Problems and Prospects of Cultivation of Bt Hybrids in North Indian Cotton Zone

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Abstract: Cotton as a crop as well as a commodity plays an important role in the agrarian and industrial activities of the nation and has a unique place in the economy of our country. Cotton popularly known as "White Gold" is grown mainly for fiber. In addition to this, cotton seed is second important source of the edible oils. India has been a traditional home of cottons and cotton textiles. The domestication of the cotton cultivation for clothing of humanity was considered to begin in Asian sub-continent using diploid cottons. India is the only country where all the four cultivated species of cotton are grown. Our economy is consistently influenced by cotton through its production and processing sectors, and by generating direct and indirect employment to more than sixty million people. Since the introduction of Bt cotton in north Indian zone, there has been a gradual increase in production and productivity and highest production of 52.1 lakh bales with productivity of 594 kg lint /ha was recorded during 2006-07. The major bio-physical constraints identified were: inadequate crop stand because of poor emergence due to crust formation by rains just after sowing; seedling burning due to high temperature at emergence; alkalinity and salinity problems; less turn-around time; rising water-table & depletion of water table in some pockets; rains during September coinciding with flowering and fruit setting; pest incidence such as cotton bollworms earlier and now, after the introduction of Bt cottons, sucking pests especially the mealy bugs, cotton leaf curl virus disease, and resistance to insecticides. In a study conducted by this regional station in Haryana and Rajasthan during 2007-08 the yield gain due to Bt cotton over traditional varieties (2006-07 & 2007-08) comes to the tune of 18.8 to 19.7 % and 22.0 to 27.8 % respectively. At the same time the reduction in insecticide sprays from 40 to 41.1% in Rajasthan and 33.3-41.7% in Haryana was observed. Research agenda needs to address constraints associated with Bt cotton hybrids considering the near and medium term futuristic needs of the region include development of technology to maintain proper plant stand of Bt hybrids, to evolve agronomic requirements of different Bt cotton hybrids for realization of maximum yield potential by the farmers, need to select parents which are tolerant/resistant to sucking pests especially jassids (*Amrasca devastans*), thrips (*Thrips tabaci*), Mealy bugs (*Phenococcus solenopsis*) and white fly (*Bemisia tabaci*) for the region, stacking of more than one gene and use of more events for minimizing the threats of breaking down of resistance and discouraging undescript Bt hybrids.

1 Introduction

Cotton as a crop as well as a commodity plays an important role in the agrarian and industrial activities of the nation and has a unique place in the economy of our country. Cotton popularly known as "White Gold" is grown mainly for fiber. In addition to this, cotton seed is second important source of the edible oils. India has been a traditional home of cottons and cotton textiles. The domestication of the cotton cultivation for clothing of humanity was considered to begin in Asian sub-continent using diploid cottons. India is the only country where all the four cultivated species of cotton are grown. Our economy is consistently influenced by cotton through its production and processing sectors, and by generating direct and indirect employment to more than eight million people.

The northern cotton zone is mainly spread in Haryana, Punjab and Rajasthan states of India (Fig.1). In Haryana the cotton area includes five major districts in this belt namely Sirsa, Fatehabad, Hisar, Jind and Bhiwani and constitute more than 90% area of crop in the state. In Punjab, the area under this zone comes in south western part of the state and includes the districts of Bhatinda, Muktsar, Faridkot, Ferozpur, Mansa and Moga and covers the major and most productive area of cotton. The area in

Rajasthan is categorized under Sriganganagar zone and includes the districts of Sriganganagar and Hanumangarh. About 80% of the total cotton area of the entire state is being grown in this zone. This is a contiguous area of around 15 lakh ha and the wheat is cultivated in the almost entire area after cotton during the *rabi* season.

