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Contents

Focus

Biotechnology for Second Green Revolution in Indian Agriculture

N. CHANDRASEKHARA RAO

The tools of biotechnology present an opportunity to infuse a new round of technology into Indian agriculture, which has been going through "technology fatigue" in recent period. These technologies follow from the conventional plant breeding techniques and complement them in improving crops to resist biotic and abiotic stresses, break yield barriers, and sustain yields in the face of resource degradation and climatic change. Though India has been making rapid strides in the field of biotechnology, the progress in harnessing agricultural biotechnology is rather slow largely due to the uncertainties created by campaigns by civil society groups based on ideological grounds. However, the commercialization of biotech cotton with a gene from soil bacterium Bacillus thuriengensis is a small step taken in the right direction in 2002. That has brought about a revolution in cotton production and productivity; catapulted India to the second leading position in cotton production in the world and earned foreign exchange worth more than Rs. 60000 crores in the last decade. Most importantly, it has improved the conditions of cotton farmers and accrued additional gains worth more than Rs. 75000 crores. Now is the time to move beyond cotton and replicate the success in other crops by providing the required enabling framework for the private sector, apart from enhanced investments in the public sector and public private partnerships and industry-academia linkages.

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Rationale for second green revolution and need for biotechnology

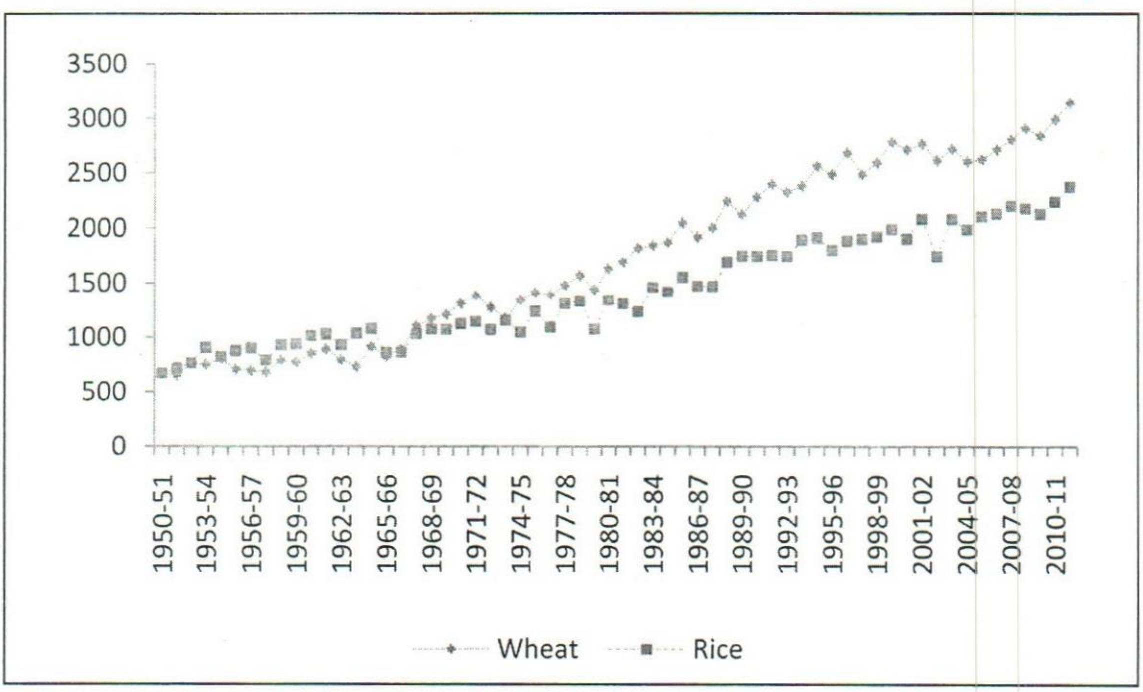
The tools of biotechnology present an opportunity to infuse a new round of technology into Indian agriculture, which has of late been going through a worst ever crisis since independence and need revival from the current morass. While discoveries in physics in the Newtonian era led to industrial revolution, developments in chemistry formed the background in which Green Revolution happened with the help of *Mendelian* genetics. The yields of several crops stagnated or increased at a very slow rate leading to starvation and hunger deaths across the world for a long time until the application of science and technology in the form of *Mendelian* genetics changed the scenario drastically and improved human welfare. For example, wheat yields in U.K took 600 years to enhance by one tone from 400-700 kgs/ha to 1.7 tonnes in 1850 AD before accelerating with modern varieties to go up by five tones in just 90 years from 1900 AD (Plucknet, 1993).

The recent advances in biology increase our understanding of life so much that experts say these discoveries are likely to define changes in the way we live in the 21st century. In fact, 21st century is predicted to be the century of biology. The biotech sector got a big boost from deciphering of human genome in the new century, which is being widely regarded as the 'biological equivalent of landing on Moon'. Several new disciplines like functional genomics, bioinformatics, proteomics etc., emerged as a result of these developments.

The tools of biotechnology especially genetic engineering have become controversial. It is worth mentioning here that all the major scientific breakthroughs were viewed with suspicion and resistance before they could prove the benefits to the society, with the unfolding information and communication technologies being the recent experience in India. In the same way, agricultural biotechnology is the centre of thriving controversies and the critics argue that there is no need for this technology. The critics argue that poverty reduction does not require production of more food and the problem is with the access to food for the destitute. This argument is flawed because poverty is concentrated in rural areas of the country[1] and livelihoods of majority of people in the rural areas depend on agriculture. Several economists concluded that raising agricultural productivity of small-scale farms reduces poverty significantly (Herdt et al, 2007; Johnston, 1970; Lewis, 1954; Mellor, 1966; Pinstrup-Andersen, 2002; Ravallion and Datt, 1998; Thirtle et al, 2003). It increases and stabilizes income and employment from agriculture. In India, the rural poverty in 2009-10 was 38.8 and higher compared to urban poverty, which was 29.8. Also, 78 per cent of the poor are from rural areas. The unique feature of the Indian agriculture is that the small and marginal farmers dominate the farming community forming 82% of all those engaged in agriculture. It was also found that the poverty among the farmers is 30% higher compared to the rural population in general in India, as calculated from the data of National Sample Survey Organsation's data in the Situation Assessment Survey of Farmers. Therefore, raising agricultural productivity through new technologies like biotechnology would be crucial for poverty reduction at this juncture of development. Several studies also showed that raising agricultural productivity can enhance growth in rural non-farm sector and thereby contribute to poverty reduction. There is a consensus in the literature that agricultural growth, which can be promoted with the same level of input use by new technology like biotechnology, is crucial for poverty reduction (Ahluwalia, 1978; Mellor, 2006).

Green revolution technologies losing steam

The improvement in the land productivity given by the growth in per hectare yield is the most crucial aspect in raising the productivity of farming and farmers especially in developing country context as mentioned above. The seed-fertiliser technologies of the green revolution brought about this desired change in India by spiking wheat and rice yields by 150% and 100% in less than three decades since mid-sixties (Figure 1), apart from improvement in several other crops. The yields of wheat went ahead of rice with the green revolution technologies and grown at relatively higher rates because of those technologies. However, the growth in yields of these crops flattened since late nineties, as could be seen from the figure.



Source: Directorate of Economics and Statistics, Government of India.

