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Socio-economic Impact of Transgenic Cotton[1]

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Abstract

The study has reported the impact of Bt cotton cultivation on cost of pesticides, cost of production and profitability across social categories, size-groups of farmers and different agro-climatic zones. The share of farmers in the additional gains from the adoption of biotechnology has also been worked out. The study has shown that Bt cotton technology is superior to the conventional cotton hybrids in terms of both yield and net returns. The Bt farmers from all size categories, agro-climatic zones and social groups are benefited from its cultivation compared to non-Bt farmers from the same categories. The study has inferred that this technology is scale neutral and smallholder cultivators are also benefited from it. It has advocated that the private sector can also play a crucial role in commercial crops like cotton and the gains from their efforts are obtained mainly for farmers. And therefore, creating enabling environment to encourage private sector investments is crucial in harnessing the biotechnology.

Introduction

The tools of biotechnology are used for the first time in cotton to incorporate a gene resistant to *Helicoverpa* bollworm, bringing out the first ever transgenic cotton in the country in 2002, often called Bt cotton. The farming community has widely adopted this technology at unprecedented rates for any agricultural technology. The area under Bt cotton reached 76 lakh hectares and 82 per cent of the total cotton area in the country in 2008 (James, 2008). The productivity and production of cotton increased at very high rates during this period of rapid Bt cotton area expansion. The productivity, which was hovering around 250 kg/ha of lint for a long time, crossed 500 kg/ha by 2008 and production reached 300 lakh bales. The exports of raw cotton reached 85 lakh bales in 2007-08. The introduction of biotechnology is widely seen as the reason for dramatic turnaround in cotton production, while the growth rates in many other crops plummeted during this period. It is argued that the success in the application of biotechnology in cotton has to be replicated in other crops (Rao and Dev, 2009). Further, as it has been clearly established that the technological gains from the green revolution technologies have exhausted their potential (Kumar *et al.*, 2008), several scholars have suggested that biotechnologies can revive the country's agriculture grappling with the lack of a genuine breakthrough in agricultural research efforts (Dev, 2008; Rao, 2004; 2005). However, there are some civil society groups who continue to say that yield growth from Bt cotton is a myth and they attribute this growth to other factors like increased cotton area under irrigation and replacement of open pollinated varieties with hybrids (e.g. Kururganti, 2009).

The empirical evidence across the countries shows that Bt cotton impacts the pesticide-use, yield, and labour-use and thereby the income distribution patterns (Table 1). There are variations across the countries on the impact on each of these factors. It is emerging from the literature that reduction in pesticide consumption is high in countries where the pesticide-

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[1] This paper is based on two longitudinal field studies conducted in Andhra Pradesh with funding from the Andhra Pradesh Netherlands Biotechnology Programme of the Institute of Public Enterprise, Hyderabad and Centre for Economic and Social Studies, Hyderabad.

Table 1. Economic and environmental impacts of Bt cotton

Country	Yield	Pesticidal expenditure	Profit
Argentina	33	-47	31
China	19	-47	340
India	26	-73	47
Mexico	11	-77	12
South Africa	65	-58	198

Source: World Bank (2007)

use is already very high, as in Mexico and China. The literature on the yield effects clearly point towards an increase in yield in all the countries studied, with higher increase in tropical and sub-tropical countries because of severe pest pressure. There were also regional winners and losers in the USA due to lack of adopted varieties (Falck-Zepeda *et al*., 2000). This finding underlines the need for research in our socioeconomic and agro-climatic context on the impact of Bt cotton.

The performance of Bt cotton in India is highly controversial. Qaim (2003) has reported yield increase of 80 per cent using trial plot data. On the other hand, Shiva *et al*. (1999) had oncluded that the yield in all the trial plots was more or less the same with no significant reduction in cost of cultivation. It was also held by them that where the bollworm pressure is not high, Bt cotton might not be economically suitable.

