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ABSTRACT

The decadal experience of Bt cotton is discussed in this article with reference to suicides of farmers, agronomy, environment and health issues. The experience of Bt cotton in India is claimed to be success but evoked lot of critical issues at the social, economic, environment and political level. The advent of Bt cotton increased the production of cotton but it is also a fact that farmers suicide was more reported in the cotton growing belts of India. The article argues that the increase in production is exclusively subscribed to the new technology without the analyzing the shift of cotton cultivation from rainfed to irrigated lands, increased input costs and the stress of farmers in imbibing the new technology. The experience of cotton revealed that the farmers are unequally placed in the operation of market. The economic reforms of the government have not strengthened the farmers to take benefit out of new technologies offered by the private. The farmers differ in their capacity to take risks to invest in the new technology and also the knowledge gap among the farmers with Bt cotton minimized the benefits of the technology.

***Key words*:** Bt cotton, Yield, Pesticide, Suicides, Pests

Bt cotton is the first GM crop in India. The introduction of Bt cotton witnessed multifarious debates on its science, environment safety, agronomic benefits, socio-economic impacts on farmers etc. With the introduction of Bt cotton a decade ago, the opinions made on GM crops also started maturing in India. The opposition and support to Bt cotton was seen as motivated vested interests of various stakeholders in India and elsewhere. The government who was the promoter of the technology had also equally failed to educate the people in understanding the biotechnology science, and this helped in forming polarized opinions on GM crops. The release of Bt cotton in 2002 and to this date has seen a lot of studies being done and discussed, focussing on its agronomic aspects, environmental safety etc. The Bt cotton studies have brought out various dynamics of the crop. The studies gave varied and polarized opinions which generated lot of interests and made one of the most discussed scientific topics in India.

Farmers' suicide

The most significant reason for the heated public discussions on Bt cotton is the high rates of farmer suicides reported in the cotton growing belts of India. It is estimated that more than three lakh farmers have taken their life in the past twenty years. The increasing farmers suicide have silenced the National Crime Records Bureau not to publish the suicide numbers for the past two years [1]. The increasing rate of farmers' suicides in the 2000s coincided with the introduction of GM cotton. There were a lot of studies conducted to prove that less yield of Bt cotton resulted in indebtness of farmers and led to suicides. None of the studies was able to directly prove that the yield loss of Bt cotton lead to farmers' suicide. Rather, the discussions on farmers' suicide were directly linked to the adoption of Bt cotton by some opposition parties, media and the environmental activists. This led4to the United Progressive Alliance-I government led by Dr. Manmohan Singh to appoint the National Commission on Farmers in 2004 under the chairmanship of Prof. M. S. Swaminathan to study condition of agriculture in India. The National Commission on Farmers (NCF) appointed in 2004 gave various other reasons like lack of institutional support, lack of adequate infrastructure, unpredictable weather conditions etc. for farmer suicides. It claimed that "the farmer suicide tragedy has several dimensions – economic distress and despair, breakdown of social and state support systems and psychological nightmare" [2]. The International Food Policy Research Institute reported that "The report rejects the presence of a surge in farmer suicides in recent years and any direct or reciprocal role of Bt cotton introduction in farmer suicides, while noting that Bt cotton may have played a role in specific cases and seasons. These cases were mainly the result of institutional, climatic, and economic constraints, among many other factors" [3].

The arguments bypassing the influence of Bt cotton in farmers suicide was not well accepted by civil society groups but the government endorsed the argument of the NCF which suited its convenience and need to subside the unrest of

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farmers' suicide. The government might have been successful in subsiding the farmers' suicide debates or any farmers' unrest; the statistics of the government itself show that 51.9% of the agricultural households are indebted (Table 1) and increased the cost of cultivation (Table 2). The suicide of farmers even though cannot be generalized to the adoption of Bt cotton but many studies have proved indirectly that the adoption of Bt cotton and the resultant impacts are serious determinants of farmers' suicide [4].