Figure 1: Per hectare yields in rice and wheat since 1950 in India

[1]Out of the total poor people of 355 million in 2009-10, 78 per cent live in rural areas in India .

The robust growth rates in yields also means that the operation of the Ricardian theory of law of diminishing returns is postponed in the country's agriculture and the same output is produced at lower costs leading to the decline in the food prices. However, this has changed with the seed-fertiliser technologies losing their steam and yields tapering off by late eighties or mid-nineties for most crops (Table 1). The yields of the two most important staple crops crucial for food security viz., rice and wheat have grown at less than 1.50% per annum, showing a decline of 50% in the growth rate in the earlier period of eighties. The same can be observed in several other crops during the latest period.

Table 1: Growth Rates in Yields of Major Crops

	1981-90	1990-99	2000-10
Rice	3	1.36	1.47
Wheat	3.6	2.87	0.73
Maize	4.1	1.37	4.13
Coarse cereals	3.1	2.03	4.64
Total cereals	—	2.38	1.69
Gram	0.92	2.97	1.19
Tur	-0.50	2.03	-0.65
Total pulses	2.3	1.82	1.21
Total foodgrains	3.1	2.43	1.37
Groundnut	1.11	-0.3	12.76
R & M	4.89	2.96	2.72
Soyabean	2.6	4.67	4.17
Oilseeds	4.8	1.76	5.18
Sugarcane	1.3	0.91	0.03
Cotton	5.3	-0.54	9.15

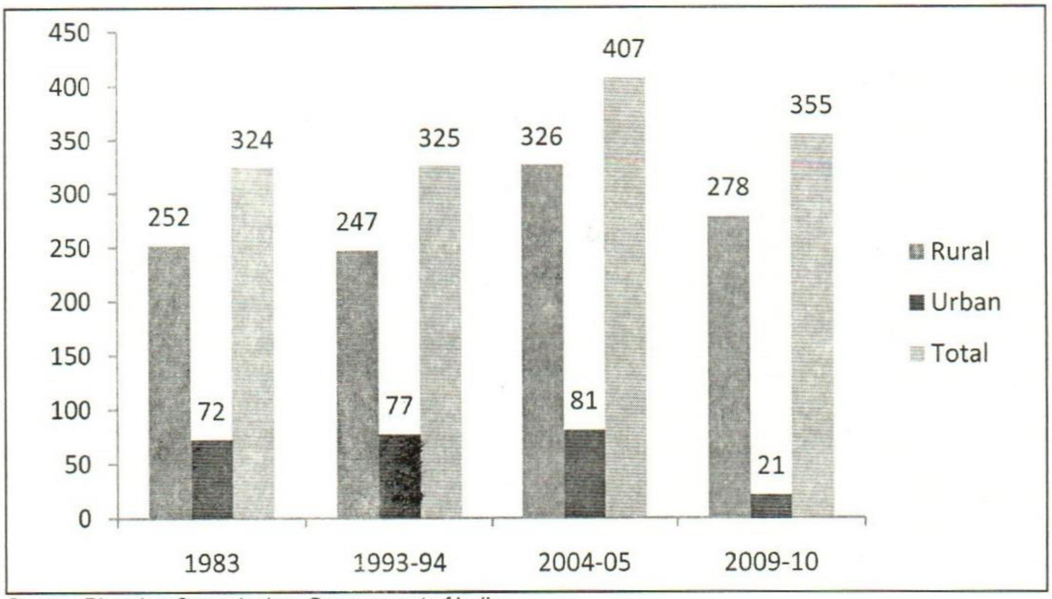
Source: Rao and Dev (2010) and GoI (2013b)

The declining crop productivity has its implications for food security and manifested by increasing cost of production after 1990s. Our studies using the farm household data generated by the Department of Economics and Statistics of the Ministry of Agriculture of Government of India provide conclusive evidence on the reversal of declining cost of food in the recent past, subsequent to the stagnation of yields in rice and wheat (Table 2). The data indicate that for both rice and wheat, the increase in cost of cultivation was more than compensated by the spike in land productivity leading to

Table 2: Reversal of Declining Cost of Food

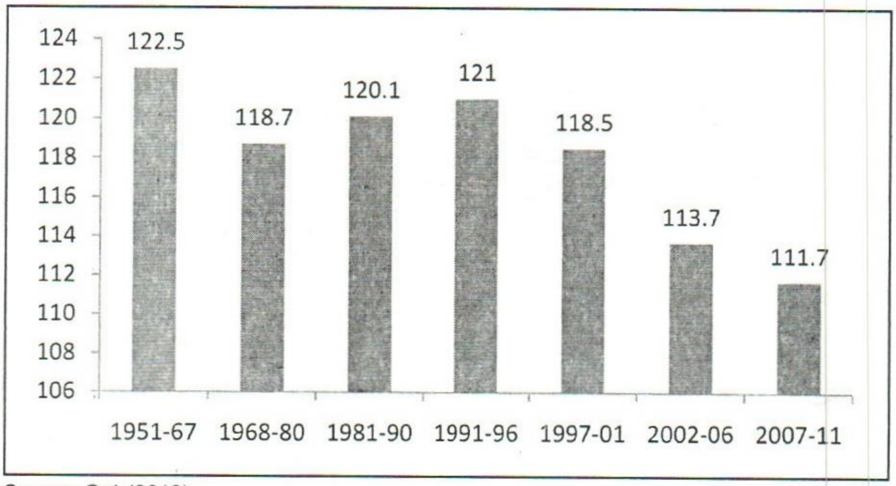
Period	Rice	Wheat
Cost of production per quintal		
1981-82 to 1992-93	-0.13	-1.96
1994-95 to 2006-07	1.46	1.41
Cost of cultivation per hectare		
1981-82 to 1992-93	2.32	1.36
1994-95 to 2006-07	1.92	1.96
Yield (Qtls/ha)		
1981-82 to 1992-93	2.67	2.54
1994-95 to 2006-07	0.86	0.52

Source: Dev and Rao (2010)



Source: Planning Commission, Government of India

Figure 2: Number of people below poverty line



Source: GoI (2013)

Figure 3: Mean annual rainfall in India since 1950 (in mm)

lower cost of production in the eighties and the same could not happen in the nineties because of lower per unit yields in both the crops. This resulted in the real cost of food to increase and form the basis for continuous rise in food prices in recent period (Figure 3).

Burden of poverty and malnutrition

The green revolution played crucial role in reducing the income poverty from around 60% in the mid-sixties to 35% by early nineties. However, the declining profitability of agriculture as a consequence of plummeting growth in yields of crops and the rising cost of food as another fall out of the same have led to unfavourable outcomes for the poor and marginalised in the country. The recent rise in food prices has to be understood in this background. As can be seen from Table 3, the prices of almost all the crops have been spiking up in India. At the same time, similar phenomenon is happening in many countries across the world and the shifting up in the level of prices is argued by several scholars as an irreversible phenomenon in the medium to long run (For e.g. Rosegrant et al, 2012).

