

## A review of production for various Bt and non Bt cotton varieties in Pakistan

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**Abstract:** Cotton is an important fibre cash crop throughout world. It is adversely affected by the attack of various biotic and abiotic factors. Among biotic factor insects/pests damage is highly adverse that caused a great loss of yield and quality of cotton. To develop resistance use of molecular biology has become an important technology for introducing genes of interest in crop plants. Development of genetically modified crops has helped to increase the yield and quality significantly in the developing countries. Bt cotton is grown throughout the world that has showed a significant effect to improve yield and quality. The present review will describe the use of Bt by various workers to evaluate its yield potential. It was concluded by many of the workers that Bt cotton should be used to meet the demand and supply of good yield and quality of cotton.

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### Introduction

Cotton is a natural fibre crop and used in several products and they range from clothing to home furnishings to 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 labour intensive activity and provides supplementary employment and income opportunities to rural farm and non-farm household. Consequently, cotton is continuously in demand due to its usage and is issue to the powers and weaknesses of the overall economy. In the world, Pakistan is the fifth largest producer and 4<sup>th</sup> largest consumer of cotton lint. However, it is the largest exporter of cotton yarn (1.3 million out of 5 million) across the globe. Farmers grow cotton over 3 million hectares and is one of the cash crops of Pakistan that serves as the lifeline of the textile industry in the country. It accounts for 7.0 % of value added in agriculture and 1.5 % to the GDP (Govt. of Pakistan, 2012-13). During 2012-13, the crop was shown on an area of 2879 thousand hectares, 1.6 % more than the last year (2835 thousand hectares). Total production was 13.0 million bales during the period 2012-13 against the target of 14.5 million bales resulted in decline of 10.3 % and decrease of 4.2 % over the preceding year production which was 13.6 million bales (Govt. of Pakistan, 2012-13). Currently, cotton crop is facing a problems which cause reduction in

yield of crop. Non-availability of inputs and their higher costs are among the major constraints towards cotton yield per acre. In addition, scarcity of irrigation water, improper cultivation methodology and unavailability of advanced technologies adversely effects the situation. Cotton is unluckily attacked by many insects as well as diseases. Severe attack of thrips, white fly and Cotton leaf curl virus (CLCuV) adversely affected the production of cotton in past which affected the production and yield per hectare as compared to last year. The thrips, aphid and jassid are the sucking insects of cotton which effect the crop at very early stages of growth, while the white fly adversely affects the crop from initial growth to the maturity of crop. The lepidopterous species effect the plant by chewing the plant leaf and bolls, the armyworm effect the plant leaves and worms (American and pink) effect the bolls drastically. In times, localized monsoon also adversely affects the crops in Punjab and Sindh (Govt. of Pakistan 2012-13).

Varieties play very important role in crop production. Overall performance of Bt varieties was better than conventional varieties. Traditional varieties have low yield potential and insect pest resistance. A good quality seed contains insect pest resistance, drought tolerance and high yield potential. Varieties varied significantly for bolls per unit area and lint percentage (Wang *et al.*, 2004). The varieties

also varied for bollworm resistance and seed cotton yield (Lisheng, 2005, Ali *et al.*, 2005, Sezener *et al.*, 2006). The varieties with Bt (*Bacillus thuringiensis*) gene provide resistance against bollworms thus reduce the cost of pesticides for pest control. Cotton Bt varieties provides an alternative by replacing pesticides with presence of an endogenous toxin. Transgenic Bt cotton can effectively control specific lepidopterous species (Arshad *et al.*, 2009). In general, high yielding varieties are always preferred for cultivation while in case of cotton this strategic become more specific due to high biotic stress and Bt varieties are considered vital for ensuring increased yield of the crop. Biotechnology has provided a large chances to make change in the genome of plants to develop required results (Qamar *et al.*, 2013a,b; Jahangir *et al.*, 2013; Tariq *et al.*, 2014; Ali *et al.*, 2014abc; Ali *et al.*, 2014 and Anwar *et al.*, 2013).

Various Bt varieties are being introduced by different public and private sectors having higher adaptability to environmental conditions and resistance against pests, diseases and considered for higher yield potential.

