

Attributes and Socio-economic Dynamics of Adopting Bt Cotton

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Bt cotton, adopted as a solution to curb losses caused by bollworms and to reduce the use of pesticides, successfully brought about a decline in pesticide consumption and expenditure, increase in productivity along with a higher output-input ratio in Punjab in 2004-05. Despite increased productivity and reduced pesticide use, Bt cotton is expected to increase the incidence of primary bollworms, which could develop resistance and secondary pests. But the undesirable, indirect and unanticipated consequences of innovation go together, as do the desirable, direct and anticipated consequences.

World over, cotton is grown on more than 32 million hectares with approximately 71 per cent of the production in developing countries. In India, cotton is an important commercial crop being grown on 8.9 million hectares, constituting 27 per cent of the world area under cotton. Despite the largest share in area and third largest share in total world production, India ranks 57th with respect to cotton productivity [FFAI 2002]. The major reasons for low productivity of cotton are multiple pest problems and the crop being grown largely on un-irrigated soil (almost 65 per cent area under cotton is unirrigated). Insect-pests are estimated to cause losses up to the extent of 50 per cent in cotton productivity [CICR 1998]. The losses, in fact, have increased from about 18 per cent in the early 1960s [Pradhan 1964] to 50 per cent in 1990s [Dhaliwal et al 2004]. In spite of the significant use of pesticides in cotton, the total crop losses amounted to Rs 287.6 billion (ibid). Chandra (1998) and Wahab (1997) estimate the annual damage by bollworm to the tune of Rs 120 billion.

Development of hybrid cotton varieties in 1970s, which occupy 45 to 50 per cent of area under the crop,¹ gave boost to its productivity in the past. As a result, cotton productivity² in India increased from 1.06 q/ha during 1970-71 to 2.65 q/ha during 1996-97. In Punjab, it jumped from 4.63 q/ha during 1990-91 to 5.02 q/ha during 1994-95 and then followed a downward slide and reached an all time low of 1.79 q/ha in 1998-99, when farmers were unable to recover even the cost of cultivation. This was due to the outbreak of American bollworm (*Helicoverpa armigera*), which is one of the major insect-pests of cotton and has developed resistance to pesticides due to selection pressure. From about two-three insecticide applications in cotton in 1970s, farmers were reported to have applied more than 30 insecticide applications in cotton³ during 2003 and 2004 [Peshin 2005].

To overcome this downward slide in the productivity of the cotton crop, many integrated pest management (IPM) programmes such as the regional programme on cotton IPM by Commonwealth Agricultural Bureau International (CABI) in 1993, FAO-European Union IPM programme for cotton in 2000, National Agricultural Technology Project (NATP) for IPM in 2000 and Insecticide Resistance Management Programme in 2002 were initiated. The focus of these IPM programmes was to reduce and rationalise pesticide use by encouraging farmers to adopt other pest management practices like cultural and manual-mechanical practices in the absence of any effective bio-agents.

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The pest scenario also underwent a change since the introduction of synthetic pesticides. The pesticide, which was considered “silver bullet” to overcome all pest-related problems, has in fact compounded the problems. Rachel Carson (1962) wrote a book *Silent Spring* that brought about the change in the mindset of the people associated with agriculture. However, it was not until 1975 that much attention was paid to the dysfunctional consequences of pesticide adoption in crop cultivation. Scientists and extension workers led farmers into “pesticide treadmill”. According to available estimates, out of the total pesticide consumption, 50 per cent and more is used for the cotton crop amounting to Rs 160 billion, of which Rs 110 billion are spent only to control bollworms [Alagh 1988; Mayee et al 2002]. The share of insecticide cost in the total cost of cultivation of cotton in Punjab increased many folds from 2.1 per cent during 1974-75 [Dhaliwal and Arora 2001] to 21.2 per cent during 1998-99 [Sen and Bhatia 2004]. In pesticide hotspots like Bhatinda district in Punjab, it was 50 per cent of the total cost of cultivation [Shetty 2004]. This was despite the fact that many IPM programmes were implemented in Punjab from time to time.

Introducing Bt cotton for cultivation was another step to reduce the pesticide use in the crop. Bt technology was found to have significantly reduced application rates of toxic chemicals, while significantly increasing yields [Qaim and Janvry 2005]. Bt cotton is grown in eight states, viz, Madhya Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Punjab and Haryana. In Punjab, the government of India approved the cultivation of Bt cotton in March 2005. However, the Punjab farmers had started cultivating Bt cotton in 2002, purchasing seeds from far off states like Gujarat. The six varieties recommended for cultivation in 2005 were: Ankur 2534, Ankur 651, RCH 134, RCH 317, MRC 6301 and MRC 6304. Out of these permission for two varieties, viz, Ankur 2534 and Ankur 651 was withdrawn by the Punjab Agricultural University (PAU), Ludhiana in 2006 due to low productivity.

The present study attempts to investigate the socio-economic dynamics, attributes and rate of adoption of Bt cotton in Punjab. The study is divided in six sections. The next section briefly outlines the controversy surrounding Bt cotton. Details of the database and methodology used in the study are given in the second section. In the third section, awareness, adoption and attributes of Bt technology have been highlighted. Input use and productivity pattern of Bt cotton have been discussed in the fourth section. The economic structure of Bt cotton is highlighted in the fifth section. The last section presents the concluding remarks.

1 Controversy Surrounding Bt Cotton

Spraying pesticide formulations based on bacillus thuringiensis (Bt) have been in limited use for the control of larvae of lepidopteran pests for more than 40 years. The transgenics

developed during recent decades are tolerant against pests and are the main alternative to the use of synthetic organic pesticides for crop protection. The first transgenic crop variety was developed in squash crop in 1994, which was resistant to viruses [Norris et al 2002]. During the same year, glyphosate-resistant transgenic varieties of maize and soybean crops were released. In the year 1995, insect-resistant cotton, maize and potatoes using Bt genes were released in the us (ibid).