Table 3: Upward shift in foodprices

Crop/s	2006	2009	2011
Rice	99	121	110
Wheat	112	127	108
C. cereals	110	123	136
Pulses	134	146	129
Vegetables	103	124	115
Fruits	99	104	119
Milk	98	112	124
Eggs,fish&meat	101	116	137
Oilseeds	85	103	102
Sugarcane	91	81	107
fibres	91	107	140
All agriculture	101	115	122

Source: GoI (2012)

Despite the massive developmental efforts and higher growth rates achieved in the economy, the extent of poverty and the absolute number of poor in India are staggering. There are more than 350 million poor in 2009-10 as the Planning Commission's estimates. What is more worrying is the fact that the poverty reduction has slowed down during the recent period and happened despite high growth rates of the economy. This underlines the need for accelerating agricultural growth, which can be broad based and dent poverty quickly and effectively.

Increasing demands on agricultural technologies

The demand for technologies have also been undergoing dramatic change in the past few decades in India, as has happened worldwide with climatic change and consumer preferences and perceptions on food safety. The degradation of lands, declining water tables, deterioration in water quality, changing rainfall and temperature patterns with climatic change require the new generation agricultural technologies to address far more issues than during the days of green revolution. The pattern of rainfall and temperatures given in Figure 1 and 2 clearly indicate that climate change in real. While the mean annual rainfall of 122.5 mm during 1951-52 to 1967-68 was never received in subsequent periods, the trend in Figure 1 points to decline in the overall precipitation levels, not to speak of the distortions in the pattern of rainfall distribution. The rise in temperatures was far more evident that the changes

Table 4: Transgenic Crops in Advanced Stage of Trials with Traits

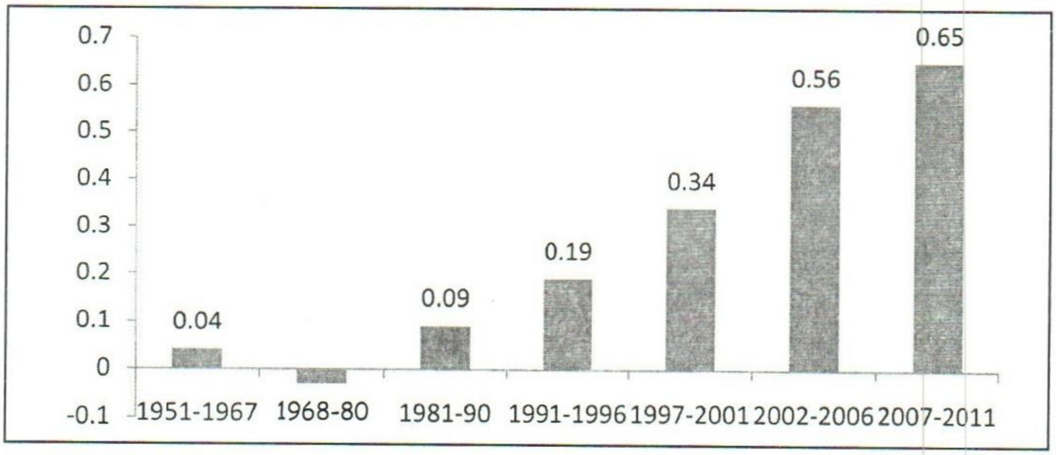
Crop	Company	Trait	Gene/Event	Stage
Corn	Pioner Ovrseas corporation	Insect resistance and herbicide tolerance NK603 (DAS-01507-1X MON-00603-60]	*cry1F&cp4epsps* genes [Stacked events TC1507x	BRL-I 2nd year conducted in 2012
	Syngenta Biosciences Pvt.ltd	Insect resistance and herbicide tolerance	GA21 event (*cry1Ab& mepsps* genes)	BRL-I 2nd year conducted in 2011
	Pioneer Overseas Corporation	Insect resistance and herbicide tolerance	*cry1F&cp4epsps & PAT* genes [Stacked events TC1507xNK603 (DAS-01507-1XMON-00603-60]	BRL-I 2nd year conducted in 2011
	Pioneer Overseas Corporation	Insect resistance and herbicide tolerance	*cry1F* & *PAT* and *CP4EPSPS* genes [TC1507xNK603 (DAS-01507-1xMON-00603-6)]	BRL-I 2nd year conducted in 2010
	Dow AgroScience India Pvt.Ltd.	Insect resistance	*cry1F* (event TC 1507) gene	BRL-I 2nd year conducted in 2010
	Monsanto India Ltd.	Insect resistance and Herbicide Tolerance	Stacked *cry2Ab2* and *cry1A.105* genes (Event MON 89034) *CP4EPSPS*genes (Event NK603)	BRL-I 2nd year conducted in 2010
	Monsanto India Ltd.	Insect resistance and Herbicide Tolerance	Stacked *cry2AB2*and *cryA.105* (MON89034) &*CP4EPSPS*	BRL-I 2nd year conducted in 2009
Mustard	University of Delhi (South Campus)	Male sterile female inbred rice lines	*barnase, barsar* and *bar*genes [Events bn 3.6 (barnase line) and modbs 2.99 (barstar line)]	BRL-I 2nd year conducted in 2011
Cotton	Dow AgroSciences India Pvt.Ltd.	Insect resistance	*cry1Ac & cry1F* (WideStrike= Event 3006-210-23 and Event 281-24-236)	BRL-I 2nd year conducted in 2010
	JK Agri Genetics Ltd.	Insect resistance	*cr1Ac* (Event-1) and *cry1Ec* (Event-24)	BRL-I 2nd year conducted in 2010
	Maharashtra Hybrid Seds Co.Ltd.	Insect resistance and Herbicide tolerance	Stacked *cry1Ac* & *cry2Ab* (MON 15985) and*CP4EPSPS* (MON88913)	BRL-I 2nd year conducted in 2009
Brinjal	University ofAgricultural Sciences	Insect resistance	*cry1Ac*	Seed multiplication Conducted in 2009
	University ofAgricultural Sciences	Insect resistance	*cry1Ac*	Multi location research trials completed in 2007
	Sungro Seeds Research Ltd.	Insect resistance	*cry1Ac*	Multi location research trials completed in 2007
	Tamil NaduAgricultural University	Insect resistance	*cry1Ac*	Multi location research trials completed in 2007
Rice	MAHYCO	Insect resistance	*cry1Ac*	Multi location research trials completed in 2007
Okra	MAHYCO	Insect resistance	*cry1Ac*	Multi location research trials completed in 2007

Source: IGMORIS website

in rainfall pattern as can be seen in Figure 2. The mean variations have been continuously increasing since 1980-81 and reached as far as to suggest an annual increase of 0.65 degree centigrade each year, which cannot be brushed aside as a routine variation and deleterious to crop growth.

The prospective agricultural technologies will have to address these demands for technologies and should be able to produce more using minimum of natural resources and in the back ground of the degrading natural resources. The tools of biotechnology offer solutions to these requirements and they can also be very quick and precise compared to the conventional plant breeding (CPB) techniques. Though they have discontinuities with the CPB techniques in that sense, they are also continuation of CPBS in the sense that the tools of biotechnology can complement them. For example, tools like marker assisted selection (MAS) can help in identifying the specific gene responsible for the desired trait and then can be followed by CPB methods.

