CAUSES OF

LOW YIELD OF COTTON

DURING COTTON CROP SEASON 2015

REPORT OF COMMITTEE CONSTITUTED BY

AGRICULTURE DEPARTMENT

University of Agriculture, Faisalabad

SUMMARY

A committee of experts was constituted by Government of the Punjab to find out causes of the low yield of cotton in the Punjab during the crop season 2015-16. The committee scrupulously investigated the crop situation and compared meteorological and agronomic factors, which could have played a role in the reduction of crop size both in terms of the average yield and production based on data obtained from veritable resources, like Crop Reporting Services (CRS) (Punjab) and Pakistan Cotton Ginners Association as well as through field surveys and meteorological studies.

Cotton arrival, as on 1st December 2015, indicates 5.103 million bales compared to 8.498 million bales during the corresponding period in 2014, reflecting a diminution of 40% in Punjab alone. Sindh province produced 3.529 million bales during the current year as compared to last year's arrival of 3.647 million bales on the corresponding dates showing a reduction of 3.26%, though. Given that even, there was a country-wide decline of 29% in the production of cotton over the last year (2014). The provisional estimate of CRS, Punjab, however, stands at an average yield of 17.12 maunds / acre during 2015 compared to 23.02 maunds / acre during 2014, showing a decline of 34%. In contrast, production in the year 2015 is estimated to be 7.432 million bales in comparability to 10.277 million bales during 2014; precipitating a pronounced attenuation of 38.3%, while area under cotton is reported to have shown 2.8% decline in the year 2015.

The committee agreed upon 10 major categories of biotic and abiotic factors casting this gloomy picture. The analyses compiled in this report have been drawn through comparison of the consecutive years 2014 and 2015 vis-à-vis looking at the chronological charting of cotton production from 1991-92 and onwards. The comparison of last two years supports the departmental view of unusual weather conditions as specified in the Table 1. However, the long-term analysis reveals that the cotton production and productivity in the country remained stagnant, and the multifarious causes evinced thereby extend much beyond mere climate change. The climate change, regrettably, has become an unavoidable reality which would remain a bigger challenge than any other in regards to breaking the stagnation, no matter how good preparations are made to cope with the future episodes of climate variations.

Table 1: Effect of various factors on cotton crop decline during 2015

Sr. No.	Parameters	Effects
1	Seed authenticity (quality for plant population)	+++++
2	Seed cotton price	++++
3	Climate change (rainfall (++++) temperature (+++)	++++
4	Insects Whitefly (++++), Pink bollworm (++++), Armyworm (+++), Jassid (+++)	++++
5	Weeds	++++
6	Bt toxin	++++
7	N-Fertilizer	+++
8	Insecticide spray (No.)	+++
9	Planting Time	++
10	Diseases (CLCuV)	+

+ Magnitude of effect out of five, +++++ means major effects

Table 1 reveals that seed quality is a major issue. Since authentic data about ecological adaptability of approved varieties is not available in the country, greater heterogeneity in plant population seems to have occurred in the field. The certified seed provision being very low (about 46% of the total required; 3% Punjab Seed Corporation (PSC) and 43% registered companies) creates doubts about the genuineness of varieties sold in the market. Despite increased availability of certified seed from 27% (2014) to 35% (2015), the results yet not vindicate optimism that creates doubts about the spread of certified seed.

Prevailing price of seed cotton during August and September 2015 remained very low Rs. 1900-2300 maunds^{-1} at the arrival of seed cotton from Sindh Province. The farmer left crop to suffer and finally harvested 8-10 maunds acre^{-1}. Less fertilizer and pesticide usage than the previous year due to consistent rains and low prices of seed cotton was evident.

Climatic change particularly the arrival of early monsoon in the months of June and July and abnormal variations in temperature had an adverse effect on the growth and development of the crop. Consistent and high rainfalls (>300 mm) during the months of June, July, August and September brought crop under severe stress.

Whitefly, pink bollworm, armyworm and jassid were the most damaging insect pests. Spraying against these pests was not admissible in the rainy period of 2015. Expression of Bt gene and its toxicity is still a question following introduction of Bt cotton for more than a decade. Toxin level in the field remained lower than the threshold level. Monsanto's Bollgard-I is reported to impart resistance against American and spotted bollworms, along with the Pink Bollworm (http://www.monsanto.com/improvingagriculture/pages/history-of-bollgard-cotton.aspx) but resistance against the latter is doubtful according to reports from India and China. CLCuV caused very little damage in different districts.

The committee, after several deliberations and discussions regarding reasons of low yield during the crop season of 2015, formulated a comprehensive strategy for next crop of 2016.

The main features of the strategy are as under:

1) Ensuring the availability of certified seed (i.e., Implementation and Enforcement of Seed Act)
2) Introduction of 2nd and 3rd generation Bt technology along with glyphosate tolerant genes
3) Efficient Pest Management Strategies: Reduction of pink bollworm population by sex pheromone, PB Robes and light traps in the affected areas; Removal of standing cotton sticks (in the field) before January; Cleaning and burying of cotton debris from the ginning factories; and Control of sucking pests on spring crops.
4) Promulgation of support price before commencement of cotton crop season.
5) Media campaigns to promote proper technological interventions.
6) Seeking ways to discourage and prevent early planting.
7) Procuring intelligent weather forecast, maintaining close coordination with Meteorological Department.
8) Enactment of Plant Breeder Rights.
9) Constitution of a permanent oversight committee.

BACKGROUND OF THE REPORT

Pakistan is the 4th largest producer and 5th largest consumer of cotton. About 1.3 million farmers (out of 5 million) cultivate cotton on an area of 3 million hectares, covering 15% of the cultivated area in the country. Cotton and cotton products account for 1.6% of the GDP and 55 % of the foreign exchange earnings of the country.

Cotton production supports Pakistan's largest industrial textile sector, comprising of 400 textile mills, 7 million spindles, 27000 and 25000 power looms in the mill and non-mill sector, respectively, 700 knitwear units, 4000 garment units, nearly1000 ginners and 5000 oil expellers.

The yield, area and production trend of cotton has shown linear increase from 1947 to 2015 (Fig. 1), but has been static since 1991-92 (Fig 2). The production target of 10.5 million bales from Punjab for the year 2015 could not be achieved due to ten biotic and abiotic factors. Therefore, the production estimate has been reduced to 7.4 million bales in Punjab. The economy of Punjab is highly sensitive to reduction in cotton production. Information collected from various farmers regarding seed cotton yield during 2014 and 2015 confirms the reduction in cotton productivity in year 2015. The yield of different varieties/advanced lines, recorded at various research stations situated in cotton zones, also confirms the above setback in cotton produce. Contrary to claims neither high yield record of transgenic cotton (reported elsewhere from 1990-onwards) to herald the era of popularization of Bt cotton nor any significant improvement in the yield in Pakistan has been observed (Fig. 2).

Fig-1: Yield, Area, and Production of Cotton in Punjab Since 1947 (5 year avg.)

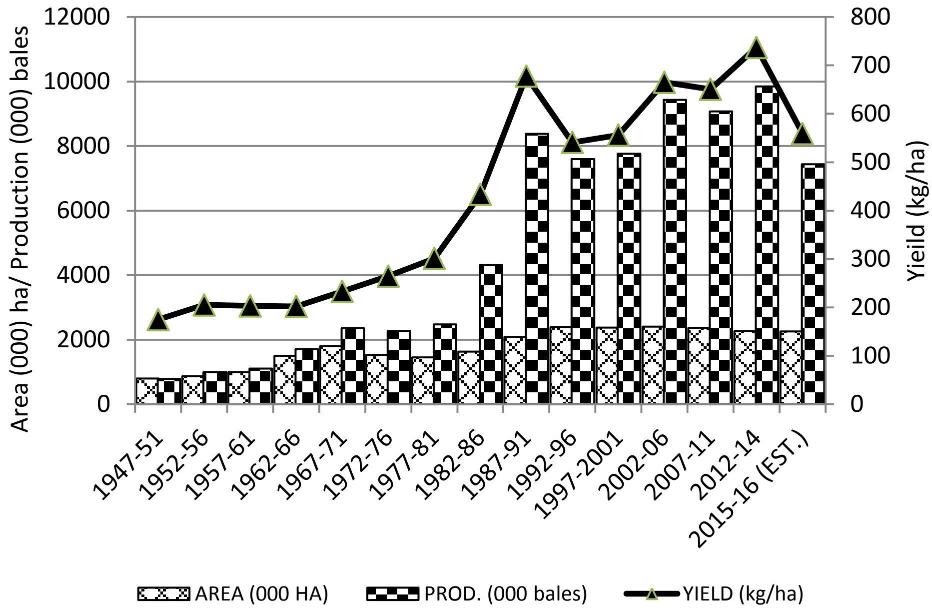
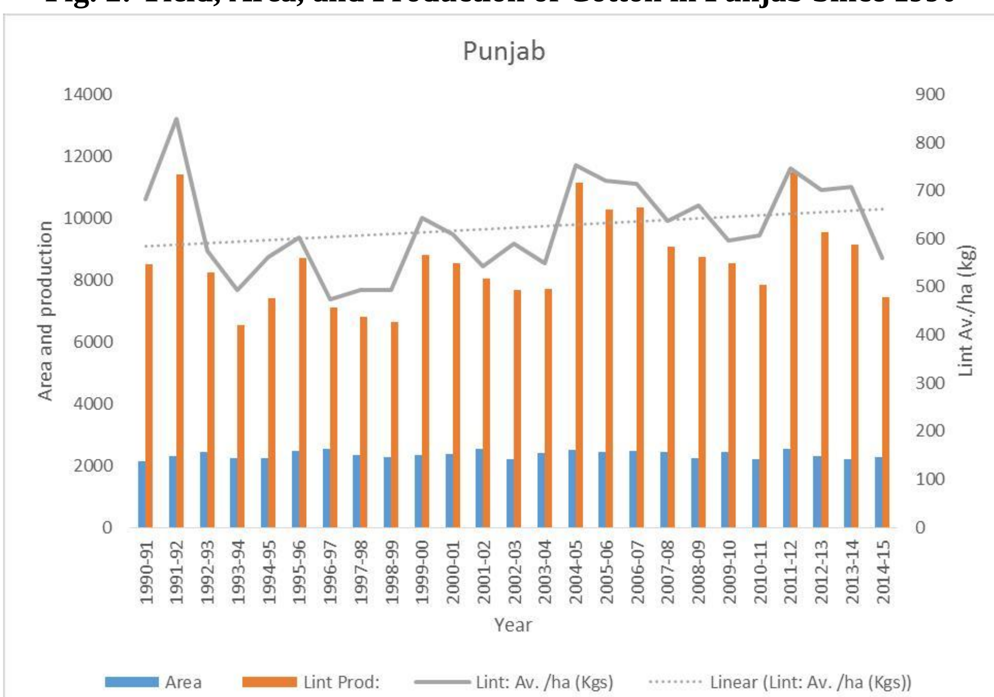


Fig. 2: Yield, Area, and Production of Cotton in Punjab Since 1990



Sensing the gravity of the situation, Government of Punjab vide letter No. 5974-81/10 (3)/P&EC/15, dated 11/11/2015, constituted a committee comprising the following members to identify the factors responsible for low production:

1.	Dr. Iqrar Ahmad Khan, Vice Chancellor, UAF	(Convener)
2.	Managing Director, Punjab Seed Corporation	(Member)
3.	Director General Agriculture (PW&QC), Punjab, Lahore	(Member)
4.	Director General Agriculture (Research), Faisalabad	(Member)
5.	Director, Central Cotton Research Institute, Multan	(Member)
6.	Chief Executive, Punjab Agriculture Research Board, Lahore	(Member/ Secretary)

The TORs of the committee are as follows:

1) Identify the causes of low yield of cotton during current season.

2) Examine the expression of Bt gene in the present array of Bt varieties.

3) Formulate strategy to protect the forthcoming crop from hazards of insect/pest attack.

4) The committee shall submit its report in a week's time, positively.

5) The committee may Co-opt any other member.

The first meeting of the committee of experts was held on 12-11-2015 at 3:00 PM, under the chairmanship of the Vice Chancellor, University of Agriculture, Faisalabad. Chief Executive PARB, Director General Agriculture (Research), Director General (PW&QC), Director General Agriculture (Extension), Director CRS, Director Central Cotton Research Institute, Director Cotton Research Institute, and the senior faculty from the University of Agriculture, Faisalabad, deliberated over a plethora of views regarding the debacle of cotton crop in 2015.

The committee again met on 15-11-2015 at 3:00 PM in the committee room, under chairmanship of the Vice Chancellor, University of Agriculture, Faisalabad to ponder upon the role of various factors influencing cotton crop. The final meeting of the committee was held on 6-1-2016. After discussion and deliberations, the current report was finalized.

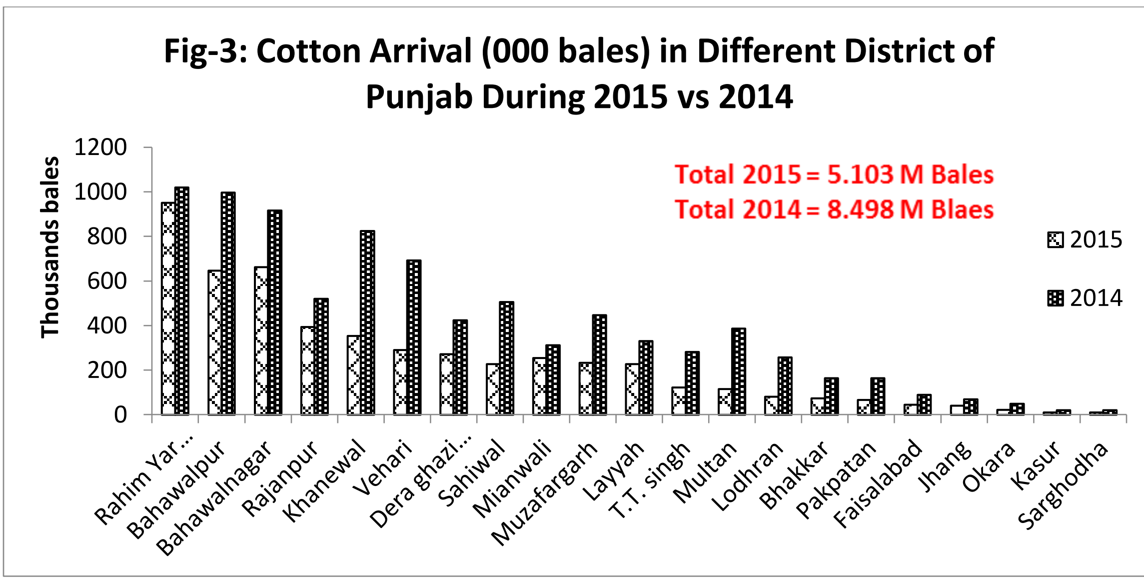
COTTON CROP SITUATION

Cotton Production

There are two sources to draw information regarding the area and production of cotton: the Directorate of CRS, Lahore, working at the provincial level; and Pakistan Cotton Ginning Association (PCGA), the consultative and regulatory body at national level. The estimates of both sources are discussed as under.

Pakistan Cotton Ginner's Association (PCGA)

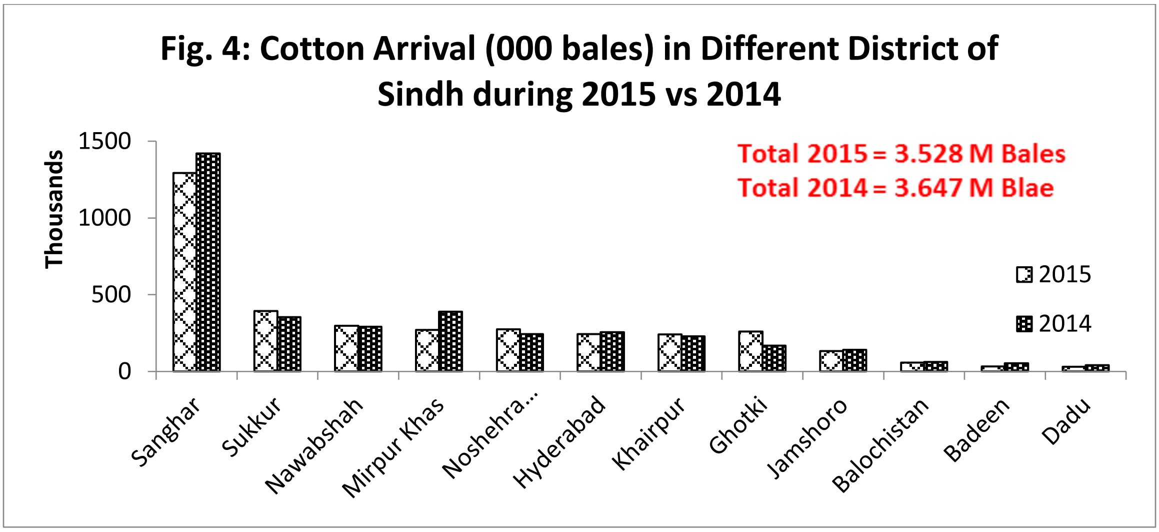
Cotton arrival on 01st December 2015 in Punjab and Sindh are shown in the figures 3 and 4.



(Source: PCGA arrival report as on Dec 01, 2015)

Fig. 3 shows substantial decline (40 %) in production in Punjab during 2015 (PCGA arrival report as on Dec 01, 2015) over the last year, 2014.

Cotton arrival in Sindh on 1st December of last two years is given below:

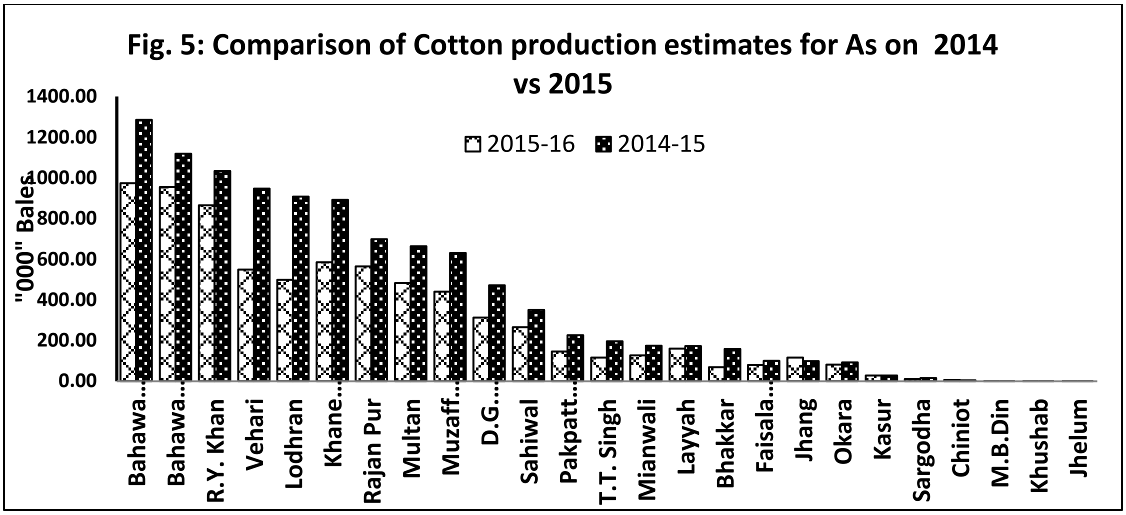


(Source: PCGA arrival report as on Dec 01, 2015)

Fig. 4 shows cotton arrival on 1st December, 2015 in Sindh which was 3.3% less in proportion than that of 2014. Therefore, the issue of yield decline is more pronounced in Punjab than Sindh province.