#### **Importance of Cotton:**

Cotton is grown in about 80 countries but only five of them i.e. China, India, USA, Pakistan and Brazil are accounted for about 81% of the global area and 75% of the world's cotton in 2009-10. In the world, Pakistan is the fifth largest producer, 4<sup>th</sup> largest consumer and the 2<sup>nd</sup> largest exporter of cotton yarn (1.3 million out of 5 million) (Akhtar *et al.*, 2005). The seed meal is a protein-rich by-product useful to feed ruminant livestock, but toxic to non-ruminant animals and human because of the existence in the salt glands of gossypol, a terpenoid aldehyde (Gerasimidis *et al.*, 2007).

#### **Insect Pest resistance**

The development of insects/pests resistant crop varieties has been one of the most successful applications of agricultural biotechnology research to date. The induction and promotion of Bt (*Bacillus thuringiensis*) cotton in Pakistan is one of the most important steps in this direction. Bt. cotton was first introduced in 1996 in the United States and Australia (Traxle, 2006). Bt. cotton has been genetically engineered with the insecticidal gene from the soil bacterium *B. Thuringiensis*. It is assumed that the trans-gene produces a protein that paralyzes the larvae of pest insects, including cotton bollworm and borers and is highly specific to the target organisms (Qaim & Zilberman, 2003; Bennett *et al.*, 2004). The Bt. cotton varieties achieve higher yields than the non-Bt. cotton varieties and better boll retention on the first fruiting branch is an agronomic advantage (Hofs *et al.*, 2006).

#### **BT Cotton**

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). For Bt. cotton, in a developed country such as USA, increase in yield is 10–15% (China, India, USA) Qaim and Zilberman, 2003. Today, biotech cotton occupies almost 60% of the world's cotton area. In India around 85% of the cotton area is under Bt. hybrids. Agronomic performance of Bt. cultivars may vary substantially from their non-Bt. counterparts (Jenkins *et al.*, 1997). Ethridge and Hequet (2000) referred from extensive studies comparing transgenic cotton varieties with their recurrent parents showed that fibre uniformity, length, strength, and elongation showed no significant differences due to transgenic technology. Qaim and Zilberman (2003) reported that 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%.

Brookes and Barfoot (2005) represented the tenth planting season since genetically modified (GM) crops were first grown in 1996. This milestone provides the opportunity to critically assess the impact of this technology on global agriculture. This study examined specific global economic impacts on farm income and environmental impacts of the technology with respect to pesticide usage and greenhouse gas emissions for each of the countries where 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.

Boonrumpun *et al.* (2005) conducted a yield trial involving 19 lines of brown fibre cotton from the Cotton Improvement for Yield and Fibre Quality Project of Kasetsart University. The tested entries included 9 lines from the backcross of Sissamrong 60 (SSR60) with Brown Fibre from the USA, 9 lines from the backcross of SSR60 with Brown Lint from Ivory Coast, one line from the backcross of C118 with Dirty White, and the white cotton 'Dora 11' as a standard. Data were recorded for the following traits:

seed cotton yield, fibre yield, seed weight, ginning outturn, bolls per plant, 100-seed weight, seed cotton per boll, earliness and plant height. The results revealed that the lines from the backcross of SSR60 with Brown Lint from Ivory Coast gave the highest and lowest yields. The line SSR604 × BLI row 641 gave seed cotton yield of 250 kg per rai and the SSR604 × BLI row 638 gave seed cotton yield of 176 kg per rai.

#### **Cotton Breeding**

Ali *et al.* (2005) conducted experiment to evaluate thirteen genotypes of cotton developed through hybridization and mutation breeding techniques during two consecutive years 2002-03-04 on eight locations covering most of the area of Punjab province including Faisalabad, Toba Tek Singh and Jhang. The eight sets of experiments were conducted in the naturally highly saline sodic soils, EC ranges from 7.8-36.1 dS/m, pH=8.1-8.8, SAR=10.1-40.5, saturation percentage 31.3-40.8 and texture sandy, claye, and clay loam. The seed yield data was collected at maturity and stability parameters were computed to know genotypic environmental interaction and varietal performance. The combined analysis of variance showed highly significant variance in case of varieties, locations and environment (Lin). It means that genotypes exhibited different behaviour in different locations/environments due to their different genetic makeup. The behaviour may be cross over (in which significant change in ranking order occurs from one environment to another) or cross over nature (in which case the ranking of genotypes remains constant across environments and the interaction is significant because of change in the magnitude of response) depending upon the ranking order of genotypes performance under different environments. Based on over all seed yield cotton, variety NIAB-999 and CIM-707 produced the highest seed cotton (3.2 t/ha, 3.17t/ha). The lowest seed cotton was noted in S-12 (1.86 t/ha). All the three parameters of stability i.e. overall mean seed yield cotton, regression coefficient and standard deviation to regression provided clear evidence that variety NIAB-999 and CIM-707 produced the maximum stable yield compared to S-12.