The tools of biotechnology, especially genetic engineering, are useful in achieving these objectives by having wide ranging applications to make crops resistant to pests, diseases, abiotic stresses like salinity, alkalinity, drought, water logging etc[2]. It can also be useful in developing fortifying foods rich in micro nutrients like iron, zinc etc and others like proteins. The much talked about Golden rice that is rich in vitamin A will reach farmers'



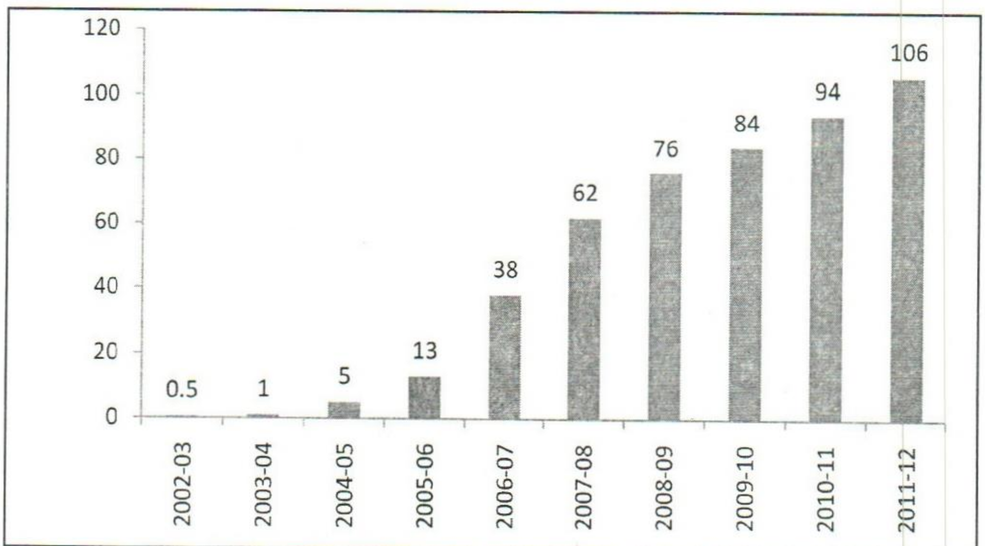
Source: GoI (2013)

Figure 4: Mean Variations in Temperature since 1951 in Centigrade

fields in a few years. Insect resistant cotton is the only crop commercialised so far in India. However, there is wide range of crops that are modified for several important and useful traits that are in trial stage. Table 4 gives some of the GM crops with their traits that are in advanced stage of trials.

Adoption and Performance of Bt cotton

Several millions of farmers across 30 countries are cultivating 170 million hectares under the genetically modified crops in corn (maize), soybean, cotton and canola (mustard) in 2012 (ISAAA, 2012). In India, the



Source: James (2012)

Figure 5: Area under Transgenic cotton in India (In lakh hectares)

[2]C.H.Hanumantha Rao as far as back in 1994 brought out the potential of biotechnology and its relevance to Indian agriculture (See Rao, 1994).

adoption of the first biotech crop viz., Bt cotton[3] has progressed at a very high rate of growth and unprecedented for any agricultural technology since its commercialisation in 2002. The demand in the past few years for the Bt seeds exceeded the supplying capacity of more than 30 companies producing more than 1000 approved Bt hybrids. It is a common occurrence across the country to see the farmers jostling with each other for the seeds, standing in long queues, often guarded by heavily armed police force. Starting with less than 50000 hectares in 2002-03, when it was first commercialised, the area reached 106 lakh hectares or more than 90% of 12 million hectares of cotton area in the country (Figure 5). An estimated seven million farmers have adopted this technology, making India the country with largest number of small farmers adopting GM crops.

The agronomic and economic impact of the introduction of Bt cotton in cotton cultivation has been one of the most thoroughly researched topic in recent times. There are broadly three types of studies on the impact of Bt cotton using different kinds of data sets viz., trial data (prior to commercialisation), industry data, and data collected from field surveys. Some of the earlier studies like Qaim (2003), Qaim and Zilberman (2003) brought out significant yield and income benefits. However, they have been questioned as the data is from the field trials and supplied by the companies involved. On the other hand, using the field trial data Shiva et al (1999) showed that the benefits are not sizeable and in fact counterproductive.

Subsequently, several studies done by scholars in different agro-ecological conditions in different socio-economic settings have found significant positive increase in yields, net returns and decrease in expenditure on plant protection chemicals as the Bt cotton gives protection against boll worm damage. Some of the studies are summarised in Table 5. As could be seen from the table, the yield increase varied from 18%-80%. The extent of yield effect varied in direct proportion to the pest pressure as shown by Qaim (2003). If the pest pressure is high and it is not properly controlled using chemical pesticides, the yield advantage with the Bt cotton can be very and high and vice versa. Another important aspect of Bt cotton cultivation in India is that the yield effect is significantly higher compared to countries like USA, China, where cotton in cultivated in temperate climate. That is because of the lack of proper control of bollworms in tropic conditions, where cotton is grown in India. Further, the employment effect can also be positive in India as the labour requirements for increased cotton yields can be high as shown by Rao and Dev (2010). However, the subsequent survey by them has shown that the higher labour requirement for harvesting is neutralised by the decline in labour use for pesticidal sprays. Therefore, it needs some more studies for conclusive evidence. However, the most important thing is that the labour productivity has increased as a result of this technology and employment has become more secure as the crop damage due to bollworm is controlled effectively. Herring and Rao (2012) in a synthesis of all the studies on the subject have brought out these effects more vividly. A meta analysis done at the International Food Policy Research Institute, Washington, D.C with all the studies done on Bt cotton impacts in India has concluded that the positive yield effect was 41% leading to a higher net returns of 50% with decline in pesticidal expenditure by 52% (Gruere and Sengupta, 2011). The studies on other impacts like employment, farmer welfare and village-wide effects found significant positive role for the technology (Rao and Dev, 2010; Subramanian and Qaim, 2009, 2010).

There was a turnaround in cotton production and productivity in the country as a fall out of the introduction of the modern biotech cotton as more than 90% of the cotton area is covered with it (Table 5). The production has increased by 250% in the last decade and per acre yields have gone up from 203 kgs/ha of lint in the five year period before 2002-03 to more than double viz., 512 kgs/ha by 2011-12. The importance of this achievement can be understood from that the previous doubling of lint yield took 34 years from 1950. As noted above, the area under cotton has also gone up substantially to more than 12 million hectares compared to the past peak of nine m.ha, as the farming community found it more rewarding to grow cotton with the availability of biotech seeds. Though there are several factors like cotton technology mission, some improvement in the irrigated area in states like Gujarat, development of new pesticide molecules for sucking pests, widespread adoption of hybrids, the major impact of this is the adoption of biotech cotton. The adoption of the technology has also resulted in India becoming second leading producer of cotton in the world and a leading exporter of cotton, which would not have happened without

[3]A gene from soil bacterium *Bacillus thuriengensis* is inserted into the cotton crop to develop resistance against the dreaded bollworm *Helicoverpa armigera*, which damages crop output by more than 50% in several cotton growing regions in India.