Table 1 Estimate number of rural households, agricultural households and indebted agricultual households

State	Estimated number of rural households ('00)	Estimated number of agricultural households ('00)	Agricultural households as percentage of rural households (%)	Estimated number of agricultural households having loan ('00)	% of agricultural households indebted
	(1)	(2)	(3)	(4)	(5)
Andhra Pradesh*	86763	35968	41.5	33421	92.9
Arunachal Pradesh	1659	1080	65.1	206	19.1
Assam	52494	34230	65.2	5995	17.5
Bihar	140611	70943	50.5	30156	42.5
Chhattisgarh	37472	25608	68.3	9538	37.2
Gujarat	58719	39305	66.9	16743	42.6
Haryana	25849	15693	60.7	6645	42.3
Himachal Pradesh	13251	8811	66.5	2457	27.9
Jammu & Kashmir	13746	11283	82.1	3463	30.7
Jharkhand	37516	22336	59.5	6464	28.9
Karnataka	77430	42421	54.8	32775	77.3
Kerala	51377	14043	27.3	10908	77.7
Madhya Pradesh	84666	59950	70.8	27414	45.7
Maharashtra	125182	70970	56.7	40672	57.3
Manipur	2584	1762	68.2	421	23.9
Meghalaya	4721	3544	75.1	84	2.4
Mizoram	936	758	81	47	6.2
Nagaland	4128	2621	63.5	65	2.5
Odisha	78120	44935	57.5	25830	57.5
Punjab	27552	14083	51.1	7499	53.2
Rajasthan	82722	64835	78.4	40055	61.8
Sikkim	1150	674	58.6	97	14.4
Tamil Nadu	93607	32443	34.7	26780	82.5
Telangana*	49309	25389	51.5	22628	89.1
Tripura	6635	2445	36.9	559	22.9
Uttar Pradesh	241328	180486	74.8	79081	43.8
Uttaranchal	16498	10608	64.3	5387	50.8
West Bengal	141359	63624	45	32787	51.5
UTs	2394	718	30	267	37.2
All India	1561442	902011	57.8	468481	51.9

Source: Situation Assessment Survey of Agricultural Households (Jan-Dec 2013), National Sample Survey Office (NSSO)
Notes: 1. Reference period for Indebtedness is "as on the date of survey".
2. Indebtedness relates to all kind of outstanding loans irrespective of the purpose for which taken.
*Separate estimates for the newly formed States of Telangana and Andhra Pradesh are provided in place of erstwhile State of Andhra Pradesh.

Table 2 State wise cost of cultivation of cotton per hectare (2002-03 to 2011-12)

Year	Andhra Pradesh	Tamil Nadu	Karnataka	Gujarat	Madhya Pradesh	Maharashtra	Haryana	Punjab	Rajasthan
2002-03	28562.63	31062.32	11914.64	15474.92	19967.52	20859.66	18877.88	27683.5	14808.03
2003-04	36202.37	34385.73	9520.02	23395.87	18863.88	20989.96	24168.98	33233.46	17410.1
2004-05	32735.15	27559.95	11631.02	23586.3	20714.67	21179.58	27288.54	34070.9	17686.72
2005-06	28413.66	28917.95	13538.81	31437.07	34866.08	20913.32	26738.08	33983.47	17594.12
2006-07	34998.8	29421.67	15801.88	27184.11	28744.82	21669.23	29779.09	36865.64	21381.19
2007-08	40307.67	26881.47	18624.08	29107.74	28321.56	24398.91	34877.09	40490.82	24481.97
2008-09	44756.72	42145.21	22239.46	42106.84	29570.49	33116.82	44018.18	50828.83	25375.16
2009-10	42919.36	47959.62	24811.57	44333.49	27374.83	35822.07	48920.33	53071.62	36416.6
2010-11	49401.41	56747.52	36216.84	54089.07	35786.99	52748.59	46815.11	59282.06	44005.58
2011-12	61659.49	61318.9	45076.61	58387.77	42289.34	61907.49	62329.97	66697.56	56097.36

Source: Directorate of Economics and Statistics

The farmers' suicide is an all India phenomenon even before the introduction of Bt cotton seeds. The incidence of increasing suicides among the farmers in India is the impact of globalization and the failure of policies to protect livelihood of farmers in the aftermath of the introduction of new technologies. The high rates of suicides are reported in the following states of India viz. Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh and Gujarat in the decade of 1990s (Table 3). R.S. Deshpande and Khalil Shah argue that the rate of suicide was reported more in the states of Karnataka, Andhra Pradesh and Maharashtra which are more associated with the performance of agriculture sector in general and cannot be directly equated with the adoption of Bt cotton. They further argued that the increasing rate of suicides in 1990s was due successive droughts as well as price of agricultural products did not pick up even though there was less production and the expenses on input kept on increasing which did not match the income from their produce [5].

