Weekly Publication of

Cotton Association of India

COTTON STATISTICS & NEWS

Edited & Published by Amar Singh

2016-17 • No. 39 • 27th December, 2016 Published every Tuesday

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Fertilizers Gave High Yields Bt Only Provided Cover

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If the yields increased it was all because of Bt. If yields decreased it was bad weather. Why does an entire country get carried away in a band-wagon? Economists need to be more incisive. Analysis by overseas economists can be overlooked. But how can we ignore the massive increase in fertilizers and irrigation that concomitantly increased along with Bt-cotton, and undoubtedly contributed to higher yields?

EXPERT's Column

Dr. K.R. Kranthi

A recent (May 2016) report "GM crops: global socio-economic and environmental impacts 1996- 2014" was published in Graham Brookes & Peter Barfoot, PG Economics Ltd, UK. http://www.pgeconomics.co.uk/pdf/2016globalimpactstudymay2016.pdf

The report states that 1. The main impact of Bt-cotton in India was major increases in yield. 2. Farmers made a net cost saving of US $ 17-15 /ha (Rs 1190-1750/ha) due to Bt-cotton. 3. Coupled with the yield gains, profitability was between US$ 82 to 356/ha (Rs. 5740 to 24,920/ha). 4. The total cumulative farm income gains from 2002 to 2014 were US$ 18.3 billion (Rs. 127,876 crores).

Several studies were conducted on Bt-cotton to understand the net gains. These studies showed that yields in Bt-cotton farms were 30 to 46% more than the yields obtained in non-Bt-cotton farms and insecticide sprays were reduced by 25 to 55%. The studies also indicated that the net returns in Bt-cotton farms were 50% to 110% more than non-Bt cotton with the increase in average net returns in Bt-cotton farms estimated to be higher by US$ 76 to 250 (Rs 5320 to 17500) per hectare compared to the non-Bt cotton farms. It is interesting that majority of the reports give complete credit to 'Bt-cotton' for all the benefits whatsoever. The fact remains that increase in yields could be due to other factors as well. Many eminent economists find the Bt-cotton factor inseparable from changes in fertiliser, hybrids, labour, pesticides and irrigation. Because of the high seed cost, farmers in India are known to bestow special attention to Bt-cotton, while non-Bt cotton is cultivated on marginal soils under neglected conditions.

Why is it important to identify key factors that may have caused significant yield gains? The answer is: these factors can be protected and saved so as to harness the gains for a longer time. If we do not know the precise factors that brought us benefits, we may lose them and will not have a handle on the gains. Interestingly, India's cotton yields increased from 302 kg/ha in 2002 to 399 kg/ha in 2003 when the Bt-area was only 0.38% and illegal Bt-area was only 0.4%. What caused the increase? In 2004 yields jumped to 470 kg/ha when the Bt-area was just 1.22% and illegal Bt-area was estimated to be about 2.5%. In 2005, Yields did not increase even when the

Bt-area increased to 11.7% along with illegal Bt-area at 8.0%. Why did the yields not increase in 2005, despite good rains and higher Bt-area?

I tried hard to unravel the key factors that caused cotton yield gains in India over the past 10-15 years. If Bt-cotton was the factor alone, then I need to surmise that a small 5.7% Bt-area with just 4 Bt-hybrids in 2004 caused a massive yield increase from 302 kg/ha in 2002 to 470 kg/ha in 2004. This was a feat that could never be repeated. On the contrary, things became worse after 2007. My own analysis leads me to two factors, fertilizers and irrigation. However, I want the readers to go through the following questions, to be able to draw their own inferences.