Table 5: Percentage Changes w.r.t Yield, Pesticides and Profit in Bt Cotton vis-à-vis Conventional Hybrids in India

Authors	Survey year	Geographic coverage	Sample size	Percentage change in			
				Yield	Pesticides	Profit	Cost
Qaim, 2003	2001-02	Maharashtra	157	80	-60	500	NA
Naik et al, 2005	2002-03	Maharashtra	341	34	-41	69	17
Nelson-ORG Marg, 2004	2003-04	Maharashtra	3063	29	-60	78	NA
Narayanamoorty and Kalamkar, 2006	2003-04	Maharashtra	150	52	-5	79	34
Gandhi and Namboodiri, 2006	2004-05	A.P, Gujarat, Maharashtra &TN	694	31	-24	88	7
Rao and Dev, 2010							
i. With and without	2004-05	A.P	623	32	-18	83	17
ii. Before and after	2006-07	A.P	814	42	-56	251	-1
Sadashivaipa and Qaim, 2009	2002-03	Maharashtra, Karnataka, AP, TN	434	34	-50	69	17
	2004-05	-Do-	465	35	-51	129	11
	2006-07	-Do-	373	43	-21	70	24
	Average	-Do-		37	-41	89	17
Kathage and Qaim, 2012	2002-04	Maharashtra, Karnataka, AP, TN	533 (1655 plots)	35	31	71	NA
	2006-08	-Do-	533h, (1655 plots)	41	0	94	NA
Crost et al, 2007	2002-03	Maharashtra	352	47	-13	NA	NA
	2003-04	Maharashtra	366	47	-14	NA	NA
Morse et al, 2012	2002-03	Maharashtra	7744 plots	40	NA	43	15
	2003-04	Maharashtra	1577plots	63	NA	73	5
Stone, 2011 (Before and after adoption)	2003/2007	Warangal district in A.P	238181	18	-55	NA	NA
Guere and Sengupta, 2011 (Meta analysis)	Peer reviewed studies upto 2008	All over India	10931-12755 plots	41	-52	50	16

Note: NA- Not available

the new technology. The country has gained valuable foreign exchange through export of Rs.66000 crores of cotton in the last decade by means of adopting the Bt cotton (Table 6). Our own estimations based on the longitudinal studies indicate that the cotton farmers gained in excess of Rs.75000 crores in the last decade through the adoption of Bt cotton.

Controversies on Bt cotton performance

It is paradoxical to see so many controversies co-existing with the unprecedented adoption and reaching more than 90% of the cotton area in less than a decade. While the initial criticisms focused on showing that there is no improvement in yield or net income (Shiva et al, 199; Qayum and Sakhari, 2005; Sahai and Rahman, 2003), the recent diatribe directs its attention on proving that the yield increases are not as a result of the biotech cotton (For e.g. Kuruganti, 2009; Stone, 2012). Kuruganti (2009) attributed the rise in cotton yields to increasing irrigation in several cotton growing states and popularisation of hybrids. However, Herring and Rao (2012) have shown that there was no significant increase in cotton area under

Table 6: Changes in Cotton Production, Productivity and Exports in India

Year	Area in m.ha	Production in lakh bales of 170 kgs each	Lint yield in Kgs/ha	Exports*	
				Quantity in lakh tones	Value in Rs. crores
Five years ending 20002-03	8.7	104	203	0.11	50
2003-04	7.6	137	307	1.80	942
2004-05	8.8	164	318	0.87	423
2005-06	8.7	185	362	6.15	2904
2006-07	9.1	226	421	11.62	6108
2007-08	9.4	259	467	15.58	8865
2008-09	9.4	223	403	4.58	2866
2009-10	10.13	240	403	13.58	9537
2010-11	11.24	330	510	18.86	13160
2011-12	12.18	352	512	20.04	21624

Source: Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India
Note: * This data pertain to cotton year October-September

irrigation. The process of replacing the open pollinated varieties with hybrids in cotton started during the nineties and completed in the the first few years of the new millennium. While the same thing happened in maize, the yield increase in that crop never matched the speed with which it happened in cotton. Some argued that there is no correlation between the growth in cotton productivity and acreage under the Bt cotton (For e.g. Stone, 2012). However, the confusion arises because they follow the data set of the Cotton Advisory Board and not the official data provider in India viz., the Department of Economics and Statistics of the Ministry of Agriculture of Government of India. Another problem is the underestimation of area under Bt hybrids due to non-accounting of unofficial seeds that have been flowing in several states in India and specifically in Gujarat[4].

Stone (2012) raised the issue of efficient farmers adopting the technology and impact studies not accounting for this. However, several studies using sophisticated fixed effects model (For e.g. Crost et al, 2007; Kathage and Qaim, 2012) and before and after adoption scenarios (For e.g. Rao and Dev, 2009; Stone, 2011) separated the farmer effect and technology effect and shown that Bt has given significant yield increase. Gruere and Sun (2012) have also isolated the technology effect and found that that was the 'engine of productivity growth'. While these are the results of several scientific studies, there are some civil society groups attributing several adverse phenomenon like suicides of farmers to the introduction of Bt cotton. However, the suicides of farmers started happening in 1997 in Warangal of Andhra Pradesh and they have tapered off after 2004. On the other hand, the biotech cotton was introduced in 2002. Therefore, it is fallacious to link the two. If there is a link, it was by way of reducing the distress of cotton farmers by making them more profitable. Several of these NGOs oppose the technologies not because they are not performing, but because they are ideologically against biotechnology.

Concerns on safety and proprietary nature of biotechnology

There are two major concerns regarding biotechnology. The first one is the risks to the plant and animal health due to the genetic modification. Several studies have been undertaken and in fact, biotechnology is most thoroughly scrutinised technology. In India, the cotton oil is consumed in different preparations for human consumption, apart from the seed cake being used as animal feed. Several billions

[4]This problem was very serious in the early years initially because of lack of regulatory approval and later because of the high price of Bt hybrid seeds. Herring and Rao (2012) brings out this in some detail.

of people have consumed the GM soybean, corn, mustard, papaya, tomato, sweet potato etc in the world over the past 16 years and there were no verifiable incidents of any harm done to any of them. The GM products are not found to be any more harmful than the products from conventional plant breeding techniques in the studies done by International Council for Science (2003), Nuffield Council (1999, 2004), Royal Society, 2003; FAO, 2004; World Bank, 2007, European Commission, 2010, apart from the world Health Organisation, and scholars like Francis Crick, and Norman Borlaug. However, it is to be noted that it has not harmed so far does not mean that they will not be deleterious in future. Therefore, continuous monitoring of the technologies even after release is essential in case of biotechnologies. All the evidence so far suggests that the benefits far outweigh any perceived risks of the technology. In this scenario, precautionary principle should not deter us from using the technologies to the benefit of the food security needs of the ever growing population.

The second major concern is that the biotechnologies are developed largely in the domain of private sector and few multinational companies dominate the field[5]. Biotechnologies have been in the development for a long time without any commercialized applications. The first generation products developed using this technology are the ones that resist some of the insect pests like root weevil in corn, bollworm in cotton etc. As these applications in particular and biotechnology in particular alter the nature of agricultural technologies leading to the primacy of seeds, the companies involved in producing plant protection chemicals acquired seed companies and have also invested heavily in plant biotechnology. In the mean time, the conclusion of Uruguay round of trade talks leading to formation of World Trade Organisation in 1995 with intellectual property rights becoming a part of trade rules have changed the bio-property regime. India has also brought three amendments to the Indian Patents Act, 1970 to make it compliant to the rules of WTO. The developments in biotechnology on one side and change in trade rules on the other, made inventions and innovations in biotechnology strongly protected through patents. To add to this, the public sector in the world as a whole through the national agricultural research systems (NARSs) of different countries and the international public research on agriculture through the Consultative Group on International Agriculture (CGIAR) have been shrinking and their expenditure on biotechnology is miniscule of even this low investment[6]. All these developments make biotechnologies proprietary and dominated by few life science companies. Though it might seem to be a disadvantage, it also can be leveraged as an advantage to develop useful traits in crops in vast country like India. The major advantage is that the seed market is developed in our country and attracting many of these bigger players to develop useful traits. The changes in cropping patterns with the growing area under both maize and soybean reaching the ten million hectare level is another significant development in harnessing these technologies, since the available basket of technologies from these companies has solutions for improving these companies. The public sector research institutions under the Indian Council of Agricultural Research and some of the universities are making rapid strides in this area. The Indian Institute of Technology, Kharagpur played a crucial role in developing Bt gene (cry 1AC) construct for use by JK Agri Genetics Ltd. There are also opportunities to harness several technologies through public private partnerships, for which Golden Rice is the shining example.