The transgenic crops are grown in 17 countries on a total area of 81 million hectares [Zehr 2006]. In India, Bt cotton was approved for cultivation in 2002. The Bt cotton acreage increased manifolds since 2002 (Table 1).

There are two schools of thought; one, advocating the adoption of Bt cotton for reducing the use of insecticides, cutting farmers’ production costs and increasing yield [Bannett et al 2004; Perlak et al 2001; Huang et al 2002] and the second criticising biotechnology and doubting its usefulness for small farmers in the developing countries [Mishra 2006; GRAIN 2001; Wang 2006].

In the us, in 1997, the farmers growing Bt cotton achieved greater productivity by \$24.43 per acre including insect control costs and the increase in returns rose to \$39.86 per acre [Boulter and Hilder 2002]. Huang et al (2002) while reporting the potential benefits and impact of Bt cotton in China highlighted that the actual use of pesticides in Bt cotton was much less ranging from 11.8 kg/ha in 1999 to 32.9 kg/ha in 2001 as compared to that in non-Bt cotton, which varied from 48.5 kg/ha to 87.5 kg/ha over the

same period. On an average, cultivation of Bt cotton helped reduce pesticide use by 35.7 kg/ha (55 per cent reduction). However, they failed to explain the significant and unwarranted rise in pesticide use in Bt cotton from 1999 to 2001.

‘Bt Technology Adoption, Bounded Rationality and the Outbreak of Secondary Pest Infestation in China’ claims that after seven years of Bt cotton introduction in China (1996 to 2004), the expenditure on pesticides for Bt and non-Bt was identical in 2004 at \$101 per ha and the earnings from Bt cotton were lower [Mishra 2006]. Narayanamoorthy and Kalamkar (2006) reported the economical viability of Bt cotton for Indian farmers (Maharashtra). Contrary to expectations, the total quantity of pesticides used in Bt cotton variety MECH 162 was higher than non-Bt cotton varieties. The average net profit from Bt cotton was Rs 31,880 per ha, about 80 per cent higher than that from non-Bt cotton. There was no significant difference in pesticide use between Bt and non-Bt cotton varieties. However,

Table 1: Rate of Adoption of Bt Cotton

Year	Total Area under Cotton (Million ha)	Area under Bt Cotton (Million ha)	Extent of Adoption of Bt Cotton wrt % Area
2001-02	8.73	–	–
2002-03	7.67	0.07	0.91
2003-04	7.63	0.23	3.01
2004-05	8.50	1.30	15.29
2005-06	8.96	1.41	15.74
2006-07	8.96	3.00	33.48

Sources: Government of Punjab (2006), Gol (2005), Zehr (2006).

Table 2: Socio-Economic Profile of the Respondents

Particular	District			Overall (n=210)
	Bathinda (n=70)	Ferozepur (n=70)	Mansa (n=70)	
A Pattern of education (% of respondent farmers)				
Illiterate	10	9	16	11
Primary	7	17	11	12
Middle	20	23	26	23
Matric	37	40	36	38
10+2	10	7	11	9
Graduate and above	16	4	0	7
B Farmers with telephone connection (%)				
	67	64	56	62
C Average size of operational holding (ha)				
	8.17	14.10	6.96	9.75
D Distribution of operational holdings (%)				
Small (below 2 ha)	11	3	6	7
Semi-medium (2-4 ha)	20	11	27	20
Medium (4-10 ha)	39	37	51	42
Large (above 10 ha)	30	49	16	31

it is too early to generalise in India, where four million small and marginal farmers have taken up cultivation of Bt cotton with estimated adoption rate of 50 per cent by the end of 2007 [Mishra 2006]. Illegal and spurious seeds coupled with non-maintenance of minimum 20 per cent refugia by these farmers may result in severe pest attack on Bt cotton due to selection pressure and outbreak of secondary pests like whitefly [Chari 2006]. The bollworm is expected to develop resistance in 2007-08, where it was introduced in 2002 [Kranthi 2006]. Cotton monoculture and non-adoption of IPM principles is the recipe for such failure.

2 Methodology

The present study was conducted in the cotton growing areas of Punjab. The state accounts for 10 per cent production from 5 per cent area under cotton in the country and the highest average productivity since 2000-01. The cotton growing districts in Punjab are Bathinda, Ferozepur, Mansa, Mukatsar, Faridkot, Sangrur and Moga with more than 70 per cent of cotton growing area falling in the first three districts.⁴ These three districts were purposively selected for conducting formative evaluation of insecticide resistance management (IRM) based IPM programmes in cotton. The IRM programme is being implemented by Central Institute of Cotton Research, Nagpur since 2002 in 28 districts, distributed over 10 states in India, which account for more than 80 per cent insecticide use in cotton.

Thirty villages (10 from each district) were covered under the IRM programme in 2004-05. From these 10 villages in each district, five villages were randomly selected for data collection, making a total of 15 villages being covered under programme. In addition, out of nine control villages (not participating in the IRM programme), six villages (two from each district) were selected randomly. Thus, out of a total of 21 villages, the data were collected from 210 farmers (10 from each selected village) for the present study.

Most of the adoption research has worked on the socio-economic attributes of farmers to predict the causes of adoption or non-adoption. Rogers' diffusion model has dealt comprehensively by generalising socio-economic characteristics responsible for adopting new technology in agriculture [Rogers 1995]. These generalisations are that formal education, income, level of living, landholding, social mobility, empathy, etc, have positive correlation with adoption, whereas age has no relationship with adoption. The personality variables and communication behaviour have also been generalised. Due to the huge already existing body of knowledge about these socio-economic and other variables, this study does not explore the relationship with adoption/rate of adoption of Bt cotton, which is conventional input technology like the green revolution technologies of high yielding varieties, fertilisers, pesticides, etc.

The diffusion research has put much effort on studying personal characteristics, but relatively little effort has been devoted to analyse innovation difference/technological attributes which affect the rate of adoption (ibid). To overcome the pro-innovation bias, alternative research approaches to after-the-fact-data collection about how Bt cotton diffused, had to be employed. To study the diffusion of technology overtime, data are to be collected during the diffusion process at different stages and not after completion of the diffusion process (ibid). This base-line study of Bt cotton adoption will serve as the base for further studies of Bt cotton adoption in Punjab.