Table 3 Total number of farmers' suicide

State	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Maharashtra	1,917	2,409	2,423	3,022	3,536	3,695	3,836	4,147	3,926	4,453
Andhra Pradesh	1,097	1,813	1,974	1,525	1,509	1,896	1,800	2,666	2,490	2,607
Karnataka	1,832	1,883	2,379	2,630	2,505	2,340	2,678	1,963	1,883	1,720
Madhya Pradesh	2,390	2,278	2,654	2,660	2,824	2,578	2,511	3,033	2,660	1,375
Gujarat	565	653	500	661	594	570	581	523	615	487
Other states	5,821	6,979	6,152	6,105	5,447	6,892	5,758	5,909	5,557	6,418
All India	13,622	16,015	16,082	16,603	16,415	17,971	17,164	18,241	17,131	17,060

Source: P. Gruère, Guillaume, Mehta-Bhatt, Purvi and Sengupta, Debdatta, *Bt Cotton and Farmer Suicides in India: Reviewing the Evidence,* Washington: International Food Policy Research Institute, October 2008

The stress of cotton farmers in the liberalized market increased due to the introduction of Bt cotton. The input cost for cultivating Bt cotton is high when compared with the hybrid cotton. The small farmers afford the heavy input cost from the private moneylenders at exorbitant interest rates. Even after the adoption of modern technologies there are so many factors which drive the yield into an unpredictable category. The risk borne by the farmers by investing more capital is with the expectation good yields through Bt cotton. The success of farmers' efforts depends in equal measure on favourable conditions of the invisible and uncontrollable external factors like reduced pest attack, good monsoon at the time of seed germination, flowering and plucking. The unfavourable condition of external factors would result in failure of the crop which drives the farmers' to unbearable financial stress. It is 'green revolution trap' even though farmers are progressive and adopting modern agriculture practices [6].

There are also various other reasons ascribed to the increasing suicides after the liberalization of the economy. A.R. Vasavi argue that "the separation of agriculturists from each other, the loss of a shared body of knowledge and practices, the onerous burden of risks borne by heads of households, enterprising individuals and the new players—can be identified as leading to the individualization of agriculture" [7] as important factors in farmer's suicide. The individualization and isolation of farmer is becoming evident after the liberalization of the economy where the farmer is dependent on all his input from the market. It prevents farmers from evolving new seeds or brings solution to problems associated with farming the co-operation of other farmers.

The suicides are more reported among the small and marginal cultivators who have shifted to cash crops like cotton, sugarcane, hybrid pulses, tobacco, vegetable and fruits [8] where new technologies have come up with assured financial success. A. R. Vasavi also points out that the small and marginal farmers are not effective to organize powerful and effective farmers' movements of the 1980s despite the enormous decentralization of power in the recent times. The 'populist and publicity garnering agrarian movement such as Karnataka's Rajya Raitha Sangha or the Bharatiya Kisan Union' [9] were not able to garner the support of farmers to address their issue at national level. The farmers' agitation in Mandsaur (June 2017), Sikar and Ganganagar (September 2017) in Rajasthan, protest in Delhi (November 2017) by All India Kisan Sangharsh Coordination Committee, protest march of farmers from Nashik to Mumbai in March 2018 and February 2019 have not offered the farmers any substantial relief or altered the position of government on agricultural policies or GM crops.