Was Bt-cotton alone responsible for high yields? Regression-correlation analysis between Bt-cotton area and yields does not indicate any trends especially with data from 2006 to 2015. There are a number of questions that need explanation. *How did yields double during 2002 to 2004, when the area under Bt-cotton was less than 5%? Why did the yields decline from 554 kg/ha in 2007 with 67% Bt-area to less than 524 kg/ha continuously for five years from 2008 to 2012 despite progressive increase in Bt-area from 80 to 93%? There are other specific questions. Why did the yields decrease despite significant increase in area under Bt-cotton in Punjab during 2007 to 2011?* Bt was introduced in 2005. Yield was 551 kg/ha in 2004 before Bt and 610 kg/ha in 2005 with just 6.7% area under Bt-cotton. Yield was high at 672 kg/ha with 20.6% area under Bt-cotton. During the subsequent 5 years, Bt-area increased from 49.7% in 2007 to 97% in 2011. But, the yields were only 432 to 607 kg/ha during these 5 years. In 2014, the yield was only 486 kg/ha with 93.3% area under Bt. It is important to analyse the reasons for these discrepancies. Why were the yield gains highly insignificant in Rajasthan during the first five years from 2005 to 2009? Yields were 452 kg/ha in 2003 when there was no Bt cotton. Yields did not increase above 459 kg/ha by the year 2009 despite the significant 67%increase of in Bt-area. Traditionally, North India was always under pure-line cotton varieties prior to the introduction of Bt-cotton hybrids in 2005. Hybrid cotton had a miniscule area prior to 2005. Though there were a few non-Bt hybrids and some illegal Bt-hybrids smuggled from Gujarat, these hybrids were not found suitable. There were a few issues that did not suit the region. Long duration did not fit into the cotton-wheat rotation. Whitefly and CLCuD (Cotton Leaf Curl Disease) started resurfacing. Excessive vegetative growth caused nutrient imbalances. The hybrid area was less than 1.0% in any case and about 99% of the area was under pure-line varieties. Yields increased mainly in Gujarat. *Was the illegal Bt-cotton a major factor in yields? Why did the yields in Gujarat decline constantly from 795 kg/ha in 2005 with just 10% Bt-cotton area to the five-year average of 660 kg/ha from 2008 to 2012, despite increase in the Bt-cotton area from 10% in 2005 to >85% after 2011?* These are difficult questions.

Bt-cotton technology was considered as a game changer for Indian cotton, because of the huge damage caused by insecticide-resistant American bollworm *Helicoverpa armigera* for more than a decade prior to 2002. However, circumstantial evidence indicates that *Helicoverpa armigera* was an induced problem on cotton in India. It was a minor, insignificant pest of cotton in India prior to 1980, but became a major monstrous pest due to two major factors, namely, introduction and indiscriminate use of synthetic pyrethroids and increased area under long duration American cotton *Gossypium hirsutum* hybrids. Initially, the pest caused severe damage on hybrids in irrigated regions of the three Central-southern states, namely, Andhra Pradesh, Gujarat and Maharashtra. Interestingly, synthetic pyrethroids were introduced into India in 1981 to control the pink bollworm and the tobacco leafworm, *Spodoptera litura*, which were major pests of long duration cotton. Synthetic pyrethroid insecticides effectively controlled these pests but within 5-6 years of intensive use, brought the American bollworms and whiteflies to the fore. By 1990 American bollworm not only became a major pest but turned into a monster that was highly resistant to all recommended insecticides. Bt-cotton was considered to be the 'messiah' at this juncture.

Bt-cotton was supposed to have conferred two major benefits to cotton production. 1. High yields due to effective protection of bolls from bollworm damage and 2. Reduction in insecticides recommended for bollworm control. Official data show that none of the two expectations were met in the past 10 years in India. India cultivates cotton in about 11.0 to 13.0 million hectares that constitutes about 36 to 38% of the global area. It is dismal that cotton production progress in India has hit a dead-end over the past 10 years. Over the period 2006 to 2015, yields stagnated at 520 + 24kg lint per hectare, despite the deployment of all available latest technologies including the introduction of new potent GM technologies and two-fold increase in the use of fertilizers, insecticides and water. India's global rank is 30-32nd in yield. The low yields are despite > 90% area under GM Bt-hybrid-seeds, which are used commercially as hybrids only in India. Further, through tremendous Government support, irrigation infrastructure in 4.8 million hectares improved significantly. But, none