Production Estimates from Directorate of Crop Reporting Services

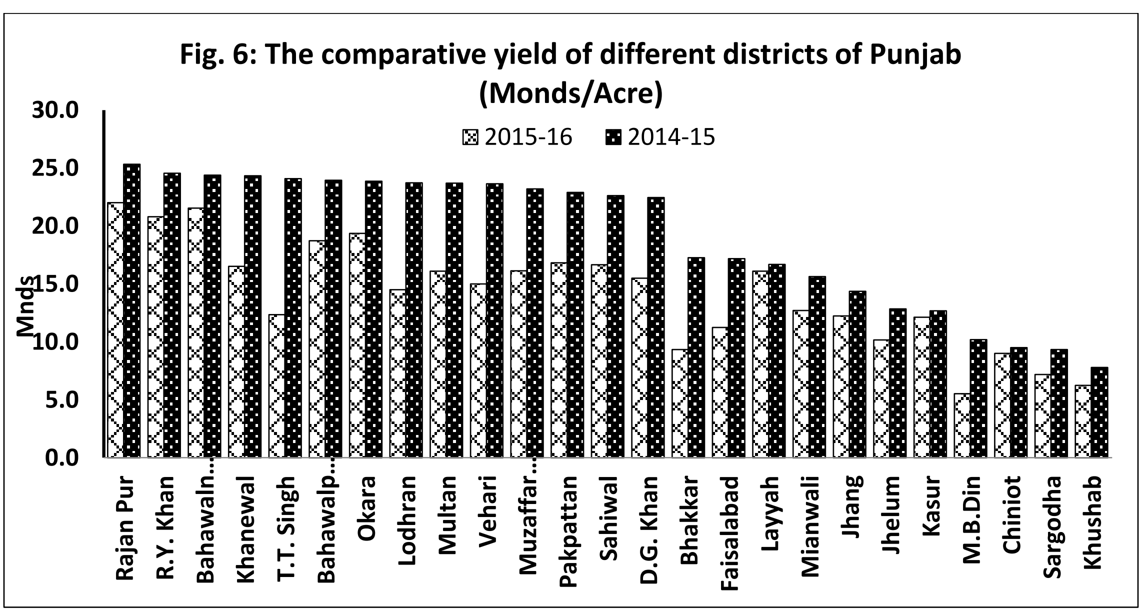
The comparison of cotton production estimates for Punjab province provided by the Directorate of CRS, Lahore for the years 2014 and 2015 is shown in Figs. 5 and 6. The Directorate reported more than 27.7% reduction in cotton production in Punjab (Fig. 5). The reduction was more pronounced in Multan division as compared to Bahawalpur division.



(Source: Directorate of Crop Reporting Services, Lahore, 2015)

Yield of Cotton Crop in Punjab

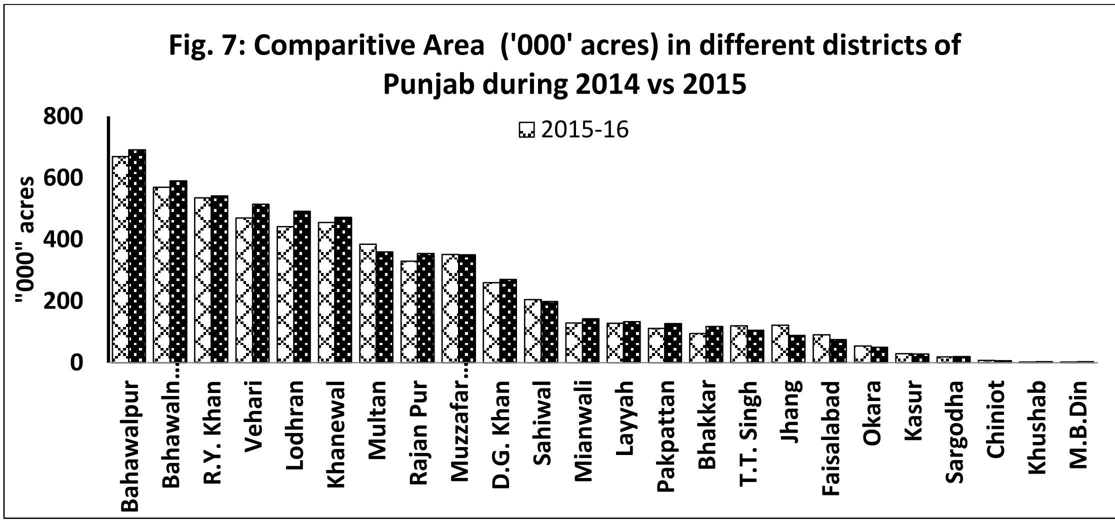
Yield comparison among different districts of Punjab from provisional estimates by Directorate of Crop Reporting Services (CRS), Lahore for the years 2014 versus 2015 is given in Fig. 6. The production target in the year 2015 has been brought down in comparison to 2014.



(Source: Directorate of Crop Reporting Services, Punjab 2015)

Area under cotton crop in Punjab 2015 vs 2014

The comparative area as reported by Directorate of Crop Reporting Services is given in Fig. 7. There was a slight reduction (2.8%) in area sown under cotton during 2015 as compared to 2014.



(Source: Directorate of Crop Reporting Services, Punjab 2015)

The above comparative data show that there is a slight reduction (2.8%) in area sown under cotton during 2015 as compared to 2014.

Crop mapping data

Data of plant height, bolls/plant, boll weight and seed cotton yield of Provincial Coordinated Cotton Trial (PCCT), in the years 2014 and 2015, are depicted in Table 2, clearly showing that plant height, bolls/plant, boll weight and seed cotton yield (kg/ha) were significantly lower during 2015.

Table 2: Average plant mapping of 3 locations (CRS: Multan, Vehari and R.Y Khan)

Sets/varieties	Plant Height (cm)		Bolls/ Plant		Boll Weight (g)		Yield (Kg/ha)	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
PCCT Set-A (24 entries)	115	90	23	19	3.3	2.5	2428	1323
PCCT Set-B (21 entries)	122	95	26	20	3.1	2.7	2116	1464
PCCT Set-Non Bt	122	109	25	20	2.8	2.8	1836	1196
NCVT	154	91	37	20	2.8	2.63	2039	693
FH-142	183	125	24	15	3.4	3.2	1515	642
MNH-886	178	118	23	13	3.5	3.3	1330	532
Average	146	105	26	18	3.2	2.8	1877	975

(Source: Director CRI Fsd.)

It is hard to believe that the reduction in plant height would have occurred due to the rain alone and in the wake of low fruiting where the energy should have been diverted to vegetative growth. A plant with normal "genetics" having no fruits should show excessive vegetative growth (height).

TOR-1

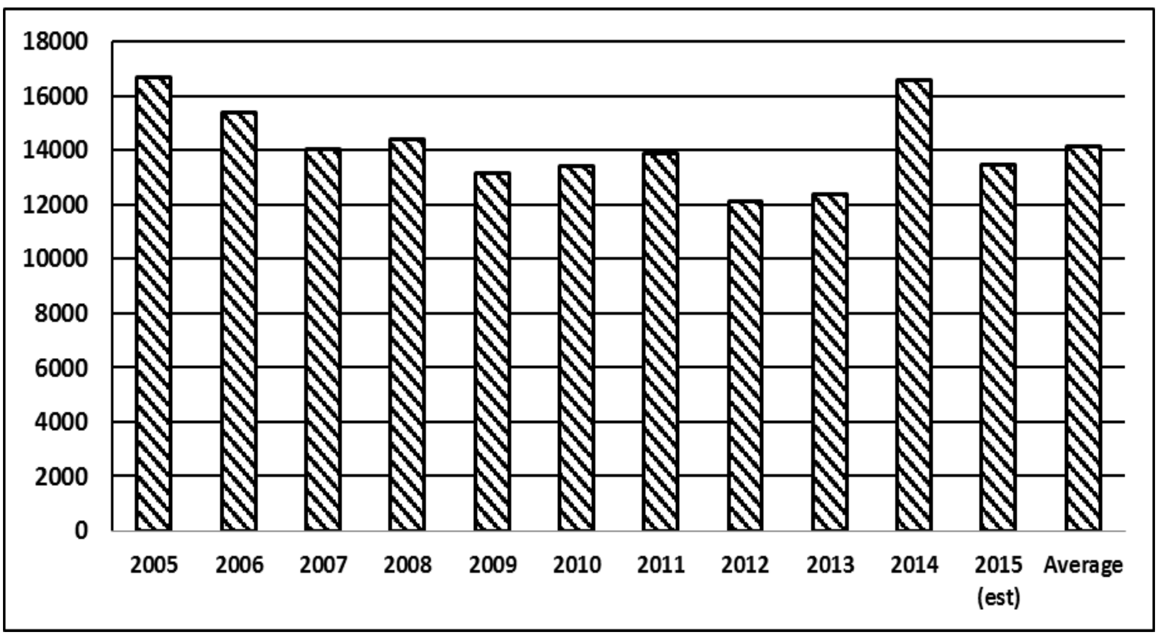
IDENTIFICATION OF THE CAUSES OF LOW YIELD OF COTTON

DURING CURRENT SEASON

Seed Quality/Plant Population

Seed quality has emerged as a major determinant of low cotton yield since it is correlated with plant population as well as with the adoption of yield enhancing parameters, affecting thereby the total output / yield. Fig. 8 shows that plant population was much lower during 2015 as compared to 2014. There is apparently poor germination due to rains in some places of cotton areas during planting times. The gaps between cotton plants were occupied by the weeds which negatively affected the plant growth. *Looking at plant population of 2015 and comparing the same with that of many previous years revealed that we have had high production with similar plant population in the past.*

Fig. 8. Plant population data of various years is presented below:



Seed authentication, availability and viability:

The availability and sale configurations of certified seed are given in Tables 3-4 during 2015-16. Only 46% of the total required seed was provided collectively by the Punjab

Seed Corporation and the private sector (over 700 registered seed companies), individually sharing 3% and 43% to this contribution, respectively. The remaining 54% seed was sold by unauthenticated venders.

According to the claims of Crop Reporting Service (CRS), 86% area is under approved varieties, however PSC and other registered companies contribute only 46% of the total requirement (Tables 3 and 4) *which is a serious contradiction. Independent surveys have revealed that the varietal complex is full of malpractices linked with the unruly seed industry. The implementation of amended seed act and promulgation of Plant Breeder's rights are perhaps the most urgently needed actions.*

Table 3. Cotton seed provided to the farmers for 2015-16 (000 kg)

Sector	**Seed**	**% contribution**
Public	**1548**	**3**
Private	**18966**	**43**
TOTAL	**20514**	**46**
Unauthentic Source		**54%**

(Source: DG FSC & RD)

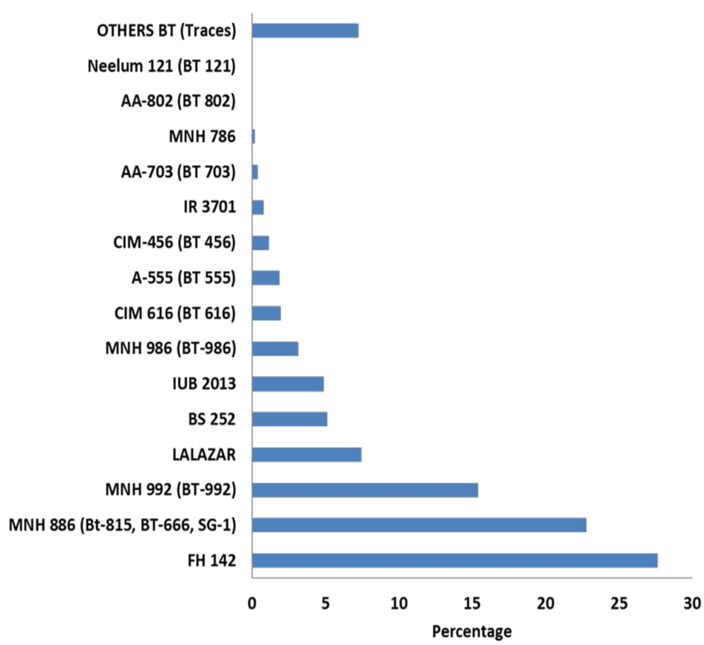
Table 4. Status of cotton varieties cultivation in Punjab

S#	**Varieties**	**Area (Acres)**	**%age**	**Approved/Unapproved**
1	FH 142	20370	27.62	Approved
2	MNH 886	14129	19.16	Approved
3	BT 992/MNH 992	11343	15.38	Un-approved
4	LALA ZAR	5491	7.45	Unapproved*
5	BS 252	3765	5.11	Un-approved
6	IUB 2013	3584	4.86	Un-approved*
7	BT 986/ MNH 986	2336	3.17	Un-approved
8	BT 666/MNH-886	1629	2.21	Approved

9	BT 616/ CIM 616	1443	1.96	Approved
10	BT 555/A-555	1361	1.85	Approved
11	BT 456/CIM-456	846	1.15	Approved
12	BT 815/MNH-886	742	1.01	Approved
13	IR 3701	589	0.80	Approved
14	SG 1/MNH-886	314	0.43	Approved
15	BT 703/AA-703	270	0.37	Approved
16	MNH 786	147	0.20	Approved
17	BT 802/AA-802	23	0.03	Approved
18	BT 121/ Neelum 121	5	0.01	Approved
19	Others Bt (Traces)	5354	7.26	Unknown
	Total	73741	100.00	

***conditionally approved:**

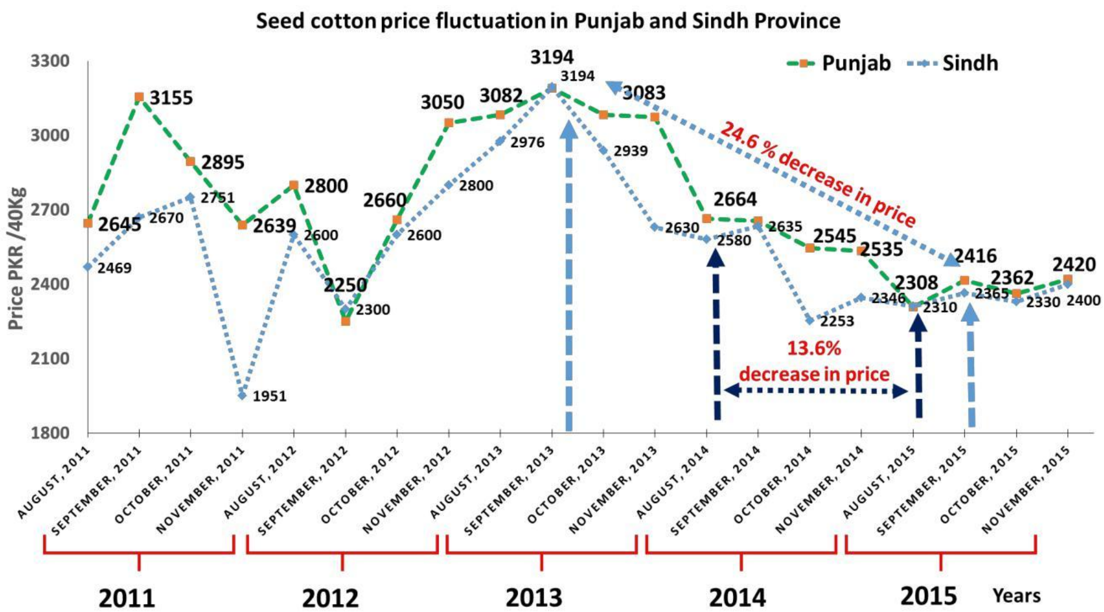
Fig-9 Area wise percentage of varieties in Punjab



Seed Cotton Price

Most of the farmers could not comply with the timely recommendations from Pest Warning and Agriculture Extension Department of the Punjab due to many factors, especially those related to climate change and low cotton prices in early stage. The prevailing prices of seed cotton during August and September 2015-16 remained nearly Rs. 1900-2300 / maund at the arrival of seed cotton in the markets from Sindh Province (Fig. 10), and that is extremely low considering the cost of production (Rs. 1600-2000 / maund). The cotton farmers lost hope and did not perform the required agronomic practices. They left the crop to its fate and got in general 8-10 maund / acre. However, under such situations the farmers who worked hard, fought with the natural calamities, performed timely interventions, were able to save the crop by obtaining 20-25 maund / acre.

Fig. 10. Comparison of seed cotton price during critical months for the last five years (Punjab and Sindh)



Climate change/weather situation 2015 versus 2014

A. Agriculture Departments

The impact of weather on cotton production was a major factor which affected the production of cotton as the prolonged duration of rainy days and total precipitation during July, August and September, 2015 caused the following.

i. Less pesticide sprays

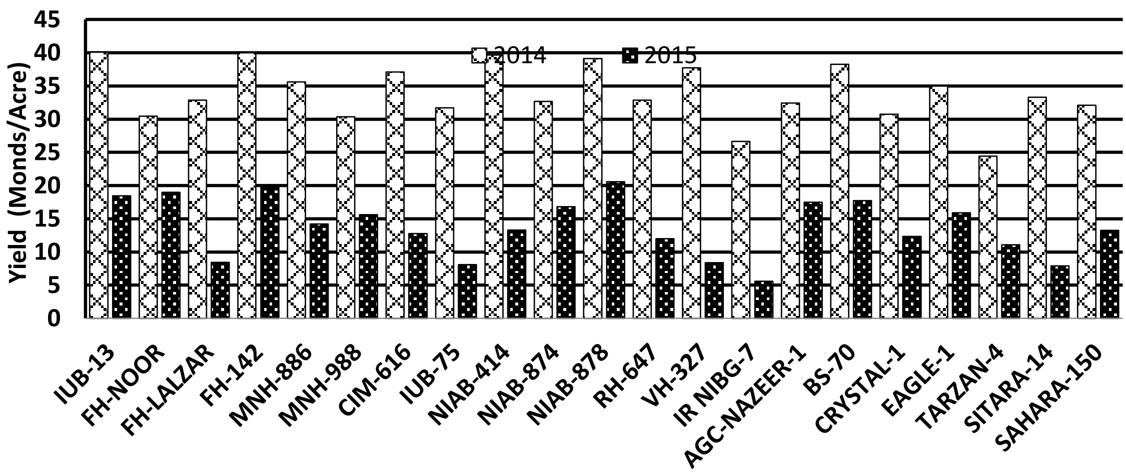
ii. Washing of pesticides

iii. High weed population which adversely affected plant growth and made picking difficult.

iv. Impaired pollination caused reduction in seed setting, flower shedding and lessened boll weight.

At Punjab Seed Corporation, Khanewal under similar management conditions, per acre yields of seed cotton of different varieties between 2014 and 2015 were compared. The trend of reduction in yield of different varieties is evident from Fig 11.

Fig.11 Seed cotton yield of different varieties at PSC Farm, Khanewal



(Source. PSC Khanewal)

Rainfall

The main reason of low yield in current year 2015 was an unusual rainfall pattern which cast certain direct and a series of indirect effects.

Direct effects

a) Creation of partial waterlogged conditions.

b) Non-development of normal feeding roots in above mentioned conditions *(No evidence)*

c) Stunted plant growth due to less or no development of feeding roots *(No* *evidence)*

d) Impaired photosynthesis mechanism, leading to stunted growth and flower and boll shedding due to less uptake of nutrients *(No evidence).*

Indirect effects

a) Creation of favorable environment for the increased breeding of whitefly and jassid.