2 The climate and soils

The climate of the area is sub-tropical, arid, continental and monsonic. The crop is sown from first week of April to first fortnight of May when weather is usually dry and atmospheric temperature ranges from 35-45^{0}C in Punjab. The annual rain fall during the cropping season ranges from 500-600 mm, a large amount of which is received during July and August though occasional rains during September/October are not uncommon which are not conducive for the crop (Anonymous, 2008).May is the hottest while December is the coolest month. The mean annual rain fall is 363.8 mm in cotton growing areas of Haryana of which nearly 60 percent of the rain fall is received during July-September. The overall trend of rain fall in general is erratic and uncertain. The mean annual minimum and maximum temperatures are 18.0 & 31.1^{0}C respectively. The maximum and minimum temperatures range between 17.0-40.9^{0}C and 6.0-28.2^{0}C respectively. Similarly the minimum and maximum relative humidity ranges between 28-82 & 49-84% respectively (Table 1). The mean daily temperature at Sriganganagar (Rajasthan State) ranges from 20.5^{0}C in January to 42.1^{0}C in June and the rain fall ranges from about 100mm in south west to about 350 mm in the east (Anonymous,1999). The soils generally consist of coarse loamy to fine loamy, mixed (calcareous) hyperthermic family of Ustic Haplocambids. Generally the soils have a very high concentration of soluble salts and exchangeable sodium. These soils have brown, sandy loam, slightly to moderately alkaline A horizon underlain by dark yellowish brown to light yellowish brown, sandy loam to loam alkaline B horizon. The lime concretions of fine to medium size occur at places and their size and quantity increase with soil depth (Anonymous 2000).

3 Area production and productivity

Looking at the entire zone, a wide fluctuation of cotton area in the zone between 12.13 to 18.9 lakh ha was noted during the past one and half decade due to various biotic and abiotic factors (Table 2). The area under cotton has almost stabilized around 14 to15 lakh ha in north zone during the past four years. The cotton production and productivity touched a peak of 45.5 lakh bales and 405 Kg lint/ha respectively during 1996-1997 and later showed a fluctuating trend mainly due to changing biotic stresses. After 1996-97 outbreak of cotton leaf curl virus (CLCuV) disease and severe attack of American bollworms led to reduction in area under cotton. There was an epidemic of *Helicoverpa armigera* in the zone during 2001-2002 and the production and productivity of the zone dipped to 24.0 lakh bales and 250 kg lint/ha. In Rajasthan non-availability of irrigation water was another reason for reduction in acreage under cotton.

India, the largest cotton growing country in the world, where 60 million people are impacted by cotton has seen that in 2007 the Bt cotton area has soared to 6.2 million hectare grown by 3.8 million small and resource poor farmers. Bt cotton has increased yield by up to 50%, reduced insecticide sprays by half, with environmental and health implications and increased income by upto US $250 or more per hectare which has contributed to social benefits and alleviation of their poverty (Anonymous, 2007). Since the introduction of Bt cotton in the area, there has been a gradual increase in production and productivity and highest production of 52.1 lakh bales with productivity of 594 kg lint /ha was recorded during 2006-07 (Table 2).

4 Production Constraints in North Zone

The fluctuations in productivity of cotton in the three states despite the total irrigated conditions has brought a question mark on the sustainability of the system. The major bio-physical constraints identified were: inadequate crop stand because of poor emergence due to crust formation by rains just after sowing; seedling burning due to high temperature at emergence; alkalinity and salinity problems; less turn-around time; rising water-table & depletion of water table in some pockets; rains during September coinciding with flowering and fruit setting; pest incidence such as cotton bollworms earlier and now, after the introduction of Bt cottons, sucking pests especially the mealy bugs, cotton leaf curl virus (CLCuV) disease, and resistance to insecticides.

Development of early-maturing cotton varieties made it possible to follow cotton-wheat cropping system in a year. This doubling of cropping intensity from 100 to 200% gave a significant boost to the economy of farmers in irrigated tract in northern India. Acreage under cotton increased in all the three states manifolds due to the double cropping. With the increase in area under cotton, insects-pests also became a serious problem in the region. In spite of usage of huge amount of pesticides, the control of insect-pests became a source of socio-economic tension to the farmers. Introduction of newer pesticide like synthetic pyrethroids during 1980s, created havoc not only in polluting the environment but also in development of insecticide resistance in bollworms of cotton.