Table 1. National average data on cost of production, fertilizers, yields and Bt-cotton

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Cost Rs per ha	15758	14872	18146	20603	23351	23987	26200	26415	29196	37809	39693	50537	59051	63751	72434
Cost per Q	1932	2236	2449	2220	1997	1851	1959	1858	1848	2302	2438	3049	3499	3994	3893
Fertilizer Kg/ha	99	91	94	96	98	112	118	131	140	164	171	206	222	197	224
Fertilizers Rs/ha	1504	1517	1644	1621	1769	2030	2154	2398	2700	3249	3409	4270	5641	7430	8246
Market Value/ha	16068	15020	14932	20033	29322	25497	28125	30571	37101	46101	50168	75220	69679	65509	87984
Insecticide usage Kg/ha	1.45	1.35	1.53	0.88	1.29	1.05	0.67	0.50	0.59	0.54	0.66	0.71	0.56	0.63	0.97
Total cotton area M ha	9	8.576	8.73	7.667	7.63	8.786	8.677	9.144	9.414	9.406	10.31	11.142	12.178	11.978	11.96
Number of Bt-hybrids				3	3	4	20	62	131	274	522	780	884	1097	1167
Area under Bollgard M ha				0.029	0.093	0.499	1.015	3.650	5.874	5.560	3.680	3.740	2.650	1.11	0.44
Area under Bollgard-II M ha								0.150	0.460	2.040	4.820	6.380	8.540	9.130	9.12
Bt-cotton Area M ha				0.029	0.093	0.499	1.015	3.800	6.334	7.600	8.500	10.120	11.190	11.140	11.12
% Area under Bt-cotton				0.38	1.22	5.67	11.70	41.56	67.28	80.80	82.44	90.83	91.89	93.00	92.98
CAB Yield Kg lint/ha	304	278	308	302	399	470	472	521	554	524	503	517	512	518	566

Compiled from Data from Ministry of Agriculture, Government of India http://eands.dacnet.nic.in/

of these technologies made any difference to the stagnant yields.

During the first four years from 2002-06, area under Bt-cotton increased to only 37%, but insecticide usage declined from 0.8 kg/ha in 2002 to 0.5 kg/ha in 2006. Yields improved significantly by 50%. However, the benefits were short-lived and did not continue in a positive trend after 2006. In 2006, Bollgard-II was introduced as a more potent bollworm-control technology. In a short span during 2007-2011, more than 1000 Bt-cotton hybrids were approved by the Ministry of Environment for commercial cultivation. Many of these were poorly tested prior to release. The area under Bt-cotton increased from 37% in 2006 to more than 95% after 2011. By 2013, insecticide usage in cotton fields doubled to 11,598 million tonnes. During 2006-2015, expenditure on insecticides increased by 2.3-fold from Rs. 1240/ha in 2006 to 2799 in 2013. During this period yields ranged from 484 to 566 kg lint per hectare in an average area of 11.0 million hectares each year. Yield stagnation was despite the 1.7-fold increase in fertilizer usage from 131 kg/ha in 2006 to 224 kg/ha in 2013. The total fertilizer use on cotton in India increased by 2.2-fold, from 1.2 metric tonnes in 2006 to 2.68 metric tonnes in 2013. Fertilizer cost increased by 3.3-fold, from Rs. 2397/ha in 2006 to 8246/ha in 2013. Finally, as a result of increased cost of inputs, the cost of production increased by 2.7-fold from Rs. 26,414/ha in 2006 to 72,434 in 2013. But yields were stagnant, only to indicate that over the past 10 years, cotton production systems were rapidly moving towards un-sustainability in India. Unfortunately, due to the excessive usage of insecticides sap-sucking pests such as leaf-hoppers, aphids, thrips and whiteflies rapidly developed high levels of resistance to almost all chemical insecticides recommended for their control. The pink bollworm has developed high levels of resistance against Bollgard-II that contains Cry1Ac and Cry2Ab toxins. Thus insecticide usage is increasing steadily in India thereby leading towards unsustainable cotton ecosystems and environment.

