Yield attributes and productivity of various Bt and non Bt cotton varieties in Faisalabad environment.

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Abstract: A field experiment was conducted during summer 2012 to evaluate the yield potential of different Bt. And non Bt. cotton varieties at Agronomic Research Area, University of Agriculture Faisalabad. The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. Net plot size was 6.0 m × 3.0 m and crop was sown on ridges manually. Ridge to ridge distance was 75 cm and plant to plant distance was 30 cm. Crop was sown on fifth May using Bt cotton varieties AA-703, AA-905, MNH-886, MNH-456, SGA-1, ST-009, Sitara-010, FH-142, CIM-506, CIM-598, CIM-599 CIM-602, IUB-222. All the other agronomic practices were kept uniform. Data were recorded for yield parameters. Data collected was analyzed statistically using Fisher's analysis of variance technique and by employing computer program MSTATC. Least significance difference test at 5% probability level was evaluated to compare the treatment means. The results expressed that the variety MNH-886 performed significantly better than other Bt varieties. The variety MNH-886 attained the maximum height of 158.1cm, while in case of number of flowers per plant, the maximum number of flowers were observed in variety MNH-886. Maximum number of flower shed was observed in variety AA-905. Maximum number of bolls were observed in variety MNH-456, while the maximum number of opened bolls per plant and boll weight was observed in variety MNH886. MNH-886 gave maximum yield which was 3111.08(kg ha^{1}).
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Introduction

Cotton is a natural fibre crop and is used in several products ranging from clothing to home furnishings or medical products. In addition, the cotton seed is crushed to make edible oil and livestock feed. It is also used in fuel fodder and textile industry. Cotton picking is a laborious activity and provides supplementary employment and income opportunities to rural farm and non-farm households. Every kilogram of fiber production is accompanied by about 1.65 kg of oil and protein-rich seeds. It is also used for several other purposes like making threads, for mixing with other fibres and extracting of oil from the cotton seed. The oil and protein contents in the cotton seed are about 17% and 24%, respectively. American varieties contain high percentage of oil. Cotton oil cakes are good organic manure with 6-3-2% of N-P_2O_5-K_2O. Cotton seed and meal are used as concentrated feed for cattle. The seed meal is a protein-rich by-product useful to feed ruminant livestock but toxic to non-ruminant animals and humans because of the existence of pigment glands of gossypol, a terpenoid aldehyde (Gerasimidis *et al.*, 2007). Consequently, cotton is continuously in demand due to its usage and is issue to the powers and weaknesses of the overall economy.

Cotton is grown in about 80 countries but only five countries viz., China, India, USA, Pakistan and Brazil accounted for about 81% of the global area and provided 75% of the world's cotton in 2009-10. Besides being the world's fourth-largest cotton producer and the third largest exporter of raw cotton and a 2nd leading exporter of yarn in the world, per acre yield of cotton ranks 13th in the world. Pakistan imports 1.5-2.00 million bales of cotton annually to meet growing demand from local textile industry. Farmers grow cotton over 3 million hectares in our country, as it is vital cash crop of Pakistan. Moreever it contributes 60% in the total foreign exchange through the exports of value added products (Iqbal *et al*., 2005; Waqas *et al*., 2014).

Pakistan is the 4th largest cotton producing country in the world after People Republic of China, USA and India, and 3rd largest consumer of cotton after People Republic of China and India (Akhtar *et al*., 2005). It is a lifeline of the textile industry in our country. That is why cotton is called silver-fibre (Arshad *et al.,* 2007; Saif-ul-Malook *et al*., 2014abcd). It accounts for 7.0 percent of value added in

agriculture and 1.5 percent of GDP (Govt. of Pakistan 2012-13).

Currently, cotton crop is facing a number of problems which cause reduction in yield of crop. These problems are non availability of inputs at the time of sowing and high cost, resulting low yield per acre, scarcity of irrigation water, improper cultivation method and non availability of advanced technologies. Cotton is unluckily attacked by many insects as well as diseases. Sever attack of thrips, white fly and Cotton Leaf Curl Virus. Cotton plant sets its bolls (fruit) over a period of about 80 days. Delayed in that period allows various environmental factor to act and affect maturation period (Iqbal *et al*., 2003). Late maturating types are ultimately affected by a later pest pressure. Cotton fiber quality is primarily influenced by late maturity of the genotype and by environmental conditions as the secondary factors (Subhan *et al*., 2001).

Earliness in cotton is a complex polygenic trait influenced by a number of factors like morphology, phenology, physiology and environmental attributes (Shah *et al*., 2010). Earliness allows development of crop during period of favourable moisture and timely picking prevent the crop from unfavourable weather (Rauf *et al.,* 2005). The benefits of growing early maturing cotton cultivars is the provision of proper time for rotation of other crops allowing timely sowing of wheat in cotton – wheat – cotton cropping system (Ali *et al*., 2003).

Genetically modified (GM) crops increase the yield significantly in the developing countries, especially in the tropics and subtropics. Actually increase or decrease in yield depends on the yield loss of the non-transgenic counterparts under the same cropping practice. For Bt. cotton, in a developed country such as USA, increase in yield is 10–15%. GM crops have been grown since 1996. The analysis shows that there have been substantial net economic benefits at the farm level amounting to a cumulative total of $27 billion. The technology has reduced pesticide spraying by 172 million kg and has reduced the environmental footprints associated with pesticide use by 14%. The technology has also significantly reduced the release of greenhouse gas emissions from agriculture, which is equivalent to removing five million cars from the roads (Brookes and Barfoot, 2005). Similarly the varieties with Bt. gene provide resistance against bollworms thus reduce the cost of pesticides to control these pests Bt. Cotton provides an alternative by replacing insecticides with a toxin within the plant. According to (Layton *et al*., 1997) overall performance of Bt. Cotton was better than conventional varieties. Transgenic Bt. cotton can effectively control specific lepidopterous species (Arshad *et al*., 2009).

There is need to check yield potential of different Bt. varieties. Therefore cotton seed was collected in respect of 13 Bt. varieties AA-703, MNH-886, AA-905 and MNH-456 from Ali Akbar group, FH-142 from Ayub Agricultural Research Institute Faisalabad, CIM-598, CIM-599 and CIM-602 from Central Cotton Research Institute, Multan (CCRI), S-G-A-1 from Cotton Research Station (CRS) Multan, ST-009 and Sitara-010 from Aziz group, and IUB-222 from Islamia University Bahawalpur. These varieties were sown and this experiment was executed with the objective. To determine the yield potential and adaptability of the Bt. cotton varieties under Faisalabad conditions.