Conclusions and way forward

Biotechnology has wide range of tools and can be applied in so diverse fields as agriculture, industry, forestry, animal husbandry, pharmaceuticals and any others that may emerge in future. This is a rapidly developing technology and can have far reaching implications in the way mankind live in the twenty first century. Some countries like USA have committed special funds and made specific plans to utilise applied research in bioeconomy, which is defined as an economic activity that is fuelled by research and innovation in the biological sciences by OECD[7]. While India has been making rapid strides in the field of biotechnology especially pharmaceutical biotechnology, the progress in agricultural biotechnology does not match the potential. There is a lot of uncertainty at the moment because of the resistance from the civil society groups opposing the technology on ideological grounds and fears created by their propaganda. The information asymmetries are also significant in this field of knowledge in view of the

[5]Rao and Dev (2009) bring out the asymmetry in the quantum of research expenditures on agricultural biotechnology among the developing and developed world and public sector and private sector.

[6]Spielman (2007)

[7]According to the OECD, the "bioeconomy," is a large and rapidly growing segment of the world economy that provides substantial public benefit.

esoteric nature of biotechnologies. However, the small step taken in 2002 allowing commercialisation of genetically engineered cotton popularly known as Bt cotton, has played crucial role in mitigating the distress of cotton farmers, brought about a revolution in cotton production and productivity and helped India become second leading producer of cotton and earning huge foreign exchange worth more Rs.60000 crores in the last decade. The additional gains to farmers are estimated to be to the tune of Rs.75000 crores in the same period. Now is the time to move beyond Bt cotton and replicate the same success in other crops. The country should not be allowed to be hijacked by some individuals and groups with regressive ideas and agendas and it needs to be taken forward using the state of the art technologies. While encouraging the public sector through investments to do basic and applied research in the field, the huge capacities created in the private sector needs to be utilised by creating a good enabling framework for development and commercialisation of the biotech products that should include forging public private partnerships and industry-academia linkages. The long awaited policy measures like Biotechnology Regulatory Authority of India need to be expedited to assuage the fears of consumers and at the same time encourage producers of the technology. The embryonic second green revolution that has started with Bt cotton needs to be sustained through complementary policy framework, driving out the present uncertainty.

References

Ahluwalia, Montek S (1978): "Rural Poverty and Agricultural Performance in India", *Journal of Development Studies,* 14: 298-323.

Crost, Benjamin, Bhavani Shakar, Richard Bennett and Stephen Morse (2007): "Bias from Farmer Self-Selection in Genetically Modified Crop Productivity Estimates: Evidence from Indian Data", *Journal of Agricultural Economics*, 58(1):24-36.

Dev, S. Mahendra and N.Chanrasekhara Rao (2010): "Agricultural Price Policy, Farm Profitability and Food Security", *Economic and Political Weekly,* Mumbai, 45 (26&27): 174-182.

European Commission (2010). *A Decade of EU-funded GMO Research 2001-2010).* European Commission Directorate-General for Research (Brussels: European Union). ISBN 978-92-79-16344-9. doi 10.2777/97784.

FAO, (2004): *The State of Food and Agriculture 2003-04: Agricultural Biotechnology- Meeting the Needs of the Poor?* FAO Agriculture Series 35, Food and Agriculture Organization of the United Nations, Rome.

Gandhi, Vasant P, and N V Namboodiri (2006): "The Adoption of Bt Cotton in India: Preliminary Results from a Study", Working Paper No. 2006-09-04, Indian Institute of Management, Ahmedabad

GoI (2013): *Twelfth Five Year Plan (2012-2017): Economic Sectors-Volume II,* Planning Commission, Government of India, Sage Publications, New Delhi.

GoI (2013b): *Economic Survey: 2012-13,* Department of Economic Affairs, Ministry of Finance, Government of India, New Delhi.

Gruere, P Guillaume, and Debdatta Sengupta (2011): "Bt Cotton and Farmer Suicides in India: An Evidence-based Assessment" *Journal of Development Studies,* 47 (2): 316-337.

Gruere, Guillaume P., and Yan Sun (2012): *Measuring the Contribution of Bt Cotton Adoption to India's Cotton Yields Leap,* IFPRI Discussion Paper 01170, April, International Food Policy Research Institute, Washington, D.C

Herdt, Robert, Gary Toenniessen and John O'Toole (2007): "Plant Biotechnology for Developing Countries", in Robert Evenson and Prabhu Pingali (eds) *Handbook of Agricultural Economics Vol. 3- Agricultural Development: Farmers, Farm Production and Farm Markets,* (Amsterdam: North-Holland, Elsevier).

Herring, Ronald H., and N.Chandrasekhara Rao (2012): "On the 'Failure of Bt Cotton': Analysing a Decade of Experience", *Economic and Political Weekly,* 47 (8): 45-53.

ICSU (2003), *New Genetics, Food and Agriculture: Scientific Discoveries- Societal Dilemmas, Paris,* International Council for Science, Paris. Also available at http: // www.icsu.org.

James, Clive (2012), *Global Status of Commercialiased Biotech/ GM Crops in 2012,* International Service for the Acquisition of Agri-Biotech Applications.

Johnston, B.E. (1970), "Agriculture and Structural Transformation in Developing Countries: A Survey of Research", *Journal of Economic Literature,* Vol. 3, Pp. 369-404.

Kathage, Jonas and Matin Qaim (2012): "Economic impacts and impact dynamics of Bt (*Bacillus thuringiensis*) cotton in India", *Proceedings of the National Academy of Sciences,* 109(29): 11652-11656.

Kururganti, Kavita (2009): "Bt Cotton and the Myth of Enhanced Yields", *Economic and Political Weekly,* 44 (22): 29-33.

Lewis, Arthur (1954): "Economic Development with Unlimited Supplies of Labor", in Gersovitz, M (ed.) *Selected Economic Writings of W. Arthur Lewis,* (New York University Press, 1983).

Mellor, John W (1966): *The Economics of Agricultural Development,* (Ithaca: Cornell University Press).

Mellor, John W (2006): "Pro-poor Growth- The Relation between Agricultural Growth and Poverty Reduction", in R

Radhakrishna, S K Rao, S Mahendra Dev and K Subbarao (eds.) *India in a Globalising World: Some Aspects of Macroeconomy, Agriculture and Poverty,* (New Delhi: Academic Foundation).

Morse, Stephen, Antoinette M Mannion and Clive Evans (2012): "Location, location, location: Presenting evidence for genetically modified crops", *Applied Geography,* 34: 274-280.