Several reports from the field indicate that the first year of Bt cotton cultivation was a disaster in many of the cotton-growing states like Andhra Pradesh (AP), Maharashtra, Madhya Pradesh (MP), Karnataka and Gujarat (Krishnakumar, 2003). It was reported that small saving in pesticide sprays (Rs 217/ac), less profits and susceptibility to pink bollworm were reported in a study conducted in Maharashtra and AP (Sahai and Rehman, 2003). Similar results with more attack of sucking pests were reported from a season-long study on Bt cotton in Andhra Pradesh (Qayum and Sakkari, 2005). In another field survey in the first year of commercialization in Tamil Nadu, Karnataka, Maharashtra and Andhra Pradesh, it was found that the yields increased by 34 per cent in Bt cotton over the conventional cotton and that the farmers of Andhra Pradesh suffered a loss in average incomes (Naik *et al*., 2005). The unauthorised Bt cotton in Gujarat was also reported to have given higher yields (Iyengar and Lalitha, 2007). In a study conducted in two districts of Maharashtra, it was found that the yield and profit increased by 52 per cent 79 per cent, respectively (Narayanamoorthy and Kalamkar, 2006).

A nationwide survey by Nielson and ORG MARG for 2003-04 season concluded that there was a 60 per cent reduction in pesticide use and 29 per cent increase in yield, leading to 78 per cent increase in net profit. The critics of Bt cotton questioned the objectivity of this survey, as Monsanto commissioned the survey. Further, these two studies did not take fixed costs into account while working out changes in costs and returns from Bt cotton cultivation over non-Bt hybrids. Qayum and Sakkari (2005) made another season-long survey and negated these claims. Another study with a large sample across all leading cotton-growing states, namely Maharashtra, Gujarat, Andhra Pradesh and Tamil Nadu, found that introduction of Bt cotton had led to 31 per cent higher yield and 88 per cent higher profitability.

On the other hand, the critics argue that the incidence of bollworms in many of these years was below normal. It is also alleged that the cotton from the Bt hybrids is of inferior quality and that it cannot stand heavy rainfall conditions, etc. Therefore, the evidence on the usefulness of this cotton in reducing the attack of bollworms is inconclusive and there is a need for empirical studies in a medium-term, as no generalization on the impact can be made from the results of a single year. Further, the future commercialization of biotechnological products in food crops, held since some time because of these controversies, depends heavily on the availability of an objective and independent assessment of the Bt technology introduced in cotton. Therefore, an *ex-post*, farm level study on the impact of Bt cotton introduced in the country is highly relevant. Against this background, the study aims to bring out the impact of the introduction of Bt cotton in Andhra Pradesh. The specific objectives of the study were:

- To find out the impact of Bt cotton cultivation on cost of pesticides, cost of production and profitability across agro-climatic zones,
- To examine the profitability across social categories and size groups of farmers, and
- To estimate the share of farmers in the gains from technology.

The study was organized in six sections. The second section describes the methodology of the study and the third section gives costs and returns in Bt vis-à-vis

conventional cotton hybrids. The fourth section discusses impact on incomes of resource-poor farmers due to the Bt technology. The fifth section provides the share of farmers in the additional gains from the adoption of biotechnology and the last section concludes with some policy suggestions.

Methodology

The study has followed the double difference method combining the 'with and without' approach with 'before and after adoption' method. The study had adopted multi-stage stratified random sampling method by taking one district from each of the four agro-climatic zones in Andhra Pradesh, where the Bt cotton hybrids were introduced. The sample selected in each agro-climatic zone was proportional to the area under Bt cotton in the respective zone. The selection of mandals was done based on the area under Bt cotton. More than one mandal was chosen from each district to see that the sample was well spread out and more representative. The number of mandals selected for the study was nine from the four districts. Fourteen villages were selected from 9 mandals based on the area under Bt cotton.