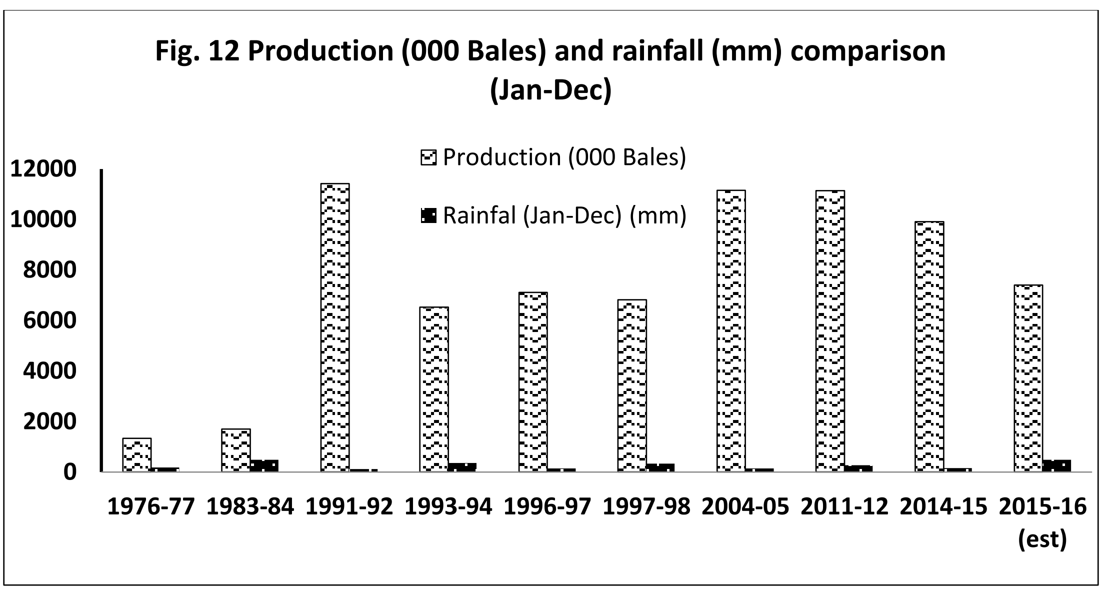
b) Less pollination, leading to flower shedding.

c) High humidity, offering favorable environment for fungal diseases.

d) Poor weed management and problem in intercultural practices and spray schedule

Historical relationship between rainfall and cotton production

It is evident from Fig 12 that cotton production was low in high rainfall years compared to that in low rainfall years.



(Source. Director, CRI, Faisalabad)

Table 5. Comparison of number of rainy days in Multan and Rahim Yar Khan

Month	2014		2015	
	Multan	Rahim Yar Khan	Multan	Rahim Yar Khan
July	4	2	12	10
August	3	1	5	2
September	4	1	2	1
October	1	0	4	1
Total	12	4	23	14

(DG, AARI, Faisalabad)

During 2015, rainy days in Multan were 23 in count as compared to 12 during 2014. In R.Y. Khan, the counted rainy days were 14 during 2015 compared to only 4 during 2014. Therefore, year 2015 can be categorized as wet season in this context. The rains in Rahim Yar khan, however, did not affect yield so much as these did in Multan due to the porous nature of the soil. In fact, in Multan heavy rain created semi waterlogged conditions that resulted in enormous shedding of squares, flowers and small bolls (Table 5). Table 8 shows that the amount of rainfall in Multan was much higher compared to R.Y. Khan that ultimately proved detrimental to the cotton crop. *On relative terms, the ratio of increase in rainy days in RYK was higher than Multan but yields were less affected.*

Table 6: Total month wise rainfall (mm) in Multan and R. Y. Khan

Months	2014		2015	
	Multan	Rahim Yar Khan	Multan	Rahim Yar Khan
July	71.3	0.2	139.3	118.2
August	26.1	2.0	80.6	0.2
September	3.3	0.1	10.3	0.6
October	23.0	0.0	11.8	0.1
Total	123.7	2.3	242	119.1

(DG, AARI, Faisalabad)

This is an argument which can lead us nowhere. The total precipitation ratio in Rahim Yar Khan is also higher than Multan.

Temperature

The maximum temperature of Multan for the months of June to September, 2015 (Fig. 13) showed that the temperature was higher as compared to 2014. High temperature during the said period reduced the yield due to flower shedding and less boll setting. In addition high temperature, coupled with high humidity, boosted whitefly population which, in turn, became one of the major causes of yield reduction during the current year (2015). At Rahim Yar Khan District, the temperature differences for the years 2015 vs 2014 were not significant that is why the yield of seed cotton was not reduced as much as was observed in Multan (Figs. 13& 14).

Fig. 13. Maximum temperature comparison in Multan for the years 2014 vs 2015

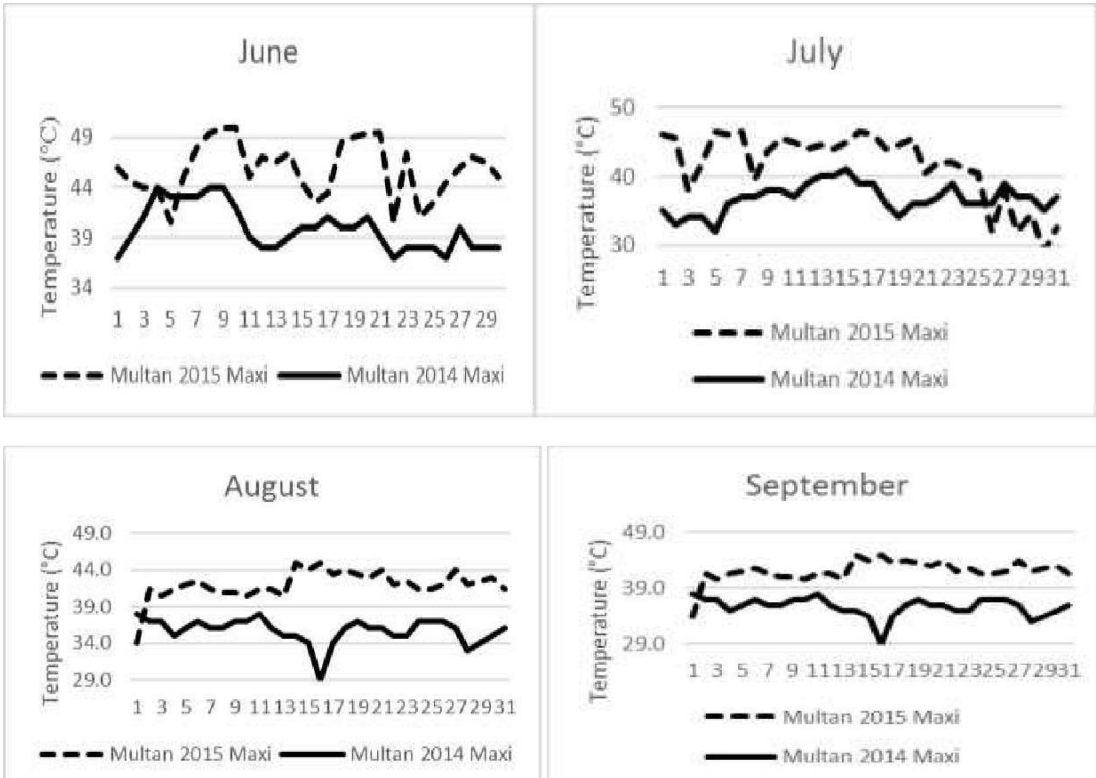
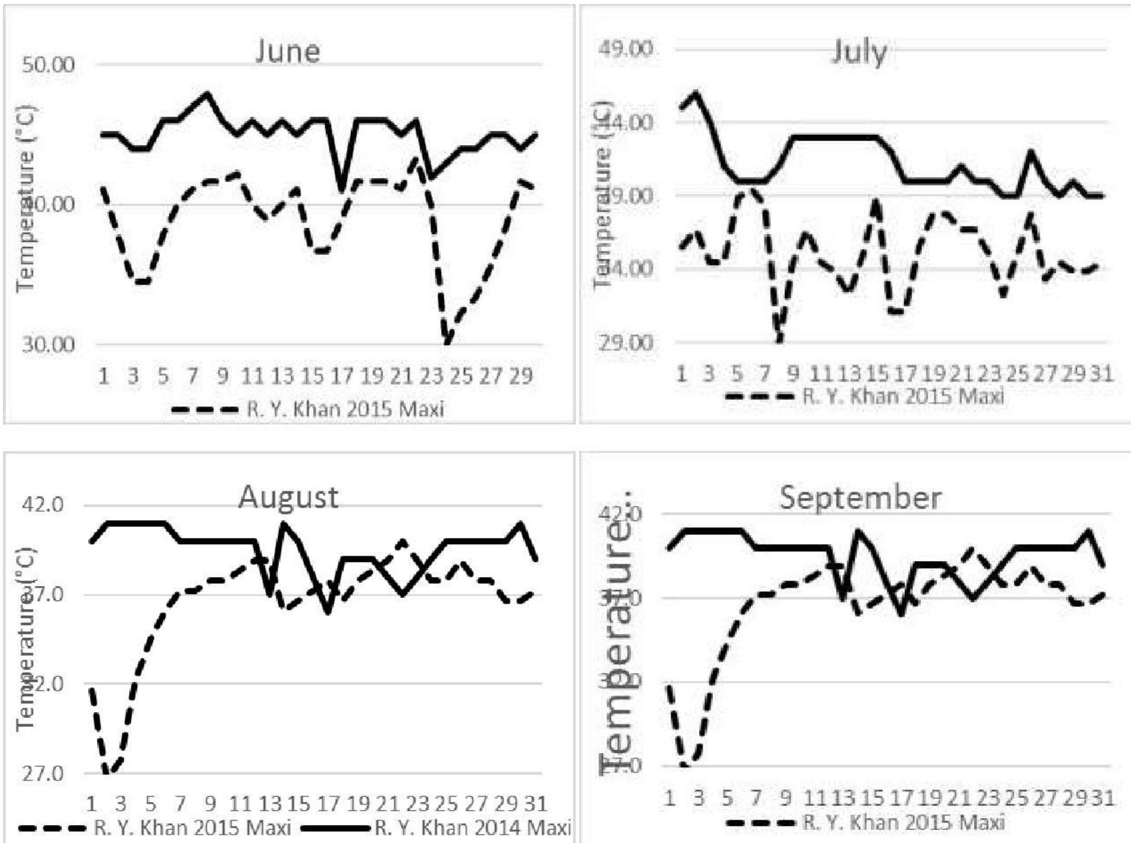
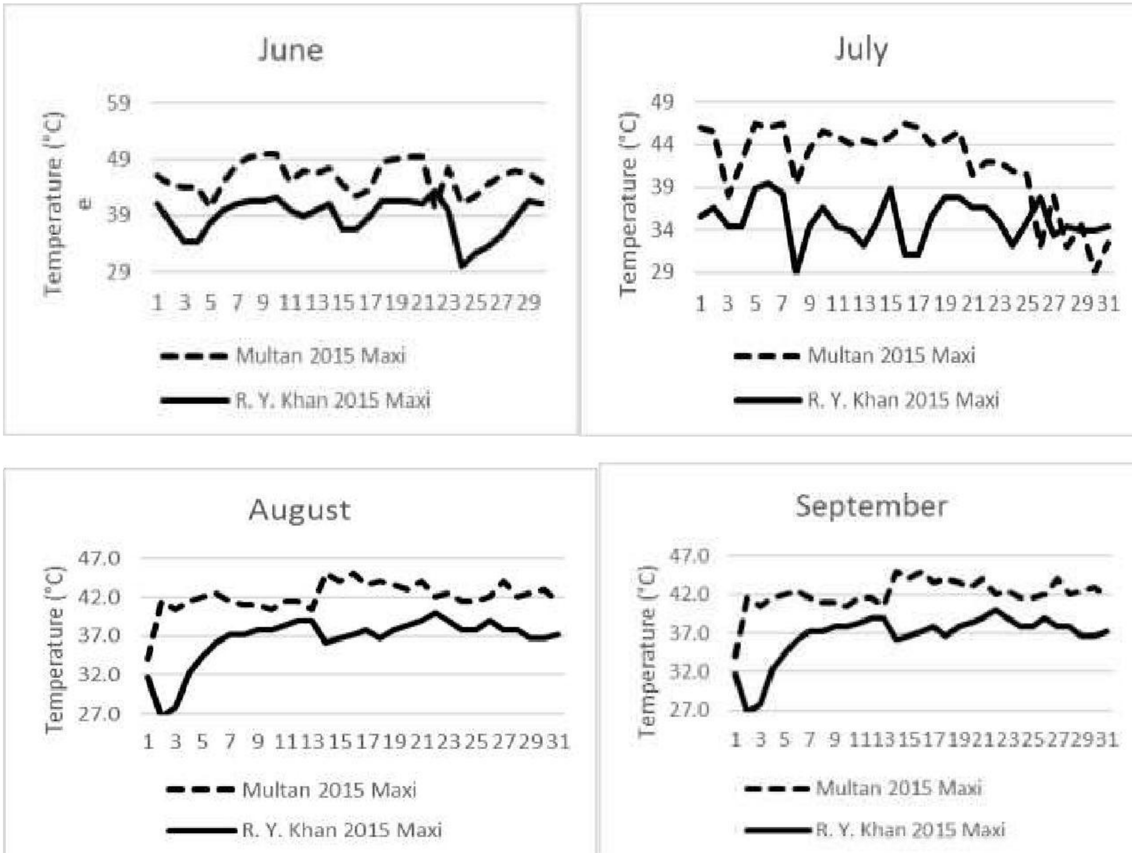


Fig. 14. Maximum temperature comparison in R. Y. Khan for the years 2014 vs 2015



but the yields were high in 2014. This temperature showing strong makes no sense either

Fig 15. Comparison of Maximum temperature of Multan and R. Y. Khan during 2015



B. Independent studies undertaken by Agro Climatology Laboratory, UAF: Understanding cotton production variability from climate perceptive

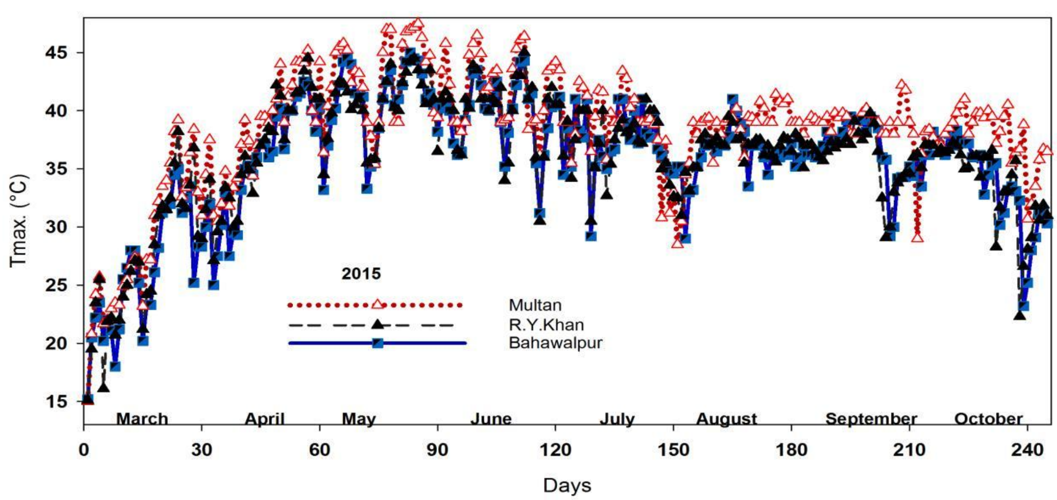
The cotton crop is sensitive to water availability and temperature, particularly at flowering and boll formation stages. High temperatures favor plant development as long as day temperature does not exceed 32°C.

Cotton needs favorable conditions with respect to temperature, sunshine and soil moisture. A marked dry season is also essential for the bolls to open properly and at harvesting time. Cotton plant, once established, rapidly develops a vertical tap root that provides resilience against drought during the growing season. The vertical tap root gives the plant rather an unhindered access to lower soil layers and nutrients therein, that even cereal crops such as maize, sorghum or millet cannot access. This also makes cotton a particularly useful plant for crop rotations. However, a crucial drawback is that the vertical tap root makes cotton sensitive to stress due to waterlogging from flood or heavy rains.

Methodology

In this report, climate data (Temperature & Rainfall) for four years (2012, 2013, 2014 & 2015) have been collected from Pakistan Meteorology Department (PMD), Islamabad while the source of cotton yield data for all the four years is Crop Reporting Services (CRS), Government of Punjab, Lahore. Mean deviation in temperature is calculated for the current year 2015 after comparison with mean values of year 2012, 2013 and 2014. Number of days exceeding threshold level temperature (>34°C) and detrimental level temperature (>40°C) were sorted out month wise in each crop season. The total rainfall and rainy days were calculated in each active cotton crop season. In each representation active cotton season (May to October) is considered to check the effects of climate variability in each year. District wise temperature variation and its impact on cotton crop yield are given below:

Fig. 16. Comparison of Maximum temperature of Multan, R. Y. Khan and Bahawalpur during 2015 growing season



(Source: PMD)

Note: Comparison of T max revealed that it remained high in Multan during all growing seasons, especially at reproductive stage (August to October) than in R.Y Khan and Bahawalpur.