The NCF appointed in 2004 submitted a total of five reports by 2006 which assessed the agricultural situation and identified reasons for the farmers' distress in India. It identified the following reasons for the agrarian crisis; "unfinished agenda in land reform, quantity and quality of water, technology fatigue, access, adequacy and timelines of institutional credit and opportunities for assured and remunerative marketing" [10]. The report created undue pressure in the ruling government which forced to initiate relief packages for the distressed farmers. The Prime Minister Dr. Manmohan Singh visited Vidarbha in 2006 and announced relief packages worth 110 billion [11]. The package assured compensation to the suicide victims, waiver of loan and interest and funds for long term loans. The package aimed to address the long-term benefits to farmers by allocating funds to complete the pending projects on dams and water shed management [12]. The government also announced a special package for the distress farmers identified in 31 districts of Andhra Pradesh, Maharashtra, Karnataka and Kerala in 2006. There were also many initiatives taken up the states across India to address the distress of farmers and improve the agricultural situation. The initiatives largely aimed to promote institutional credits to the farmers and relief packages in terms of interest waiver on loans or total waiver of loan. The policies of the government, however did not attempt to address issues like land reforms or regulating the market which could have been more beneficial to farmers than the interim relief packages.

The debates on yield and production

The other important debate and suspicion surrounding Bt cotton was to do with its promise of increased yield. The private companies promoted a sustained campaign that Bt

cotton would increase the yield; which according to the experts' opinion stood untrue. Dr. K. R. Kranthi, Ex-Director, Central Institute for Cotton Research, Nagpur, one of the acclaimed scientists in the world noted in his work that "Bt protects the crop against bollworms and a few other caterpillars and does nothing else" [13]. The Bt gene is capable of controlling the bollworm pest attack which might result in increased yield. Instead, it was promoted as by the companies that Bt cotton seed itself would increase the yield. However, Bt cotton failed in many areas where it could not control the attack of the bollworm pest. The companies witnessed lot of failure cases reported in the dailies acknowledged the fact and subsided their advertisements by claiming that the Bt gene would not increase the yield of cotton but only control the attack of bollworm pest [14].

The agronomy studies which sprang up after the release of Bt cotton showed a pattern of opinion linked with the sponsor of the study. The study sponsored by the seed companies found the agronomy of Bt cotton showing increased yield of cotton and good savings for the farmer. The studies conducted by NGOs, on the other hand, showed the yield of Bt cotton to be inferior to desi cotton and proved it to be a costly exercise for the farmers [15]. With the passage of time the studies declaring the failure of Bt cotton were less reported and discussed in the public. The statistics of the government declared the increased yield of cotton over the years. The GoI's 'Cotton Status 2017' reported that "the yield has increased to 510 kg per ha yield in 2014-15 from a meagre of 191 kg lint per ha in 2002-03 (Table 4). The report claimed that the per hectare net income of farmers increased from Rs. 7058 in 2001 to Rs. 16125 in 2010 under rainfed conditions and Rs. 25000 under irrigated conditions. The report also claimed that the country achieved the status of exporter of cotton in 2011-12 after meeting the domestic needs. The Bt cotton performance in rainfed conditions performed dismally when compared to the irrigated lands" [16]. The Bt cotton cultivation in India has evoked a lot of interest in the non-cotton growing regions as well; more areas have come under the influence of irrigation. In Maharashtra, a study identified a marginal shift in cotton cultivation from the Vidarbha region to the Marathwada and Khandesh regions where they had better irrigation facilities [17]. In Gujarat it was reported that the shift of Bt cotton cultivation to irrigated lands increased by 43.3% [18].

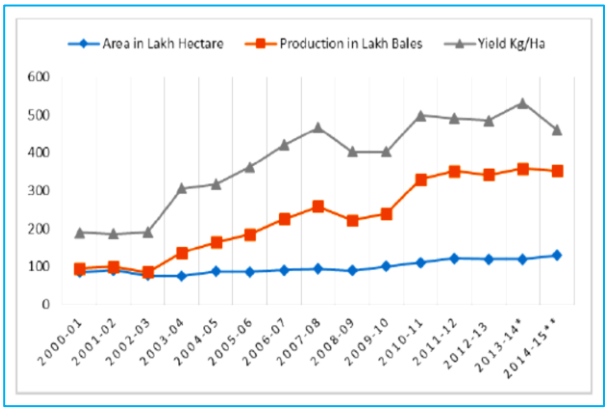

Fig 1 Area, production and yield in pre and post Bt cotton phase in India (2000-01 to 2014-15)
Source: Department of Agriculture and Cooperation