A semi-structured questionnaire, in the local language, was distributed amongst selected farmers before the start of the cotton-growing season in 2004-05. This was done in order to avoid the problems/discrepancies associated with recall/recollection of information by the farmers after the growing season is over. The respondents were revisited after regular intervals (with a time gap of not more than three weeks) during the crop growing season, to ensure proper and correct recording of the required information and to dispel doubts emanating when recording the data. The questionnaire focused on the socio-economic characteristics of the respondents, extent and level of adoption, input use, cost of cultivation, production and returns.

3 Awareness, Adoption and Attributes of Bt Cotton

Majority of the farmers (around 89 per cent) was literate with the proportion of illiterate being 11 per cent. The modal level of education was matriculation. Sixty-two per cent of these farmers had telephone connections. Average size of the operational holding was the highest in Ferozepur (14.10 ha), followed by Bathinda (8.17 ha) and Mansa (6.96 ha) with an overall average landholding of 9.75 ha (Table 2, p 74). The average holding size was much higher than the average size of 3.61 ha in the state largely due to the progressive farmers (active farmers or larger landholders) being trained under IRM project and the sample consisting largely of these farmers. The fact is further strengthened from pattern of distribution of the sample holdings, majority of which (more than two-thirds) belonged to the medium and large size categories.

3.1 Adoption of Different Cotton Cultivars

Cotton is the main 'khraif' crop in the study area. About 64 per cent of the total area was under cotton, with its proportion being the highest in Bathinda (67.92 per cent) and that being the least in Mansa (58.30 per cent). About 60 hybrid cotton, 24 non-hybrid cotton, Bt cotton and 'desi' cotton varieties are being cultivated in Punjab [Peshin 2005]. The extent of adoption of Bt cotton and other varieties was measured in terms of percentage of area covered under different varieties and percentage of farmers adopting Bt cotton and other varieties. The extent of adoption of Bt cotton revealed a varied picture in the three districts. The extent

Table 3: Adoption of Varieties of Cotton

	District			Overall (n=210)
	Bathinda (n=70)	Ferozepur (n=70)	Mansa (n=70)	
A Average size of operational holding (ha)	8.17	14.10	6.96	9.75
B Average area under cotton crop (ha)	5.63 (67.92)	9.22 (64.47)	4.10 (58.30)	6.32 (63.97)
C Extent of adoption (% farmers) ¹				
Bt cotton	93	42	83	72
Other hybrids	71	268	93	63
Other varieties ²	45	88	38	57
D Per cent of total cotton area under				
Bt cotton	42	10	21	22
Other hybrids	29	8	58	25
Other varieties ¹	29	82	21	53

Figures in the parenthesis are % of cultivated area (i.e, B as % of A);

(1) Represents multiple responses.

(2) It includes non-hybrid varieties and second progeny (F2 generation) Bt cotton varieties.

All decimals have been rounded up to nearest whole numbers.

of adoption of Bt cotton was higher in Bathinda and Mansa districts, where 93 per cent and 83 per cent of the farmers, respectively, had cultivated Bt cotton, but extent of area was highest in Bathinda (42 per cent) compared to that in Mansa (21 per cent). The extent of such adoption was the least in Ferozepur, where 26 per cent of farmers had cultivated Bt cotton on 10 per cent of the area under cotton cultivation (Table 3, p 75). Overall, Bt cotton was adopted by 72 per cent farmers in the area and accounted for 22 per cent of the total area under cotton during 2004-05. The results clearly put the Bathinda district ahead in adoption of Bt cotton with Ferozepur lagging far behind. One reason for the varied adoption pattern was an earlier start by the farmers in Bathinda and Mansa districts in 2002-03 than in Ferozepur, where its adoption started in 2004-05. In Punjab, it has been a case of adoption of Bt cotton without the approval of Genetic Engineering Approval Committee (GEAC), ministry of environment and forests government of India, and without the recommendation of PAU. Another reason for low adoption of Bt cotton in Ferozepur is the salinity of groundwater making these varieties less compatible in the area. Despite the largest average size of landholding, the technological constraint of higher water requirement (of non-saline quality) has been a limiting factor for adoption of Bt cotton in Ferozepur. The same reason prevailed for low adoption of other non-Bt hybrid varieties in this district and thus the dominance of non-hybrid varieties.

There was large inter-district diversity in the adoption of cotton varieties (both hybrids and non-hybrids). In Bathinda, 41.6 per cent of the area was under Bt cotton, followed by Bt cotton first progeny (16.1 per cent), H 8 (3.9 per cent), Vikram 11 (3.8 per cent), RCH 134 (3.4 per cent) and Ankur 651 (2.8 per cent). The detail of the varieties of cotton having area coverage of more than 1 per cent is listed in Table 4. In all, more than 35 varieties of cotton were cultivated in the study villages of district Bathinda. In the case of Ferozepur, the distribution of area under different varieties of cotton was somewhat evenly distributed between seven varieties. The extent of adoption of F 414 was maximum