Sezener *et al.* (2006) performed experiment for distinction, uniformity and stability tests of the cotton advanced lines were at Nazilli Cotton Research Institute in Aegean Region of Turkey. Studies were conducted in three locations of (Nazilli, Soke and Saraykoy).to evaluate the lint yield and fiber characteristics of 20 genotypes during 2005. The location×genotype interaction was significant for all characters except fiber length and fiber strength. Ozbek 142- S for lint percentage and Carmen for

fiber strength considerably gave the highest values for all locations. The most adaptable genotypes in yields were N/D-121 for Nazilli, Saraykoy, and Ozbek 142. Hofs *et al.* (2006a) recorded boll distribution on the plant under optimal large-scale irrigated farming conditions, the transgenic variety was found to have undisputed advantages by Providing better early plant protection, earlier picking, and nearly 13% higher yields than the non-Bt cotton variety. Hofs *et al.* (2006b) reported that, the boll distribution pattern can explain the origin of yield differences by assessing pest damage and crop management in the field. Better boll retention on the first fruiting branch is an agronomic advantage.

Copur *et al.* (2006) found that seed cotton yields varied between 1884-4322 kg ha<sup>-1</sup>. In all the observed characters, statistically significant differences were determined among cultivars. As a result, Stone Vile 453 was the highest yielding cultivar just ahead of Sayar-314 under irrigated conditions in South Eastern Anatolia. Bt. cotton had been commercialized to protect the losses of fruiting forms by the entomological factors because Bt. cotton had better retention of early formed squares and bolls due to better insect control. Bt. plants were full of developing bolls on the lower canopy, while non-Bt. plants had few squares, flowers, and developing bolls spread intermittently on the canopy. This resulted in yield improvement with Bt. cotton cultivation as shown by earlier studies Hebbbar *et al.* (2007)

Arshad *et al.* (2007) showed findings Based on farm-level-data collected in the main cotton growing district of the Punjab Pakistan, analysis that farmers were very eager to adopt Bt. cotton, but its poor performance in some areas damaged the confidence of the farmers. Results indicated that there were many reasons for the non-adoption of Bt. cotton, but the main ones were the higher irrigation and fertilizer requirements of the Bt. cultivars. Most reasons given by the farmers related to agronomic and management practices, might had been due to a lack of knowledge and information on the genetically modified insect resistance of Bt. cotton. The higher seed cost was also a main factor in the non-adoption of Bt. cotton. The findings of this study may have important implications for the adoption and agronomic practices for insect-resistant Bt. cotton.

#### **Growth and Yield of Cotton**

Khan *et al.* (2007) reported that the cultivar Karishma produced the maximum staple length (29.57mm), boll weight plant<sup>-1</sup> (4.7 g), G.O.T (36.47%) and lint yield (798.9 kg ha<sup>-1</sup>). The cultivar CIM-446 produced the maximum seed index (9.80g). From the results it was concluded that the cultivars Karishma and CIM-1100 have the best performance for parameters under study and hence recommended

as the most suitable commercial cotton cultivars for agro-climatic conditions of D.I. Khan. Ehsan *et al.* (2008) assessed the growth and yield performance of five Bt. cultivars of cotton i.e. FH-115, FH-207, FH-901, FH-113 and MNH-786, by sowing in spring 2006. Significant differences in plant height, sympodial branches per plant, 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 increased sympodial branches, bolls per plant and ginning out turn.

Saleem *et al.* (2008) conducted an experiment to determine all the characters related to growth and yield of crop among the Bt. cultivars (CIM-496, MNH-786 and FH-901) cultivar MNH-786 attained the maximum plant height, bolls per plant, average boll weight, seed index and seed cotton yield per plant and per hectare while, monopodial and sympodial branches per plant were found to be non-significant among the cultivars.