Materials and Methods

This trial for yield attributes and productivity of various cotton varieties was conducted at Student Farm, Department of Agronomy, University of Agriculture, Faisalabad. Plot size was 6.0 m × 3.0 m and the crop was shown on 75 cm a part ridges keeping 30 cm plant to plant distance. Randomized Complete Block Design (RCBD) was used with four replications. Soil sample from the experimental field were collected before sowing for determining the soil physiochemical properties.

Treatments

V_1 = AA-905, V_2 = MNH-886, V_3 = AA-703, V_4 = SGA-1, V_5 = Sitara-009, V_6 = Sitara-010, V_7 = FH-142, V_8 = CIM-506, V_9 = CIM-598, V_{10} = CIM-602, V_{11} = MNH-456, V_{12} = IUB-222, V_{13}= CIM-599

Crop Husbandry

Soil was prepared using one time disc harrow plus two cultivations followed by planking, ridges were made using ridger. Bt cotton varieties were sown by manual seeding using seed rate of 15 kg/ha. Recommended dose of nitrogen, phosphorous and potash (NPK) were applied in the form of urea, DAP and potassium sulphate. One third of N and full amount of P and K was applied at the time of sowing, while 1/3 of N was applied at flowering and 1/3 at boll formation. Plant protection measures were adopted to keep crop free of pest and diseases. Three picking were done 1st September, 1st October and 20th November on basis of 50% boll maturity. Following observations were recorded during crop season viz. Germination counts (m^{-2}), Number of flowers per plant, Number of flower shed per plant, Days between bud to flower formation, Days between flower to boll formation, Monopodial branches per plant, Sympodial branches per plant, Plant population (m^{-2}), Plant height at harvest (cm), Number of bolls per plant, Number of opened bolls plant, Number of unopened bolls per plant, Boll weight (g), Number of seeds per boll, Boll size width (cm), 100 seed weight(g) and Seed cotton yield (t ha^{-1}).

Weather Data

Weather data during the experimental period were obtained from Agro-metrological cell, Department of Crop Physiology, University of Agriculture, Faisalabad situated 200 m away from the experimental site. The weekly mean values of temperature, relative humidity, evapo-transpiration, sunshine hours, pan evaporation, rainfall and wind speed are given in Fig. 1, 2, 3, 4, 5 and 6 respectively.

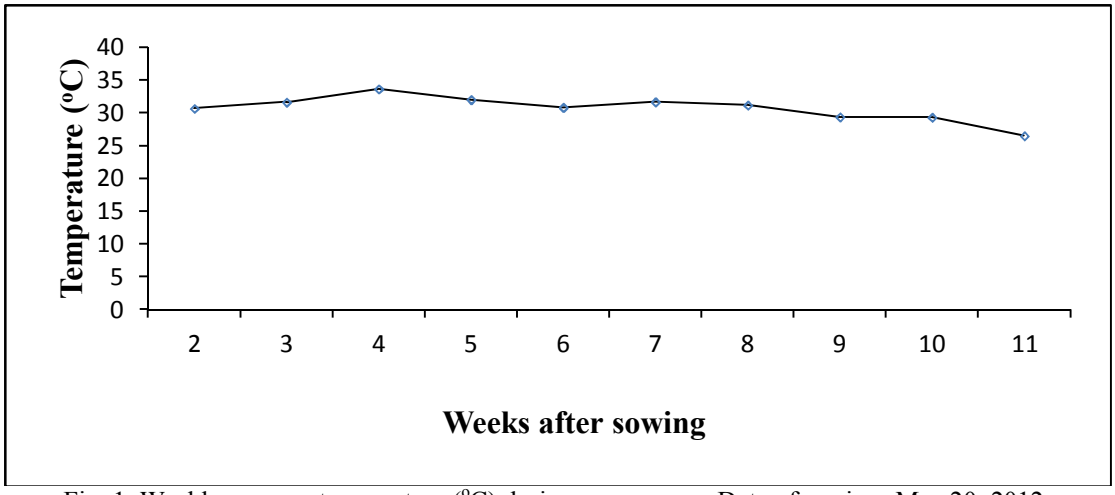

Fig. 1. Weekly average temperature (°C) during crop season. Date of sowing: May 20, 2012.

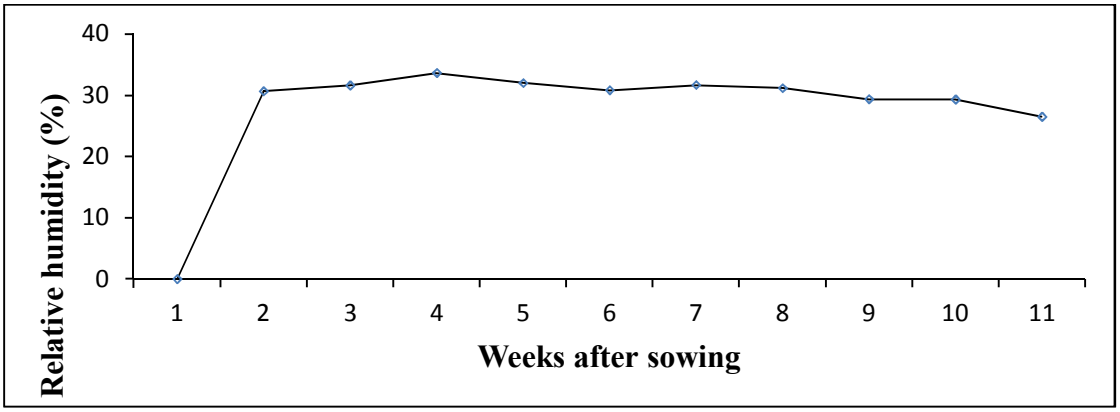

Fig.2. Weekly average of relative humidity (%) during crop season. Date of sowing: May 20, 2012