The farmers were selected after stratification based on farm size and social category. The farmers were stratified as small, medium and large, based on the size of owned landholding. The farmers owning less than 4.99 acres were considered small; owning between 5 and 9.99 acres were considered medium and those who possessed 10.0 acres and more were termed as large farmers. The sample size was of 623 farmers. The number of farmers from Warangal, Nalgonda, Guntur and Kurnool was: 262, 188, 103 and 70, respectively. Primary survey was undertaken with pre-tested schedules and participatory methods like focus group discussion were used as supplementary. The data collected pertained to 2004-2005, and to be specific *kharif* 2004-2005. These sample growers were surveyed again in 2006-07. As all the 186 non-Bt farmers in 2004-05 had switched on to the new technology by the time of resurvey in 2007, 200 more farmers growing conventional hybrids were selected to represent the control group. The monetary values in both the years were deflated using the consumer price indices for agricultural labourers with 1986-87 for the state provided by the Indian Labour Bureau, while comparing these two.

Costs and Returns in Bt and Non-Bt Cottons

The farmers incur costs directly and also indirectly. While the cash expenses are directly seen, the utilization of his fixed assets (like land, farm buildings, implements, etc.) and owned inputs like family labour in production have also to be accounted to give a realistic picture of the total costs incurred. It was attempted in the study by taking both the fixed and operational costs. Different cost concepts (Costs A, B, C) used in standard farm management studies, were calculated in the study and corresponding farm business measures like net income, farm business income, family labour income and farm investment income were calculated.

Survey Results in 2004-05

The cost of production per acre was 17 per cent higher in Bt cotton at Rs 16975 than for non-Bt cotton (Rs 14507) in the state and this difference was statistically significant (Table 2). It included paid-out costs and imputed costs of depreciation, interest on owned fixed capital, rental value of owned land, family labour, etc. The expenditure on insecticides decreased by 18.2 per cent in Bt cotton over non-Bt cotton. This decrease in cost of insecticides by Rs 594 was more than matched by the increased costs on seed, labour, fertilizers and irrigation. All these changes are statistically significant, except in fertilizers. Out of Rs 801 increase on labour, human labour accounted for the major portion, viz. Rs 676.

The reduction in insecticide-use was only 18 per cent, whereas Qaim and Matuschke (2004) showed from the review of studies that this reduction was to the extent of 77 per cent in Mexico, and 65 per cent in China. In the study area, farmers sprayed pesticides with a fear of attack of Heliothes larvae from the adjoining fields as they are still not fully aware of the nature of Bt technology. This had resulted in more savings in insecticide-use. Ismael *et al*. (2002) have also observed that during the early stages of adoption, Bt growers use more insecticides than needed. Several studies (*see* for exaple, Qaim and Matuschke, 2004; Huang *et al*. 2002) have shown that the Bt technology adopting farmers also increase their input-use. This also increases the cost of cultivation compared to non-Bt farmers. The study by Narayanamoorthy and Kalamkar (2006) has also found a 34 per cent increase in the cost of cultivation of Bt cotton over non-Bt cotton.

Table 2. Costs and returns in Bt cotton and non-Bt cotton in Andhra Pradesh

(Rs/acre)

Item	Bt	Non-Bt	Per cent change over non-Bt
Casual labour	1780	1476	21**
Attached labour	218	127	71**
Family labour	1128	846	33**
Total human labour	**3125**	**2449**	**28****
Bullock labour	859	855	0
Machine labour	708	587	21**
Seed	1402	598	134**
Chemical fertilisers	1579	1603	-1
Manure	515	406	27**
Total fertilisers	**2094**	**2008**	**4**
Insecticides	2673	3267	-18**
Irrigation charges	98	54	83**
Interest on working capital	412	379	9
Miscellaneous	94	84	12*
Operational cost	11466	10282	12*
Rental value of owned land	3608	2716	33**
Rent paid for leased-in-land	753	523	44**
Depreciation	354	280	26**
Interest on fixed capital	794	706	12*
Fixed cost	5509	4225	30**
Cost of production	**16975**	**14507**	17*
Cost A1	10692	9716	10*
Cost A2	11445	10239	12*
Cost B1	12239	10945	12*
Cost B2	15847	13661	16*
Cost C1	13367	11791	13*
Cost C2	16975	14507	17*
Physical yield in quintals	9.49	7.21	32**
Cost A1/quintal	1127	1348	-16*
Cost A2/quintal	1206	1420	-15*
Cost B1/quintal	1290	1518	-15*
Cost B2/quintal	1670	1895	-12*
Cost C1/quintal	1409	1635	-14*
Cost C2/quintal	1789	2012	-11*
Average price per quintal	1750	1711	2
Farm business measures			
Gross income, Rs	16612	12338	35**
Net income, Rs	-363	-2169	83**
Farm business income, Rs	5166	2099	146**
Family labour income, Rs	765	-1323	158**
Farm investment income, Rs	4038	1253	222**