Ahmad *et al.* (2008) carried out an experiment to determine yield contributing traits in five upland cotton cultivars viz. CIM-473, CIM-496, CIM-499, CIM-506 and CIM-707. All the genotypes revealed highly significant differences for monopodial and sympodial 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 per sympodia was having non-significant differences in mean values. All the parameters manifested positive correlation with seed cotton yield except monopodia per plant and first internode length. Cultivar CIM-499 performed better by having improved boll set, early maturity and increased seed cotton yield, while other four cultivars were having statistically at par seed cotton yield.

Sarwar *et al.* (2010) evaluated the Bt. and non-Bt. cotton (*Gossypium hirsutum* L.) in the Department of Agronomy, University of Agriculture Faisalabad, Pakistan. In this study two cotton cultivars MNH-786 (non-Bt) and IR-1524 were included. Both cultivars showed significant differences. Cultivars were compared for different earliness indicators. In this study two cotton cultivars MNH-786 (non-Bt) and IR-1524 (Bt), three nitrogen levels (115, 145 and 175 kg/ha) and two sowing dates (mid March and mid May) were included. He showed that with regards to sowing date, May sowing produced more earliness and less days for floral bud initiation, flowering, first boll split and less days to node above white flower than mid March sowing. Both cultivars showed non-significant differences in earliness related parameters with relatively more earliness in non-Bt cultivar than Bt. cultivar.

Sohu *et al.* (2010) concluded that significant additive genetic variance was detected for monopods per plant, length of first sympod and length of sympod at 50 per cent plant height. Dominance variance was significant for node first monopod and node first sympod, while for rest of the traits, it was highly significant. Epistasis was found to be present only in the inheritance of boll weight. Zhao *et al.* (2010) expressed that in the past scientific research has predicted a decrease in the effectiveness of Bt. cotton due to the rise of secondary and other sucking pests. It is suspected that once the primary pest is brought under control, secondary pests have a chance to emerge due to the lower pesticide applications in Bt. cotton cultivars. This article furnished empirical evidence that farmers in China perceived a substantial increase in secondary pests after the introduction of Bt. cotton. The research was based on a survey of 1,000 randomly selected farm households in five provinces at China. Reduction in pesticide use in Bt. cotton cultivars was significant than that reported in research elsewhere. This is consistent with the hypothesis suggested by recent studies that more pesticide sprayings are needed over time to control emerging secondary pests such as aphids, spider mites, and lygus bugs. Apart from farmers' perceptions of secondary pests, it was also assessed that their basic knowledge of Bt. cotton and perceptions of Bt. cotton in terms of its strengths and shortcomings (e.g., effectiveness, productivity, price, and pesticide use) in comparison with non-transgenic cotton were meagre.

#### **Cotton Response to Fertilizer**

Reddy *et al.* (2010) concluded that A field experiment was carried out to study the fertilizer response studies in Bt. cotton hybrid (Brahma) during kharif 2006. The treatment combination comprised three nitrogen levels, namely, 150, 200 and 250 kg/ha and two levels each of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O, 30 and 60 kg/ha in split plot design with three replications. In Bt. cotton hybrid (Brahma), nitrogen response observed up to 150 kg/ha only (2928 kg/ha) with further increase in N level cotton yields was reduced. Application of 60 kg P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O/ha significantly recorded higher seed cotton yield over 30 kg/ha. Phad *et al.* (2010) reported that Yield potential of approved Bt. cotton hybrids under rainfed condition with an objective to identify suitable Bt. cotton hybrids for Marathwada region. Pooled data revealed that Bt. cotton hybrids viz., MRC 7301 BG II (2095 kg/ha) and Ajeet 11 BG II (1928 kg/ha) recorded highest seed cotton yield with significant superiority over checks, Ankur 651 BG I and NHH 44 (Non-Bt). These hybrids also depicted superior fibre quality. Considering agro-climatic conditions of Marathwada region, Bt. cotton hybrids viz., MRC 7301 BG II,