The difference in the yield of Bt cotton versus the local hybrid cotton is not so dramatic in the rainfed regions. In countries like China the substantial increase in the yield of Bt cotton was short lived and it is showing downward trends [19]. The Lok Sabha Standing Committee on Agriculture [20] in its report on *Cultivation of Genetically Modified Food Crops – Prospects And Effects (2012)* made some observations on the yield of Bt cotton. The committee was of the view that the yield of Bt cotton increased but in some years the yield decreased due to the resistance of bollworms. The report claimed that "the decline in yield after initial two three years of increase due to reduction in yield loss caused by pests caused additional distress to the farmers" [21] and "the better productivity of Bt cotton also has not stood the test of time as in the latest estimates productivity figures have gone considerably down" [22]. The Rajya Sabha Committee [23] made a sharp observation that cotton yield was increasing at 69% in the years between 2000 to 2005 but after the introduction of Bt cotton it was less than 6% even though 94% was Bt cotton [24].

Bt cotton presupposes some established infrastructure which would ensure the desired yield. This is similar to the Green Revolution technologies which also presupposes established infrastructure to yield the desired results. The primary need of the Bt cotton crop is good irrigation and the crop cannot yield to the expected levels in the rainfed regions. This information was little known to the farmers and they treated the Bt cotton seed and the hybrid seed equally. The lack of clarity and improper implementation of the guidelines by the farmers led to mismatch in the yield, increase in the use of pesticide, less understanding on the pest management etc. led to differing results in Bt cotton. The introduction of GM crops thus initiated fresh debates in the research establishments and among global policy promoters.

The Bt cotton technology is considered to be scale neutral in the sense that the experience of small farmer to the large farmer would remain the same in terms in yield, pesticide use, irrigation, growing the crop, harvesting, etc. In most of the surveys by the government or by the private had measured the success of Bt cotton with the final yield which a farmer achieved in employing a new technology. The experience of each category of farmer and individual farmer tends to be different in the social, economic and political setup. The farmers were introduced to the technology but he was not trained to take the best experience out of the new technology. The techniques of the cultivation were learned by the farmers with trial and error process even though the state apparatus had made arrangements through Krishi Vigyan Kendras to educate them. The National Sample Survey Office (NSSO) of India in its survey number 499(2005) accounted that "only 8.4 percent of agriculturists had accessed information from the Krishi Vigyan Kendras, 17 percent received information from other agriculturists and 13 percent from agricultural input dealers" [25].

The assessment of the farmer when done only with the yield misses the overall assessment of a technology. The extension of state's help is too limited in the post reform period unlike the GR where the state extended support to the inputs, infrastructure of agriculture and regulated markets [26]. The success of the technology in the post reform period has to take account of the financial stress a farmer would have undergone to buy the seed packet or the kind of help he might have received from co-farmers and labourers or the struggle to protect the crop from the unpredictable weather condition or the engagement of family labour or the weak financial bargaining he/she have in the society. The technology can be compared with one category of farmers; the behaviour of

technology across all categories of farmers tends to miss the social existence of farmers. The reports on the total yield achieved in a year across all categories of farmers cannot be the best method to access the yield of Bt cotton even though the statistics of the government shows that there has been a record growth in yield [27].

The use of pesticide

The pesticide use in cotton cultivation is also one of the important debates in the GM crops experience in India. The technology was assured by Monsanto Mayhco Biotech Private Ltd. (MMB) and its sub-licenced seed companies to reduce the pesticide use and claimed to be superior to the green revolution technologies in this regard. The cotton crop occupies around 5% of total area of cultivation and consumes 36-50% of the total pesticide applied in agriculture [28]. The use of pesticide peaked in the 1990s at 75,000 metric tons in which insecticide occupied around 80%. More than 40-50% insecticides were used in Cotton to control bollworms [29] and secondary pests [30]. The use of more insecticides (pyrethroids and organo phosphate) increased the outbreaks of bollworms and white fly attack in cotton. There were also reports that established the fact that insects like *Spodoptera litura* (commonly called Tobacco cutworm or Cotton leafworm) acquired resistance to increased spray of insecticides in the cotton field [31].