Table 4: Extent of Adoption of Cotton Varieties during 2004-05

Bathinda		Ferozepur		Mansa	
Variety/Hybrid	Area (%)	Variety/hybrid	Area (%)	Variety/hybrid	Area (%)
Bt cotton	41.6	Bt cotton	9.6	Bt cotton	20.9
Bt cotton 1st progeny	16.1	Bt cotton 1st progeny	1.1	Bt cotton 1st progeny	7.6
Ankur 651	2.8	Ankur 651	1.13	Ankur 651	9.08
RCH 134	3.4	F 1861	3.39	Ankur 2226	10.56
RCH 317	1.0	LH 1556	1.51	Ankur 2534	1.97
Dhaval 2	2.5	F 1378	9.68	Ankur 655	3.94
Birla 88	2.3	F 414	16.56	RCH 134	1.69
Vikram 11	3.8	Rosian wali	8.23	Birla 88	1.69
H 8	3.9	Rawat Saria	12.69	Nath Rani	2.39
Paras	1.9	Kiker Khara	1.57	Ganga Kaveri	1.40
Raja Sikander	2.6	PK 54	3.14	Kohinoor	2.11
F 846	1.2	F 1352	2.67	H-8	7.32
F 1378	2.4	Punjab Gold	8.61	Govinda	1.69
Other varieties (22+ varieties)	14.5	SML 8	7.82	Krishma	2.39
		Other varieties (35+ varieties)	12.29	LH 1556	3.45
				F 1378	5.07
				Sikanderpuria	2.25
				Other varieties (28+ varieties)	14.47
Total area (ha)	388.8		636.6		284.05

Varieties having area coverage more than 1% are listed. Rest included in other varieties.

(16.56 per cent), followed by Rawat Saria (12.69 per cent), Bt cotton (9.6 per cent), F 1378 (9.68 per cent), Punjab gold (8.61 per cent), Rosianwali (8.23 per cent) and SML 8 (7.82 per cent). More than 48 varieties of cotton were being cultivated in the district. In Mansa, the maximum area was under under-script Bt cotton (20.9 per cent), followed by Ankur 2226 (10.56 per cent), Ankur 651 (9.08 per cent), H 8 (7.32 per cent) and F 1378 (5.07 per cent). In addition, 7.6 per cent area was under the first progeny (F 2 generation) of Bt cotton. The area under different Ankur varieties was 25.55 per cent. In all, more than 44 varieties of cotton were cultivated in IRM and non-IRM villages of district Mansa. The farmers in Punjab, having adopted Bt cotton even before it was officially recommended, were cultivating different Bt cotton varieties in addition to the ones recommended by the PAU in 2005. Same is the case with non-Bt hybrid and non-hybrid varieties as 53.84 per cent area was under the varieties not recommended by the PAU for cultivation in Punjab.

3.2 Awareness-Knowledge and Rate of Adoption

Mass media channels like newspapers and representatives of seed companies were initially responsible for spreading information about Bt cotton. During the initial years, farmer-to-farmer communication (interpersonal communication channel) also spread awareness about Bt cotton being introduced in India in 2002 from farmers who visited other cotton growing states like Gujarat. The incidence of awareness about Bt cotton started as early as in 2000, even before its cultivation was allowed by the government of India, and by 2004-05 such awareness was complete (100 per cent). Majority of the farmers (71 per cent) had become aware about Bt cotton in 2003 and 2004 (Figure 1). The sources of their information (Table 5, p 77) were other farmers (76 per cent), representatives of seed/pesticide companies (19 per cent), newspapers (11 per cent) and commission

Figure 1: Awareness-Knowledge and Rate of Adoption

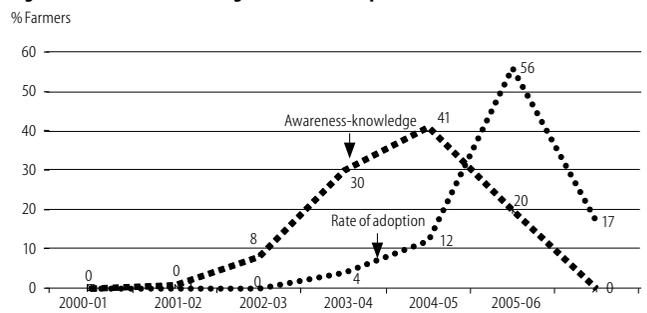
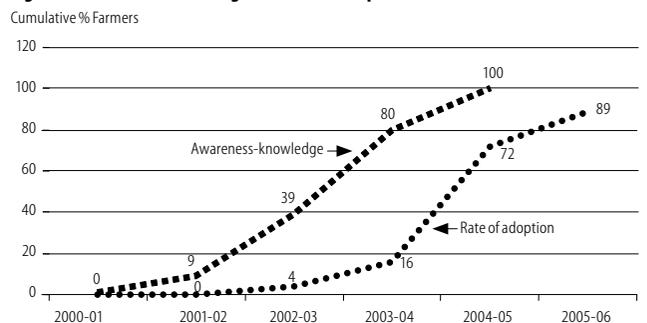


Figure 2: Awareness-Knowledge and Rate of Adoption



agents (5 per cent). Interpersonal communication channels were the main source of diffusion of this innovation.

The awareness pattern formed 's' shaped curve overtime when cumulative number/percentage of farmers was plotted on a graph, while the frequency distribution of the number of farmers getting awareness per year approached normality (Figure 2, p 76). The rate of adoption of Bt cotton also formed an 's' shaped curve, when cumulative number/percentage of farmers adopting Bt cotton overtime was plotted and approached normality when the frequency distribution of farmers adopting it over time was plotted on a graph. These results are in agreement with Rogers' diffusion theory revealing that knowledge precedes adoption at a faster rate.

Bt cotton being similar to green revolution technologies, the diffusion theory fits in here, which is not the case with inter-dependent complex technologies like IPM. Against 4 per cent rate in 2002 (the seed of Bt cotton was purchased by farmers from Gujarat or through commission agent as the government of India allowed cultivation of Bt cotton in Punjab only in 2005), the adoption multiplied to 16 per cent in 2003-04 and then jumped to 80 per cent during 2005-06.

3.3 Technological Attributes

The attributes of technology are important variables that determine the rate of adoption. Diffusion studies have mostly tended to regard all technologies/innovations as equivalent [Rogers 1995]. Technological attributes are more important to speed up the rate of adoption. The generalised attributes, which affect adoption are: relative advantage, compatibility, trialability, observability and complexity. Out of these, first four attributes are positively related to the rate/extent of adoption, while complexity is negatively related to it. The attributes of Bt cotton as reported by farmers have been presented in Table 5.