Bahawalpur

Rainfall (mm)

The maximum rainfall (365 mm) was observed during active cotton crop season (May to October) 2015 as compared to Kharif season 2012 (156 mm), 2013 (92 mm) and 2014 (54 mm). Regression analysis (2012-2015) revealed strong negative association (R^2 = -0.95) between the rainfall and the yield. As far as the number of rainy days are concerned in relation to cotton crop, the graphical representation showed that there was no significant difference among all years, however the rainfall in Kharif season 2015 was much higher in intensity than the previous three seasons. The heavy rainfall in Kharif season 2015 may have caused suffocation, water saturation in the root zone of cotton plant and increased weed-crop interaction and on the other hand plant tended towards blooming and flourishing instead of fruiting. Hence, the cotton plant could not get significant fruiting and ultimately yield decline was recorded in Kharif season 2015 (18.73 maund / acre) as compare to 2012 (22.41 maund /acre), 2013 (22.37 maund / acre) and 2014 (23.94 maund / acre)

Fig. 17. Seasonal rainfall and yield at Bahawalpur during 2012-2015

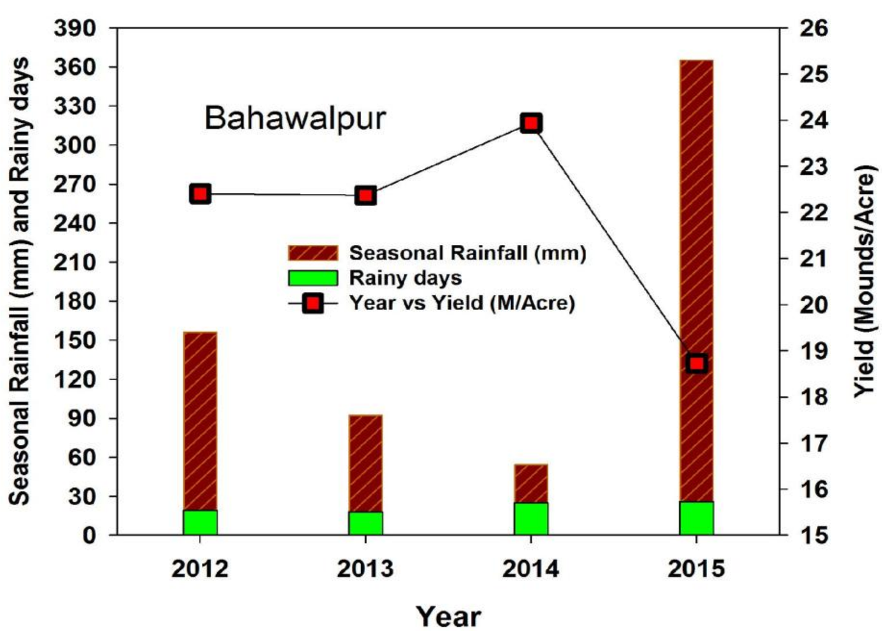
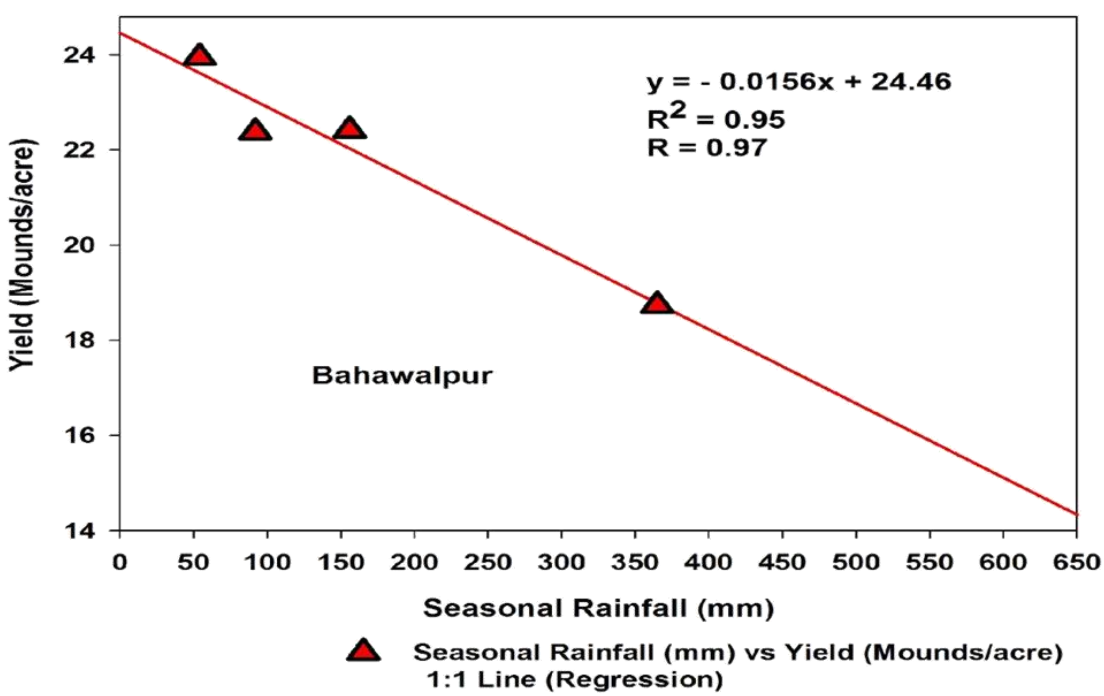


Table. 7

Bahawalpur

Year	Yield (Maund / acre)	Seasonal rainfall (mm)	Rainy days	Mean daily Rainfall Intensity
2012	22.41	156	19	8.21
2013	22.37	92	18	5.11
2014	23.94	54	25	2.16
2015	18.73	365	26	14.04

Fig. 18



Temperature

The increase in temperature during the month of May, June and July and severity in intensity beyond 40°C caused serious damage to cotton crop in year 2015 (18.73 maund / acre) as compared to 2012 (22.41 maund / acre), 2013 (22.37 maund / acre) and 2014 (23.94 maund / acre). It is very clear from the data that, during active growth period of 184 days (May to October), maximum number of days (107) remained hot i.e., having temperature above 40°C in year 2015 as compared to the situation in 2012 (68 hot days), 2013 (64 hot days) and 2014 (54 hot days). However, optimum temperature ranged between 34°C - 40°C during all the four years that may not be considered in connection with the reduction of cotton yield. Literature showed that diurnal temperature >40°C (12:00noon to 16:00 pm daily) in cotton season caused sudden decrease in cotton yield due to detrimental effect on boll formation and growth. The results from many reviews also indicated that increase in temperature by 2-3°C (with an average daily temperature of 31.1 to 35.2 °C) declined the biomass by 10%, while the cotton yield suffered a loss of 30%-40% (He *et al.*, 2013). In view of the above assertions, it is the numbers of hot days (as these were observed significantly higher than the previous years) that have affected the crop growth, yield and quality.

Fig. 19.

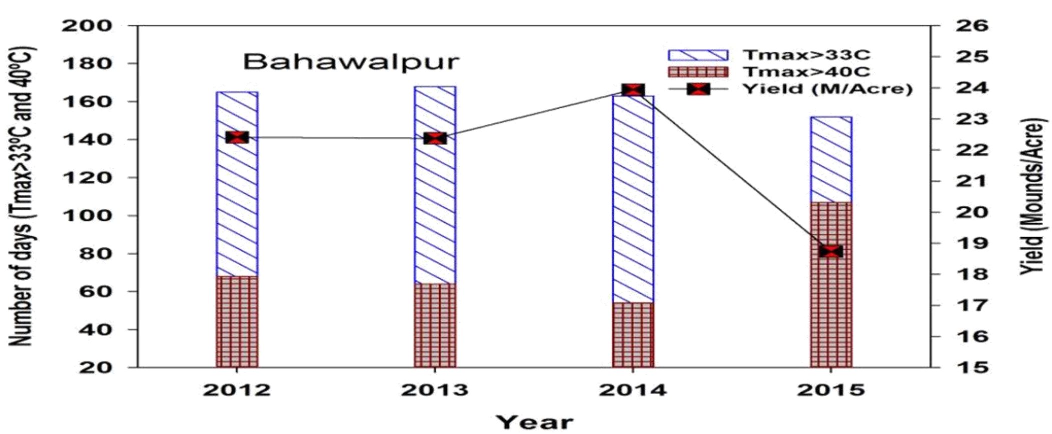


Table 8.

Bahawalpur

Year	Yield (Maund /acre)	Days (Tmax.>33ºC)	Days (Tmax.>40ºC)
2012	22.41	165	68
2013	22.37	168	64
2014	23.94	163	54
2015	18.73	152	107

Temperature vs yield in different years in Bahawalpur

Rahim Yar Khan

Rainfall (mm)

Seasonal rainfall pattern in District Rahim Yar Khan was relatively variable. Maximum rainfall was recorded in Kharif season 2012 (288 mm) followed by the season 2015 (94 mm). Minimum rainfall was observed in Kharif season 2014 (13 mm) with maximum yield of 24 maund /acre. Other than Kharif season 2014, there was no significant difference in cotton yield in Kharif season 2012 (22 maund /acre), 2013 (23 maund/acre) and 2015 (21 maund / acre). The rainfall interval (number of rainy days) in active growth period of cotton (May to October) was observed to be more than that in other seasons. Rainfall had negative impact on cotton yield as it is indicated by regression analysis. The trend of rainfall and number of rainy days is graphically depicted.

Fig. 20

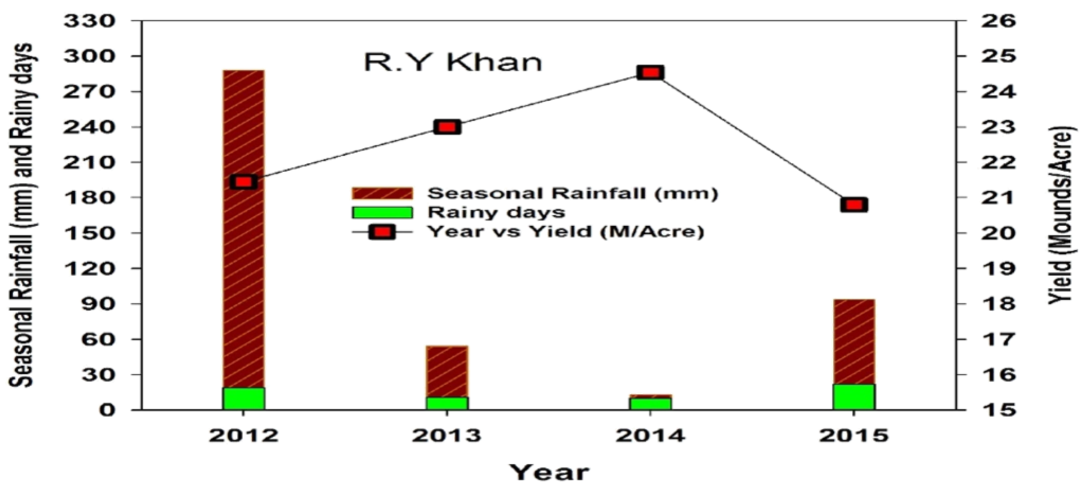
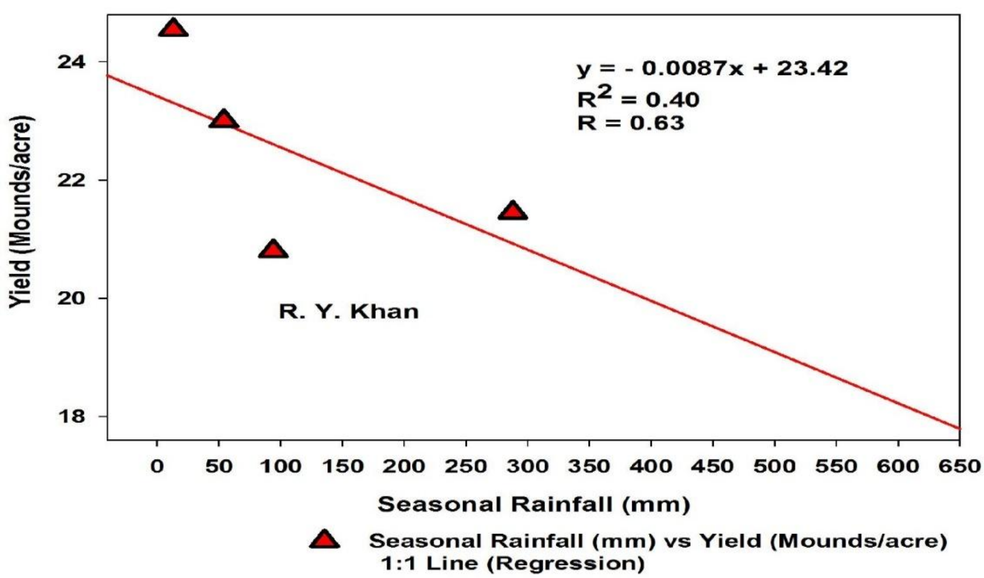


Table 9.

R.Y. Khan

Year	Yield (Maund / acre)	Seasonal rainfall (mm)	Rainy Days	Mean daily Rainfall intensity
2012	21.45	288	19	15.16
2013	23	54	11	4.91
2014	24.54	13	10	1.30
2015	20.8	94	22	4.27

Fig. 21



Temperature

Number of hot days at detrimental level (>40°C) were 96 in Kharif season 2015 in Rahim Yar Khan District which were at par with Kharif season 2012 & 2013 and were less than those in Kharif season 2014 (109 days); however, cotton yield (24 maund/acre) was maximum as compared to season 2015 (21 maund/acre). The difference of decline in cotton yield in this district in Kharif season 2015 was non-significant as compared to the mean value of Kharif season 2012 (21 maund / acre), 2013 (23 maund / acre) and 2014 (24 maund / acre). Hence, it may be added that the number of rainy days with equal interval may have resulted in less number of hot days in season 2015 but even then the temperature remained higher in season 2015. Such highly intense temperature might have caused decline in the yield of cotton which is represented in graph below.

Fig. 22

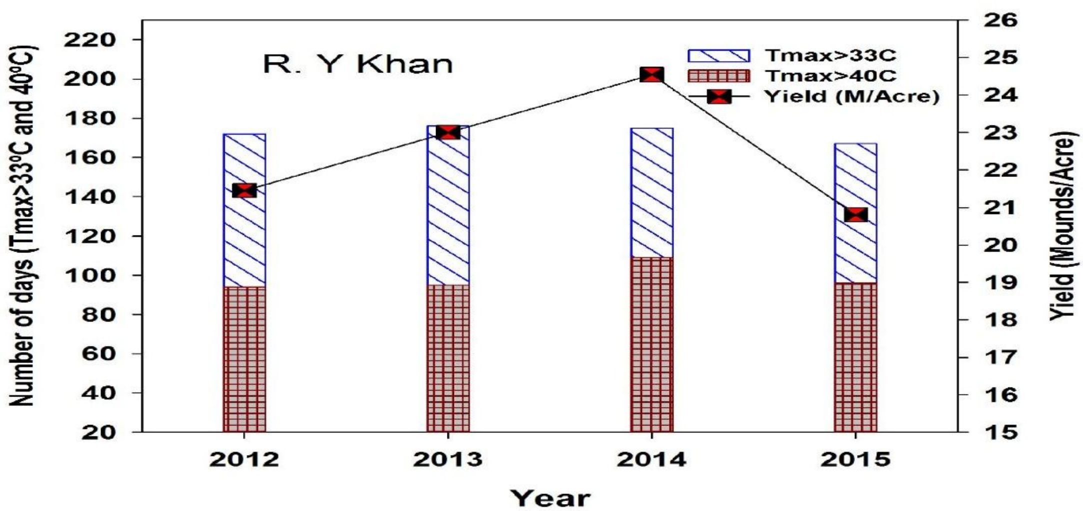


Table 10.

R. Y. Khan

Year	Yield (Maund / acre)	Days (Tmax.>33ºC)	Days (Tmax.>40ºC)
2012	21.45	172	94
2013	23	176	95
2014	24.54	175	109
2015	20.8	167	96

Multan

Rainfall (mm)

Data illustrated that maximum rainfall to the value of 238 mm was observed with 34 rainy days in crop season 2015 followed by 230 mm rainfall in 2012. Regression analysis indicates the negative impact of rainfall on cotton yield. It leads to propose that greater number of rainy days with hot days cause hot and moist air around the canopy of crop that might have caused decline in cotton yield.

Fig. 23

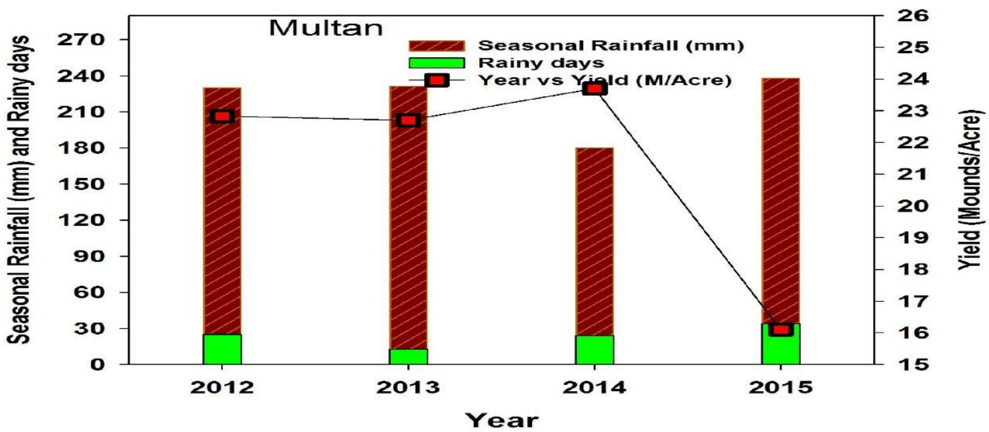


Table 11.

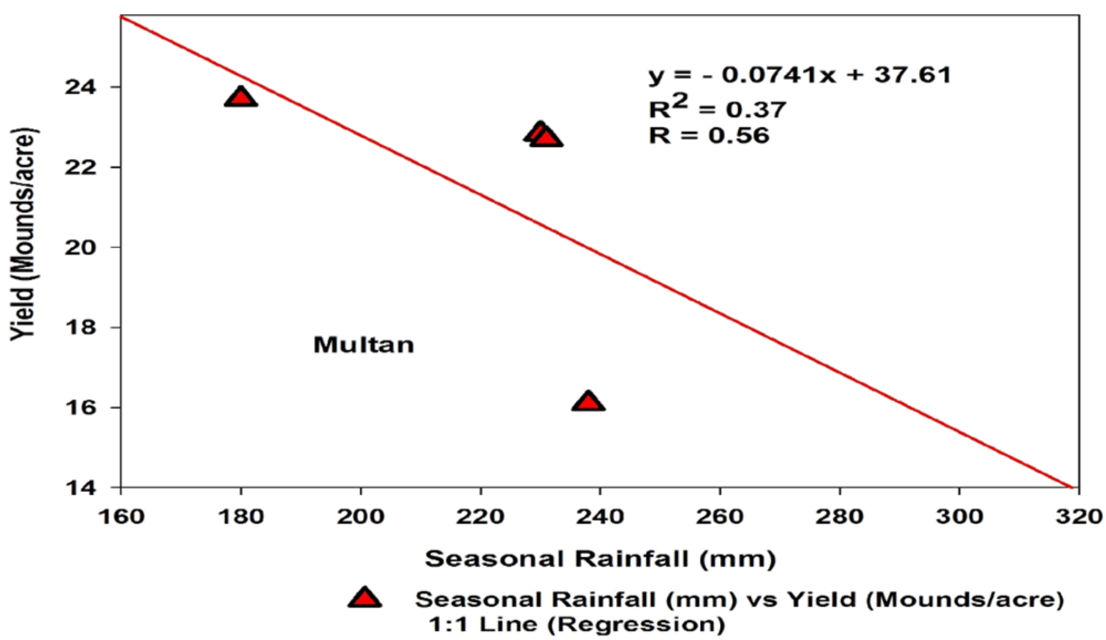
Multan

Year	Yield	Seasonal rainfall	Rainy days	Mean daily
	(Maund / acre)	(mm)		Rainfall intensity
2012	22.83	230	25	9.2
2013	22.7	231	13	17.76
2014	23.7	180	24	7.5
2015	16.1	238	34	7

2012 and 2015 similar in rain but different yield.

2012 and 2014 have same yield and different rain.

Fig. 24



Temperature

There was uniform distribution of number of days in which temperature exceeded threshold level (34 to 40°C), and the phenomenon was observed on 163 days out of 184 days' active crop season (May to October). Contrarily to other districts, minimum hot days (83) were observed during crop season 2015 compared with R.Y. Khan (96), it might be due to relatively greater number of rainy days (34) in Multan. Regular intervals in rainy days caused temperature fluctuation which resulted in blooming and flourishing during crop season with minimum crop termination. This could be one of the reasons of reduction in cotton yield in season 2015 (16 maund /acre) as compared to the maximum take obtained in season 2014 (24 maund /acre) followed by that in crop season 2012 (23 maund /acre).