The statistics of the government, according to 'Status of Cotton-2017', claimed to have reduced the use of pesticides in Bt cotton cultivation after its adoption in 2002. The pesticide uses in controlling bollworm from 1995-2004 was 6767 million tonnes and it reduced to 1089 million tonnes in 2005-2011. The use of pesticide in controlling the sucking pests from 1995-2004 was 3335 million tonnes and it increased to 4600 million tonnes between 2005-2011 (Table 4). The increase in the use of pesticide in controlling sucking pests has thrown up a new challenge to the pest management system of Bt cotton. The environmental activists [32] raised many apprehensions that targeting one single pest would result in resistance and this might be a challenge in controlling other pests. The GEAC was very much aware of this fact, insisted the companies to submit a report on the pest attack pattern in cotton for three years. The trend of increased use of pesticide to control sucking pest suggests that there should be a serious attempt by the government agencies to study the pest controlling patterns after the introduction of Bt cotton and reveal the reports of the companies in the public domain.

The BG-I which was released in 2002 started failing in controlling the pink bollworm in 2009 while the BG-II started failing in 2014. BG-I and BG-II were considered to be very effective in controlling the attack of pink bollworm. The failure of BG-I and BG-II were not witnessed in other GM cultivating countries of the world. The technological failure in India made the scientists and the companies to offer new solutions. It is identified that the pest management system practiced by the Indian farmers needs re-orientation since the technologies are showing effectiveness in controlling Tobacco cutworm and American bollworm.

The bollworm pest was not a predominant problem in the cotton cultivation of India. The American cotton was introduced by the British in 1790 and when they left the country the total area of American cotton was just 2-3%. The desi cotton dominated the cotton cultivation of India until the introduction of hybrid 'H-4' in 1970. The area of hybrid cotton cultivation was more than 50% by 1990 and the Helicoverpa armigera popularly now known as 'American Bollworm' acquired the status of monster in the cotton cultivation of India. The pest came to be known as American bollworm due to the exotic variety of American hybrid cultivated in India. The pest has developed enormous resistance to sustain in all types of weather and insecticides. The solution to increase the productivity of cotton in the way of introduction of hybrid cotton has itself have become the problem by 1990s [33]. The scientific solution to bollworm management was the Bt technology which itself now facing the threat of failure and seeks more technological intervention to solve the problem.

Refugee area

One of the important reasons for the technology failure is the non adoption of refugee area in cotton plantation. The success of Bt technology in pest management in the initial days showed huge success and by seasons passed the bollworms have gone out of control. The Bt technology prescribes that the 20% of the total area of Bt cotton should be planted with non Bt cotton to evade the attack of bollworms. It is believed that the bollworms would attack the non Bt cotton allowing the Bt cotton to prolong the resistance to bollworms especially American bollworm.

The 20% refugee area is prescribed in the seed packets of the Bt cotton. Most of the farmers have not adopted the practice of planting 20% of their area with non Bt cotton seeds. The farmers argue that their area would get reduced due to the planting of non Bt cotton seeds. The cotton farmers as well the land holding size of farmers in India is more than 70% belong to the category of small scale holding below 2 acres. The Bt cotton hybrids tend to be bigger and bushier which allows the farmers to plant less number of seeds give genesis to the fear of less yield. Thus, the farmers are not affordable to devote 20% of their land to the refugee plantation. The impact of non-adoption of refugee area has impacted the pest management system. The state governments must have known through its extension service but it does not have any legal provisions to implement it. The Bt cotton which was totally controlling the attack of American bollworm has fast attained resistance to the Bt. Even though there have been so many reports in the dailies reported the failure of Bt in containing the pink bollworm the government has so far not accepted the failure of Bt in controlling the bollworms [34].