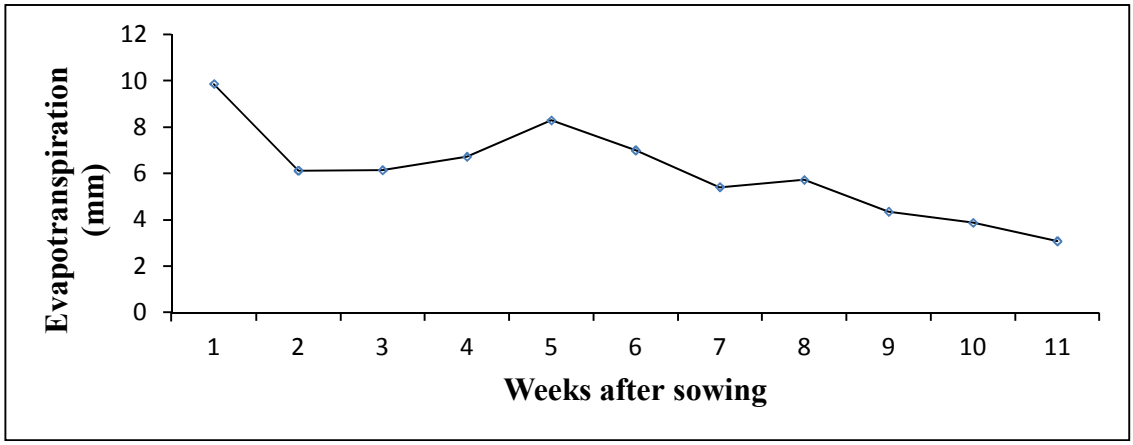

Fig.3. Weekly average of evapotranspiration (mm) during crop season. Date of sowing: May 20, 2012

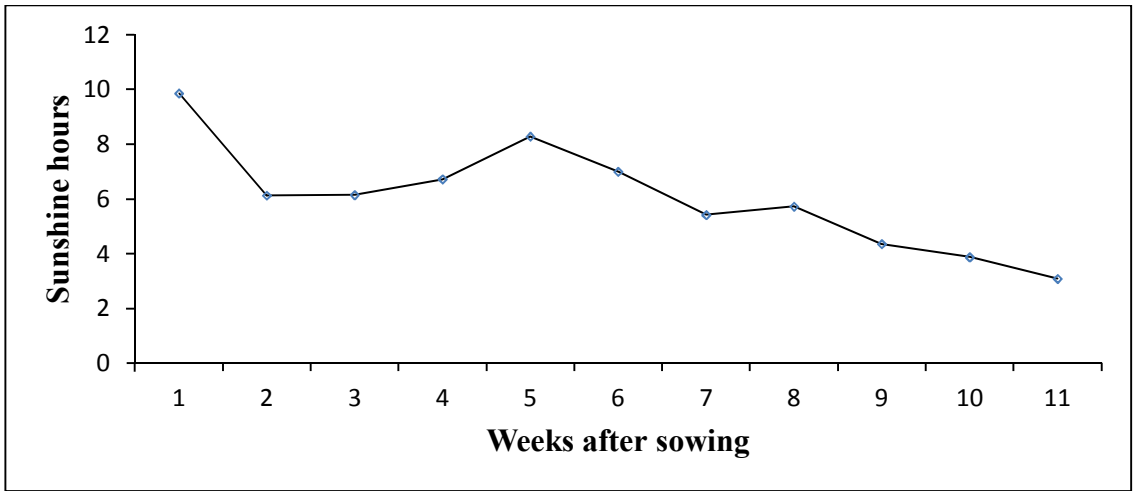

Fig.4. Weekly average of sunshine hours during crop season. Date of sowing: May 20, 2012

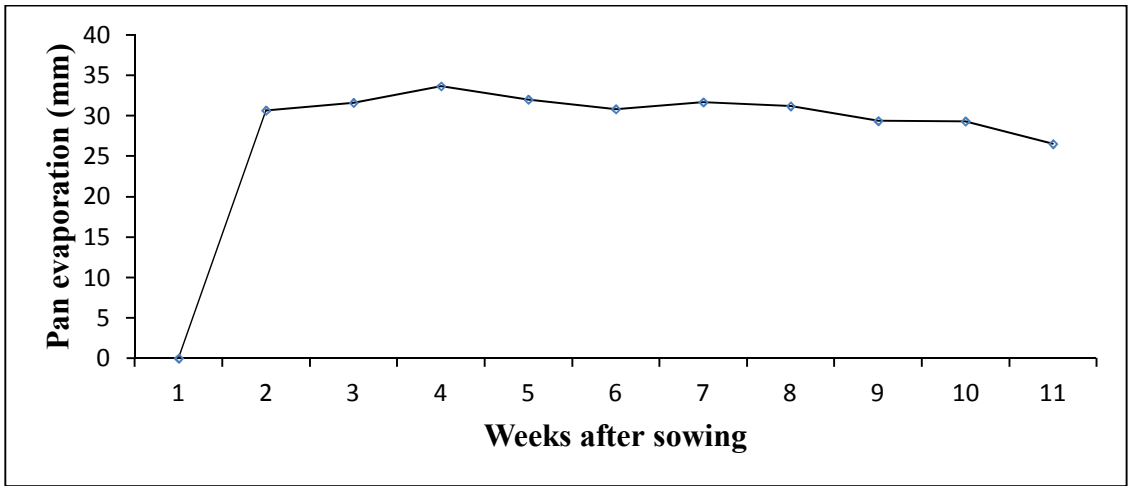

Fig.5. Weekly Average of Pan evaporation (mm) during crop season. Date of sowing: may 20, 2012

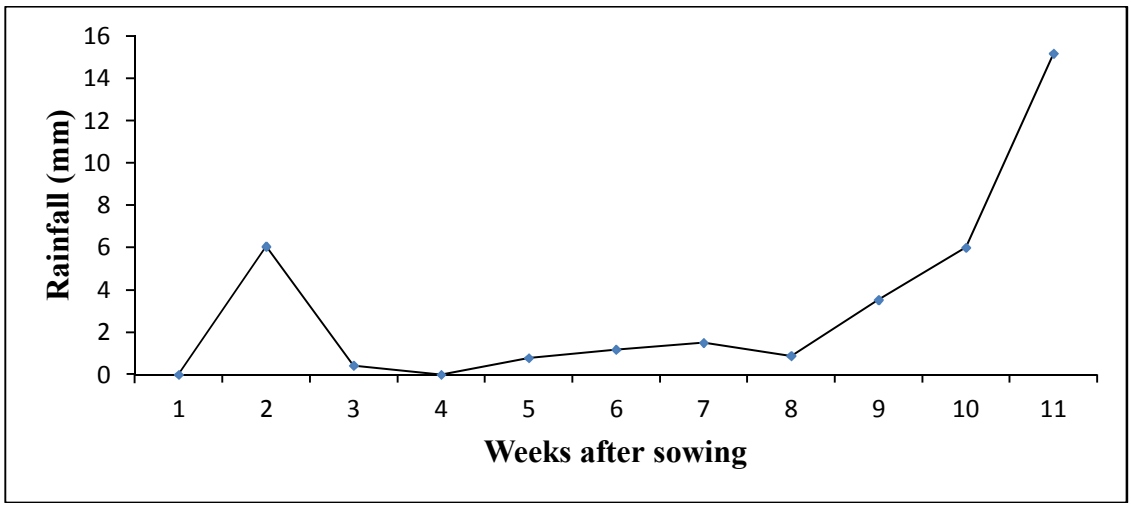

Fig. 6. Weekly average of rainfall (mm) during crop season Date of sowing: May 20, 2012