Fig. 25

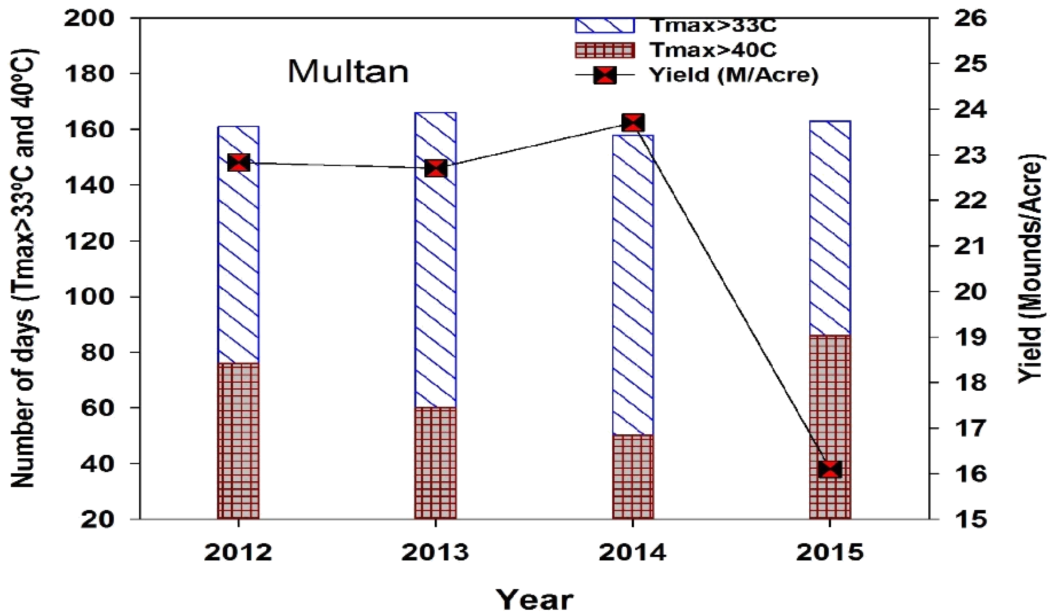


Table 12

Multan

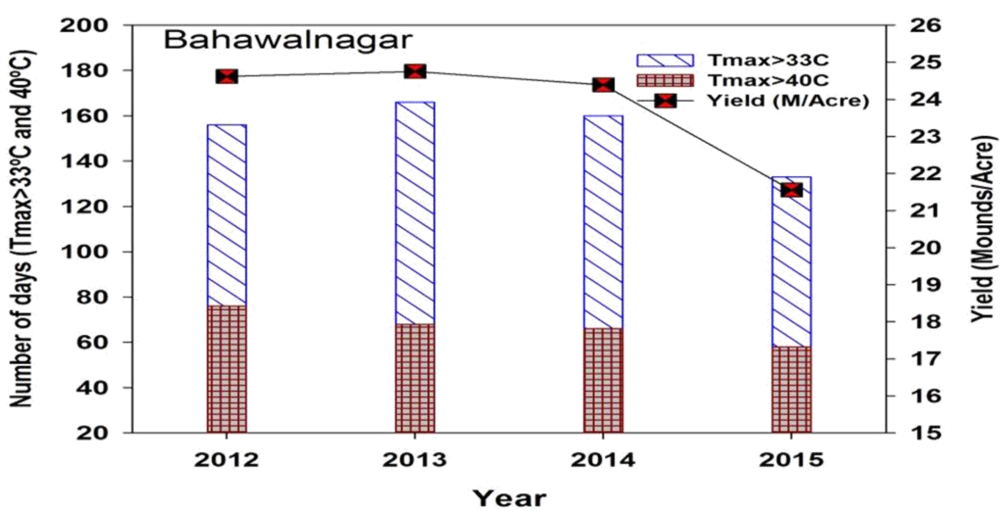
Year	Yield	Days	Days
	(Maund / acre)	(Tmax.>33ºC)	(Tmax.>40ºC)
2012	22.83	161	76
2013	22.7	166	60
2014	23.7	158	50
2015	16.1	163	83

Bahawalnagar

Temperature

It is clear from graphical representation that the mean deviation in maximum and minimum temperature in year 2015 was higher than the previous three years that may have caused decrease in cotton yield during current year of crop. However, the decrease in yield during crop season 2015 was 12% as compared to that in previous years which, in turn, had similar yield record (24 maunds / acre).

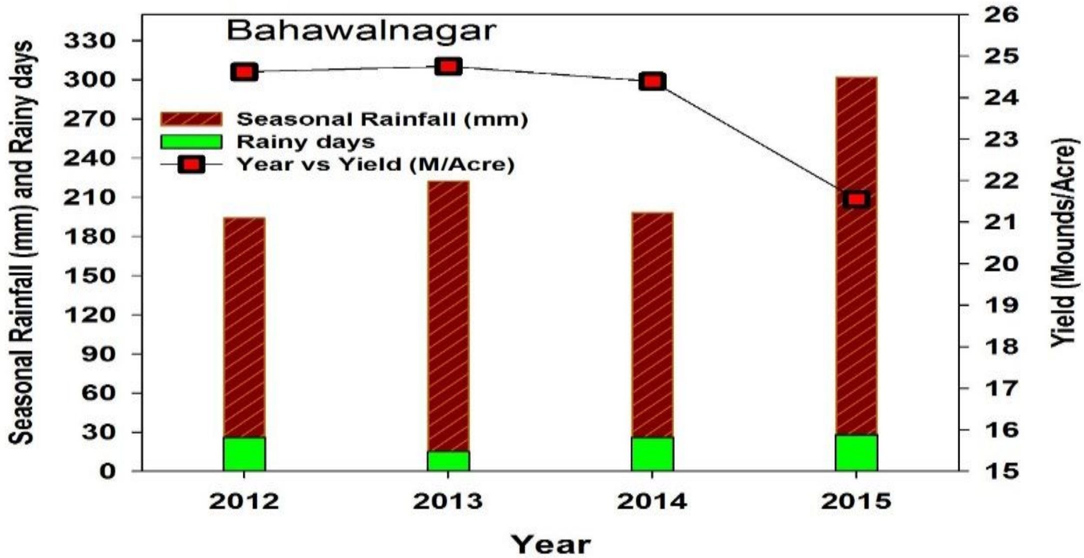
Fig.-26



Rainfall (mm)

Maximum rainfall (302 mm) was received during the year 2015 that was 35% more in proportion than observed in the previous years in District Bahawalnagar. More rainfall resulted into more root zone moisture saturation, weeds infestation and flower and square shedding that may have affected cotton yield during year 2015 (22 maund / acre). Maximum rainfall was received during the months of July (128 mm) and September (145 mm) in year 2015 with more number of rainy days (38) during active crop season. This pattern resulted in continuation of blooming, vegetative growth and late termination of crop.

Fig. 27

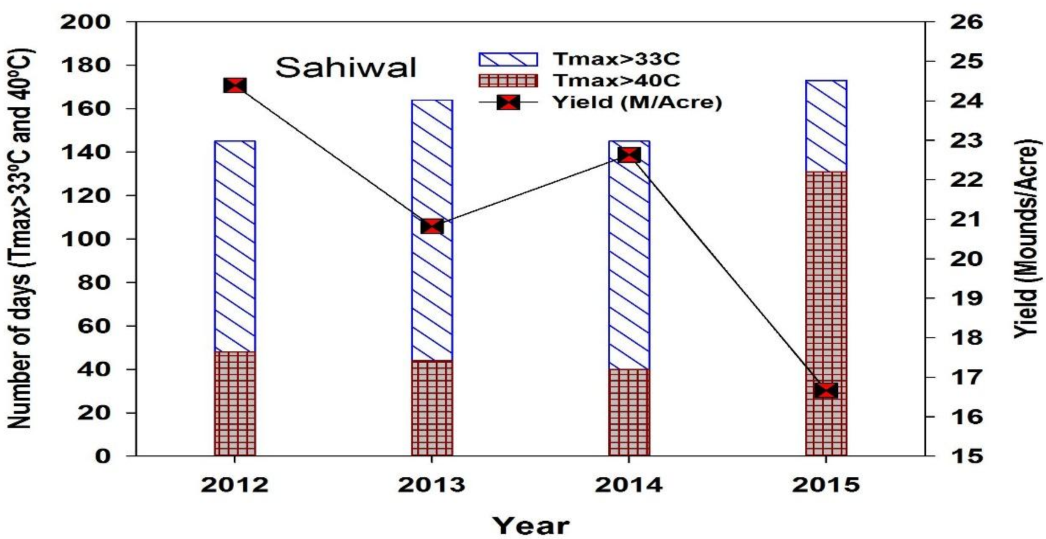

Bahawalnagar
Seasonal Rainfall (mm)
Rainy days
Year vs Yield (M/Acre)
Seasonal Rainfall (mm) and Rainy days
Yield (Mounds/Acre)
Year
2012
2013
2014
2015
0
30
60
90
120
150
180
210
240
270
300
330
15
16
17
18
19
20
21
22
23
24
25
26

Sahiwal

Temperature

The graph below shows the mean deviation of temperature of Kharif season 2015 to previous years' pattern. Data showed that maximum number of hot days (131 days) with >40°C temperature were observed out of 184 days of active growth period (May to October) of cotton crop in Kharif season 2015 as compared to Kharif season 2012 (48 days), 2013 (44 days) and 2014 (40 days). These maximum hot days surely disrupted the physiological processes, such as photosynthesis, respiration and transpiration, within plants and resulted in decline of cotton yield.

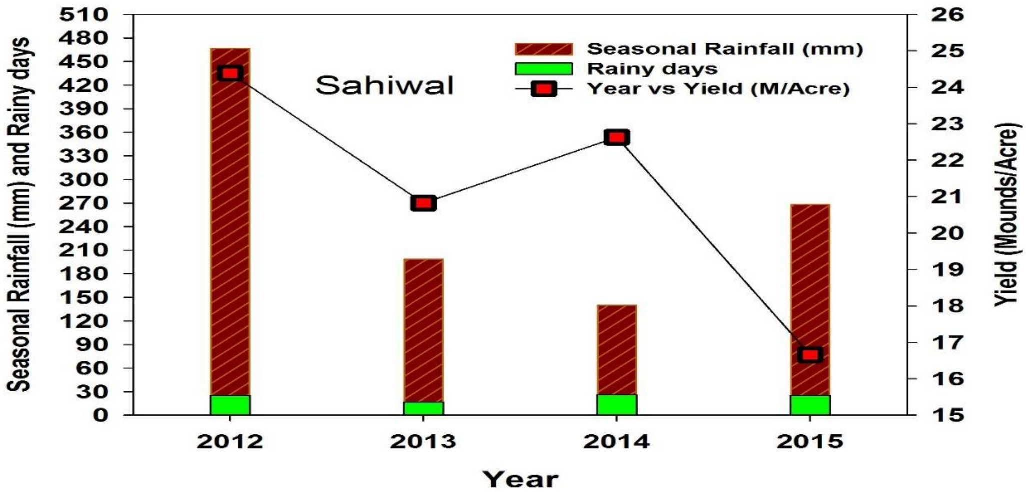
Fig. 28



Rainfall (mm)

It is obvious from data that maximum rainfall was observed in Kharif season 2012 (467 mm) in Sahiwal as compared to 2013 (199 mm), 2014 (140 mm) and 2015 (268 mm) with average yield of cotton crop 24.39 maund / acre (2012), 21 maund / acre (2013), 23 maund /acre (2014) and 17 maund / acre (2015). Hence, it may be ascertained that rainfall was not the only single reason for decline in cotton yield rather other factors are also important to be considered equally for studying decline of cotton yield.

Fig. 29



Options to Adapt to Climate Change

Climate change is altering the economics of production, and forcing rural cotton farming communities to consider multiple livelihood strategies including planting different crops and seeking alternative non-farm income streams. This entails complex and resource-intensive responses from government. Another discouraging factor is that with respect to the production level, cotton has limited capacity to respond to heat stress through 'compensatory growth'. In this backdrop, a number of adaptation strategies to tackle the hazard may include:

- Using Climate Resilient Cotton Varieties
- Breeding of varieties with better root architecture
- Maximizing plant diversity
- Observing flexibility of sowing dates
- Maintaining soil cover
- Minimizing soil tillage
- Introduction of Alternate Crop
- Changing Cropping pattern
- Cotton-wheat to Wheat-Soybean/millet. It will save 24 inch water
- Draining of rain water

Comparative Summary

Agriculture Department

The department has compared climatic factors (Tmax and rainfall) to explore the possible reasons of decline in cotton yield during crop season 2015. It is reported that high temperature with high humidity reduced the cotton yield due to flower shedding and less boll setting (Page XV, 1.1.2). In addition to temperature, it is pointed out that more number of rainy days in Multan (23) and Rahim Yar Khan (14) were observed during crop season 2015. This rainfall pattern resulted in semi water logged conditions in Multan that caused hazardous effects on cotton yield while porous soil of Rahim Yar Khan took advantage and yield was not affected significantly (Page XV, 1.1.1).

Agro Climatology Laboratory, UAF

The department has analyzed only two districts (Rahim Yar Khan & Multan), comparing the climatic factors and decline in cotton yield during Kharif season 2015. This is not sufficient to conclusively determine the possible effects on cotton yield. It is very clear that high temperature causes significant damage to cotton crop growth and yield. That is why the soils of Bahwalpur, which are also sandy and porous in nature, showed decline in cotton yield (-22%) in year 2015.

The analysis of temperatures above threshold level (>34°C) and detrimental level (>40°C) intensity and intervals of rainfall showed that maximum number of hot days (the temperature >40°C) and rainfall significantly reduced the cotton yield in all the five selected districts (Bahawalpur, Bahawalnagar, Sahiwal, Rahim Yar Khan & Multan). The comparative analysis of the districts of Multan, R.Y. Khan and Bahawalpur revealed that the number of hot days with temperature >40°C in Bahawalpur (107) were more than R.Y. Khan (96) and Multan (83) while maximum seasonal rainfall was recorded in district Bahawalpur (365 mm) and Multan (238 mm) than in R. Y. Khan (94 mm). The possible reasons of the less number of hot days are more rainy days with regular intervals in Multan. Variations in temperature and continual rainfall in Multan district with more number of rainy days (34) could have promoted vegetative growth phase instead of fostering flowering, furthermore maximum temperature during reproductive phase (August to October) had significant impact and ended up with 23% reduction of cotton yield in Multan than R. Y Khan.

Early Severe outbreak of insect pests due to changed rain pattern

Due to improper management under the influence of unfavorable weather conditions (as mentioned above), major insect pests of cotton appeared at an early stage (Jassid; June, Whitefly; June, Armyworm; April-May, August, Pink bollworm; July) as compared to the previous years, and maintained their population burst throughout the season much higher above the economic threshold level, resulting in massive destruction of the crop. In addition several other secondary insects such as dusky cotton and red cotton bugs also became an important hazard in many areas. For example, while comparing the two districts Multan and Rahim Yar Khan it was observed that early rains induced early emergence of the major insect pests in Multan.

Whitefly

Whitefly infestation had started at a significantly early stage of crop, i.e., till 4th week of October (Fig. 30). Due to high infestation of whitefly crop growth was adversely affected by sucking cell sap (loss of chlorophyll). On the other hand, honeydew released by the adults caused the growth of sooty mold on leaves, which affected the normal photosynthesis and ultimately resulted in low crop yield.

In Punjab this year, total of 6072 hotspots of whitefly have been observed as compared to 4615 hotspots during the last year. Bahawalnagar, Lodhran, Sahiwal, Vehari and Multan were severely affected by whitefly infestation (Fig 31).

Fig. 30. Week wise infestation of white fly above ETL on cotton crop for the year 2014 & 2015

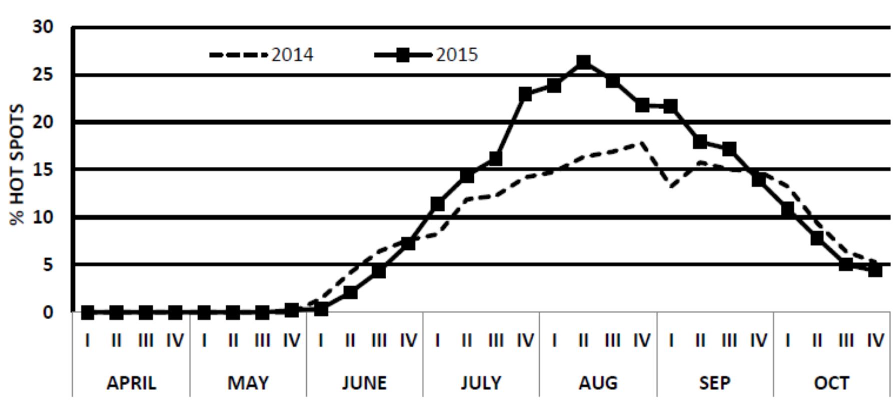
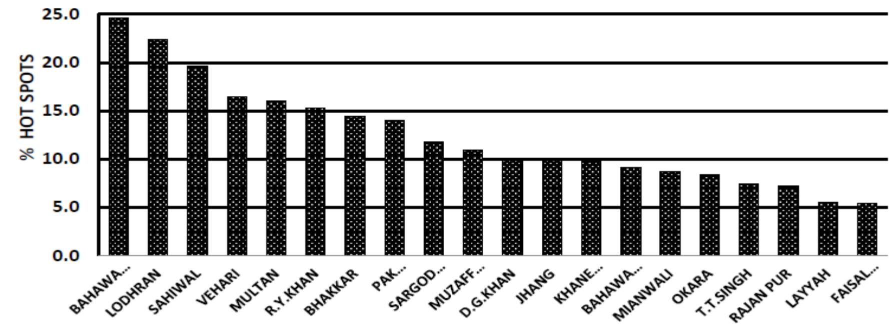


Fig. 31. District wise Whitefly Hotspots %age on Cotton during 2015



(Source: DG, PW&QC, 2015)

Pink Bollworm

Pink bollworm emerged as a serious pest at a later stage of crop growth i.e. from 3rd week of August to 4th week of October with 1314 hotspots in the year 2015 as compared to129 during the last year 2014.

Hotspots were observed in Lodhran, Bahawalnagar, Vehari, TT Singh, Bhakkar, Multan, Bahawalpur and Khanewal (Fig 33) whereas infestation remained below ETL throughout other cotton growing areas of Punjab at later stages of the crop (Fig. 34).