Note: * and ** indicate significance at 1 per cent and 5 per cent levels, respectively.

Source: Field Surveys

The physical yield obtained in Bt cotton was 9.49 quintals of seed cotton per acre compared to 7.21 quintals per acre for non-Bt cotton, which is 32 per cent higher than non-Bt and the difference is statistically significant. The coefficient of variation of yield reduced from 0.39 in the non-Bt cotton to 0.34 in Bt cotton, showing that the variations across farms in terms of yield have come down in the farms growing Bt hybrids. The immediate fall out of the higher yield in Bt cotton is that all its per quintal costs are lower over non-Bt cotton, though the absolute costs are higher. The per quintal Cost A_2, Cost B_2 and Cost C_2 are lower by 15 per cent, 12 per cent and 11 per cent, respectively in Bt cotton over non-Bt cotton.

The net income (NI), farm business income (FBI), family labour income (FLI) and farm investment income (FII) improved by 83 per cent, 146 per cent, 158 per cent and 222 per cent, respectively in Bt cotton over non-Bt cotton. The NI, FBI, FLI and FIIs are defined as excess of gross income over Cost C_2, Cost A_1/A_2, Cost B_2 and A_1/A_2+family labour, respectively. All these are statistically significant at one per cent level. This clearly shows that Bt cotton outperformed non-Bt cotton in regard to all the measures. The farmer entrepreneur must be covering all these costs if farming is to be termed profitable. If he/she could not cover all costs, then covering the paid-up costs (Cost A_1/A_2) is crucial to remain in business. The farm business income, which shows the excess of gross income over variable costs (Cost A_2), is Rs 5166 per acre in case of Bt cotton, which is 146 per cent higher comparatively.

Economic Impact after Adoption of Bt in 2006-07

The results from re-survey in 2006-07, presented in Table 3, have confirmed the results obtained in 2004-05 regarding the significant yield advantage with Bt cotton. The major findings are:

- There was a 42 per cent increase in yield after adoption of Bt cotton for the non-adopters in 2004-05.
- The adoption reduced the use of chemical insecticides considerably, viz. to an extent of 56 per cent compared to an 18 per cent reduction in 2004-05. This has become possible because of the rising awareness among the farmers as they continued to cultivate Bt hybrids compared to the initial stages of adoption. The adopters in 2004-05

Table 3. Costs and returns before and after adoption of Bt cotton

(Rs/acre)

Item	Before (non-Bt cotton)	After (Bt cotton)	Per cent change
Total human labour	2449	3249	18
Bullock labour	855	906	-6
Machine labour	587	886	34
Seed	598	897	34
Total fertilizers	2009	2103	-7
Insecticides	3267	1599	-56
Other costs	601	489	-19
Total operation cost	10282	10129	-12
Total fixed cost	4225	5927	25
Total cost	14507	16056	-1
Physical yield	7.21	10.27	42
Cost A1 per quintal	1348	922	-39
Cost A2 per quintal	1420	986	-38
Cost B1 per quintal	1518	1023	-40
Cost B2 per quintal	1895	1421	-33
Cost C1 per quintal	1635	1165	-37
Cost C2 per quintal	2012	1563	-31
Average price per quintal	1711	1920	0
Gross income	12338	19722	42
Net income	-2169	3667	251
Farm business income	2099	9596	307
Family labour income	-1323	5122	445
Farm investment income	1253	8141	478