Ajeet 11 BG II, NCS 145 BG I (Bunny BG I), NCS 954 BG I, NCS 207 BG II, MRC 6301 BG I, RCH 144 BG I, RCH 386 BG I, SP 504 BG I and NCS 929 BG I will prove helpful to farmers to get the better yield. Pal *et al.* (2010) reported that Performance of eight Bt. and their corresponding non-Bt cotton hybrids for sucking pests and yield was studied at Research Farm of CCS Haryana Agricultural University, Hisar Bt. genotypes MRC-6301 (0.91 nymphs/leaf), ANKUR-2226 (0.92 nymphs/leaf) and MRC-6304 (0.93 nymphs/leaf) and non-Bt genotypes ANKUR-2534 (0.88 nymphs/leaf), MRC-6304 (0.91 nymphs/leaf) and RCH-317 (0.88 nymphs/ leaf) harboured less leaf hopper population as compared to others under unprotected conditions. While under protected conditions Bt. genotypes RCH-138 (0.65 nymphs/leaf), RCH-317 (0.75 nymphs/leaf) and non-Bt. genotypes MRC-6304 (0.76 nymphs/leaf) and ANKUR-2534 (0.77 nymphs/leaf) had less population. Regarding whitefly under unprotected conditions, the genotypes RCH-138 Bt. (0.46 adults/leaf), MRC-6301 Bt. (0.47 adults/leaf) and RCH-138 non-Bt. (0.41 adults/leaf) and MRC-6301 non-Bt (0.42 adults/leaf) supported less population. In protected conditions, the entries RCH-138 Bt (0.49 adults/leaf), ANKUR-2534 Bt (0.51 adults/leaf), ANKUR-2534 non-Bt (0.52 adults/leaf) and RCH-134 non-Bt. (0.56 adults/leaf) recorded low population. The yield of seed cotton was higher in Bt. genotypes than their corresponding non-Bt. genotypes. In Bt. genotypes, the yield ranged between 13.71 to 27.84 q/ha with an average of 19.78 q/ha and 13.02 to 26.47 q/ha with an average of 18.64 q/ha under unprotected and protected conditions respectively. In non-Bt genotypes the yield ranged between 4.66 to 12.75 q/ha with an average of 8.50 q/ha; 5.34 to 14.39 q/ha with an average of 10.43 q/ha under unprotected and protected conditions, respectively.

#### Genetics of Cotton

Khan *et al.* (2010) found that genetic potential range of was recorded as seeds locule-1 (6.33 to 6.60), seeds boll-1 (26.10 to 28.47), seed index (8.61 to 9.69 g), lint index (5.35 to 6.05 g), lint % (35.17 to 38.13 %), seed cotton yield (1200 to 2450 kg ha<sup>-1</sup>) and cottonseed oil % (27.52 to 30.15%). High broad sense heritability and selection response were also formulated for seeds boll<sup>-1</sup> (0.67, 0.84), seed index (0.77, 0.47 g), lint index (0.96, 0.33 g), lint % (0.96, 1.66 %), seed cotton yield (0.98, 643.16 kg) and cottonseed oil % (0.87, 1.28 %), respectively. Correlation of yield with other traits was found positive for majority of traits except seeds locule<sup>-1</sup> and cotton seed oil %. Seed cotton yield is our ultimate goal in growing cotton besides lint %. Nazli *et al.* (2010) revealed that Farmers in Pakistan have

been growing cotton that contains the first generation of Bt. gene since 2002. The cultivation of these varieties, although formally unapproved and unregulated, increased rapidly after 2005. In 2007, nearly 60 percent of the cotton area was under BT varieties. This paper examines the economic performance of Bt. cotton in Pakistan based on data collected through a structured questionnaire survey in January-February 2009 in two districts (Bahawalpur and Mirpur Khas). Baig *et al.* (2011) found that great variations exist in the agro ecological conditions within the region in terms of altitude, temperature and soil characteristics etc. Saleem *et al.* (2010) reported that the cultivar MNH 786 showed maximum fiber strength, fineness, uniformity, fiber elongation and minimum GOT, while FH 901 showed maximum GOT against minimum values for other quality traits.