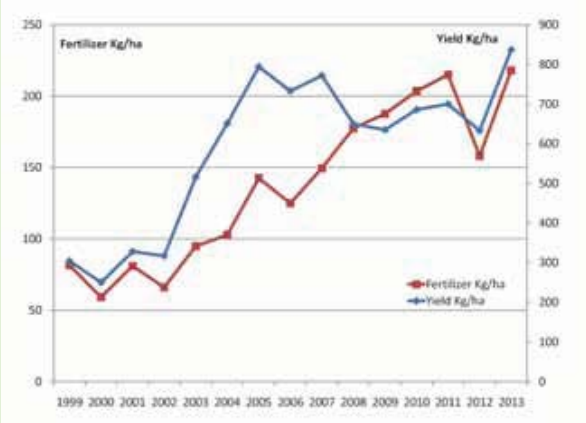
Did illegal Bt-cotton area contribute to yield increases? There is an argument that though the

Figure 1. Correlation of yields with fertilizer usage in Punjab

Figure 2. Correlation of yields with fertilizer usage in Haryana

Figure 3. Correlation of yields with fertilizer usage in Rajasthan

Figure 4. Correlation of yields with fertilizer usage in Gujarat



area under Bt-cotton was less than 5% in 2004, illegal Bt-cotton was rampant. Our surveys during 2000 to 2005 showed that illegal versions of Bt-cotton were available mainly in Gujarat, Maharashtra and AP. But the quality was not always good. Many of them were contained F-2 seed. A paper by professor Ramaswamy http://www.isid.ac.in/~bharat/Research/worlddevt_Ramaswami_feb11.pdf states that during the first three years from 2002, the area under illegal Bt was 0.4, 2.5 and 8% respectively. Therefore it would be grossly incorrect to presume that the yield gains were mainly from Bt-cotton, illegal or legal, during the period 2002-2004.

Was it hybrid cotton? The hybrid area increased from 38% in 2002 to 95% in 2011. Did the new proprietary Bt-hybrids of the rejuvenated seed industry make the difference? Indian seed industry made huge competitive investments into development of new proprietary hybrids. More than 1000 new Bt-hybrids were released in just 4 years from 2007 to 2011.

Was it the new insecticides? Trials conducted by CICR showed that seed treatment of cotton hybrids with imidacloprid (Gaucho) was found to increase yields by 25-30%. Along with Imidacloprid, new insecticides such as Acetamiprid and Thiomethoxam were also released almost about the same time as that of Bt-cotton hybrids in 2002. Simultaneously new insecticides such as spinosad, indoxacard, emamectin benzoate and chlorfenapyr were released around the same time. These insecticides were highly effective for bollworm control and were used extensively from 2001 to 2005 when the area under Bt-cotton was just increasing and was less than 11% even in 2005.

Was it the bollworm-retreat? Pheromone trap catches and field damage levels indicate that the bollworms had taken a back-seat in majority of the cotton growing states from the year 2000 itself. It is widely believed that large-scale use of the insecticides 'synthetic pyrethroids' promoted the American bollworm from an inconsequential pest prior to 1981 on cotton, to a major monstrous pest by 1986. After 1998, the usage of pyrethroids declined significantly due to bollworm resistance to this group of insecticides. Was it the pyrethroid decline that caused the bollworm populations to decline?