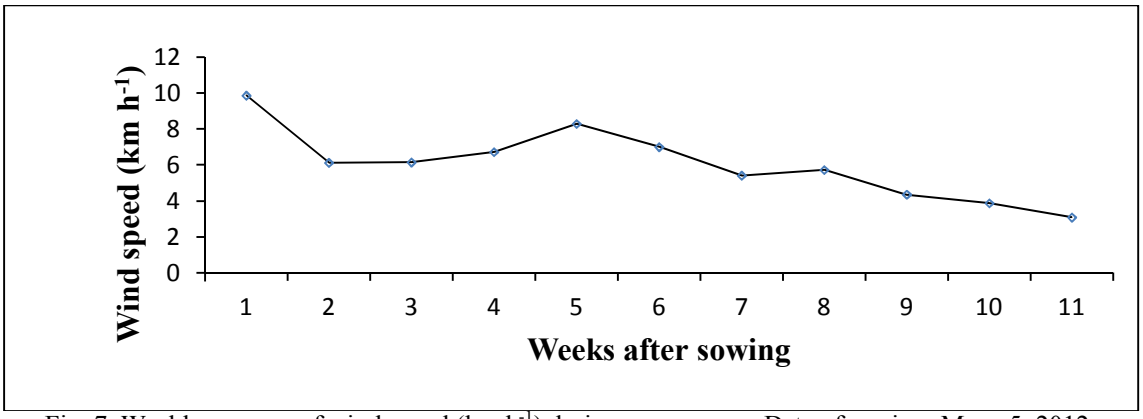

Fig. 7. Weekly average of wind speed (km h^{-1}) during crop season. Date of sowing: May o5, 2012

Statistical analysis

The data collected were analyzed by using the Fisher's analysis of variance technique and applying LSD test at 5% probability to compare the treatments' means (Steel *et al.,* 1997).

Results and Discussion

Growth parameters

Germination Count

Optimum crop stand bears key significance in crop production system. If we become unable to ensure good crop stand ultimately yield will fall down. It is more or less controlled by the environmental factors in which the plants are grown. In cotton germination has great influence on plant population. Number of germinated seeds per m^2 were counted and data were analyzed statistically. Results obtained are presented in table 1. Maximum germinated plants per m^2 were recorded in MNH-886 and AA-905 with average of 4.20 and 4.18 respectively followed by IUB-222 with an average of 3.98 germinated plants per m^2. Whereas, the minimum number of germinated plants per m^2 (3.17) were recorded in Sitara-009 which was at par with SGA-1 having 3.21 average number of germinated plants per m^2. In our study varieties MNH-886 and AA-905 produced the maximum germinated plants per m^2 probably due to good seed vigour. The seed of these varieties might contained the maximum seed viability in comparison with seeds of all the other varieties. Our results are supported by the earlier findings of Anwar *et al.* (2002) and Copur (2006) who reported significant differences among cotton cultivars for germination.

Plant height at maturity

The final height reflects the growth behaviour of a crop, so plant height is considered the good indicator of crop growth. The plant height was recorded and data were analyzed statistically. Results obtained are presented in table 1. The results indicated that plant height of different varieties varied significantly.

Maximum height was recorded in MNH-886 with an average of 158.15 cm whereas Sitara-010, CIM-506, SGA-1, FH-142, MNH-456, IUB-222 and AA-905 were found to be at par with an average of 156.84 cm, 151.13 cm, 149.22 cm, 149.22 cm, 147.41 cm, 145.42cm and 143.51 cm plant height and these are statistically at par but significantly different from others.

The variety Sitara-009 showed intermediate results with an average of 130.18 cm while non-significant different from CIM-506, SGA-1, FH-142, MNH-456, IUB-222 and AA-703 showed average height with an average of 127 cm but FH-142, MNH-456, IUB-222, AA-905 and Sitara-009 showed similar results as AA-703. Whereas, CIM-602 showed lower height 123.82 cm and is statistically alike as AA-905, Sitara-009, AA-703 and CIM-598 showed lower plant heights than CIM-602 with an average plant height of 108.58 cm but it was statistically at par with CIM-602 and AA-703. However lowest plant height was recorded in CIM-599 with an average plant height of 101.6 cm but it was statistically at par with AA-703, CIM-602 and CIM-598. Difference in plant height may be due to genetic character but it may also be influenced by environment. The variety MNH-886 and Sitara-009 gained the maximum plant height due to having good genetic characters and better adoptability to the environmental conditions as compared to all other varieties. Our findings are supported by the earlier findings of Ehsan e*t al.* (2008) who revealed that differences observed for plant height among cotton cultivars can be attributed to variation in genetic makeup of crop plants. These results are also supported by the findings of Ahmad *et al*. (2008) and Copur (2006) who reported significant differences among cultivars for plant height.

Number of days from bud to flower formation

Number of days from bud to flower is an indicator of crop growth as when crop is in stress it will switch from bud to flower earlier than normal time and if the crop is in healthy conditions then it

will take normal time. Days from bud to flower formation were counted and data were analyzed statistically. Results obtained are presented in table 1. Table revealed non-significant difference in number of days from bud to flower formation. Difference in days taken from bud to flower formation may be due to genetic character but it may also be influenced by environment. It may be influenced by increase in temperature and rainfall. Our results are supported by Rehana *et al*. (2001) and by Khan *et al*. (2002) who observed non-significant difference in cultivars for number of days taken to open first flower. The number of days from squaring to flowering as well as the days from flowering to boll opening may be influenced by temperature or it may be genetically controlled.