Note: 1. The percentage change was worked out using the monetary values in constant prices

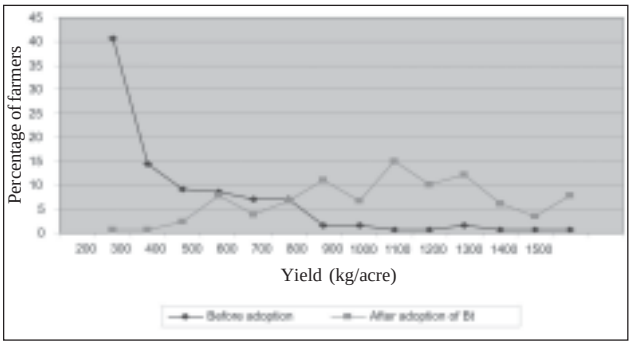
2. The data from 2004-05 were used for 'before adoption' and that from 2006-07 were used for 'after adoption'

Source: Field Surveys

were found applying insecticides with anxiety of pest attack. Now, it seems they had understood that there was no need to spray for bollworms up to a certain time period. It compares well with several other countries, as brought out by Ismael *et al*. (2002).

- The cost of cultivation after adoption remained more or less similar compared to 30 per cent increase in 2004-05. As a result, the cost C_2 per quintal had declined by 31 per cent after adoption in 2006-07, compared to an 11 per cent reduction in 2004-05.
- The net income became positive after adoption in 2006-07 and improved by 2.5-times after covering all direct and indirect costs.
- The farmers gained a farm business income of Rs 9596/acre after adoption of Bt cotton.

The pattern of yield distribution for the farmers before and after adoption of Bt cotton was given by the non-parametrically estimated density functions for yield of cotton for the sample farmers in Figure 1, following Qaim (2003). It clearly shows the rightward movement of density function after adoption of the Bt by the same farmers in 2006-07. In fact, more than 70 per cent of farmers got less than 500 kg/acre of cotton *kapas* yield before adoption and this situation changed altogether after adoption. Nearly 80 per cent of them got more than 700 kg/acre of cotton *kapas* yield after adoption of Bt cotton. This brings out the reason why the adoption rates have been increasing so rapidly in the country, despite adverse media coverage and campaigns against the use and profitability in Bt cotton cultivation.

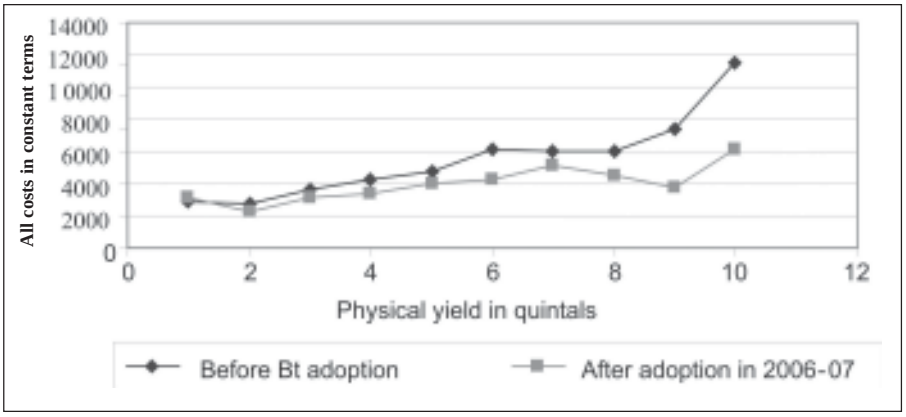


Source: Field Surveys

Figure 1. Estimated density functions for yield

As already discussed, any new technology of production is supposed to shift the cost function downward with the reduced costs for unit of output. The costs before and after the introduction of Bt cotton have been plotted against the cost C_2 in constant prices (Figure 2). It clearly shows that almost all the outputs were produced with lower level of cost with introduction of Bt hybrids in cotton compared to the conventional hybrids.