Naik, Gopal, Marin Qaim, Arjunan Subramanian and David Zilberman (2005), 'Bt Cotton Controversy: Some Paradoxes Explained', *Economic and Political Weekly*, Vol.40, No. , April 9, Pp. 1514-1517.

Narayanamoorthy, A and S.S.Kalamkar (2006), 'Is Bt Cotton Cultivation Economically Viable for Indian Farmers? An Empirical Analysis', *Economic and Political Weekly,* Vol.41, No.26, June 30, Pp.2716-2724.

Nielsen, A C (2004): "Nationwide Survey by AC Nielsen ORG-MARG Underscores Benefits of Bollgard™ Cotton, Press Release", A C Nielsen ORG-MARG, Mumbai.

Nuffield Council on Bioethics (1999): *Genetically Modified Crops: The Ethical and Social Issues: London, May*

Nuffield Council on Bioethics (2004): *The Use of Genetically Modified Crops in Developing Countries,* (London: Nuffield Council on Bioethics).

Qaim, Matin (2003), "Bt Cotton in India: Filed Trial Results and Economic Projections", *World Development,* Vol.31, No.12, Pp.2115-2127.

Qaim, Matin and D Zilberman (2003): "Yield effects of genetically modified crops in developing countries", *Science,* 299(5608): 900–902.

Qayum, Abdul and Kiran Sakkhari (2005): *Bt cotton in Andhra Pradesh*, Hyderabad: Deccan Development Society.

Pinstrup-Andersen, Per (2002): "Food and Agricultural Policy for a Globalizing World: Preparing for the Future", *American Journal of Agricultural Economics,* 84: 1201-1214.

Plucknett, Donald L., (1993): *Science and Agricultural Transformation,* Lecture Series, International Food Policy Research Institute, Washington D.C.

Rao, C.H.Hanumantha, (1994), Agricultural Growth, Rural Poverty and Environmental Degradation in India, New Delhi: Oxford University Press.

Rao, N Chandrasekhara and S Mahendra Dev (2009): "Biotechnology and Pro-Poor Agricultural Development" *Economic and Political Weekly,* 44 (52): 56-64.

Rao, N Chandrasekhara and S.Mahendra Dev (2010): *Biotechnology in Indian Agriculture: Potential, Performance and Concerns,* (New Delhi: Academic Foundation).

Rao, N.Chandrasekhara (Forthcoming): "Bt Cotton Yields and Performance: Data and Methodological Issues", *Economic and Political Weekly,* Mumbai.

Ravallion, Martin and Gaurav Datt (1998): "Farm Productivity in India", *Journal of Development Studies*, 34 (4): 62-85.

Rosegrant, Mark W., Simla Tokgoz and Prapti Bhadary (2012): "The New Normal? A Tighter Global Agricultural Supply and Demand Relation and Its Implications for Food Security", *American Journal of Agricultural Economics, 95 (2): 303-309.*

Royal Society (2003): "The Farm Scale Evaluations of sping-sown genetically modified crops. A themed issue". *Philo.Trans.R.Soc.Lond.* B, 358 (1439):1775-1913.

Sadashivappa, Prakash and Matin Qaim (2009): "Bt Cotton in India: Development of Benefits and the Role of Government Seed Price Interventions", *AgBioForum,* 12(2): 172-83.

Sahai, Suman and Shakeelur Rehman (2003), 'Performance of Bt Cotton: Data from First Commercial Crop', *Economic and Political Weekly,* Vol. 38, No. , July 26, pp.

Shiva, Ashok Emani and Afsar H Jafri (1999), 'Globalisation and Threat to Seed Security: Case of Transgenic Seed Trials in India', *Economic and Political Weekly,* Vol 34, Nos 10 and 11, March 6-13, pp 601-613.

Spielman David J. (2007): "Pro-poor Agricultural Biotechnology: Can the International Research System Deliver the Goods", *Food Policy,* 32:189-204.

Stone, Davis Glenn (2011): "Field *versus* Farm in Warangal: Bt Cotton, Higher Yields and Larger Questions", *World Development,* 39(3):387-398.

Stone, Glenn (2012): "Constructing Facts: Bt Cotton Narratives in India", *Economic and Political Weekly,* 47 (38): 62-70.

Subramanian, Arjunan and Matin Qaim (2009): "Village-wide effects of agricultural biotechnology: the case of Bt cotton in India", *World Development*, 37(1): 256-267.

Subramanian, Arjunan and Matin Qaim (2010): "The Impact of Bt Cotton on Poor Households in Rural India", *Journal of Development Studies*, 46 (2): 295-311.

Thirtle, C., L.Beyers, Y.Ismael, and J.Piesse (2003), "Can GM-Technologies Help the Poor? The Impact of Bt Cotton in Makhathini Flats, KwaZulu-Natal", *World Development,* Vol.31, No.4, Pp.717-732.

World Bank (2007): *World Development Report 2008: Agriculture for Development*, The World Bank, Washington, DC.

Any sufficiently advanced technology is indistinguishable from magic.

—Arthur C. Clarke

Safety Aspect of Transgenic Crops: Methods and Issues

AKRAM A. KHAN AND MOHD FARHAN

Current Indian agriculture sector situation necessitates that we innovate. Impacts of modern agricultural biotechnology are well documented. But, safety of GM crops is a serious issue and it's important to address safety concerns. It's important to assure that India has developed adequate regulatory instruments and infrastructures. GM foods are the most studied food products ever produced. Bt. brinjal completely fulfills norms of substantial equivalence and well structured Indian regulatory system. India has more serious food safety risks to worry about, such as unsanitary food processing, availability and affordability of food. Priority must go to more clearly demonstrated safety risks instead of hypothetical risks.

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Importance of GM crops

GM food contributes to sustainable development by maintaining soil and water quality. It has the potential to reduce the use of pesticide and thus less CO_2 emissions the storage of organic matter in the soil, which helps to retain soil moisture (Christoffoleti et al., 2007, pp. 383–389) and reducing agricultural energy use, (Clewis, and Wilcut, 2007, pp. 45–52).

Scope of the Study

Relatively large number of transgenic events have been approved for cultivation in the developed world as compared to developing countries. This gap in approvals is unfortunate because crop biotechnology, appropriately applied, has the potential to address key production constraints affecting resource-poor (Cohen et al., 2003). Too much of hue and cry has been made about safety aspect in India whereas America who have got most stringent food safety standard in the world have been promoting it at an impressive rate. The US continues to be the lead producer of GM crops globally. Despite impressive growth and substantial potential of GM crops, Indian policy towards it has not been encouraging (Paarlberg, 2000). Bt. brinjal has passed all the regulatory procedure that is formed by government of India and yet the government imposed a ban. It has put a question mark on the future of GM foods in India (Bandopadhyay et al., 2012, pp. 238–240). It's true that safety of GM crops is a serious issue and hence the subject matter of this article. We will attempt to address questions like do we have safety mechanism in place? What are the principles of GM food safety assessment and regulatory system? Further, we have to investigate that how authentic is our apprehension about safety. It is safety issue or something else which has been blocking it.