Number of days from flower to boll formation

Days from flower to boll formation were counted and data were analyzed statistically as presented in table 1. This revealed non- significant difference among varieties for days taken from flower to boll formation. There was difference in number of days from flower to boll formation in different cotton varieties but it was not significantly different. Variety MNH-886 took the minimum days from flower to boll formation because having good genetic characters in comparison to all other varieties. Our results are supported by Rehana *et al*. (2001) and Arshad *et al*. (2007) who observed non-significant difference in cultivars for number of days taken to open first flower. The number of days from squaring to flowering as well as the days from flowering to boll opening may be influenced by temperature or it may be genetically controlled.

Yield Parameters

Plant population at harvest

Optimum number of plants per unit area ensures good crop stand and yield, which ultimately leads to higher crop yield. Out of various important yield determinants, plant population is the most important factor with respect to its role in contribution to final yield of crop. Results obtained are presented in table 1 showing significant difference among varieties for plant population at harvest. Maximum plant population at harvest was recorded in AA-905 along with MNH-886 with an average of 4.00 plants per m^2 while varieties IUB-222, CIM-602,MNH-456,CIM-598, CIM-599, CIM-506, FH-142, AA-703 and Sitara-010 revealed non-significant difference with AA-905 and MNH-886 with an average of 3.8, 3.6, 3.6, 3.55, 3.51, 3.3, 3.25 and 3.25 plants per m^2 respectively. Difference in plant population may be due to genetic character but it may also be influenced by environment. The varieties MNH-886 and AA-905 gained the maximum plant population due to having better adoptability to the environmental conditions as compared to all other varieties. Our results are supported by the earlier findings of Anwar *et al*. (2002) and Copur (2006) who reported significant differences among cultivars for plant height and plant population.

Number of flowers per plant

Number of flowers per plant are directly linked with total yield of that crop plant. These characters are genetically controlled but also sensitive to environmental conditions. The cultivar which possesses higher number of flowers in extreme environment will be favourite in all environments. Number of flowers per plant were counted and data were analyzed statistically. Results obtained are presented in table 1 and 2. This revealed that considerable different number of flowers per plant were recorded in different cotton varieties. Table showed the comparison of mean number of flowers per plant. Maximum number of flowers per plant were recorded in AA-905 and MNH-886 which were statistically at par with each other and with MNH-456. These were significantly different from the rest of the treatments with an average of 40.25, 40.25 and 37.5 flowers per plant respectively.

Varieties CIM-599, FH-142, Sitara-010 and IUB-222 were statistically at par with each other and showed intermediate results with an average of 35.5, 34.75, 34.5, and 34 flowers per plant while, MNH-456 was also found similar to these varieties. Minimum number of flowers per plant were recorded in CIM-506 with an average of 30.5 while CIM-598 was found to be similar with CIM-506 with an average of 30.75 flowers per plant. The maximum number of flowers per plant were attained by MNH-886 and AA-905 because these varieties had good genetic characters, maximum adoptability and resistance against the environmental stresses as compared to all other varieties. Our findings are supported by the findings of Lamas (2006) that varieties varied due to environmental factors. Hodges *et al*. (1993) reported that the primary factor affecting crop development is temperature. They also observed that initiation of first flower and its development was temperature and cultivar dependant.

Number of flower shed per plant

Flower shedding is of vital importance as it indicates the adaptability of any cultivar in any area. Cotton crop is sensitive crop which does not bear harsh conditions. It sheds its flowers whenever undergo adverse conditions. Flower shedding is more common in Bt. varieties which harders their adaptation in many regions. As Sahai and Rahman (2003) reported that premature drying and shedding of fruiting parts, were the main reasons for the poor performance of Bt. cotton and its adoption. Results presented in table 1 and 2 showed significant difference for flower shedding among cotton varieties.

Statistically maximum number of flower shedding was observed in AA-905 with an average of 14.5 number of sheded flowers while, the variety MNH-886 also showed similar results as of AA-905. The cotton varieties MNH-456, CIM-599, FH-142 and CIM-602 showed number of flower shed of 11.75, 11.5, 11 and 10 respectively which was statistically at par with each other and with MNH-886 as well. While varieties AA-703, Sitara-010 and CIM-598 showed average number of flower shed with an average of 9.75 and these were statistically similar with each other and with CIM-602, MNH-456, FH-142 and MNH-456.

However minimum number of flower shed was noted in IUB-222 with an average of 08 and it was statistically at par with CIM-506, Sitara-009, SGA-1, CIM-598, Sitara-010 and AA-703. The flower shedding is major constraint limiting yield in cotton while, the varieties having the good genetic characters were less influenced by this mechanism. Minimum flower shedding was observed in treatment IUB-222 which might have high resistance against temperature stress and water stress in comparison to all other varieties. This difference is due to the genetic characters of different varieties. Our findings are supported by Mehmood *et al*. (2012) who indicated the impact of Bt. cotton varieties for productivity in district Vehari of Punjab province. Primary data were collected from 6 villages of Vehari district. From each village, ten respondents each from Bt. cotton and conventional cotton growers were selected randomly. Along with the plus point of Bt. cotton the flower shedding was mentioned as the problem in gaining higher yield.

Number of monopodial branches per plant

Number of monopodial branches reflect the vigour of variety and are directly linked to yield. As their number increases chances of more fruiting increases. We can't ignore the importance of number of monopodial branches as the yield contributing trait of cotton. Number of monopodial branches per plant was counted and data were analyzed statistically. Results obtained were presented in table 1 and 2. This revealed significant difference in number of monopodial branches per plant among the varieties.

Table indicated the comparison of average number of monopodial branches per plant. Maximum number of monopodial branches per plant was recorded in AA-905 and SGA-1 along with MNH-886 and Sitara-010 which were statistically at par but significantly different from the rest of varieties with an average of 2.5, 2.5, 2 and 2 number of monopodial branches. While cotton cultivars MNH-456 and AA-703 produced monopodial branches as of 1.5 and 1.3 which were statistically at par with Sitara-010 and MNH-886.Whereas CIM-598, CIM-599, Sitara-009, CIM-506, FH-142, CIM-602 and CIM-599 produced the minimum number of monopodial branches with an average of 1.31, 1.25, 1.25, 1. Results showed significant difference among varieties for number of monopodial branches. The number of monopodial branches is the genetic character. Our results are supported by earlier findings of Ehsan *et al*. (2012) who revealed that monopodial branches per plant can be attributed to differences in genetic makeup of the cultivars. The significant differences among varieties for number of monopodial branches per plant had also been reported by Copur (2006).