First, there has been a clear relative advantage of Bt cotton cultivation over the other varieties as reported by the farmers. Almost 97 per cent of farmers admitted to its resistance to bollworms, 87 per cent to relatively higher yields, 84 per cent for their potential to save expenditure on pesticides. Even 72 per cent of the farmers reported that Bt cotton varieties were easy to adopt. Further, almost 60 per cent of the farmers reported compatibility of Bt cotton with their farming systems and soils, etc. However, there were some reports of its non-compatibility (although small), Bt cotton being water-intensive (29 per cent) and fertiliser-intensive (3 per cent). Further, 11 per cent of the farmers cited Bt seed to be very costly, and 3 to 5 per cent reported their susceptibility to cotton leaf curl virus (CLCV) and tobacco caterpillar. Bt cotton being susceptible to CLCV and tobacco

caterpillar needs to be researched. These non-compatibility issues can hinder the adoption of Bt cotton. Recently, the new state government has slashed the seed prices by almost 40 per cent to give a further push to the adoption.

Finally, resistance to bollworms and higher yields were the benefits (observability) and the respondent farmers reported no complexity during Bt cultivation. All these attributes of Bt cotton have pushed up the rate of its adoption even before it was given an official go-ahead for cultivation in Punjab.

4 Pattern of Input Use and Productivity

In this section, based on the field study carried out during 2004-05, a comparative analysis of Bt cotton with other varieties has been done with respect to the input use pattern. The impact of Bt cotton in reducing the insecticide use and its productivity advantage as a result of reduced insect pest losses has also been discussed.

4.1 Input Use

The variety-wise input use pattern for cotton is depicted in Table 6 (p 78). The recommended seed rate for hybrid and non-hybrid cotton varieties is 3.75 kg/ha and 10 kg/ha, respectively. In case of non-hybrid varieties, the PAU recommendation has changed over time. The seed rate recommended was 20 kg/ha in 1979, 10 kg/ha in 2004 and 8.75 kg/ha in 2005 [PAU 1979, 2004, 2005]. However, the actual seed rate has differed from the recommended levels as farmers used the seed on the basis of their own experience and feasibility analysis. In hybrid varieties of cotton, 97 per cent farmers had applied 1.87 kg to 2.25 kg seed per ha, whereas in case of non-hybrid varieties 80 per cent of the farmers applied higher seed rate (more than 10 kg/ha). The average seed rate in Bt cotton was 2.07

kg/ha and that in non-Bt hybrid varieties was 2.25 kg/ha. In case of non-hybrid varieties the average seed rate used was 13.65 kg/ha. It is clear that the farmers were using less than recommended seed rate for the hybrid varieties, which was largely due to higher cost of hybrid seeds, and the seed companies recommending seed rate of 2.25 kg/ha, which is lower than the PAU recommendation of 3.75 kg/ha.

Fertiliser use was the highest in the case of Bt cotton, followed by hybrid cotton and was the least in the non-hybrid cotton varieties. The nitrogenous fertiliser use in Bt cotton was higher by 23 and 31 per cent when compared to the other hybrid and non-hybrid varieties, respectively. The respective phosphatic fertiliser use was higher by 17 and 50 per cent and the potashic fertiliser use was higher by 104 and 413 per cent. The use of zinc-sulphate was also higher in Bt cotton by 25 and 10 per cent, respectively. Although there was no difference in the

Table 5: Awareness, Attributes and Expected Adoption of Bt Cotton

	Percentage of Farmers			
	Bathinda	Ferozepur	Mansa	Overall
A Sources of awareness/information (multiple response)				
Other farmers	77	73	78	76
Representative of a company	21	20	16	19
Commission agent	2	6	6	5
Newspapers	13	10	10	11
Extension officer	2	0	0	1
B Sources of seed (2004-05)				
Authentic	52	42	33	43
Not authentic	44	58	60	52
Cannot say	4	0	7	5
C Attributes of Bt cotton (multiple response)				
Resistance to bollworms	96	100	98	97
Higher productivity	83	87	93	87
Saving on pesticide expenditure	94	57	93	84
Easy to adopt	92	37	75	72
Compatible	77	23	68	60
Not compatible	6	0	8	5
Facilitates timely sowing of wheat	0	7	10	2
High cost of seed	8	10	15	11
More water requirements	46	17	18	29
Higher fertiliser requirements	8	0	0	3
Susceptible to cotton leaf curl virus	0	0	3	1
Susceptible to tobacco caterpillar	6	3	0	3
No benefit	4	3	8	5
D Estimated adoption of Bt cotton in 2005-06				
Area under Bt cotton (ha)	67.02	28.30	51.70	46.26
Farmers growing Bt cotton (%)	100	78	80	86

pesticide⁵ use between the other hybrid and non-hybrid varieties, its use declined significantly by almost 137 per cent in case of Bt cotton. There was no such difference in the number of irrigations applied. Hence, there was a clear comparative advantage of Bt cotton in terms of pesticide use when compared to the other hybrid and non-hybrid varieties, translating ultimately into relatively lower costs of cultivation and hence more returns.

4.2 Reducing Insecticide Use

There has been a significant decline in pesticide consumption in the case of Bt cotton when compared to the other hybrid and non-hybrid varieties. However, the impact on the insecticide use needs to be discussed. We have attempted to highlight such an impact in terms of the number of insecticide applications, quantity consumed (technical grade material) and the costs incurred. Bt cultivation has resulted in a significant decline in the number of insecticide applications, its average consumption as well as the costs incurred. The average number of insecticide applications in Bt cotton was 4.7 as compared to 10.5 in case of non-Bt cultivars (Table 7). In all districts, the number of applications reduced by more than half in Bt cotton as compared to non-Bt varieties. The consumption of insecticides was 2.57 kg/ha and 6.44 kg/ha in Bt and non-Bt varieties, respectively. The average cost of insecticide use reduced significantly by more than 60 per cent when compared to non-Bt varieties. The results followed the same pattern in all the districts although they varied in their extent.