5 Prospects of Bt cotton cultivation

Efforts on breeding for resistance or tolerance to insects in cotton were made during 1980s and early 1990s. These conventional efforts are still going on by utilizing traits responsible for non-preference, anti-biosis and avoidance. As a result of this, a number of cotton cultivars having resistance against sucking pests were identified. However, these efforts never resulted in a perfect genotype, which exhibited resistance against bollworms (Khadi, 1996). Meanwhile, biotechnological tools came handy in transferring pest resistance in cotton. The crystal protein gene (*Cry 1AC*) derived from the soil bacterium, *Bacillus thruingiensis* was transferred to cotton through *Agrobacterium* mediated gene transformation. The cry protein produced in transgenic cotton was found to be toxic to bollworms, *Helicoverpa zea, H. virescens* and *Pectinophora gossypiella* (Bartlett 1995; Bartlett *et al,* 1997; Fitt,1998; Forrester et al., 1998; Niwancho et al,1998).

The commercial cultivation of such transgenic cotton conferring pest resistance began during 1996 in USA and 2002 in India. During 2005, six Bt cotton cultivars were approved for cultivation in north zone of the country by GEAC/DBT. During 2006, eight new Bt cotton cultivars were approved for this zone. With the approval of eighteen more Bt hybrids during 2007 and twenty one in 2008-09, there are at present 53 approved Bt cotton hybrids for cultivation in northern zone of the country. These Bt hybrids have four major events: (Cry 1 Ac gene (Bollgard-I), Cry1Ac gene (Event 1) sourced from IIT Kharagpur, Fusion genes (cry 1Ab and cry 1 Ac) known as (GFM event) sourced from China, Stacked Cry (Cry I Ac and Cry 2 Ab) genes (Event MON 15985 or BG-II) sourced from Monsanto. Almost 50% area in north zone has now come under Bt cotton hybrids in a short span of three years (Table 3).

Detailed survey on cultivation, adoption and performance of Bt cotton conducted by various agencies revealed significant multiple benefits. These include: increase in yield, decreased production cost, and reduction of insecticide application, resulting in substantial environmental and health benefits to farmers along with significant social and economical benefits. In a study conducted by this regional station (Monga,2008) in Haryana and Rajasthan during 2007-08 the yield gain due to Bt cotton over traditional varieties (2006-2007 & 2007-2008) comes to the tune of 18.8 to 19.7 % and 22.0 to 27.8 % respectively. At the same time the reduction in insecticide sprays from 40 to 41.1% in Rajasthan and 33.3-41.7% in Haryana was observed (Table 4). There is a need to popularize and regulate the Bt cotton hybrids and the

area under Bt cottons can be further increased to 70~80 percent for increased production and productivity of the zone.

In addition to this, primary observation revealed that in Bt cultivars early reproductive (fruiting) bodies are protected from bollworm damage due to inbuilt resistance mechanism provided by *Cry1 ac* gene. Thus, in these cultivars vegetative phase is shortened and plants mature early. In case of non-Bt genotypes, damage of early-fruiting bodies prolonged the vegetative phase and so maturity was delayed. Therefore, Bt cultivars fit well in cotton-wheat rotation in comparison to non-Bt cultivars. It is being observed that in Punjab where Bt cotton cultivation has taken a lead as compared to Haryana and Rajasthan, acreage under timely-sown wheat after Bt cotton has increased considerably. Therefore, growing of Bt cotton cultivars gives better yields not only of cotton but of following wheat as well.