Number of sympodial branches per plant

Number of sympodial branches indicate the vigour of variety and is also considered a good contributor towards yield. The significance of number of sympodial branches as the yield contributing factors of cotton could not be ignored. Number of sympodial branches per pant was counted and data were analyzed statistically. Results obtained are presented in table 1 and 2. This revealed that significant difference in number of monopodial branches per plant was found.

Table 1 and 2 showed the comparison of average number of sympodial branches per plant. Maximum number of sympodial branches per plant was recorded in MNH-886 with an average of 22.5 numbers of sympodial branches and statistically similar with Sitara-010 and Sitara-009 with an average of 22 and 20.50 branches. Variety AA-905 showed results with an average of 20.25 sympodial branches and were statistically at par with Sitara-009 and Sitara-010. SGA-1 showed average number of sympodial branches per plant with an average of 18.25 sympodial branches which was significantly different from rest of treatments and statistically at par with Sitara-009 and AA-905.

However the varieties MNH-456 and IUB-222 produced 17.5 average number of sympodial branches per plant which statistically not differed with SGA-1. FH-142 showed lower number of sympodial branches per plant with an average of 15.5 sympodial branches and these were statistically at par with IUB-222 and MNH-456. Whereas minimum number of sympodial branches were observed in AA-703 with an average of 10.5 sympodial branches per plant and found to be at par with CIM-602, CIM-598, CIM-599 and CIM-506 having 11.75, 12, 12.25 and 12.5 branches respectively. Results showed that varieties differed significantly for number of sympodial branches. The variety MNH-886 gained the maximum number of sympodial branches

because of its good genetic makeup. These results are similar to the earlier findings of Ehsan *et al*., (2012) who revealed that the difference in number of sympodial branches per plant can be attributed to differences in genetic makeup of the cultivars. The

significant differences among varieties for number of sympodial branches per plant had also been reported by Copur (2006).

Number of bolls per plant

Number of bolls per plant is an important yield attribute, which is the genetically controlled character but altered by field and environmental conditions. Numbers of researchers have shown that there is significant difference among varieties for number of bolls per plant. In our study we tried to evaluate the variety which could gave the maximum number of bolls under agro-ecological conditions of Faisalabad.

Number of bolls per pant was counted and data were analyzed statistically. Results obtained were presented in table 1 and 2. This revealed that significantly different number of bolls per plant was recorded in different varieties. Table showed the comparison of average number of bolls per plant. Maximum number of bolls per plant were recorded in MNH-456 and Sitara-009 with an average of 31 bolls per plant which were statistically at par with IUB-222, MNH-886, Sitara-010 and FH-142 with an average of 30 and 29.75 but significantly different from the rest cotton cultivars. While, CIM-602 and SGA-1 showed average results which were statistically at par with an average of 27 bolls per plant. Minimum number of bolls per plant were observed in AA-905 which were 26 while, CIM-599 and CIM-598 exhibited similar performance. Difference in number of bolls per plant might be due to genetic makeup but it may also be influenced by environment. Cotton varieties MNH-456 and Sitara-009 having good genetic character and adoptability to various environmental conditions gained the maximum number of bolls per plant in comparison to all other varieties.

The variety having the maximum number of sympodial branches contained maximum number of bolls also. We found significant difference for number of bolls per plant among varieties and our results are in agreement with the earlier findings of (Ehsan *et al*., 2012), he assessed the growth and yield performance of five cultivars of cotton i.e. FH-115, FH-207, FH-901, FH-113 and MNH-786, during spring 2006. Significant differences in plant height, number of sympodial branches per plant, number of bolls per plant, average boll weight, seed cotton yield, ginning out turn, fiber length and fiber fineness were recorded among the varieties. However the cultivar FH-115 statistically produced maximum yield due to more number of sympodial branches, number of bolls per plant and higher ginning out turn. The significant differences among varieties for number of bolls per plant had also been reported by Ahmad *et al*. (2008)

Number of opened bolls per plant

Number of bolls per plant is an important yield attribute which is the genetically controlled character but influenced by field and environmental conditions. Numbers of researchers have shown that there is significant difference among varieties for number of opened bolls per plant. In this study we tried to evaluate the variety which could give the maximum number of opened bolls under agro-ecological conditions of Faisalabad. Number of opened bolls per plant were counted in different cotton varieties and data were analyzed statistically. Results obtained were presented in table 1 and 2. This revealed that significantly different number of opened bolls per plant were recorded in different cotton varieties. Maximum number of opened bolls per plant were recorded in MNH-886 and Sitara-010 as 26.5 and 23 opened bolls per plant which were statistically at par with AA-905, IUB-222, MNH-456 and FH-142 with an average of 22.5, 22.5, 21.5 and 21.5 number of opened bolls per plant respectively. While, CIM-599 showed results with an average of 20.75 opened bolls per plant but had the similar letter with SGA-1, AA-703 with 20.5 opened bolls per plant and also with AA-905, IUB-222, MNH-456 and FH-142. Minimum number of opened bolls per plant were observed in CIM-598 with an average of 18.75 opened bolls per plant while, CIM-599, SGA-1, AA-703, CIM-602, Sitara-009 and CIM-506 exhibited similar performance. Difference in number of opened bolls per plant may be due to genetic character but it may also be influenced by environment. Varieties MNH-886 having good genetic characters contained maximum number of opened bolls per plant with respect to all other varieties. We found significant difference for number of opened bolls per plant among varieties and our results are supported by the findings of (Ehsan *et al*., 2012), who studied the growth and yield performance of five cultivars of cotton i.e. FH-115, FH-207, FH-901, FH-113 and MNH-786 during spring, 2006. Significant differences in plant height, number of sympodial branches per plant, number of bolls per plant, average boll weight, seed cotton yield, ginning out turn, fiber length and fiber fineness were recorded among the varieties. The cultivar FH-115 statistically produced the maximum yield due to more number of sympodial branches, number of bolls per plant and higher ginning out turn. The significant differences among varieties for number of bolls per plant had also been reported by Saleem *et al.* (2010) and Copur (2006).