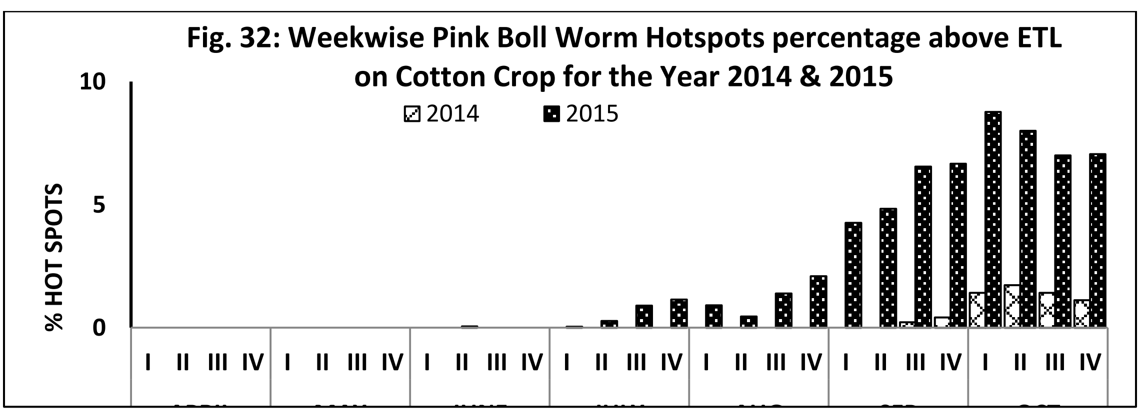
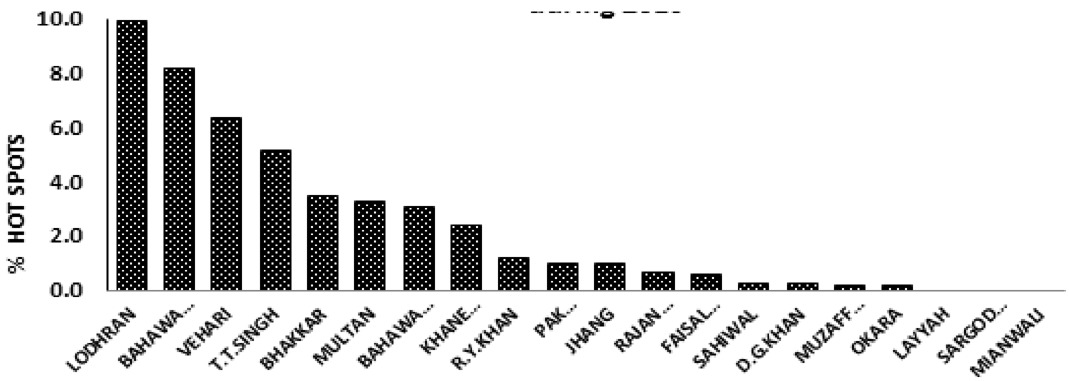


Fig. 32: Weekwise Pink Boll Worm Hotspots percentage above ETL on Cotton Crop for the Year 2014 & 2015

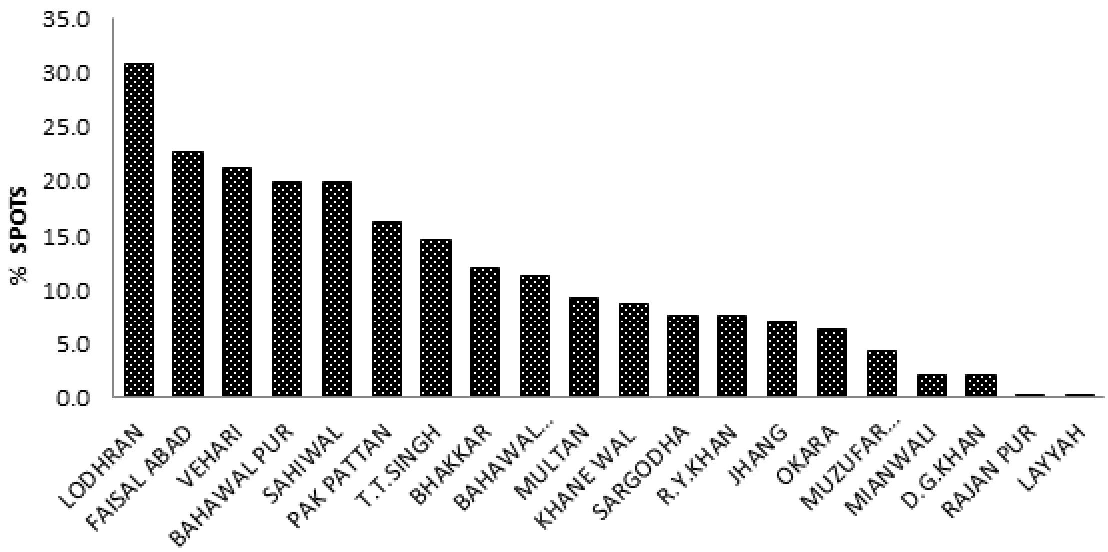
(Source: DG, PW&QC, 2015)

Fig. 33: District wise Pink Bollworm Hotspots percentage on Cotton during 2015



Source: DG, PW&QC, 2015)

Fig.-34:District wise pink Boll worm spots percentage (Below ETL) on Cotton During 2015

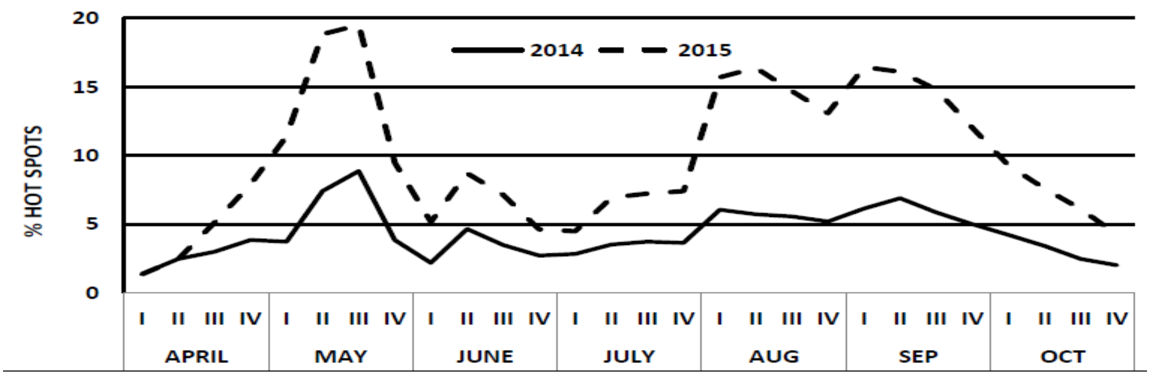


Source: DG, PW&QC, 2015)

Army Worm

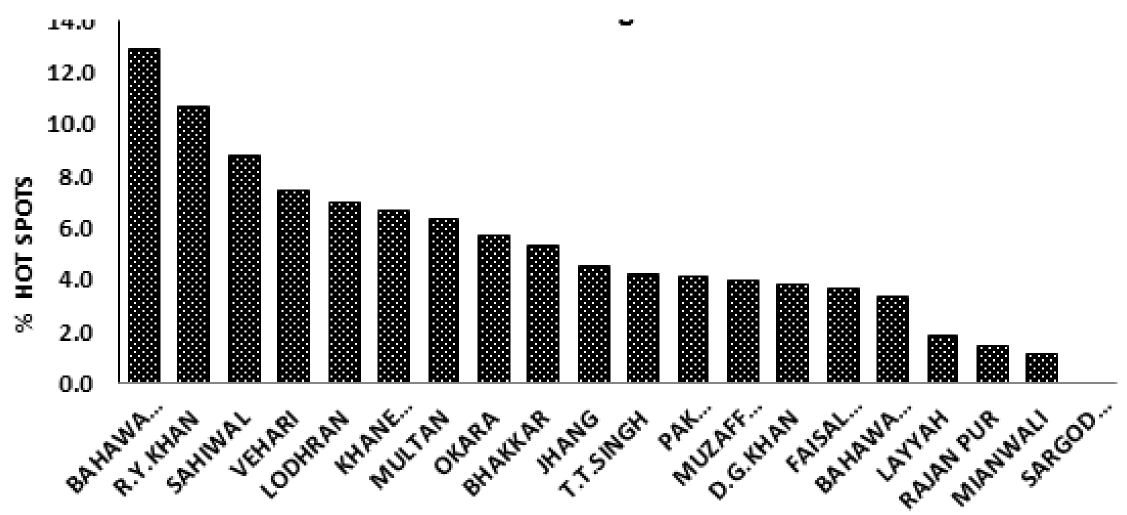
The infestation of Army worm remained high due to high weeds population during April-May and August-September at critical stages of crop in comparison to its infestation level last year (Fig 40). Hotspots were observed in Bahawalpur, Rahim Yar Khan, Sahiwal and Vehari (Fig 41). The direct effect of army worm was the loss of active green leaf area, and indirectly it caused less canopy size, bolls' number and weight.

Fig. 35. Weekly Army Worm Hotspots %age above ETL on Cotton Crop for the Year 2014 & 2015



(Source: DG, PW&QC, 2015)

Fig. 36. District wise Army Worm Hotspots %age above ELT on Cotton During 2015



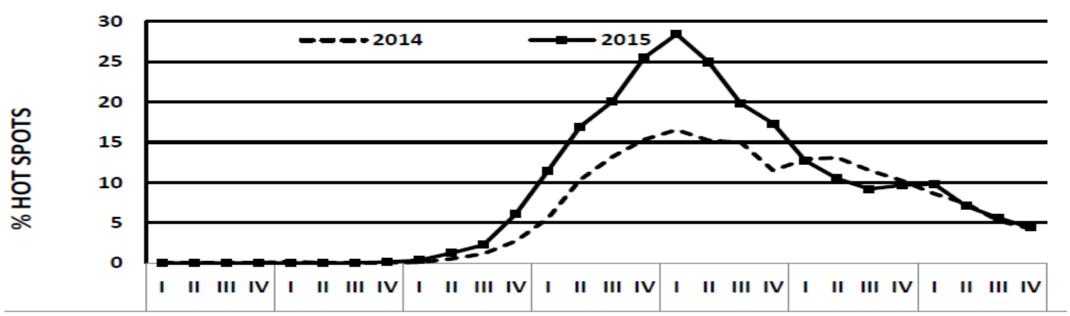
(Source: DG, PW&QC, 2015)

Jassid

Jassid population remained high throughout the cotton season (hotspots), especially from the 2nd week of June up to the 4th week of August due to hot and humid weather conditions. It adversely affected normal growth of the plant resulting in decline in yield during this year as compared to last year (Fig. 37).

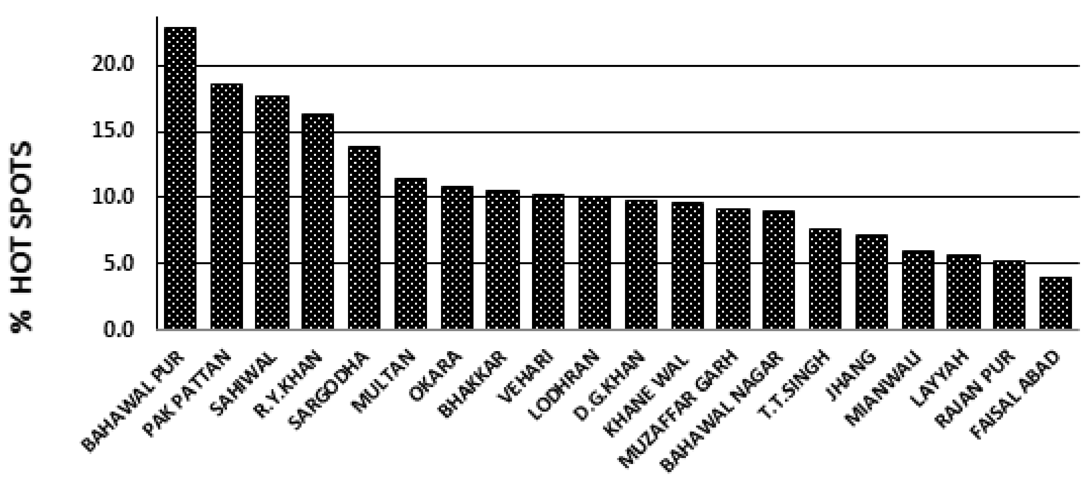
During 2015, total 5349 hotspots of Jassid were observed as compared to 3733 hotspots during the last year. Jassid infestation remained high in Bahawalnagar, Pakpatan and Sahiwal during the current year (Fig. 38).

Fig. 37. Weekly Hotspots percentage of Jassid above ETL on Cotton Crop for the Year 2014 & 2015



(Source: DG, PW&QC, 2015)

Fig. 38. District wise Jassid Hotspots percentage above ETL on Cotton during 2015



1.5 Weeds Infestation

Abundant rainfall particularly at early and mid-season in 2015 created ideal conditions for weed growth across the cotton belt. Higher weed densities were reported with increasing precipitation. *Echinochloa colona* (Jungle rice/Swanki Ghass), *Cynodondactylon* (Bermuda grass/Khabbal ghass), *Dactyloctenium aegyptium* (Crowfootgrass/Madhana ghass), *Cyperus rotundus* (Purple nutsedge/Deela) and *Trianthemaportulacastrum* (Horse pursslane/Itsit) grew uncontrolled, producing huge dry matter, consuming soil moisture and nutrients. In fact, such weeds weighed higher than normal in terms of their respective per plant weights. These weeds attained a height/length of 30-75 cm in between cotton plants (120 cm height) that lead to increased weed-crop competition not only for moisture and nutrients but for radiation as well. A yield reduction of 5-15% higher has been reported by the farmers as compared with the previous season.

Improper germination either due to unfavorable conditions or the use of poor quality seed also resulted in poor crop stands, giving to the weeds an edge early in the season. Poor branching in cotton was reported, either due to using seed of unapproved, outdated varieties or heavy insect attack or root rot, thus giving the weeds an edge over scarce canopy of the cotton crop. Ultimately, the weeds became dominant and caused greater yield losses in these areas.

In some areas, rainfall at the time of sowing or immediately after, reduced the efficacy of pre-emergence herbicides to control weeds in cotton which had minimized the cotton-to-weed height differential. Farmers could not afford to invest more on weed control for a larger outbreak of weeds at later stages of crop growth. In some areas of Bahawalpur continuous rains led to standing of water in fields, that was more harmful to the crop than weeds, thereby shifting the balance in favor of the weeds. Such a situation was further aggravated by a favorable environment for weed growth. Some of the farmers ploughed up the cotton crop due to poor growth and abundance of weeds.

Change in weed flora of cotton has also been reported in Rahim Yar Khan and Muzafargarh districts with *Mukia maderaspatana* (Wild cucurbit/Makru) and *Ipomea* Spp. (Morning glory/Basharmi booti), respectively, as an emerging invasive weeds. Herbicides available in the market failed to show any control of these weeds.

Fertilizer Availability and Usage

Fertilizer availability and usage had no relation with decline in cotton yield in 2015 (Table 13). Sale of urea fertilizer, especially during the month of July, August and September, was less during 2015 than during the previous years. Urea is mostly used in these months on cotton crop.

Table 13. Urea off take in kharif season compared to targets in Punjab. (000 tons)

Month	Target	Actual	Target	Actual	Target	Actual	Target	Actual
	2012	2012	2013	2013	2014	2014	2015	2015
April	343	204	281	230	242	178	196	238
May	478	241	327	294	309	235	259	267
June	451	704	425	382	400	326	358	373
July	428	259	348	296	310	331	364	279
August	264	186	294	323	339	419	428	282
September	241	167	269	324	340	268	295	126
Total	2206	1761	1944	1849	1940	1757	1900	1565

Source: DGA (Ext & AR), 2015

Pesticides Availability/Quality

Pesticides availability during 2015 is given in Table 14. Pesticides availability was sufficient. However, personal communications with the different pesticide companies revealed that pesticide sale was much low as compared to the previous year. According to the farmers, main reason for low pesticide use was low price of cotton and extended rainfall season during 2015.

Table 14. Summary of pesticide import in Pakistan during 2015 (as on 31-10-2015)

Month	Import Item	Quantity (L/kg)	Formulated Products (L/kg)		
			Total	Kharif Crops	Rabi Crops
Jan-Mar	Technical Concentrate	2,413,731	22,220,042	21,300,264	919,778
	Formulated	2,897,907	2,897,907	1,169,068	1,728,839
	Sub-total:	5,311,638	25,117,949	22,469,332	2,648,617
April	Technical Concentrate	1,706,861	9,740,427	9,740,427	0
	Formulated	1,916,998	1,916,998	1,916,998	0
	Sub-total:	3,623,859	11,657,425	11,657,425	0
May-June	Technical Concentrate	2,489,228	16,936,814	16,905,147	31,667
	Formulated	3,253,536	3,253,536	3,253,536	0
	Sub-total:	5,742,764	20,190,350	20,158,683	31,667
July	Technical Concentrate	1,721,895	18,481,533	18,481,533	0
	Formulated	2,660,775	2,660,775	2,652,775	8,000
	Sub-total:	4,382,670	21,142,308	21,134,308	8,000
August	Technical Concentrate	1,339,659	12,441,975	12,364,375	77,600
	Formulated	2,218,982	2,218,982	2,060,152	158,829
	Sub-total:	3,558,641	14,660,956	14,424,527	236,429
	Technical Concentrate	525,100	3,977,462	3,684,183	293,279
September	Formulated	1,365,126	1,365,126	544,151	820,975

	Sub-total:	1,890,226	5,342,588	4,228,334	1,114,254
	Technical Concentrate	512,475	1,937,297	0	1,937,297 1,457,918
October	Formulated	1,457,918	1,457,918	0	
	Sub-total:	1,970,393	3,395,214	0	3,395,214
	Grand Total	26,480,191	101,506,791	94,072,609	7,434,181

Pesticide Used & Quality Issues

Pesticide adulteration was not an issue as percent unfit samples were very low.

Table 15. Pesticide sampling registered during 2010-2015

Year	Samples Drawn	Analyzed Samples	Unfit Samples	% Age Unfit		Immediate Arrests	FIRs Registered
2010	6160	5614	180	3.21		117	232
2011	7650	8441	281	3.33		142	356
2012	8122	7933	204	2.57		95	250
2013	8232	8217	303	3.69		125	362
2014	7374	7431	288	3.88		90	255
2015(31-Oct)	7543	7292	188	2.58		90	232

(Source: DG, PW&QC, 2015)

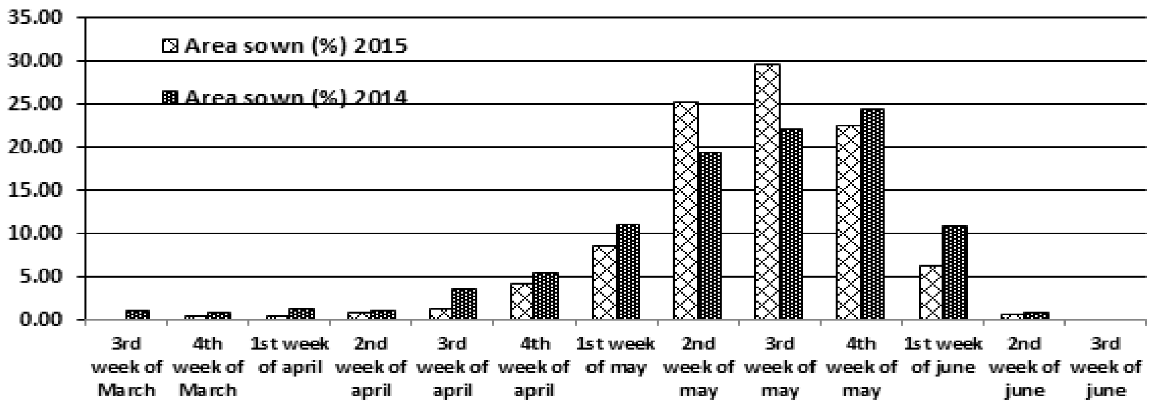
Pesticides and their efficacy

Due to continuous rains at regular intervals, the pesticide spray regime was adversely affected and number of sprays was not adequate during fruiting period, and that is one of the reasons of flare up of whitefly and Pink bollworm.