The results of multiple linear regressions using field surveys' data have shown that there was a significant impact of Bt cotton hybrid on the yield of the farmers (Table 4). The coefficient for Bt dummy turned out to



Source: Field Surveys

Figure 2. Cost function before and after adoption of Bt cotton

Table 4. Estimated production functions for yield in Andhra Pradesh

Item	With and without Bt in 2004 (N = 623)		Before and after Bt (N=367)		With and without Bt in 2006 (N = 814)	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Constant	5.514*	0.433082	3.441*	0.634988	3.968*	0.382053
Bt dummy	2.826*	0.249625	3.915*	0.400266	4.234*	0.409716
Education	0.08297*	0.026825	0.0808**	0.033836	0.04337	0.024797
FYM (Rs/ac)	0.00008	0.000174	0.00216**	0.000944	0.00056*	0.00019
Fertilizers (Rs/ac)	0.00065*	0.000169	0.00397*	0.00082	0.00081*	0.000125
Pesticides (Rs/ac)	0.00023**	9.15E-05	0.00141*	0.000506	0.00031*	7.57E-05
Irrigation (Rs/ac)	0.00052**	0.000259	0.00408*	0.001566	0.00235**	0.001187
Kurnool dummy	-3.850*	0.369375	-1.320*	0.508671	-0.04295	0.401402
Small farmer dummy	-0.631*	0.228292	-0.485	0.314527	-0.330	0.25076
F		45.390		26.462		49.144
Adjusted R^2		0.363		0.358		0.321

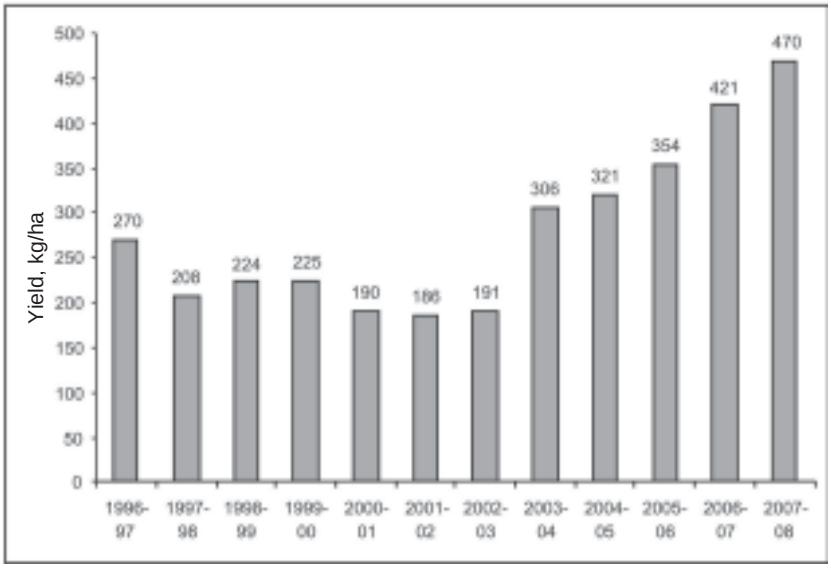
Note: * and ** indicates significance at 1 per cent and 5 per cent levels, respectively.
Source: Field surveys

be significant at 1 per cent level in both 'with and without' Bt cotton scenarios in 2004-05 and 2006-07 as well as 'before and after' adoption scenarios. All the other variables have contributed positively to the yield and the signs of the coefficients are in line with the economic logic.

When nearly 70 per cent of the cotton area is covered with transgenics, it is expected to have some impact on productivity and production in the country as a whole. A look at the data shows that the yield per hectare doubled from a five-year average ending 2002-03 of 203 kg/ha to 470 kg/ha in 2007-08 (Figure 3). There is a turnaround in cotton production during the same period from 104 lakh bales to 258 lakh bales, at a time when most other crops showed stagnancy in production and productivity. Though there are several promotional efforts by the central and state governments during this period, more than 50 per cent of this growth in yield is attributed to the introduction of biotechnology (GoI, 2008). Similar economic and environmental impacts are seen across countries, as per the information presented in the *World Development Report* 2008 (World Bank, 2007).