Number of unopened bolls per plant

Un-opened bolls per plant were counted and data were analyzed statistically. Results obtained were then shown in table 1 and 2. This revealed significant difference in number of un-open bolls per plant among the cotton varieties. Maximum numbers of un-open bolls per plant was recorded in Sitara-009 with an average of 11.25 number of un-open bolls and

statistically non-significant with CIM-598 and MNH-456 having 9.25 and 8.5 un-open bolls. FH-142 showed intermediate results with an average of 8.25 average number of un-open bolls per plant and was similar with CIM-598 and MNH-456 and also with CIM-506, CIM-602, AA-703, IUB-222, Sitara-010 and SGA-1 with an average of 8.25, 7.25, 7.25, 7, 6.75 and 6.5 number of un open bolls. AA-905 and MNH-886 showed minimum number of un-open bolls and were statistically at par with each other with an average of 3.5 and 3.25 un-open bolls.

In this study we found significant result in number of opened bolls per plant, this may be an inherited character or may be controlled by environmental conditions. The significant differences among varieties for number of bolls, number of opened boll and number of un-opened bolls per plant had also been reported by Anwar *et al.* (2002) and Copur (2006).

Boll weight

Boll weight is directly related to the final seed cotton yield of cotton. As weight of bolls increases economic return increases. There is always significant difference in boll weight among varieties at farmer field. In this study we tried to investigate varieties which could produce maximum boll weight under agro-ecological conditions of Faisalabad.

Weight of bolls was measured and data were analyzed statistically. Results obtained are presented in table 1 and 2. Table showed the comparison of average boll weight of different cotton varieties. Maximum boll weight was recorded in Sitara-009 which was statistically different from the rest of varieties with an average of 3.5 g. FH-142 with an average of 3.12 g gave average results and it was statistically at par with AA-905, MNH-456, IUB-222, MNH-886, SGA-1, Sitara-010 and CIM-506 with an average of 3 g and also with CIM-602 having 2.9 g average boll weight. AA-703 showed minimum boll weight with an average of 2.8 g and was similar to CIM-598 and CIM-599 having 2.8 g average boll weight of both varieties.

Variety Sitara-009 gained the maximum boll weight due to having good genetic characters and ability to gain more boll weight under different environmental conditions in comparison to all other varieties. Our results are supported by Ehsan *et al* (2012), who found that boll weight is directly related to the final seed cotton. He assessed the growth and yield performance of five cultivars of cotton i.e. FH-115, FH-207, FH-901, FH-113 and MNH-786, during spring 2006. Significant differences in plant height, number of sympodial branches per plant, number of bolls per plant, average boll weight, seed cotton yield, ginning out turn, fiber length and fiber fineness were recorded among the varieties. The cultivar FH-115 statistically produced maximum yield having maximum number of sympodial branches, number of bolls per plant and higher ginning out turn.

Number of seeds per boll

Number of seed per boll is directly linked to the yield of cotton crop. If numbers of seed are more ultimately yield will be higher. This is genetically controlled character but up to some extent can be altered by environmental conditions.

Number of seeds per boll was measured and then analysed statistically. Data then presented in table 1 and 2. This showed significant difference in number of seeds per boll in MNH-886 which statistically differed from other varieties. Table showed the comparison of average number of seeds per boll. Maximum number of seeds per boll was recorded in MNH-886 with the average of 34.25 seeds per boll and it was significantly different from the rest of varieties. Sitara-009 showed intermediate results with average of 28 seeds per boll and it was statistically at par with AA-905, Sitara-010, MNH-456, SGA-1, CIM-598, IUB-222, FH-142, AA-703, CIM-506 and CIM-599 with the average of 27.75, 27, 26.75, 26.75, 26.5, 26.25, 26.25, 26 and 25.75 seeds per boll, respectively. Minimum number of seeds per boll was observed in CIM-602 which was statistically at par with Sitara-010, MNH-456, SGA-1, CIM-598, IUB-222, FH-142, AA-703 and CIM-506 with average of 27.75, 27, 26.75, 26.75, 26.5, 26.25, 26.25 and 26 seeds per boll respectively. Our results are supported by the earlier findings of Ahmad *et al*. (2008) who carried out an experiment to determine yield contributing traits in five cotton cultivars viz. CIM-473, CIM-496, CIM-499, CIM-506 and CIM-707. All the genotypes revealed highly significant differences for monopodia and sympodia branches per plant, bolls per plant and seeds per boll while, the plant height, first internode length, boll weight and seed cotton yield per plant manifested significant variations among the cultivars.

Boll size width

Results presented in table 1 and 2 explained that there was significant difference among cultivars for boll size width. Maximum boll size width was recorded in variety MNH-886 with an average of 2.99cm and it was statistically at par with Sitara-009 and IUB-222 having 2.84 and 2.82cm average boll size width. MNH-456 showed average results with 2.80 average boll size width and it was statistically similar with Sitara-010 and SGA-1 with 2.79cm and 2.72cm average boll size width. And this was also similar with Sitara-009 and IUB-222. AA-703 showed poor performance and resulted in 2.61cm average boll size width. Lowest boll size width was recorded in AA-905 with an average of 2.22cm average boll size width and it showed similar results as CIM-506 with

2.40cm average boll size width. The difference in boll size width may be genetically controlled or it may also be affected by environmental conditions. The variety MNH-886 gained the maximum boll size width due to having its good genetic characters. Our results are supported by the earlier findings of Ehsan *et al.* (2012) who assessed the growth and yield performance of five cultivars of cotton i.e. FH-115, FH-207, FH-901, FH-113 and MNH-786, during spring 2006. Significant differences in plant height, number of sympodial branches per plant, number of bolls per plant, average boll weight, average boll size, seed cotton yield, ginning out turn, fiber length and fiber fineness were recorded among the cotton varieties.

100 seed weight

Weight of 100 seed is also directly linked to the yield of crop. Yield of crop varieties varies from variety to variety and area to area. None of variety remained at same production level for all agro-ecological zones. In this study we have compared the best Bt. cotton varieties for the agro-ecological conditions of Faisalabad. Results presented in table 1 and 2 showed the significant difference among the varieties for yield. Maximum 100 seed weight was recorded in MNH-886 with an average of 2.99 g and it was statistically similar with treatments Sitara-009 and IUB-222 with an average 2.84 g and 2.83 g average weight Respectively, MNH-456 showed average 100 seed weight with an average of 2.8 g and it was statistically at par with Sitara-010 and SGA-1 with an average of 2.79 g and 2.72 g 100 seed weight.

Lowest 100 seed weight was observed in AA-905 with an average of 2.25 g and it was identical with CIM-506 having 2.4 g 100 seed weight. Our results are supported by the findings of Ehsan *et al.* (2012) assessed the growth and yield performance of five cultivars of cotton i.e. FH-115, FH-207, FH-901, FH-113 and MNH-786, during spring 2006. Significant differences in plant height, number of sympodial branches per plant, number of bolls per plant, average boll weight, seed cotton yield, ginning out turn, fiber length and fiber fineness were recorded among the varieties.