The highest numbers of insecticide application were registered in Ferozepur both in Bt cotton (6.51) as well as other cultivars (13.08). The farmers in this district were also using more number of cocktails of insecticides. The maximum number of insecticide applications by tank mixing of insecticides separately was 30 in non-Bt cotton, while it was the minimum in Bt cotton (just two). The Abohar area in this district is the hot spot of insecticide use in Punjab. In Bt cotton, farmers had mainly applied insecticides for sucking pest such as jassid, whitefly and in certain pockets for tobacco caterpillar due to its outbreak. A few farmers also applied insecticide for bollworms, either due to its attack in later stages of crop cycle (or fear of such attack) or owing to some incidences of spurious seeds of Bt cotton. Despite all this, there was lesser

number of insecticide applications in Bt cotton when compared to other cotton cultivars.

4.3 Productivity of Bt Cotton

Insect pest losses caused by the bollworm complex especially *Helicoverpa armigera* (American bollworm) in Bt cotton were significantly reduced thus, resulting in higher productivity. The overall productivity of Bt cotton⁶ was 24.17 q/ha as compared to the productivity of 23.39 q/ha and 18.51 q/ha of other hybrid and non-hybrid varieties, respectively (Table 8). The seed cotton yield of recommended

Bt cotton varieties (RCH 134, RCH 317, MRC 6,301 and MRC 6,304) was 25.19, 26.54 and 25.26 in district Bathinda, Ferozepur and Mansa, respectively. In this field study, we have included as well as recommended other varieties of Bt cotton, non-Bt cotton hybrids and non-hybrid varieties to provide a comprehensive overview of the cotton growing scenario in Punjab. The average yield of different recommended varieties of cotton recorded by the PAU based on research and farmer field trails is given in Table 9 (p 79). It is evident that the yields recorded by the PAU in case of recommended Bt cotton varieties are higher than the yield obtained by the farmers in the study area except in Bathinda. The Bt cotton varieties cultivated by the farmers were those approved by the GEAC and recommended by the PAU in 2005 and other under-script Bt varieties like Tulsi, Navbharat 151, etc. But in case of non-Bt hybrid varieties the farmers had recorded higher yield than the average yield recorded by the PAU, but more than 50 per cent of the cotton growing area was under the varieties not recommended by the PAU like Ankur 2,226, Ankur 2,534, RCH 134, RCH 317 etc. Though PAU recommends non-Bt Ankur

Table 8: Productivity of Bt Cotton, Other Hybrids and Non-hybrid Varieties in Punjab

	Districts			Overall
	Bathinda	Ferozepur	Mansa	
A Productivity (q/ha)				
Bt cotton	27.89	21.20	21.37	24.17
Other hybrids	24.89	20.17	23.15	23.39
Other varieties ¹	19.23	18.32	18.10	18.51
B Difference in productivity of Bt cotton wrt				
Other hybrids	12.05*	5.11	-8.33	3.33
Other varieties ¹	45.03***	15.72**	18.07**	30.58***

¹It includes non-hybrid varieties and second progeny (F2 generation) Bt cotton varieties.
 ***, ** and * represent significance at 1, 5 and 10% levels.
 The yield difference between Bt cotton and other hybrids is not significant.
 This can be due to the fact that farmers had sown under-script Bt cotton, mostly in district Mansa.

651 for cultivation in Punjab, it has withdrawn the recommendation for Ankur 651 Bt cotton due to its lower yields (17.50 q/ha) compared to other Bt cotton varieties (Table 9). Some of the non hybrid and desi cotton varieties (F 1861, F 846) have comparable or higher average yield potential than Bt cotton varieties but the losses caused by insect pests (especially bollworms) neutralise that higher yield potential.

Table 6: Input Use

Input	Bathinda			Ferozepur			Mansa			Overall		
	Bt Cotton	Other Hybrids	Non-hybrids									
Fertiliser use (kg/ha)												
Nitrogenous	253.83	231.12	159.29	305.66	239.54	209.33	236.54	194.85	146.02	260.59	211.36	199.50
Phosphatic	113.19	110.61	82.34	179.02	109.32	80.77	93.48	100.63	87.84	122.30	104.78	81.47
Potashic	13.19	3.83	6.88	17.89	17.37	1.81	17.55	7.54	10.34	15.23	7.45	2.97
Zinc sulphate	2.16	5.09	1.61	1.33	0	2.81	6.42	0	3.41	3.01	2.40	2.73
Seed (kg/ha)	2.07	2.28	10.80	2.00	2.26	15.04	2.13	2.25	12.54	2.08	2.26	13.65
Pesticide* (weedicide+insecticide)	2.82	4.63	4.63	3.20	8.25	8.25	2.96	5.15	5.15	2.82	6.68	6.68
Average no of irrigations	7.47	7.47	7.47	5.60	5.60	5.60	5.71	5.71	5.71	6.26	6.26	6.26

*Average technical grade material. Figures in parentheses represent % difference wrt Bt cotton.

Table 7: Pattern of Insecticide Use and Cost of Insecticide Applications

Input	Bathinda			Ferozepur			Mansa			Overall		
	Bt Cotton	Non-Bt	% Difference	Bt Cotton	Non-Bt	% Difference	Bt Cotton	Non-Bt	% Difference	Bt Cotton	Non-Bt	% Difference
	Average no of insecticide applications	3.78	7.79	106.08*	6.51	13.08	100.92*	4.98	10.01	101.00*	4.76	10.46
Insecticide use@ (kg/ha)	2350	7470	217.87*	3978	7934	99.45*	3258	7228	121.85*	2934	7546	157.19*
Cost of insecticides (Rs/ha)	2.45	4.25	73.70*	3.08	8.13	164.12*	2.63	4.82	83.27*	2.58	6.44	149.86*

@Technical grade material. * means significant at 1% level.