Resource-poor Farmers and Bt Technology

The study on benefits to farmers of different social and size categories, agro-climatic zones, and both irrigated and rainfed conditions has revealed that all of



Source: Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India

Figure 3. Cotton yields before and after Bt cotton in India

them could get significant increase in yield and net income (Table 5). The participation of small farmers and farmers from dryland areas has been significant, unlike the green revolution technologies, which took some time to reach these groups of farmers. The net income considered was after accounting for both direct and indirect costs like imputed value of family labour, rental value of owned land, etc. Even after accounting for all these, the small farmers have got higher and positive incomes compared to that from conventional technology. Therefore, it can be concluded that this new technology has helped in improving the viability of small farmers. Here lies the significance of the technology. However, the rainfed farmers do not seem

Table 5. Per Cent changes in yield and net income in Bt Cotton vis-à-vis non-Bt cotton

Sl. No.	Category	Yield			Net income		
		With and without in 2004	After adoption	With and without Bt in 2006	With and without in 2004	After adoption	With and without Bt in 2006
I	Small farmers	10.09*	39*	49*	69	214*	221*
	Medium farmers	20.56*	33*	136*	90*	212*	730*
	Large farmers	83.04*	93*	244*	120*	460*	211*
II	Irrigated farmers	34.86*	34*	67*	149*	294*	306*
	Rainfed farmers	28.08*	32*	100*	46	185	180*
III	Warangal	40.05*	41*	82*	139**	430*	249*
	Nalgonda	30.21*	16	101*	44**	92*	141*
	Guntur	18.85*	49*	62*	19*	359*	884*
	Kurnool	85.85*	213*	62*	82	222*	200* times#
	Total sample	31.62*	**42***	**80***	83*	251*	263*

Notes: * and ** indicate significance at 1 per cent and 5 per cent levels, respectively;
# indicates that the net income increased from –Rs 25 to Rs 4480 per acre

Source: Field surveys

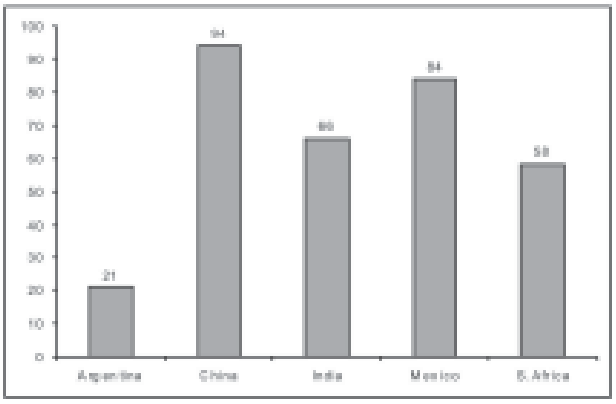
to be getting significant increase in the net income in 2004-05 and also after adoption in 2006-07.

The regression results given in Table 2 have also confirmed these findings. The small farmer dummy has turned out to be significant and negative, implying that these farmers are getting 5 per cent lower yields than that for other farmers in 2004. By 2006, the small farmers also got yields on par with other farmers and there was no significant difference. This is because the small farmers take some time to adjust to the new technology. The scanty rainfall zone represented by Kurnool was found to be getting significantly lower yields compared to other districts. This means that developing drought-resistant varieties is still very important in the country. On the whole, this technology has proved to be scale neutral and profitable to all the groups of farmers. Huang *et al*. (2002) have also reported benefits to small farmers in China with Bt cotton.