Sudha *et al.* (2011) reported that the performance of different Bt. cotton hybrids were compared in mother and baby trial design to assess the potentiality under researcher managed (mother) Vs farmers growing practices (baby trial) in black soil under rainfed situation. The results indicated that Bunny BG-II Bt. recorded significantly higher seed cotton yield (2385 kg/ha) than JK-99 Bt (1920 kg/ha), Brahma Bt. (1770 kg/ha) and DHH-11 Bt. (1615 kg/ha). RCH - 708 Bt. (37.05 mm) recorded significantly higher 2.5% span length (mm) compared to all other cotton genotypes except MRC - 6918 Bt. (35.90mm). Bundle strength did not differ significantly with the cotton genotypes. In baby trial, the seed cotton yield of RCH-708 Bt, RCH-2 Bt. JK-99 Bt. and Brahma Bt. could not vary significantly between mother and baby trial. Hence, in the present investigation it can be concluded that RCH-708 Bt. RCH-2 Bt, JK-99 Bt and Brahma Bt. genotypes have recorded the maximum potential in both researcher managed (mother) and farmers practice (baby trial). Bibi *et al.* (2011) revealed that highly significant differences in yield and yield parameters were observed among cultivars, nitrogen levels and the interaction of cultivars vs. nitrogen levels for the given parameters. Application of N significantly increased plant height, sympodia per plant, bolls per plant, boll weight and seed cotton yield but various cultivars responded differently in term of percent increase over control. Maximum value of the given parameter for the given cultivar was observed at higher N level of 150 kg N ha<sup>-1</sup>.

#### Bt Vz Non Bt

Arshad and suhail (2011) reported that the efficacy of transgenic Bt. cotton genotypes containing Cry1Ac was investigated against beet armyworm, *Spodoptera exigua* (Hubner) in the field and laboratory experiments. The results showed that

*S. exigua* larvae had low susceptibility to Bt. cotton. No significant differences in larval densities between transgenic Bt. and conventional cotton under unsprayed conditions were observed and insecticides were used to control the population in sprayed Bt. and non-Bt. cotton plots. The laboratory bioassays showed no significant impacts of Bt. cotton plant structures (leaves and flower-bolls) on the larval mortality as compared to conventional non-Bt cotton. However, the results indicated sub lethal effects with significant differences in larval development time and pupal weight.

Hosmath *et al.* (2011) the effect of organic and inorganic nutrient sources studied on Bt. cotton (MECH-162) under irrigated and rainfed conditions. The experiment was laid out in split plot design, replicated thrice on vertisol under rainfed (during 2002-03 and 2004-05) and irrigated (during 2003-04 and 2004-05) conditions in the Agricultural College Farm, Bijapur and farmers field, respectively. The year 2003-04 was drought year. Treatments comprised of three main plots *viz.*, Bt. (MECH-162), non Bt. (MECH-162) and DHH-11 and seven sub plots *viz.*, recommended dose of fertilizer, farm yard manure, vermicompost, green manure crops and recommended dose of fertilizer in conjunction with farm yard manure, vermicompost, green manure crops. Green manure crop *Crotalaria juncea* was incorporated *in situ*. Pooled analysis indicated that under rain-fed and irrigated conditions, Bt. cotton out yielded DHH-11 and non Bt. Of the nutrient sources, significantly higher seed cotton yields (1066.22 kg/ha and 1806.28 kg/ha, respectively under rain-fed and irrigated eco-systems) and net return (Rs.14101/- and Rs. 31263, respectively under rain-fed and irrigated eco-systems) were obtained in recommended dose of fertilizer + farm yard manure compared to other nutrient sources. They recommended for general cultivation in arid to semi-arid tropics. No doubt Ahsan *et al.* (2011) identified the superior genotype with comparative growth and yield performance of four cotton cultivars namely, CIM-496, BH-162, VH-144 and Bt. 121. They concluded that Bt-121 is the most suitable cotton variety for good quality higher seed BH-162 and CIM-496 yielded fiber with better staple length and fineness but unfortunately, agronomic performance of these cultivars was unacceptable which was likely due to several factors such as, susceptibility to virus infection, lack of ability to exploit a long season environment while tolerating intermittent periods of heat and drought stress. There is also a dire need to screen more genotypes and to verify their usefulness for cultivation in broader agro-ecological zones of the world as proved.