There was no significant difference between the productivity of Bt cotton and other hybrid varieties in the state. It was only in Bathinda that a significant difference (12 per cent) was recorded. In district Mansa, the Bt cotton yield was on the lower side than non-Bt hybrids. This may be due to the fact that in this district the Ankur

Table 9: Average Potential Yield of Different Varieties in Punjab

Variety	Average Yield (q/ha)
A Bt cotton varieties	
RCH 134 Bt	28.75
RCH 317 Bt	26.25
MRC 6301 Bt	25.00
MRC 6304 Bt	25.25
B Non-Bt hybrid varieties	
Ankur 651	17.50
Whitegold	16.25
LHH 144	19.00
C Non-hybrid cotton varieties	
F 1861	16.25
F 1378	25.00
F 846	27.25
LH 1556	21.25
D Desi cotton varieties	
PAU 626 H	24.50
Moti	21.25
LD 694	17.50
LD 327	28.75

Average lint yield for the state as a whole for cotton is 731 kg/ha. Source: PAU (2007).

varieties 651,2226, 2,534 and 655 were the most widely adopted varieties and the majority of farmers had cultivated undescript and Ankur Bt cotton varieties which are lower yielding (17.50q/ha) than other Bt cotton varieties (Table 9). The recommendation of Ankur Bt cotton varieties was withdrawn for the same reason by the PAU in 2006. However, the productivity of Bt cotton differed significantly from that of non-hybrid cotton varieties in the entire study area, the overall difference being more than 30 per cent. The difference was the largest in Bathinda (45 per cent), while the difference (although significant) was just 15.7 per cent and 18.1 per cent in Ferozepur and Mansa, respectively. The productivity of different cultivars of cotton was higher in Bathinda district than that in Mansa and Ferozepur districts.

5 Economic Structure of Bt Cultivation

The relative advantage of a technology in terms of economic returns plays an important role in the rate/extent of its adoption. The cost-returns structure of different cultivars of cotton has been discussed below to highlight the economic benefits of Bt cultivation in the state.

The expenditure on cotton production was divided into six categories, namely land preparation, sowing cotton seed, inputs, cost of spraying, hoeing and other expenditure (Table 10). The overall cost of cultivation (per ha) of Bt cotton, other hybrids and non-hybrids was Rs 22,431, Rs 24,259 and Rs 21,713, respectively. The cost of cultivation of Bt cotton was lower by 7.54 per cent than that of other hybrid varieties but was higher by 3.31 per cent than that of non-hybrid varieties. The major reason for lower costs in the former case is the significant reduction in the insecticide cost (including the cost of sprays), which even neutralised the higher cost of Bt seed. The higher cost of cultivation than non-hybrid varieties was due to the reason that the difference in the cost of seed was much higher, which could not be neutralised by reduced insecticide cost and the labour charges for the sprays. The average per ha cost of seed was Rs 4,621 for Bt cotton, Rs 1,914 for other hybrids and Rs 484 for non-hybrids. The cost of insecticides was Rs 3,005 and Rs 7,546 per ha and the labour cost of sprays was Rs 476 and Rs 1,046 per ha for Bt and non-Bt varieties, respectively. The cost of insecticides amounted to 17, 37 and 41 per cent of the total cost of cultivation of Bt cotton, other hybrids and non-hybrids, respectively. It is thus clear that adoption of Bt cotton in the state has helped in reducing the cost of cultivation of the crop.

Table 10: Cost-returns Structure for Different Cultivars of Cotton in Punjab

	Districts			Overall
	Bathinda	Ferozepur	Mansa	
Cost of Cultivation (Rs/ha)				
A Land preparation				
Pre sowing irrigation ¹	472	375	496	448
Ploughing and planking ²	2,336	2,172	2,076	2,195
Sowing ²	415	415	415	415
Inputs				
B Seed³				
Bt cotton	4,607	4,445	4,733	4,621
Hybrid cotton	1,960	2,030	1,846	1,914
Other varieties (includes non-hybrid varieties and Bt cotton F2 generation)	512	458	512	484
C Chemical fertilisers⁴				
Bt cotton	2,351	3,212	2,192	2,494
Hybrid cotton	2,235	2,224	1,887	2,051
Other varieties	1,578	1,800	1,620	1,764
D FYM⁵				
	150	64	161	118
E Insecticide⁶				
Bt cotton	2,350	3,978	3,258	3,005
Hybrid cotton and other varieties	7,470	7,934	7,228	7,546
F Weedicid⁷				
	306	134	261	234
G Irrigation¹				
	3,574	2,142	2,577	2,765
H Cost of spraying (Rs ha⁻¹)				
H1 Insecticides				
Bt cotton	378	651	498	476
Hybrid cotton and other varieties	779	1,308	1,001	1,046
H2 Weedicid⁷				
	80	39	88	69
Hoeing (Rs ha⁻¹)				
Manual	746	560	713	673
Tractorised	350	247	256	284
J Other expenditure (Rs ha⁻¹)³				
J1 Picking				
Bt cotton	4,741	3,604	3,633	4,109
Hybrid cotton	4,231	3,429	3,936	3,976
Other varieties	3,269	3,114	3,077	3,147
J2 Cleaning bunds	175	175	175	175
J3 Cleaning of field after picking	350	350	350	350
Total cost of cultivation (A to J)				
Bt cotton	23,434	22,519	22,009	22,431
Hybrid cotton	25,479(+8.03)	23,598(+4.57)	23,466(+6.07)	24,259(+7.54)
Other varieties	22,562(-3.86)	21,287(-5.79)	21,006(-4.77)	21,713(-3.31)
Output (q/ha) and returns (Rs/ha)				
A Average seed cotton yield				
Bt cotton	27.89	21.20	21.37	24.17
Hybrid cotton	24.89	20.17	23.15	23.39
Other varieties	19.23	18.32	18.10	18.51
B Gross returns⁸				
Bt cotton	50,760	38,584	38,893	43,989
Hybrid cotton	45,300(-12.05)	36,709(-5.11)	42,133(+7.69)	42,570(-3.33)
Other varieties	34,999(-45.03)	33,342(-15.72)	32,942(-18.07)	33,688(-30.56)
C Net income				
Bt cotton	27,326	16,065	16,884	21,558
Hybrid cotton	19,821(-37.86)	13,111(-22.53)	18,667(+9.55)	18,311(-17.90)
Other varieties	12,437(-119.77)	12,055(-33.26)	11,963(-41.14)	11,975(-80.28)
D Returns-cost ratio				
Bt cotton	2.17	1.71	1.77	1.96
Hybrid cotton	1.78	1.56	1.80	1.75
Non Hybrid cotton	1.55	1.57	1.57	1.55
E Pesticide (including application) cost as % to total cost of cultivation				
Bt cotton	13.29	21.32	18.65	16.87
Hybrid cotton	33.89+20.6	39.90+18.58	36.56+17.91	36.67+19.80
Non-hybrid cotton	38.27+24.98	44.23+22.91	40.84+22.19	40.97+24.10