Planting Time

The cotton sowing pattern of Punjab is given in figures below and data originated from two sources. Both figures clearly indicate that cotton sowing was delayed, which resulted in less plant height, less canopy during 2015 than during 2014.*However, the net difference between the two years is non-significant.*

Fig. 39. Sowing Time Pattern of Cotton for the year 2014 vs 2015



(Source: DGA Ext & AR, 2015)

Data of trial on sowing dates at Cotton Research Station Multan for the year 2015 compared with 2014 clearly showed that crop sown after 1st week of May was inferior in yield enhancing parameters in 2015 as compared to 2014. Due to unexpected rains and cool weather, wheat harvesting was prolonged and resultantly delay in cotton sowing during 2015 was experienced (Table 8). Plant canopy remained below normal, increasing whitefly and pink bollworm attack due to delay in planting crops.

Table 16. Comparison of the effect of sowing date on Plant height, No. of Bolls, Boll weight and yield of cotton variety MNH-992 for 2014 & 2015

2015					2014				
Sowing dates	Plant height (cm)	No. of Bools/plant	Boll weight (g)	Yield (kg/ha)	Sowing dates	Plant height (cm)	No. of bolls/plant	Boll weight (g)	Yield (kg/ha)
16-2-2015	175	45	3.7	5325	16-2-2014	140	39	3.6	5154
2-3-2015	185	59	3.6	5617	01-3-2014	151	42	3.7	5333
16-3-2015	180	58	3.6	5197	16-3-2014	136	33	3.6	4771
1-4-2015	175	54	3.6	4432	1-4-2014	130	30	3.6	4365
16-4-2015	168	46	3.6	3937	16-4-2014	125	29	3.5	3946
2-5-2015	112	24	3.3	1990	1-5-2014	116	26	3.5	2774
16-5-2015	81	14	3.1	1275	16-5-2014	108	22	3.4	2332
1-6-2015	60	8	3.0	676	1-6-2014	101	15	3.3	1793
16-6-2015	48	5	3.0	199	16-6-2014	75	6	3.2	693

(Source: CRS, Multan)

CLCuV Infestation

Incidence of CLCuV remained low as compared to the previous year. Maximum spots of CLCuV were observed in the district of Pakpatan, Vehari, Multan, Lodhran and Muzaffargarh areas. Stunted plant growth, reduced boll weight and less yield were also benchmarked in these areas (Fig 41).

Fig. 40.

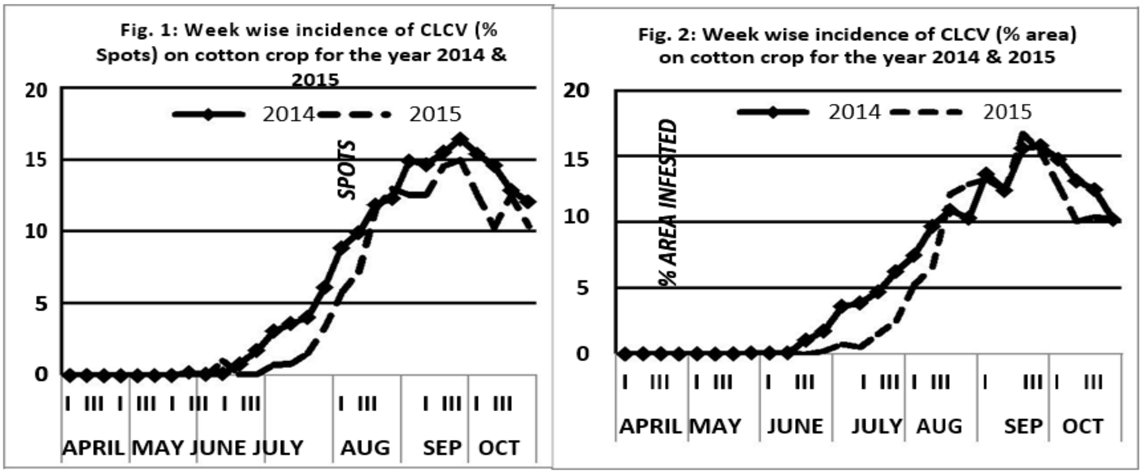
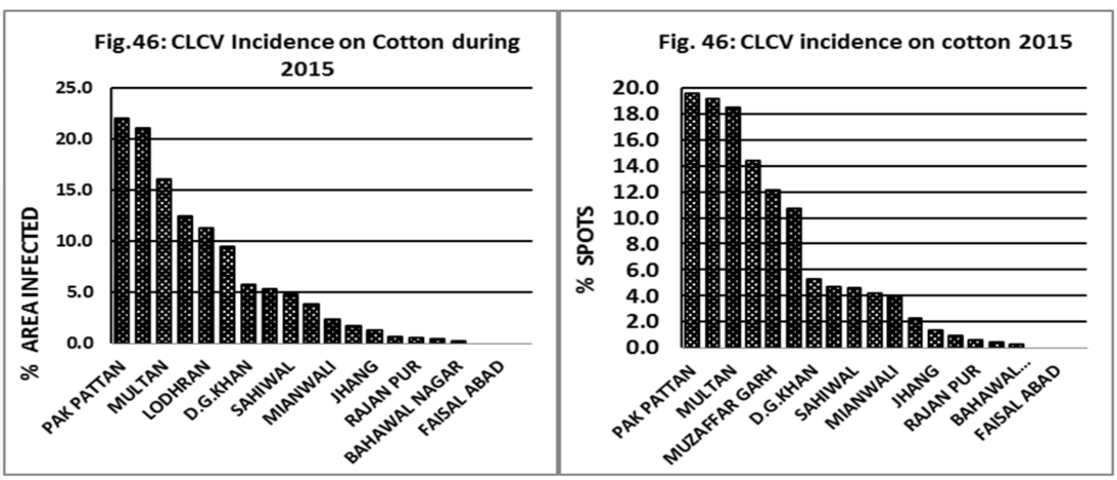


Fig. 41.



(Source: DG, PW&QC, 2015)

TOR-II

EXAMINE THE EXPRESSION OF BT GENE IN PRESENT ARRAY OF BT VARIETIES

The varieties recommended for 2015-16 are given below.

Approved Bt varieties (19)

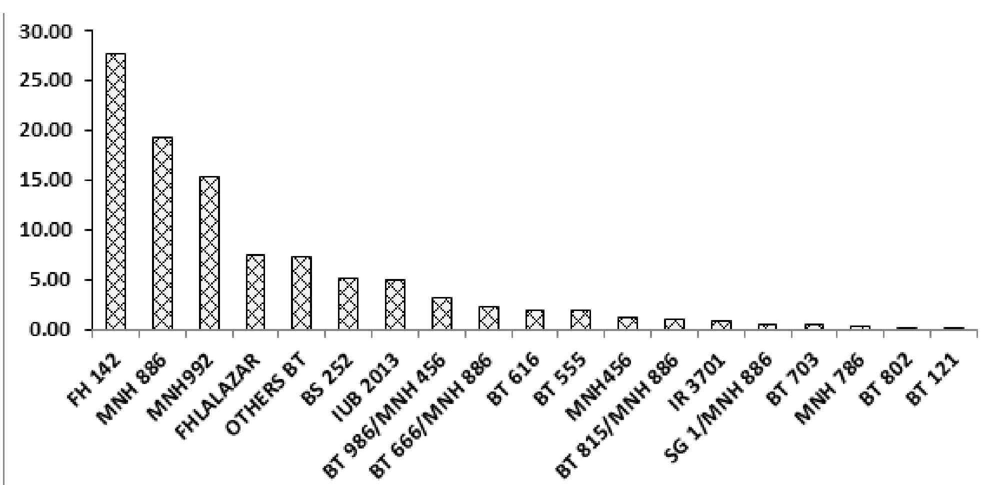
MNH-886, FH-142, FH-114, IR-3701, VH-259, BH-178, CIM-599, CIM-602, FH-118, IR-NIAB-824, IUB-222, CEMB-33, SAYBAN-201, SITAR-11M, A-555, KZ-181, TARZAN-1 & 2, CA-12

Approved Non Bt varieties

NIAB-112, NIAB-KIRAN, CIM-608, GS-1

Area under different cotton varieties is given below. Apparently major cotton area was under FH-142, MNH-886, MNH-992 and FH-Lalazar (Fig. 42).

Fig. 42: Varietal frequency of cotton crop for the year 2015



Source: DGA (PW&QC), 2015

Bt Toxin level of Commercial Varieties under cultivation

The toxin level of popular cotton varieties is given in Table 17. The toxin level during last five years remained effective against American bollworm. However, during 2015 all Bt varieties were severely affected by Pink bollworm. The cotton varieties under cultivation carry first generation Bt gene (Cry1Ac) which was commercialized in 1995. At that time its age was estimated to be 3 to 7 years and target pest since then as American Bollworm. First generation Bt gene produce maximum toxin in leaves up to 80 days only. After that quantity of Bt toxin decreases gradually and becomes very low in 120 days crop. In 2002, second generation Bt cotton was introduced and commercialized (outside Pakistan) which tackled simultaneously three bollworms (American, Pink and Spotted) throughout the season. Now, the third generation Bt cotton coupled with herbicide tolerance gene is also available in most of the cotton growing countries.

Bt toxin level in existing recommended and unapproved varieties is not a serious issue (Table 18&19). Data recorded by the entomologists of various cotton research institutes and Pest Warning and Quality Control showed negligible or no attack of bollworms after the introduction of Bt varieties in Punjab (Fig 42) while a significant damage by boll worm was observed in non Bt varieties.

This year few spots of PBW have been reported which is not indicative of the failure of Bt cotton but these were the environmental conditions, created by extended rainfall spell, optimum temperature and improper spraying, which favored the pink bollworm attack.

Table 17. Bt toxin level of cotton varieties from 2011-2015

Varieties / Genotypes	2011 (Av.2 Labs)	2012 (Av. 4 labs)	2013 (Av. 3 labs)	2014 (Av. 4 labs)	2015 (ABRI)
MNH-886	1.49	0.795	3.20	4.41 (ABRI)	3.18
FH-142	-	0.965	2.19	1.298	1.83
FH-Lalazar	-	-	2.77	1.361	2.00
FH-Noor	-	-	-	0.842	1.39

(Source: Director ABRI, Faisalabad, 2015)

Independent observation of UAF regarding toxin level, its lethality and status of cultivated varieties

University of Agriculture Faisalabad (UAF) was proactive regarding the field performance of Bt cotton against target pests. The analysis of the expression level of the transgenic cotton was also main objective. Therefore, the first round of sample collection from the farmers and seed dealers was conducted in 2012 after two years of release of Bt cotton. An extended survey for collection of leaf and boll samples from farmers' field was conducted in 2013 covering the whole cotton belt. Before sharing the findings of these studies to dissect the possible reasons of reduced cotton production due to pink boll worm (PBW), a short review supported with facts from published literature is presented to clarify certain myths and revealing the facts about 1st generation Bt technology containing single gene (*Cry1Ac*) in cotton.

Efficacy of *Cry1Ac* against bollworms

Crystalline protein of *Bacillus thuringiensis* possesses insecticidal properties. Transgenic crops expressing one or more recombinant Cry toxins have become agriculturally important. Individual Cry toxins are usually toxic to only a few species within an order, and receptors on midgut epithelial cells have been shown to be critical determinants of Cry specificity (Craig and David, 2007). The only GM event present in the fields of Pakistan is Mon531 in cotton which was developed by the US based company Monsanto under the commercial name of Bollgard I. The first planting of MON 531 cotton was in the US in 1996. According to Monsanto's own claim, this event contains *Cry1Ac* gene to confer resistance against Tobacco budworm (*Heliothis virescens*), pink bollworm (*Pectinophora gossypiella*), and cotton bollworm (*Helicoverpa zea*) (Betz *et al*., 2000; Monsanto, 2002; Monsanto EMEA, 2015, CERA). It was observed that earlier instars of tobacco budworm and pink bollworm (PBW) were more sensitive to Cry1Ac (Halcomb *et al*., 1996).

This short literature review showed that this is myth that *Cry1Ac* is only effective against American Bollworm (*Helicoverpa armigera*). Monsanto has claimed the PBW as a target pest of Cry1Ac protein.

The outbreak of PBW in Pakistan is the same story as was observed in other countries where first generation Bt cotton was introduced and cultivated. Monsanto website describes that it was natural that insects developed resistance against Bt protein. Many reports ultimately confirmed pink bollworm resistance to Bt cotton (Bollgard I) in five districts of Gujrat; Amreli, Bhavngarh, Junagarh, Surendranaga and Rajkot in 2009 and 2010 (Dhurua and Gujar, 2011; Mohan *et al*., 2015; Ojha *et al*., 2014, Tabashnik and Carriere, 2010; Monsanto, 2010). Ability of PBW to develop resistance to Cry1Ac was also demonstrated by laboratory selection of the field sourced strains in Arizona (Timothy *et al*., 2004). Bollgard I cotton is no longer registered against bollworm, *Helicoverpa zea* (Boddie) in USA and has been replaced primarily by Bt cotton that produces Cry1Ac and Cry2Ab (Bollgard II) (Tabashnik and Carriere, 2010). In China, Bt cotton producing Cry1Ac was commercialized in 1997 and has been useful against its primary target, cotton bollworm (*H. armigera*) a serious pest of many crops. Although pink bollworm is not the primary pest targeted by Bt cotton throughout China, it is a major pest in the Yangtze River Valley of China (Ministry of Agriculture of China, 2000-2010). In addition, inherent susceptibility to Cry1Ac is greater for PBW than *H.armigera*. The concentration of Cry1Ac in Bt cotton varies over time, allowing the survival of susceptible larvae of both pests. Field data indicated 1 to 11% survival of susceptible pink bollworm on Bt cotton in the Yangtze River Valley during October 2001 and 2002, respectively. Thus, a high dose of Cry1Ac is not maintained against pink bollworm in this region, ad this further boosted resistance (Tabashnik *et al*., 2012; Wan *et al*., 2004; Wan *et al*., 2012).

Possible reasons for PBW outbreak

i. Non compliance of refuge crop

To delay the evolution of resistance in target pest, the cultivation of non-Bt cotton is highly recommended as a refuge crop (Jin *et al*., 2015). But in Pakistan no farmer complied with this recommendation, and it resulted in the outbreak after five years of formal approval and cultivation of Bt varieties in the cotton belt. Another argument quoted, in favor of not using refuge crop, is that alternate hosts can serve as refuge. This is true for American bollworm (Ravi *et al*., 2005) which attacks many other plants but can't work for PBW that entirely feeds on cotton (Tabashnik *et al*., 2012). We can compare this outbreak with the case study of China where single gene (*Cry1Ac*) in cotton is available till date. The resistance against PBW has been reported in China as discussed earlier.

ii. Use of unapproved genotypes and uncertified seed

According to the provided data of varietal frequency of cotton crop for the year 2015, among top 19 cultivated Bt cotton genotypes, only three were approved. It is an open secret that the list of cotton seed companies is growing day by day that makes sure the availability of new Bt cotton lines every year. Increasing demand of new lines from farmers has pushed the business of unapproved genotypes in the market. These genotypes were never tested for their performance and no data is available about the status of *cry1Ac* gene expression. This leads to the spread of Bt cotton with sublethal level of toxin in the plants (Cheema *et al*., 2015; Khan *et al*., unpublished). The Indian case study of PBW outbreak was also blamed to some extent to the spread of unapproved Bt cotton hybrid in Gujrat, well before the regulatory approval of Bollgard hybrids in 2002. In addition Gujrat had the highest cultivation of unapproved Bt cotton hybrids and also was the first where PBW resistance was observed in India against *Cry1Ac* (Lalitha *et al*., 2009; Mohan *et al*., 2015).

iii. Sub-lethal level of toxin in cultivated Bt cotton

Cry1Ac is still effective in controlling American bollworm, so sub-lethal and temporal expression cannot be blamed for PBW outbreak. The findings of our previous study, in which leaf and boll samples of 922 plants in 19 districts of Punjab cotton belt were analyzed, showed the average concentration of toxin in leaves and bolls were 0.97 and 0.58 µg/g, respectively (Khan *et al*., unpublished). In the second study during 2014, lab bioassay for *H. Armigera* showed that LD_{50} and LD_{95} were 0.6 and 1.59 µg/g respectively (Khan *et al*., unpublished). These findings suggested the survival of American bollworm in cotton fields. Data from fields in Pakistan showed that *Cry1Ac* is still effective in controlling American bollworm. The reason is that resistance in this pest is delayed due to the presence of alternate non Bt hosts throughout the year (Ravi *et al*., 2005). But PBW has no alternate hosts in Pakistan, and it needs relatively much higher concentration especially in the square and bolls.

In addition, the temporal and intra plant variability of *Cry1Ac* expression showed that least toxin concentration was in squares and bolls after the blooming in the crop (Kranthi *et al*., 2005) which is the time of attack of PBW. High level of temporal and tissue variability of *cry1Ac* gene expression in Bt cotton coupled with seed malpractice has boosted the pace of resistance development in PBW in Pakistan.

iv. Immigration of Resistant PBW from neighborhood

The development of resistance in PBW against Bollgard I was reported in India in 2009 and there are certain areas of cotton growing regions which coincide with each other (Fig 48). There might be a possibility of migration of some resistant pests of PBW from India but there is no scientific proof till date. The import of Indian cotton might be a carrier of the resistant pest.

v. The use of single Bt gene

To delay pest adaptation, many countries now grow Bt crop “pyramids” that produce two or more toxins that kill the same pest, rather than first generation Bt crops that each produce a single toxin. The rationale for such pyramids is that insect resistant to one toxin will be killed by the other toxin in the pyramid.

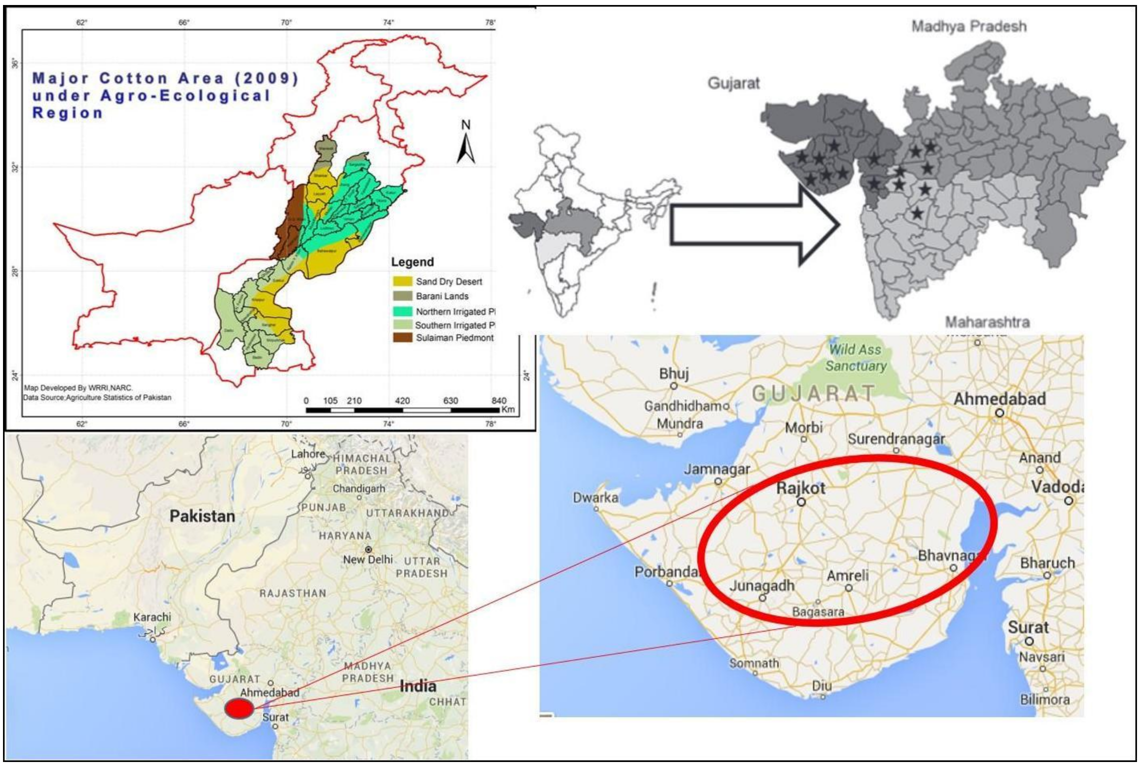


Fig. 43. Possibility of physical transfer of resistant Pink bollworm from India.Red circled zone indicated districts of Gujrat (Amreli, Rajkot, Bhavnagar, Junagarh and Surendranaga), India, where Resistance against Pink Bollworm was confirmed in 2009. The stars represent districts within each state of Gujarat, Maharashtra and Madhya Pradesh, where resistant Pink bollworms were sampled in 2010 (Mohan *et al*., 2015).