Ashok kumar (2011) conducted experiment to find out the morphological diversity and performance of yield component traits, yield and a fibre quality traits eleven genotypes (four *G. hirsutum* cultivars *viz.*, MCU-5, MCU-12, SURABHI and SVPR-2 and seven *G. hirsutum* genetic accessions *viz.*, F-776, F-1861, SOCC-11, SOCC-17, TCH-1641, TCH-1644 and TCH-1646) during kharif 2005. The cultivar MCU-12 produced the maximum yield (95.33 gm/plant) due to more sympodia (24.17/plant), bolls (25.17/plant), boll weight (4.20 g), ginning outturn (35.43 %), lint index (6.12 g) and seed index (10.44 g). Among the eleven genetic accessions, most of them expressed lowest value in yield and quality traits except SOCC-17 superior in micronaire (4.60µg/inch-1), SOCC-11 superior in fibre elongation (9.60 %) and TCH 1641 had high sympodia (28.97/plant) and seeds per boll (32). The maximum genotypes were included in cluster I (four genotypes) and the minimum number in cluster II having only one genotype. The cluster III & IV each had three genotypes. In future, greater morphological diversity shown among the genotypes can be used to generate potential and promising hybrids.

Mari *et al.* (2011) concluded that the overall calculated average results for all three locations revealed that HoTh-409 remained superior by producing maximum average cane yield against check variety Thatta-10. However, the variety HoTh-420 displayed almost equal performance for average cane yield against the check variety. Likewise, the rest of the varieties like HoTh-438, HoTh-432 and HoTh-401 exhibited comparable performance with regard to average cane yield but could not surpass the Thatta- 10. Sabir *et al.* (2011) reported that area under Bt. cotton was increasing in the recent past. Empirical results revealed that Bt. cotton area was increasing firstly at the expense of wheat area and sugarcane area secondly. In cotton zone 8.15% and in the central zone 6.5% wheat area undergone to Bt. cotton. Similarly, 4.5% area of sugar cane from cotton zone and 1.5% in central zone shifted to Bt. cotton. Out of the total sampled farmers, 70% wheat growers and 28% sugarcane growers showed their interest to shift some areas from their respective crops to Bt. cotton. Thus, there were the chances that textile sector will groom but in future, it will create food insecurity problem.

#### **Effect of sowing time**

Kakar *et al.* (2012) reported that on an average basis the cultivar Sohni exhibited maximum seed cotton yield (3096) kg ha<sup>-1</sup> followed by cultivar NIA-77 (2881) kg ha<sup>-1</sup> and Malmal (2878) kg ha<sup>-1</sup>. The sowing date, May exhibited significantly maximum effect on plant height, sympodial branches, bolls plant<sup>-1</sup>, seed cotton yield, GOT %, seed index, oil

content and low micronaire value followed by May 25 sowing date. Seed cotton yield and other characters were adversely affected by early (April 25) and late (June 10) sowing. Thus, the cultivation of cultivar Sohni, NIA-77 and Malmal on May 10 showed best response in yield of seed cotton. It was concluded that May 10 sowing is the most appropriate sowing time for these cultivars under agro-climatic condition of Tandojam, Pakistan. Mehmood *et al.* (2012) carried out a survey to check the impact of Bt. cotton varieties on productivity in district Vehari of Punjab province. Primary data was collected from 6 villages of Vehari district. From each village, ten respondents each from Bt. cotton and conventional cotton growers were selected randomly. Thus the sample size for the present study was 120 respondents. The data was analyzed by using well renowned Cobb-Douglas Production Function (CDPF). Study revealed that Bt. Cotton varieties had significant and positive impact on productivity.

Ullah *et al.* (2012) found that the information on genetic diversity among Bt. cotton varieties is lacking. We evaluated genetic divergence among 19 Bt. cotton genotypes using simple sequence repeat (SSR) markers. Thirty-seven of 104 surveyed primers were found informative. Fifty-two primers selected on the basis of reported intra-*hirsutum* polymorphism in a cotton marker database showed a high degree of polymorphism, 56% compared to 13% for randomly selected primers. A total of 177 loci were amplified, with an average of 1.57 loci per primer, generating 38 markers. The amplicons ranged in size from 98 to 256 bp. The genetic similarities among the 19 genotypes ranged from 0.902 to 0.982, with an average of 0.947, revealing a lack of diversity.