The figures have been given separately for Bt cotton, hybrid cotton and non-hybrid cotton for all those operations where the difference was estimated to exist. For rest of the operations the cost estimates are the same. The yield levels and returns have also been given separately. Figures in parenthesis are % difference over Bt cotton. The cost of cultivation includes the labour costs – family and hired labour (Rs 80 per man day). The cost of spraying pesticides Rs 100 per ha for both tractorised and manual spraying. The expenditure on account of hoeing was computed on uniform market rates. The average number of hoeings, tractorised and manual were multiplied with Rs 250 ha⁻¹ and Rs 625 ha⁻¹, respectively. The other expenditures included cost of picking (Rs 170 q⁻¹), cleaning of bunds (Rs 175 ha⁻¹) and cleaning of fields after picking (Rs 350 ha⁻¹). All these were calculated at uniform market prices.

(1) Irrigation as per expenditure given by a farmer for canal and tube well irrigation. (2) At uniform market rates. (3) Price of purchased seed or own seed at market price (Bt cotton: Rs 4,621; hybrid cotton: Rs 875-2,250; non-hybrid: Rs 312-500/ha). (4) Fertilisers at market price plus cost of application. (5) Farm Yard Manure (FYM) @ Rs 150/trolley (40 tonnes). (6-7) Insecticides and weedicides at market price. (8) Returns are computed by using average actual market price (Rs 1,820/q).

As a result of such adoption, not only the proportion of insecticide use in the total cost has reduced but the net returns have also followed an increasing pattern. Increased attack of American bollworm on the crop during the late 1990s seriously endangered the economic viability of this crop in the state resulting in fast depletion of this crop from the cultivation map. However, attractive economics of cultivation of Bt cotton in the form of reduced cost of cultivation and higher returns due to better yields have facilitated its fast adoption by the state farmers ensuring its significant revival in the state. Owing to the difference in yields of these cultivars, the cost of picking also varied accordingly and was Rs 4,109, Rs 3,976 and Rs 3,147 per ha for Bt cotton, other hybrids and non-hybrids, respectively. On the productivity side, the average yield of seed-cotton was 24.17 q/ha, 23.39 q/ha and 18.51 q/ha for the respective cultivars. As a result, the gross returns (per ha) were Rs 43,989 for Bt cotton, Rs 42,570 for other hybrids and Rs 33,688 for non-hybrids.

Hence, at present, Bt cotton cultivation seems economically viable in Punjab. The economic viability of Bt cotton is reflected by the fact that the ratio between gross returns and cost of cultivation was 1.96 compared to 1.75 in other hybrids and 1.55 in non-hybrids. The ratio is even better in Bathinda at 2.17, which might be due to the benefits of an earlier and hence, greater extent of adoption in the district. It is a positive sign and implies that the benefits can improve once the adoption picks up, spurious Bt cotton seed is eliminated from the market and the cultivation practices based on IPM principles are standardised in the state.

6 Conclusions

The base line study of adoption of Bt cotton in Punjab has reinforced the diffusion theory that input intensive technologies follow the normal distribution curve of awareness-knowledge

and rate of adoption with the latter following the former. Bt cotton cultivation has resulted in higher external input use, namely, fertilisers and irrigation water but reduced the insecticide use. The cost of Bt cotton seed and higher fertilisation cost has been offset by lower expenditure on account of insecticides. The higher gross returns due to higher productivity have resulted in improving the economic viability of Bt cotton cultivation. This being a base line study, we need to follow the Bt cotton cultivation in Punjab over a period of time to study its functional (desirable) and dysfunctional (undesirable) consequences. The “silver bullet” technology for control of bollworms needs to be studied without the innovation bias otherwise we may again prove wrong as we have been in the case of “pesticide” introduction in agriculture. Pesticides were termed as solution of all pest problems but it led the farmers onto a “pesticide treadmill”. The integrated pest management principles need to be applied for developing IPM to avoid development of resistance to bollworms against Bt cotton. Despite increased productivity and reduced pesticide use in us, China and India, the monoculture Bt cotton is expected to increase the incidence of primary pest bollworms, which could develop resistance and develop secondary pests like caterpillars. The dying of Bt technology in China in seven years (1997-2003) has also been reported. The scientists and change agents/agencies over-emphasising adoption per se, assuming that the consequences of adoption of a technology will be positive and usual survey research methods being inappropriate to investigate consequences [Rogers 1995], may lead the farmers into transgenic-cum-pesticide treadmill. Hence, there is need to study short term, long term, desirable and undesirable consequences of Bt cotton cultivation over a period of time, to evaluate its sustainability.

NOTES

- 1 The hybrid varieties occupied 45 to 50 per cent of the total area under cotton before the introduction of Bt cotton.
- 2 It refers to the total quantity of lint produced per hectare. Lint is produced at the rate of one-third of seed cotton yield.
- 3 The cotton here refers to non-Bt varieties.
- 4 The total area under cotton in Punjab was 589 thousand ha during the period of study (2004-05), out of which the area in Bathinda, Ferozpur and Mansa was 141,133 and 82 thousand hectares, respectively.
- 5 Pesticide included both weedicides and insecticides.
- 6 Productivity is in terms of seed cotton.

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