Sharing of Gains from Technology

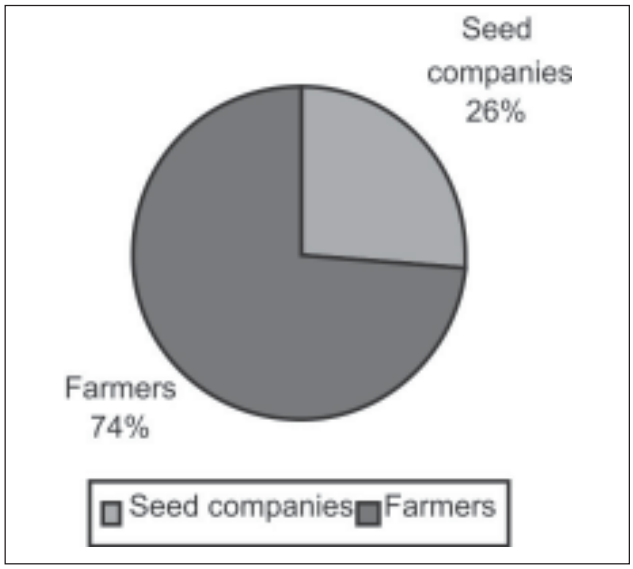
The major concern regarding biotechnological applications by private companies is that the seed developer will appropriate all the benefits. Therefore, we tried to see the farmers' share of additional benefits across different countries. As can be seen from Figure 4, farmers get the major share and that is the reason for the faster adoption rates. Wherever their share is less, as we can see in the case of Argentina, the diffusion is slow. Our field studies in Andhra Pradesh have also shown that the farming community could get a major share of 74 per cent in 2004-05 (Figure 5). Later, as the cost of seed went down consequent to intervention by the state, the share reached more than 90 per cent in 2006-07, like in China.

Summarising the experience of the first biotech product in the country, it can be concluded that biotechnology has helped in reducing the yield gap between the actual and the potential yields by resisting the dreaded American bollworm. Though Bt cotton has been developed for use in industrialized countries, it is also useful in the developing countries. Smallholder cultivators are benefited from its adoption and it proves that proper application of technology in product development can have positive impact on equity. Further, the major benefits from private research are not necessarily appropriated by the seed developers. Our field studies have indicated that farmers perceived



Source: Qaim and Matuschke (2004)

Figure 4. Per cent share of benefit to Bt farmers



Source: Field Surveys

Figure 5. Per cent share of benefit in India

research on drought-tolerant and open-pollinated varieties to be very important. The issues of biosafety and environmental impacts continue to be critical and are to be monitored in a medium-term.

Conclusions

The results of two field studies have clearly shown that the Bt cotton technology is superior to the conventional cotton hybrids in terms of yield and net returns. The yield increase results from closing the yield gap of the hybrids from the potential yield by incorporating resistance to bollworms. It has been found from the production functions that Bt cotton impacts the yield significantly and positively. The Bt farmers

from all social groups, size categories and agro-climatic zones are benefited from its cultivation compared to non-Bt farmers from the same categories. The study has also proved that many of the small farmers and SC farmers have participated in using the technology and have improved their position with regard to profitability by growing Bt cotton. Therefore, it can be inferred that this technology is scale neutral and smallholder cultivators are also benefited from it.

The empirical results on the performance of the first biotech product in the country, viz. Bt cotton, have brought certain issues before the policymakers. The foremost among them is the fact that the private sector can also play a crucial role in commercial crops like cotton and the gains from their efforts are obtained mainly for the farmers. Therefore, creating enabling environment to encourage their investments is crucial in harnessing the technology. Further, the proprietary nature of these technologies necessitates the public sector to step up efforts to bring out varieties in 'orphan crops' like minor millets, pulses and oilseeds, where the markets are not attractive for the private players (Herring, 2007; Pingali and Raney, 2005). It is also noteworthy that the applications in biotechnology at present are not focusing efforts on evolving varieties with higher yield potential or drought- and salt-resistance, which are crucial for poverty reduction in our country. The farmer-respondents in the surveys have also opined that open-pollinated varieties and drought-tolerance are important attributes that can be achieved through the tools of biotechnology. The poverty reduction efforts will need improvements in staple food crops and appropriate steps are needed in that direction.

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