With the advancement of science and technology, the existing problems of Bt cotton may also be taken care off. For example, Bollgard II cotton hybrids are tolerant to spodoptera. In order to preserve *Bt* cotton well into the 21st century, producers, seed companies, scientists, and regulators need to foster strong collaboration to ensure the effectiveness and longevity of the technology. The institutions and private companies are striving hard to develop new genes for insertion into cotton plant DNA to provide other possibilities for improving agronomic traits and pest control characteristics. Genes for new insecticidal toxins with different target site will be important for managing a wider spectrum of insects and for slowing the pace of resistance. The Bt gene developed by the public institutes in India, e.g., Cry *1 Ac* by NRCPB and UAS Dharwad, Karnataka has also been approved for transgenic research by GEAC and cleared from environmental safety and is soon likely to be commercialized. It will be available in the pure line varieties of cotton, thus the farmers will not be required to purchase the seed of Bt hybrids every year. With the development and release of new transgenic events, the probability of development of resistance by the bollworms complex has reduced.

Research agenda needs to address constraints associated with Bt cotton hybrids considering the near and medium term futuristic needs of the region

- Highly vulnerable and extreme climatic conditions of North India, i.e., high temperature, rains and hot winds during sowing and seeding stage in May and June result in the poor/negligible plant stand in some fields which require re sowing, hence technology to maintain proper plant stand of Bt hybrid needs to be evolved.
- The agronomic requirements of different Bt cotton hybrids have not been studied thoroughly which hinder the realization of maximum yield potential of these hybrids by the farmers. The state agricultural universities can evolve location/region specific agronomic packages to further boost the technology and to harness maximum benefits out of it.
- As the problem of sucking pests is increasing, there is an urgent need to select parents which are tolerant/resistant to sucking pests especially jassids (*Amrasca devastans*), thrips (*Thrips tabaci*), Mealy bugs (*Phenococcus solenopsis*) and white fly (*Bemisia tabaci*) for the region.
- The stacking of more than one gene and use of more events shall go a long way in minimizing the threats of breaking down of resistance of this extremely useful technology.
- The area under spurious/underscript hybrids of Bt cotton and even F2 seed of Bt cotton hybrids is quite high which creates favorable environment for the development of insect-pests and diseases. There is a need to advocate the farmers not to grow unapproved hybrids of Bt cotton to harvest the maximum benefits from this technology.