The 'failure' of Bt in the pest management system has been claimed by scientists all over the world that it is obvious to occur if the refugee technique is not effectively followed. It is also advised by the scientist that crop rotation and proper cleaning of the residues of the cotton crop cultivated earlier in the field help to reduce the incidence of the bollworm attack [35].

With the failure of Bt technology the relevance and execution of the technology is being questioned. Bt technology had the option to be introduced in a closed pollinated variety of cotton hybrid. This is not the case in countries like USA, China or Australia where Bt is introduced to open pollinated variety of cotton which helps in prolonging resistance to bollworms. The Bt introduced in hybrids express only one copy of Bt gene which means that some bolls in the cotton plant might be poisonous to bollworm and some bolls might not be poisonous to bollworm. The good chance of effective control against the bollworm had been missed due to the wrong selection of hybridization. The companies also invested on the opinion of introducing the Bt gene in hybrid

cotton in order to bring farmers every year to them for seeds. The hybrids are allowed to be reused in India and this is not the case anywhere in the world. The companies were happy to introduce in the hybrids due to inability of the hybrids to produce effective offspring. Thus, when the Bt is introduced in hybrids the Indian companies were silent due to their future economic prospect. Another most important chance missed was to introduce Bt in short duration cotton varieties which could have prolonged the resistance of bollworm. The short duration variety cotton unlike the hybrid cotton is not busier and tall. The Bt varieties of cotton throughout the world belong to the short duration variety and can be planted closer than the Bt cotton hybrids introduced in India.

The cotton crop in India is grown for more number of days to reap more yields. The prolongation of season enhances the ability of the bollworms to attack the crop. Most of the Indian farmers tend to leave the crop unmanaged at the end of the season if it is infested with bollworms. The residues of the bollworm infested crop left over in the field if not destroyed plant emerge as potential carriers of the enzymes of the bollworm. They would be able to regenerate and infest the crop in the next season of cultivation. The pest attacks become more difficult to control and repeated spray of insecticide makes them more resistant in further seasons.

The Bt technology was introduced to mitigate the use of pesticide but most of the farmers engaged in spraying pesticide to control bollworm. The farmer even though has bought the high-end technology ended up spraying pesticides to control bollworm which is not a must. The extra precaution of Indian farmer towards cropping Bt cotton revealed the questionable belief about the science of Bt technology even though the farmers acknowledge that technology actually performed in the initial years of release. There was technological information gap which the promotors used it to their advantage to sell their products.

Table 5 Usage of insecticide in cotton

Year	Value of insecticides/pesticide in Rs crores						Quantity of insecticides in Metric tonnes				
	Insecticide used for bollworms	Insecticide used for sucking pests	Total insecticides on cotton	Total insecticides	Fungicide in cotton	Herbicide in cotton	Sucking pests	Bollworm	Other pests	Total insecticide in cotton	Total insecticide
2002-03	415.6	181	597	1683	3	1	2110	4470	283	6863	25962
2003-04	680.5	245	925	2146	8	3	2909	6599	537	10045	32571
2004-05	718.1	314	1032	2455	6	4	2735	6454	178	9367	35432
2005-06	385.7	263	649	2086	8	8	2688	2923	302	5914	31363
2006-07	307.4	272	579	2223	11	12	2374	1874	375	4623	31750
2007-08	287.8	445	733	2880	25	22	3805	1201	536	5543	35807
2008-09	236.7	554	791	3282	31	26	3877	652	528	5057	26624
2009-10	140.1	694	834	3909	52	45	5816	500	410	6726	35404
2010-11	122.8	758	880	4283	67	87	7270	249	366	7885	36761
2011-12	96.3	894	991	4103	6	6	6372	222	234	6828	34469

Source: Kranthi and Reddy (2012), CICR

The Bt technology was marketed that it would increase the yield without explaining the underlying causes to increase yield. The econometric analyses always showed that with the decrease in the use of pesticide there would be an increase in yield. The analyses missed to explain the dynamics of the pest pattern and their effect on the overall yield. The pest development in the irrigated lands and their prevalence on the rainfed lands were not experimented before the introduction of Bt cotton. The laboratory born studies which showed positive results in controlling bollworm were extended to successful introduction of the technology.