Was it irrigation? Yield increases in Gujarat

Figure 5. Correlation of yields with fertilizer usage in Andhra Pradesh

Figure 6. Correlation of yields with fertilizer usage in Karnataka

Figure 7. Correlation of yields with fertilizer usage in Tamilnadu

were the most significant. More than 1.5 lakh ponds and 1.6 lakh check dams were constructed after 2002 in the main cotton growing districts of Gujarat. Micro-irrigation increased in cotton growing regions of Maharashtra and MP by leaps during the period after 2002. Irrigated area increased significantly in the cotton growing regions of South India.

Was it good rainfall? Four consecutive years from 1999 to 2002 were drought year in India. The cotton growing regions suffered the most. It was sheer coincidence that good rains were received during the subsequent 10-15 years, except for 2014 when the shortfall in rains was actually not felt because of good distribution.

Was it the new fertile area? About 7.5 lakh hectares of new area was added to cotton in Gujarat from 16.47 lakh ha in 2003 to 23.9 lakh ha in 2006. A massive area of 14.28 lakh hectares was added in Andhra Pradesh from 9.72 lakh ha in 2006 to 24 lakh ha in 2012. Interestingly the new area of 21.78 lakh hectares in these two states came mostly from irrigated legume crops such as ground-nut and pulses, which fixed nitrogen.

Was it fertilizers? Prior to 2003, fertilizer usage never exceeded 100 kg/ha on cotton. After Bt-cotton hybrids were introduced, fertilizer usage went up to 222 kg/ha in 2011. Needless to say, increased use of fertilizers leads to yield increase.

A clear look at data http://eands.dacnet.nic.in/ shows that fertilizer usage increased like never before in the history of cotton cultivation in India. Analysis also shows a clear correlation in yield increase with fertilizer increase, at least in the initial years from 2000 to 2007.

A few examples are being shown in Figures 1-7 and data in Table 1, here to impress the reader on the correlation of yields with fertilizer usage and the lack of relationship with yields.

The trends and patterns of data in the seven graphs clearly show that yields were directly influenced by fertilizer usage. Data from central India are a bit skewed primarily because majority of the seasonal conditions. In Gujarat, much of change happened with fertilizers plus irrigation. Exact data on the changes in irrigation technologies and the new area were unavailable. Therefore proper correlation analysis was not done. Nevertheless it is clear that the check dams and farm ponds were constructed mainly during 2002 to 2008 and it is only during this time that the yield increases were exactly not commensurate with fertilizer usage and were influenced by other factors as well. One major factor of course could be irrigation. Data from Maharashtra also indicates the relationship of yields with fertilizer usage. However, there are several variables that are related to the vast expanse of area and the highly different conditions that are prevalent in Vidarbha, Marathwada and Khandesh regions that do not permit a uniform assessment for the whole state.

CONCLUSION: Bt-cotton undoubtedly did a great job in controlling the bollworms. Instead of crediting the technology with all the yield benefits, it would be appropriate to appreciate the excellent season-long bollworm control from 2002 to 2009, before pink bollworm struck with resistance. Thus Bt-technology provided cover from bollworm damage to allow the best genetic potential of cotton to be expressed under suitable seasonal conditions and better management practices. While Bt-cotton conferred excellent protection cover, high yields could have been due to the better management practices that farmers resorted to. High market prices mainly due to the higher cotton exports to China, Bangladesh, Vietnam and Indonesia ensured that Indian farmers got a higher price in the domestic market. This led to higher investment and higher cost of cultivation. Increased usage of fertilizers coupled with increase in the area under irrigation eventually helped farmers to obtain higher yields. Bt-cotton plus higher fertilizers plus increased irrigation also received a protective cover from the seed treatment of neonicotinoid insecticides such as imidacloprid, without which majority of the Bt-cotton hybrids which were susceptible to sucking pests would have yielded far less. It can safely be said that yield-increase in India would not have happened with Bt-cotton alone without enhanced fertilizer usage, without increased irrigation, without seed treatment chemicals, and the absence of drought-free decade.

The views expressed in this column are of the author and not that of Cotton Association of India