cm^2. The plant spacing of 60 x10 cm^2 recorded higher benefit : cost ratio than plant spacing 60 x15 cm^2 and 45 x10 cm^2. The duration of first flower, 50% flowering, first boll bursting and 50% boll bursting was significantly influenced by different plant spacing. Closer plant spacings of 45 x 10 cm^2 and 60 x 10 cm^2 were found to be earlier in respect of first flower, 50% flowering, first boll bursting and 50% boll bursting than spacing 60 x15 cm^2.

It is inferred from this study that variety AKH-081 recorded significantly superior performance for all the traits studied with B:C ratio of 3.15. Similarly plant spacing of 60 x 10 cm^2 showed significant and superior performance for all the traits studied having B:C ratio of 3.22. The variety AKH-081 responded well to higher plant density with a spacing of 45 x 10 cm^2 and recorded maximum seed cotton yield (2356 kg ha^{-1}).

Table 1. Crop phenology and yield contributing characters influenced by varieties and plant geometry

Treatments	Days to emergence	Days to first square appear	Days to first flower appear	Days to first boll bursting	Days to 50% boll bursting	No. of bolls harvested $plant^{-1}$	Boll wt. (g)	Seed cotton weight $plant^{-1}$ (g)	Seed cotton yield (kg $plot^{-1}$)	Seed cotton yield (kg ha^{-1})	Cotton stalk yield (kg $Plot^{-1}$)	Cotton stalk yield (kg ha^{-1})	Biological yield (kg $plot^{-1}$)	Biological yield (kg ha^{-1})	B:C ratio
Main plot treatment- Varieties (Genotypes)															
V_1- AKH-1301	5.67	47.56	53.89	89.78	113.67	4.71	2.83	13.18	1.15	1993	3.09	5367	4.24	7368	2.94
V_2- AKH-1302	5.67	47.46	54.22	90.44	113.78	4.69	2.81	13.41	1.15	2001	3.04	5277	4.19	7353	2.93
V_3- AKH-081	5.33	44.44	52.33	86.89	109.22	5.00	2.74	14.12	1.24	2155	2.99	5197	4.24	7270	3.15
V_4- SURAJ	5.56	45.67	53.10	90.56	114.44	4.73	2.82	13.50	1.16	1997	3.06	5320	4.22	7330	2.96
SE(m)±	**0.22**	**0.38**	**0.31**	**0.65**	**0.46**	**0.08**	**0.01**	**0.07**	**0.01**	**14.22**	**0.02**	**27.64**	**0.02**	**29**	
CD at 5%	**-**	**1.31**	**1.08**	**2.26**	**1.60**	**-**	**0.04**	**0.26**	**0.03**	**49.22**	**0.06**	**95.64**	**-**	**-**	
Sub plot treatment - Plant densities (Spacings)															
S_1-45 X 10 cm^2 (2,22,222 plants/ha)	5.42	46.75	51.50	87.42	109.58	3.62	2.66	9.56	1.19	2058	3.95	6860	5.14	8919	2.99
S_2- 60 x 10 cm^2 (1,66,666 plants/ha)	5.67	45.67	52.92	89.42	112.92	4.97	2.82	13.83	1.26	2190	2.96	5145	4.23	7336	3.22
S_3- 60 x 15 cm^2 (1,11,111 plants/ha)	5.58	46.50	55.11	91.42	115.83	5.73	2.93	17.23	1.08	1871	2.23	3865	3.30	5737	2.77
SE(m)±	**0.14**	**0.36**	**0.29**	**0.26**	**0.46**	**0.05**	**0.02**	**0.10**	**0.01**	**13.56**	**0.01**	**19.01**	**0.01**	**24**	
CD at 5%	**-**	**-**	**0.88**	**0.78**	**1.38**	**0.14**	**0.05**	**0.30**	**0.02**	**40.65**	**0.03**	**56.98**	**0.04**	**73**	
Interaction (V X S)															
V_1S_1						3.40		9.54	1.16	2017	4.04	7011	5.20	9029	
V_1S_2						5.00		13.73	1.26	2193	3.00	5216	4.27	7410	
V_1S_3						5.73		16.26	1.03	1791	2.23	3875	3.26	5667	
V_2S_1						3.33		9.07	1.12	1951	3.93	6826	5.06	8777	
V_2S_2						5.00		13.87	1.26	2182	2.98	5169	4.23	7351	
V_2S_3						5.73		17.29	1.06	1847	2.21	3836	3.27	5683	
V_3S_1						4.20		10.99	1.36	2356	3.87	6720	5.23	9076	
V_3S_2						5.11		14.03	1.27	2210	2.88	5006	4.16	7216	
V_3S_3						5.67		17.33	1.09	1899	2.23	3866	3.32	5765	
V_4S_1						3.53		8.78	1.10	1908	3.97	6885	5.07	8793	
V_4S_2						4.87		13.67	1.25	2175	2.99	5190	4.24	7365	
V_4S_3						5.80		18.05	1.12	1947	2.24	3885	3.36	5832	
SE(m)±	**0.28**	**0.72**	**0.59**	**0.52**	**0.92**	**0.09**	**0.03**	**0.20**	**0.02**	**27.12**	**0.02**	**38.01**	**0.03**	**48**	
CD at 5%	**-**	**-**	**-**	**-**	**-**	**0.28**	**-**	**0.60**	**0.05**	**81.31**	**0.07**	**113.97**	**0.08**	**145**	
GM	**5.56**	**46.31**	**53.47**	**89.42**	**112.78**	**4.77**	**2.80**	**13.55**	**1.18**	**2040**	**3.05**	**5290**	**4.22**	**7330**	**3.00**

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