Feiyua *et al.* (2012) conducted field experiment to compare the mean performance of yield components and morphological traits among Bt. cotton hybrids with diverse yield level, and to evaluate their relationships of the lint yield. Thirty insect-resistant transgenic cotton crosses were divided into three types (high, medium, low) based on lint yield per hectare by squared Euclidean distance and Ward linkage. The results showed there was statistically significant difference in bolls per plant and lint percentage for the three types, which increased with increasing lint yield. The Pearson's correlation coefficients between them and lint yield were the highest. The direct path coefficient was the maximum for bolls per plant to lint yield. No statistically significant difference was found for the ten morphological traits in the three types. The direct path coefficient of fruiting sites per sympodia to lint yield was positive and significant at 0.05 levels. The minimum direct path coefficient to lint yield was due to height of the first fruiting branch.

Kathage and Qaim (2012) revealed that despite widespread adoption of genetically modified crops in many countries, heated controversies about their advantages and disadvantages continue. Especially for developing countries, there are concerns that genetically modified crops fail to benefit smallholder farmers and contribute to social and economic hardship. Many economic studies contradict this view, but most of them look at short-term impacts only, so that uncertainty about longer-term effects prevails. We address this shortcoming by analyzing economic impacts and impact dynamics of Bt. cotton in India. Building on unique panel data collected between 2002 and 2008, and controlling for non random selection base in technology adoption, we show that Bt. has caused a 24% increase in cotton yield per acre through reduced pest damage and a 50% gain in cotton profit among smallholders. These benefits are stable; there are even indications that they have increased over time. We further show that Bt. cotton adoption has raised consumption expenditures, a common measure of household living standard, by 18% during the 2006–2008. We conclude that Bt. has created large and sustainable benefits, which contribute to positive economic and social development in India.

Sarwar *et al.* (2012) reported that Bt. and non-Bt. cotton (*Gossypium hirsutum* L.) reported that the cultivars MNH-786 (non-Bt.) and IR-1524 (Bt.), three nitrogen levels (115, 145 and 175 kg/ha) and two sowing dates (mid March and mid May) were included. Layout system was RCBD with split split plot arrangement in a plot measuring 6.0 x 4.5 m. Nitrogen levels and sowing dates showed significant effect on earliness related parameters. Nitrogen level of 115 kg per hectare showed more earliness index (59.2) than 145 kg (51.1) and 175 kg N (48.5). Nitrogen level of 115 kg also took less days for floral bud initiation (30.5), flowering (50.1), first boll split (93.1) and also less days to node above white flower (95.9). With regards to sowing date, May sowing produced more earliness index (57.5) and less days for floral bud initiation (30.5), flowering (49.6), first boll split (91.1) and less days to node above white flower (99.4) than mid March sowing. Both cultivars showed non significant differences in earliness related parameters with relatively more earliness in non-Bt. cultivar than Bt. cultivar. The study concludes that 115 kg N per hectare and mid May sowing produced early maturity in cotton.

Efe *et al.* (2013) found that the highest sympodial number was taken from Agdas-3 variety (13.79), the highest boll per plant was taken from Agdas-17 (15.41) and the highest seed cotton weight per boll was taken from Agdas-7 (5.54 g). All Agdas varieties had less ginning outturn than local standard

varieties. The highest seed cotton yield was obtained from Agdas-17 (3654.2 kg ha<sup>-1</sup>), followed by Agdas-3 (3593.8 kg ha<sup>-1</sup>). All Agdas varieties had more seed cotton yield than standards except Agdas-7. Among Azerbaijan varieties, Agdas-3 was the earliest maturing variety with 81.3% of first harvest ratio. All investigated varieties were similar to each other in fiber technological properties. In conclusion, it can be said that among Azerbaijan varieties, Agdas-17 and Agdas-3 had higher seed cotton yield than local standard varieties, and they are the most hopeful varieties for Southeast Anatolian Region. Abbas *et al.*, (2013) and Abbas *et al.*, (2014) reported better performance of Bt cotton varieties as compare to non Bt for yield and quality traits.

### Conclusion

It was concluded from all above discussion that the use of Bt may be helpful to improve yield and quality of cotton seed and fibre.

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