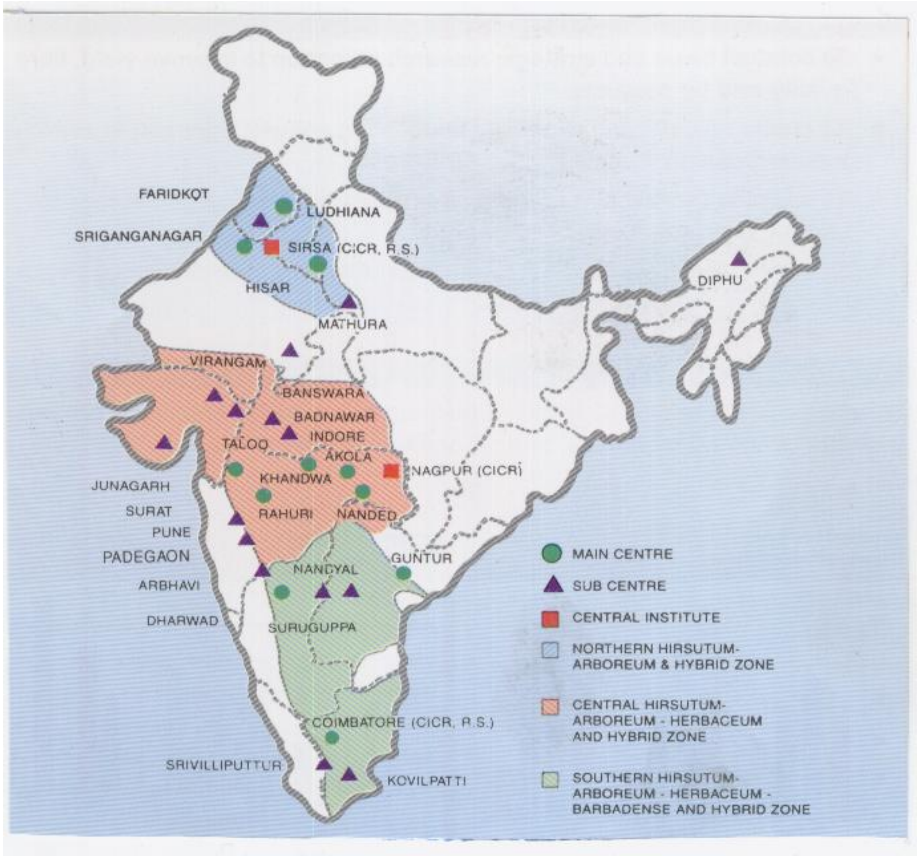

Fig. 1 Cotton cultivation area in the country

Table 1 Average Weather Data for the Block Years 1998-2007

month	Max Temp. °C	Min. Temp. °C	Mean Temp. °C	R/F mm	RH %	
					I	II
Jan.	17.0	6.0	11.5	7.6	84	46
Feb.	19.4	12.0	15.7	17.5	81	67
Mar.	29.5	14.1	21.8	15.2	69	64
Apr.	37.6	19.6	28.6	4.1	49	29
May	40.9	25.6	33.2	33.3	50	31
June	39.3	26.9	33.1	50.7	60	45
July	36.6	28.2	32.4	121.8	73	79
Aug.	35.5	26.8	31.1	53.1	74	82
Sep.	34.1	19.1	26.6	35.1	74	78
Oct.	33.2	19.1	24.3	19.1	64	38
Nov.	28.2	10.8	19.5	2.1	65	28
Dec.	22.3	7.5	14.9	4.2	72	34
Total	31.1	18.0	24.4	363.8	67.9	51.7

CICR Regional Station Sirsa, Haryana observatory (200m above sea level)

(Latitude 29° 02′ 3" N, Longitude 75° 02′ 11" E)

Table 2 Area, production and productivity of cotton in north zone

Year	Area (000 ha)	Production (lakh bales)	Productivity (Lint kg / ha)
1993-94	15.67	33.36	354.33
1994-95	15.63	39.08	396.33
1995-96	18.65	43.15	391.33
1996-97	18.90	45.50	405.33
1997-98	17.53	24.92	239.67
1998-99	16.93	22.06	224.67
1999-00	14.65	30.56	351.67
2000-01	14.41	32.59	377.67
2001-02	15.71	24.01	250.00
2002-03	12.19	25.48	346.00
2003-04	12.13	35.61	500.00
2004-05	13.86	48.43	572.67
2005-06	14.88	48.20	540.33
2006-07	14.06	52.10	594.33
2007-08	14.99	50.85	561.00

Source: AICCIP annual reports

Table 3 Area trends under Bt cottons in North Zone (lakh ha)

	Punjab	Haryana	Rajasthan	Total
2005	0.5	0.1	traces	0.6
2006	1.73	0.4	0.02	2.15
2007	3.89	2.75	0.4	7.04

Source: State departments of agriculture

Table 4 Performance of Bt cotton hybrids in North Zone

	Rajasthan(2006-2007)		Rajasthan(2007-2008)		Haryana(2006-2007)		Haryana(2007-2008)	
SCY(q/ha)	Av. Sprays	SCY*(q/ha)	Sprays	SCY(q/ha)	Av. Sprays	SCY(q/ha)	Av. Sprays	SCY(q/ha)
Bt hybrids	4.0	25.94	5.0	23.81	3.5	25.40	4.0	26.60
G.hirsutum var.	7.5	18.72	8.5	18.58	6.0	20.40	6.0	21.60

*Seed cotton yield

Source: Sir Ratan Tata Trust Project report, CICR, RS, Sirsa.

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