Pink bollworm moths can travel 170 miles and their physical traveling to the Pakistani cotton belt can be investigated.

Findings of UAF studies regarding Bt cotton performance in the field

1. The study conducted in 2012 showed that the unapproved Bt cotton genotypes were widely adopted by the farmers. Fourteen percent genotypes didn't contain any transgene, though they were sold as Bt cotton. The expression level of the transgene was also less than the optimum level (Cheema *et al*., 2015), (Annexure V).

2. An extended survey of cotton belt in Punjab was conducted in 2013 with improved strategy of randomized sampling. Fresh leaf and boll samples were collected from 922 plants in 19 districts at 70 DAS. Quantitative ELISA analysis showed the average concentration of toxin in leaf and boll samples were 0.97 and 0.58µg/g, respectively. We endorse the fact mentioned in section 2.3 that the toxin concentration gradually decreases in various plant parts as the plant grows older. The analysis of same plants at 120 DAS showed significant decrease in concentration of Cry1Ac. Another important finding was the long list of cotton genotypes, being cultivated at farmers' field (Annexure VI).

3. 3rd round of survey was conducted in 2015. Under this study seed dealers and farmers were randomly selected from various districts of cotton belt in Punjab and Sindh. The seed samples (404 and 479 from seed dealer and farmers) were obtained for further analysis. Though the quantitative ELISA analysis has not been carried out, yet the frequency of various varieties/genotypes showed almost the same pattern as was presented by DGA (Fig. 42). But the number of varieties and genotypes available with seed dealers and farmers are again more than 50 (Annexure VII).

4. In 2014, in vitro bioassays were conducted at UAF. First generation of field collected *Helicoverpa armigera* were fed on detached cotton leaves. Analysis of data showed that LD_{95} was 1.59 µg/g, which is higher than the average concentration present in genotypes at farmers' field. While a high concentration is must for PBW. This higher LD (in comparison to the earlier claimed LD of 0.2 µg/g) might indicate the development of resistance in American bollworm after 3 years of legal approval and 8 years of illegal introduction of Bt cotton in Pakistan.

Conclusion

1. First generation Bt cotton, harboring single gene (*Cry1Ac*), was effective in controlling all bollworms, including American and Pink bollworms. Though the transgene is under the control of constitutive promoter, yet it has an inherent problem

of inconsistent and temporal expression of transgene. Genetic background of cotton genotypes plays an important role in attenuating this expression. Therefore extreme care must be taken in breeding Bt cotton varieties. To delay the resistance up to extended time, toxin level must be higher for PBW than it is required for American bollworm due to monophagous nature of PBW.

2. Keeping in view the experience of single gene Bt cotton cultivation in India and China, the development of resistance in PBW was expected sooner than American bollworm, reasons have already been described in detail in section 2.3.2.
3. The root cause of spread of poor quality Bt cotton seed is the unregulated seed industry in Pakistan. Breeders might have developed good Bt cotton varieties with better expression level but the farmers are not getting the pure and high quality seed of these varieties at all.

It is proposed that Government may allow to commercialize second/third generation Bt cotton technology coupled with herbicide tolerance for effective control of bollworms and weeds. For this purpose following proposals are suggested for deliberation and consideration by the Government:

1. International Companies should be allowed to work and develop second/third generation Bt cotton for farmers e.g. Plant Breeding Rights (PBR) bill should be urgently enacted.
2. APTMA/PCGA may be involved for the collection and provision of technology fee to the second/third generation Bt cotton providers.
3. Technology fee to the companies may be paid out of Cotton Cess Fund under cotton control act.
4. Punjab Agricultural Research Board (PARB) has mandate of importing emerging agricultural technologies, hence PARB may be entrusted with the task of importing the second/third generation Bt cotton technology coupled with herbicide tolerance. Funds may be provided to PARB for this purpose.

A selective list of new biotech genes is given in Table 18, whereas detailed biotech genes are shown in Annexure-III. But before allowing the introduction and cultivation at farmers' level, laboratory based bioassays of the introduced transgenic cotton must be performed to know the base-line susceptibility of the existing target pests. Field collected insects must be challenged to the existing Bt cotton or the forthcoming stacked gene cotton on regular basis to determine the shift of field evolved resistance in the pests.

Table 18. Second and third generation Bt cotton options available with different companies

Sr.No.	Developer / Company	Genes	Event Name	Trade name
1	Monsanto	Cry1AC+Cry2Ab2	MON15985	**Bollgard II™ Cotton**
		Vip3A(a) + Cry1AC+Cry2Ab2	COT102 x MON15985	**Bollgard® III**
		CP4 EPSPS	MON88913	**Roundup Ready**
2	Dow Agro Sciences	Cry1AC+Cry1F+ Vip3A(a) + CP4 EPSPS	3006-210-23 x 281-24-236 x MON88913 x COT102	**Widestrike™ x Roundup Ready Flex™ x VIPCOT™ Cotton**
3	**Bayer CropScience**	Cry1Ab+ Cry2AE+ 2mepsps+bar	T 303-3 x GHB614 x GHB119	**Fibermax™ Liberty Link™**
4	Syngenta	Cry1Ab+ Vip3A(a)	COT102 x COT67B	**VIPCOT™ Cotton**

Detail of the second and third generation Bt cotton genes, their developers and functions is attached as annexure-III.

Candidate Varieties

Toxin level of varieties which have completed spot examination are given below:

Table 19. Toxin level of candidate varieties in NCVT during 2014

Entry Code PCCC	Decoded Entries	Entry Code ARI, Faisalabad	Cry1Ac 80 days after sowing (µg/g of fresh leaf weight)				
			ABRI, Faisalabad	NIGAB, Islamabad	NIBGE, Faisalabad	CEMB, Lahore	Average
V-22	Baghdadi	A-1	1.780	1.216	0.975	1.182	1.288
V-21	CEMB-77	A-2	2.500	0.741	0.648	0.894	1.196
V-20	CIM-622	A-3	1.840	2.377	0.605	0.818	1.410
V-19	Cyto-178	A-4	2.320	0.255	0.650	0.911	1.034
V-18	IR-NIBGE-7	A-5	3.930	0.544	0.926	0.845	1.561
V-17	BH-185	A-6	Negative line	0.000	0.400	0.867	0.422
V-16	FH-Noor	A-7	0.330	0.249	1.895	0.894	0.842
V-15	VH-327	A-8	1.055	0.167	0.845	0.965	0.758
V-14	NIAB-874B	A-9	1.700	1.410	0.555	1.212	1.219
V-13	RH-647	A-10	1.970	1.610	0.760	0.692	1.258
V-12	TH-21/09	A-11	3.430	3.897	1.488	0.741	2.389
V-11	IUB 63	A-12	1.490	0.086	0.470	1.013	0.765
V-10	IUB-13	A-13	0.670	2.118	1.638	1.005	1.358
V-9	CEMB-66	A-14	1.050	2.022	2.438	1.035	1.636
V-8	IR-NIBGE-6	A-15	1.060	1.962	2.176	0.931	1.532
V-7	FH-Lalazar	A-16	1.210	1.762	1.594	0.878	1.361
V-6	MNH-988	A-17	3.150	0.926	1.324	0.962	1.591
V-5	VH-305	A-18	2.660	0.045	1.674	1.060	1.360
V-4	SLH-8	A-19	Negative line	0.000	1.141	0.963	0.701
V-3	BH-184	A-20	4.320	1.103	1.295	0.634	1.838
V-2	Cyto-177	A-21	2.850	1.100	1.538	1.087	1.644
V-1	CIM-616	A-22	2.090	0.119	2.434	1.008	1.413
V-44	CRIS-342 Non Bt. Standard)	A-23	Negative line	0.000	0.000	0.215	0.072

(PCCC, 2015)

A wide range of variation in toxin level of varieties has been cleared by expert subcommittee. Many factors contribute in creating variation of toxin level in the samples including climatic conditions, age and position of leaf samples along with the standard operating procedure (SOP) and reagents. It is strongly recommended to perform the testing of boll samples along with leaf samples by opting highly uniformed SOPs. There are 14 promising strains which have toxin level of 1.25. Some of these, having other desirable characters, may be considered for approval before the next cropping season. The detailed characteristics of varieties recommended by expert subcommittee have been given in Annexure-IV.

Plant Breeding Rights

There is an urgent need of enactment of plant breeder's rights bill to create enabling environment for multinational company's investment, sector of seed and cotton research.

TOR-III

FORMULATE STRATEGY TO PROTECT THE FORTHCOMING CROP FROM HAZARDS OF INSECT/PEST ATTACK

<u>Pre-season preparations</u>

- A Year round process is required to improve cotton production in the country
- Cotton residue management in the field
- Cotton residue management in ginning factories by the enforcement of sec. 144
- Sucking insect pests especially whitefly management on spring crops/alternate hosts (Cucurbits and other vegetables)
- Weeds free water channels and field sanitation
- Discourage early sowing
- Seed bed preparation

Selection of Varieties

- Immediate approval of candidate varieties / lines
- Certified seed supply / subsidy for the use of certified seed
- Collect reliable statistics on certified seed supply (PSC data enclosed)
- Hold a dialogue / meeting with seed supply organizations / companies
- Launch campaign to use certified seed of approved varieties
- Campaign for production technology
- Delinting of seed for the control of pink bollworm
- Seed treatment with recommended insecticide / fungicide
- Fumigation of stored seed with recommended dose of Aluminium Phosphide to control overwintering larvae of Pink bollworm
- Develop a mechanism for the warranty of presence of Bt in the certified transgenic seed
- Temporal monitoring of Bt expression in field

Land Preparation and Crop Sowing

- Weather forecasting and advisory on weekly basis throughout the season
- Announce support/minimum price of the produce
- Encourage ridge sowing
- Ensure proper drainage
- Involvement of irrigation department for timely supply of irrigation water at critical crop stages
- Ensure availability of required fertilizers
- Promote plantation of refuge crop (Non Bt varieties)
- Weed management / encourage application of pre-emergence followed by post-emergence weedicides
- Maintain plant population (18000-20000 plants/acre)
- Special recommendations for seed crop to be followed (incentive)
- Installation of sex pheromone traps around the ginning factories (involve ginners) for control of pink bollworm carryover
- Early focus on Sahiwal division for sowing and pest management

Crop Management (June onwards)

- Critical first 40 days period after germination
- Constitute a committee for periodic review (biweekly) of crop
    - Weather
    - Irrigation and input supply
    - Insect pests and diseases (Special initiatives for wet seasons)
    - Weed management
- TCP intervention to maintain price level in the market upon the early arrival of PHUTTI

<u>Medium Term Plan</u>

- Enforcement of amended Seed Act
- Approval of Plant Breeders Rights Act (Preferably as an Ordinance)
- Introduction/acquisition of next generation Bt and Glyphosate/weedicide resistance genes
- Activation/review of National Bio-safety Committee (NBC)

- Explore (experimental) the introduction of mating disruption transgenic pink bollworm
- Allocation of funding for problem oriented commissioned research and development
- Training of farmers, pickers and labor
- Up-gradation of ginning machinery
- Promote zones for better staple length (Baluchistan, lower Sindh, Thal and Northern Punjab)
- Experiment introduction of hybrid cotton in Pothoar and other rainfed areas
- Promote balanced use of fertilizer
- Establishment of Insecticide Resistance Management Laboratory
- Revival of Biological Control Labs

Long Term Plan

- Revamp the federal cotton oversight mechanism by creating a forum of five concerned ministries (Food Security, Textile, Commerce, Climate Change and Science and Technology)
- Strengthening of germplasm development/acquisition program
- Marketing reforms
- Mechanized cotton picking system (Breeding to picking machines)
- Climate resilient cotton production technology
- Sustain the cotton virus and virus vector resistance programs
- Explore new insecticidal genes other than Bt
- Dedicated breeding program for long staple cotton varieties
- Effective Quarantine mechanism

Executing Agencies

- Federal Government
- Government of Punjab
- Ministry of Food Security and Research
- Ministry of Commerce
- Ministry of Textile Industry
- Director, CCRI

- Agriculture Department
- Punjab Seed Corporation
- Punjab Seed Council
- DG, Agriculture Research
- DG, Extension and Adaptive Research
- DG, Pest Warning and Quality Control of Pesticides
- Director Agri. Information
- Universities, PCCC, NIAB, NIBGE
- National Bio-safety Committee
- Private Seed Companies

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NEW COTTON GENE TECHNOLOGY (NEXT GENERATION) OPTIONS AVAILABLE WITH DIFFERENT COMPANIES

Company/ Developer	**GENES**	**EVENT NAME**	**TRADE NAME**	**FUNCTIONS**
Monsanto	Cry1Ac	MON531	Bollgard™ Cotton, Ingard™	Confers resistance to *lepidopteran* insects by selectively damaging their midgut lining.
	Cry1Ac + Cry2Ab 2	MON15985	**Bollgard II™ Cotton**	Confers resistance to lepidopteran insects by selectively damaging their midgut lining
	Cp4 epsps	MON88913	**Roundup Ready™ Flex™ Cotton**	Decreases binding affinity for glyphosate, thereby conferring increased tolerance to glyphosate herbicide
	Bxn	31707	**BXN™ Plus Bollgard™ Cotton**	Eliminates herbicidal activity of *Oxynil* herbicides (eg. *bromoxynil*).
	Vip3A (a)	COT102 x MON15985	**Bollgard® III**	Confers resistance to feeding damage caused by *lepidopteran* insects by selectively damaging their midgut lining.
	Cry2Ab 2			Confers resistance to *lepidopteran* insects by selectively damaging their midgut lining.
	Cp4 epsps (aroA: CP4)	COT102 x MON15985 x MON88913	**Bollgard® III x Roundup Ready™ Flex™**	Decreases binding affinity for glyphosate, thereby conferring increased tolerance to glyphosate herbicide.
	Dmo	MON88701	Not available	Confers tolerance to the herbicide *dicamba* (2-methoxy-3,6-dichlorobenzoic acid) by using *dicamba* as substrate in an enzymatic reaction.
	Bar	MON88701 x MON88913 x	Not available	Eliminates herbicidal activity of *glufosinate*

		MON15985		(*phosphinothricin*) herbicides by acetylation.
Dow AgroSciences LLC	Pat (syn)	281-24-236	Not available	Eliminates herbicidal activity of *glufosinate* (*phosphinothricin*) herbicides by acetylation.
	Cry1F			Confers resistance to *lepidopteran* insects by selectively damaging their midgut lining.
	Cry1Ac	281-24-236 x 3006-210-23 (MXB-13)	**WideStrike™ Cotton**	Confers resistance to *lepidopteran* insects by selectively damaging their midgut lining.
	Pat (syn)	3006-210-23	**not available**	Eliminates herbicidal activity of *glufosinate* (*phosphinothricin*) herbicides by acetylation.
	Cry 1Ac			confers resistance to lepidopteran insects by selectively damaging their midgut lining
	Vip3A (a)	3006-210-23 x 281-24-236 x MON88913 x COT102	**Widestrike™ x Roundup Ready Flex™ x VIPCOT™ Cotton**	Confers resistance to feeding damage caused by *lepidopteran* insects by selectively damaging their midgut lining.
	Cp4 epsps (aroA: CP4)			Decreases binding affinity for glyphosate, thereby conferring increased tolerance to glyphosate herbicide.
	pat	81910	Not available	Eliminates herbicidal activity of *glufosinate* (*phosphinothricin*) herbicides by acetylation.
	aad-12			Catalyzes the side chain degradation of 2,4-D herbicide
Bayer Crop Science	bar	GHB119	**Not available**	Eliminates herbicidal activity of glufosinate (phosphinothricin) herbicides by acetylation

	Cry2Ac			Confers resistance to *lepidopteran* insects by selectively damaging their midgut lining.
	2mepsps	GHB614	**GlyTol™**	Decreases binding affinity for glyphosate, thereby increasing tolerance to glyphosate herbicide
	Cry 1Ac	GHB614 x LLCotton25 x MON15985	Not Available	Confers resistance to *lepidopteran* insects by selectively damaging their midgut lining.
	Cry2Ab 2			Confers resistance to lepidopteran insects by selectively damaging their midgut lining.
	bar	LLCotton25	**Fibermax™ Liberty Link™**	Eliminates herbicidal activity of *glufosinate* (*phosphinothricin*) herbicides by acetylation
	Cry1Ab	T303-3	Not Available	confers resistance to lepidopteran insects by selectively damaging their midgut lining.
Syngenta	Vip3A (a)	COT102 (IR102)	**VIPCOT™ Cotton**	confers resistance to feeding damage caused by lepidopteran insects by selectively damaging their midgut lining.
	Cry 1 Ab	COT102 x COT67B	**VIPCOT™ Cotton**	Confers resistance to *lepidopteran* insects by selectively damaging their midgut lining.
	Cry 1 Ab	COT67B	**not available**	Confers resistance to *lepidopteran* insects by selectively damaging their midgut lining.
Chinese academy of Agricultural Sciences	Cry 1Ab-Ac	GK12	Not available	Confers resistance to *lepidopteran* insects by selectively damaging their midgut lining.

	Cry 1 A	SGK321	Not available	Confers resistance to *lepidopteran* insects by selectively damaging their midgut lining.
	CpT1			confers resistance to a wide range of insect pests.
Central Institute for Cotton Research and University of Agricultural Sciences Dharwad (India)	Cry 1Ac	BNLA-601	Not available	Confers resistance to *lepidopteran* insects by selectively damaging their midgut lining.
DuPont (Pioneer Hi-Bred International Inc.)	S4-HrA	19-51a	**Not available**	allows the plant to synthesize essential amino acids in the presence of sulfonylurea herbicides
JK Agri Genetics Ltd (India)	Cry1Ac	Event1	**JK 1**	Confers resistance to lepidopteran insects by selectively damaging their midgut lining
Metahelix Life Sciences Pvt. Ltd (India)	Cry1 C	MLS 9124	**not available**	Confers resistance to lepidopteran insects, specifically Spodoptera
Nath Seeds/ Global Transgenes Limited, India	Cry1Ab -Ac	GFM Cry1A	**not available**	Confers resistance to lepidopteran insects by selectively damaging their midgut lining

Source: DGA Research, 2015