Seed cotton yield

Yield of crop varieties varies from variety to variety and area to area. None of variety remained at same production level for all agro-ecological zones. In this study we compared various cotton varieties for yield performance in the agro-ecological conditions of Faisalabad. cotton yield with an average of 2638.8 kg ha^{-1} and 2505.5 kg ha^{-1} which was statistically at par to each. Lowest yield was obtained in SGA-1 with an average of 1799 kg ha^{-1} and it was statistically similar with CIM-598 and AA-703 with an average of 1877 kg ha^{-1} and 1816 kg ha^{-1}.Differenc in seed cotton yield may be due to genetic makeup but it may also be influenced by environment. Variety MNH-886 contained the maximum seed cotton yield due to having good genetic characters. This variety gained the maximum number of plants per m^2 and maximum number of opened bolls per plant as compared to all other varieties. The plant population is basic yield contributing component. Our results are supported by the earlier findings of Jatt *et al*., 2007, who reported a significant difference in seed cotton yield and net return among different cotton varieties.

Table 1 Mean performance of different varieties for various growth and yield related traits in cotton.

	GC	PH	BF	DFB	PP	FPP	FSPP	MBPP	SBPP	BPP	OBPP	UBPP	BW	SPB	BSW	HSW	SCY
AA-905	4.18a	143.5ab	6.00	16.5	4.0a	40.2	14.2a	2.5a	20.bc	26.00d	22.bc	3.5d	3.bc	27.75bc	2.220h	8.170a	2638.8b
MNH-886	4.20a	158.1a	3.25	11.7	4.0a	40.25a	12.5a	2.ab	22.7a	29.abc	26.5a	3.2d	3.0bc	34.25a	2.990a	8.07ab	3111.0a
AA-703	3.55d	127cde	5.500	13.00	3.25ab	32.cde	9cdef	1bc	10.5f	27bcd	20cde	7.250bc	2.80c	26.00bc	2.600cde	7.500e	1816ef
SGA-1	3.21e	149.2ab	5.750	14.00	3.00b	31cde	9def	2.5a	18.25cd	27.00cd	20cde	6.500bc	3.00bc	26.75bc	2.870b	7.110f	1799.9 f
Sitara-009	3.17e	130.1bcd	5.000	13.75	3.00b	32.cde	9def	1.2c	20.5abc	31.0a	19de	9.950a	3.50a	28.50b	2.840ab	7.480e	1994 d
Sitara-010	3.55d	156.8a	4.700	12.75	3.25ab	34.5cd	9cdef	2ab	22.00ab	29.75abc	23.0b	6.750bc	3.00bc	27.00bc	2.790bcd	7.61de	2238.8c
FH-142	3.57d	147.3abc	5.750	14.50	3.30ab	34.7c	11b	1.1c	15.50e	29.75abc	21bcd	8.250 b	3.12b	26.25bc	2.490fg	7.80bc	2161.0c
CIM-506	3.66cd	151.1ab	4.740	14.25	3.50ab	30.50e	9ef	1.2c	12.50f	27.50bcd	19de	9.250ab	3.00bc	26.00c	2.400gh	7.160e	1994.4d
CIM-598	3.72cd	108ef	3.750	13.50	3.55ab	30.7de	9cdef	1.3c	12.00f	25.750d	18e	9.250bc	2.80c	26.50bc	2.500fg	7.010f	1877ef
CIM-602	3.72cd	123.8de	5.250	13.75	3.60ab	32.cde	19bc	1.0c	11.75f	27.00cd	19de	7.250bc	2.90bc	25.25c	2.600def	7.120f	1983.3d
MNH-456	3.78 c	145.4abc	5.750	13.50	3.60ab	37.5ab	11bc	1bc	17.50de	31.00a	21bcd	8.500ab	3.00bc	26.75bc	2.800bc	8.0abc	2266.6c
IUB-222	3.98b	145.4abc	6.000	12.75	3.80ab	34.bcd	8.0f	1.2c	17.50de	30.00ab	22.bc	7.000bc	3.00bc	26.25bc	2.830ab	7.76cd	2505.5b
CIM-599	3.68cd	101.6 f	4.000	14.00	3.51ab	35.5bc	11bc	1.0c	12.25f	25.75d	20cde	5.250cd	2.80c	25.75bc	2.590efg	7.000f	1961de

Table 2 Analysis of variance of different varieties for various growth and yield related traits in cotton.

SOV	DF	GC	PH	BF	DFB	PP	FPP	FSPP	MBPP	SBPP	BPP	OBPP	UBPP	BW	SPB	BSW	HSW	SCY
Replication	3	0.022	153.7	0.326	3.916	0.284	7.794	4.070	0.130	10.17	23.84	0.512	25.66	0.052	8.743	0.048	0.046	0.131
Treatment	12	0.383	1285	3.102	4.599	0.427	43.71	11.01	1.092	72.73	15.46	17.14	19.39	0.127	20.69	0.179	0.700	1.864
Error	36	0.019	226.6	1.576	3.458	0.379	7.308	2.348	0.202	2.645	4.165	2.610	4.132	0.030	3.243	0.017	0.030	0.035

GC=Germination counts (m^{-2}), PH= Plant height at maturity, FPP=Number of flowers per plant, BF= Number of days from bud to flower formation of different cotton varieties, FSPP=Number of flower shed per plant, DFB= Days between flower to boll formation, MBPP=Monopodial branches per plant, SBPP=Sympodial branches per plant, PP=Plant population (m^{-2}) at harvest, Plant height at harvest (cm), BPP=Number of bolls per plant, OBPP=Number of opened bolls plant, UBPP=Number of unopened bolls per plant, BW=Boll weight (g), SPB=Number of seeds per boll, BSW=Boll size width (cm), HSW=100 seed weight(g), SCY=Seed cotton yield (t ha^{-1}).

Authors' contributions

This work was carried out in collaboration between all authors. "Authors Saif-ul-Malook and GM' designed the study, Saif-ul-Malook wrote the first draft of the manuscript. 'Authors 'Ehsanullah, Ejaz Ahmad, Muhammad Sarfaraz, Saeed Ahmad Qaisarani managed the literature search. All authors read and approved the final manuscript."

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