Environmental and Health concerns in Bt cotton

The public opinion on GM crops was polarized with the sections of people favouring the release and cultivation of Bt cotton to the sections of people who wish moratorium on Bt cotton due to various environmental and health concerns it might bring in. The opinions which favoured the introduction of Bt cotton did not categorize GM crop to be substantially different from hybrid crop. It was generally accepted that even if there might be any issues which are general to the introduction of new technology in the environment it might be well controlled by the expertise in science with the cooperation of the government. The public opinion which was against the introduction of Bt cotton argued that it might bring in environmental and health issues which has to be analyzed for a long-term study. They argued that the Bt cotton crop might disturb the genetic makeup of other plants when pollens from Bt cotton pass on crops planted near the Bt fields. It was also argued that since the Bt cotton crop has the potential of producing insecticide, the plant itself might possess poison and when the seeds of the cotton plant is consumed by animals it might result in the death of those animals. Also, it was argued that the Bt cotton crop might bring great changes in the soil fertility which might make the land unfit for cultivation of any crop in future. It was also argued that the oil produced from cotton plant when made into products might result in irritation and allergy. Thus, there were many concerns expressed by the public opinion which opposed the introduction of Bt cotton. The hypothetical risks expressed by the public opinion against the introduction of Bt cotton surfaced now and then but could not establish the fact that genetic makeup of the cotton crop were the reasons for the problems.

One of the important ecological benefits accrued out of Bt cotton was the reduced insecticide spray to control bollworm. The farmers have benefitted out of this not only on the economic front but also it paved a way to improve their health with the result of reduced insecticide spray. Even though Bt cotton has resulted in decreased number of sprays but the farmers have continuously engaged in unsafe spraying methods. Every year during the cultivation season there were news reported deaths due to unsafe spraying methods in cotton fields. The Maharashtra government recently have enacted a law to make the land owner responsible for any accident due to unsafe spraying in his/her land [36]. It is not clear in the law what would be if the land owner himself turns to be engaged in unsafe spraying practice and the role of

pesticide companies in curtailing the unsafe method of spraying.

The experience of Bt cotton cultivation in India had its impacts on the approval of other GM crops. The following governments' institutional opinion also created an environment of scepticism towards approval of other GM products in the country.

a. The Ex-minister of ministry of forest and environment, Jairam Ramesh's report on Bt Brinjal, 2010
b. The Sopory Committee Report, 2012
c. Lok Sabha Standing Committee on Agriculture, cultivation of genetically modified food crops – Prospects and effects, 2012
d. Supreme Court appointed Technical Expert Committee, Interim report -2012 and Final report 2013
e. Rajya Sabha Standing Committee on Science and Technology, Environment & Forest, report on "Genetically Modified Crops and its impacts on the Environment". December 2017.

The above reports questioned the procedure, scientific trials, safety of human consumption, biosafety and various issues related with the introduction of Bt cotton. The reports initiated public debate on the necessity of GM crops and gave a chance to the public to know about the status of GM crops across the world. The political parties seems to possess a opinion about GM crops but the parties project an opinion when they are in opposition and shift their opinion when they form government. The political parties become less vocal about their stand when they are in power and operate towards introducing GM crops. The issues of Bt cotton add fuel to their stand either to project GM crops as a successful experiment or a phenomenon of failure. The parties use the experiment of Bt cotton to their own benefit in raking up the consciousness of the people. The perception of GM crops is an unsettled debate in the political sphere but it has emerged to be a success in economic aspects in the data of government.

CONCLUSION

The study argues that while Bt cotton has led to increased yields at a macro level, it has also introduced complex challenges, particularly financial stress for farmers due to high input costs and reliance on external factors. The direct link between Bt cotton and farmer suicides remains debated, but the escalating indebtedness and cost of cultivation point to an indirect correlation. The efficacy of Bt technology is compromised by poor implementation of recommended practices like refuge areas and the initial choice of hybrid varieties, leading to evolving pest resistance and increased use of other pesticides. The overall assessment of the technology should go beyond mere yield figures to consider the social and economic realities of diverse farming communities and the adequacy of state support in the post-liberalization era.

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