Performance of GM Crops

From 1996 to 2011, GM crops contributed to food security, sustainability, and climate change by increasing crop production valued at US$98.2 billion; providing a better environment, by saving 473 million kg active ingredients of pesticides; in 2011 alone reducing CO2 emissions by 23.1 billion kg conserving biodiversity by saving 108.7 million hectares of land; and helping alleviate poverty by helping more than 15.0 million small farmers, and their families totaling more than 50 million people, who are some of the poorest people in the world. Economic gains at the farm level of US$78 billion were generated globally by GM crops during the fifteen year period 1996 to 2010, of which 40% were due to reduced production costs (less ploughing, fewer pesticide sprays, and less labor) and 60% due to substantial yield gains of 276 million tons,(Brookes and Barfoot, 2012, forthcoming).

A record 170.3 million hectares of GM crops were grown globally in 2012. GM crops the fastest adopted crop technology in recent history, the reason it delivers benefits. In the period 1996 to 2012, millions of farmers in approximately 28 countries worldwide, adopted GM crops at unprecedented rates. GM crops deliver substantial, sustainable, socio-economic, and environmental benefits. Developing countries plant more GM crops than industrial countries.

Principles of GM Food Safety Assessment: A Comparative Approach

Concerted efforts have been made internationally to harmonize the risk assessment of foods derived from modern biotechnology. Consultations have resulted into the development of internationally accepted approaches to assessing the safety of GM foods as articulated in two important documents published in 2003 by the Codex Alimentarius Commission (CAC) "Principles for the Risk Analysis of Foods Derived from Modern Biotechnology" ("Codex Principles") and "Guideline for the Conduct of Food Safety Assessment of Foods Derived from Recombinant-DNA Plants".

Substantial Equivalence

The safety assessment of GM foods has been based on the principle that these products can be compared with traditional foods that have an established history of safe use. This comparative approach has been embodied in the concept of substantial equivalence: a concept which was developed before GM foods came to the market. It was first described in an OECD publication in 1993. The concept of substantial equivalence was further endorsed by an FAO/WHO joint expert consultation in 1996. It recognized that the establishment of substantial equivalence is not a safety assessment per se, but that establishing the characteristics and composition of the GM food as equivalent to those of a familiar, conventional food with a history of safe consumption means that the new product will be no less safe under similar consumption patterns and processing practices. The concept of substantial equivalence also recognizes the fact that existing foods often contain toxic components (usually called anti nutrients) and are still able to be consumed safely, for example, cassava root is quite toxic, but proper processing converts it into a nutritious and widely consumed food (DoAC, 2012). Thus, there is some tolerable chemical risk with all foods and hence a comparative method for assessing safety needs to be adopted (Novak, W. K.; Haslberger, 2000: 473–483; OECD, 2000).

The Food Safety and Standards Act, 2006

In India, the Food Safety and Standards Act, 2006 established the FSSAI as the statutory body for "laying down science based standards for articles of food and regulating manufacturing, processing, distribution, sale and import of food so as to ensure safe and wholesome food for human consumption" (FSSAI, 2011). So, FSSAI is the agency responsible for administering or determining the substantial equivalence of GM crop. In India, Brinjal is the common man's vegetable. Typically, farmers indiscriminately apply a cocktail of insecticides on brinjal, including insecticides such as monocrotophos that are restricted or banned for use on vegetable crops. The increasing amount of insecticide residues in vegetables has been a major concern to consumers who currently have no choice except to buy brinjal of inferior quality, with high insecticide residues, and infested with larvae of FSB (Choudhary and Gaur, 2009).

Various studies based on the concept of substantial equivalence point that cooked Bt brinjal is safe for human consumption (MRC, 2005), safe and non-toxic on rats (INTOX, 2003), and non-irritant to rabbit skin (INTOX, 2004).The alkaloid profile from power samples of fruit and roots of Bt and non Bt Brinjal were the same with no significant variation in their relative abundances (IICT, 2006). There were no significant difference on health and growth found between the rabbit and goat group who fed with Bt Brinjal and non Bt Brinjal fruit (Advinus Theraputic, 2006).

Table 1. Substantial equivalence: composition of fruit tissue of bt and non-bt brinjal entries*

	Moisture percentage	Protein percentage	Oil percentage	Ash percentage	Carbohydrate percentage	K cal/100g
Bt brinjal	88.4	2.2	0.2	0.9	8.3	43.6
Non Bt brinjal	88.4	2.0	0.3	0.8	8.6	44.4

Note: * All values are expressed on fresh weight basis and mean of four replication.
Source: Study conducted at Kallakal, (MRC 2004)

On comparison of different parameters like moisture, protein, oil, ash, carbohydrate, and calorie value of BT and non Bt brinjal, it was found that both types of food have same properties (Table 1).

Thus, studies have confirmed that first Indian GM food Bt brinjal completely fulfills international norms of substantial equivalence and is as safe as a natural brinjal. Bt and non-Bt brinjals show similar results and no significant differences were noted in the leaves, stems and root tissues either. Studies on food and feed safety, including toxicity and allergenicity tests, have been conducted on rats, rabbits, and goats, and findings have confirmed that Bt brinjal is as safe as its non-Bt counterpart.

Further studies about Bt cotton also show that it is environmentally sustainable. In India, conventional cotton consumed more pesticide than any other crop. In 1998, total pesticide market of India was US$770 million and approximately 30% of the total pesticide was used in cotton production. In 2006, total pesticide market of India increased to US$900 million but cotton insecticide market decrease from 30 to 18%. And a significant decrease of US$ 69 million has been observed particularly in cotton pesticide (chemical Industry 2007).This decrease in use of pesticide due to Bt cotton leads to an overall 20% decrease in consumption of pesticide in India. And a sharp increase also observed in yield of cotton from 2001 to 2009 (Table 2). Further, EC-II concluded development and safety assessment of Bt brinjal event EC-1 is in accordance with the prevailing bio-safety guidelines and is fully compliant with the conditions stipulated by GEAC, while according approval for large-scale trials. The EC-II also noted that the data requirements for safety assessment of GM crops in India are comparable to the internationally accepted norms in different countries and by international agencies and therefore no additional studies need to be prescribed for safety assessment (EC-II, 2009).

Indian Regulatory System: The Biotechnology Regulatory Authority of India

Table 2. Consumption area of GM crops (Bt cotton) and use of pesticides in India, 2001–2009

Years	Total cotton area in hectare	Bt cotton area in hectare	Yield (kg/acre)	Total consumption of pesticides(m.t.)
2001–02	8730000	50000	125	47020
2002–03	7670000	100000	122	48350
2003–04	7630000	500000	161	41020
2004–05	8920000	1300000	190	40672
2005–06	9158000	3800000	191	39773
2006–07	9400000	6200000	210	37959
2007–08	9617000	7605000	224	NA
2008–09	9925000	8381000	NA	NA

Sources: 1: ICAR (2009) frontline demonstration of cotton (2002–09).
2: Central Insecticide Board and Registration Committee, Ministry of Agriculture (2008).
3: James (2008).

In 1989 India established regulatory system for the import, testing and commercialization of genetically engineered material (Scoones, 2003). It is based on the bio-safety guidelines first developed and implemented in some of the leading OECD countries. In certain countries, the regulatory authority for GM foods is the same authority that is responsible for administering food safety law(s). This recognizes that the safety assessment of GM foods is part of, and not separate from, programs that address the broader context of ensuring the safety of the foods that the public consumes. But in case of India, we have two different bodies (FSSAI and BRAI) to accomplish the task of administering food safety and regulating GM crops. In 2007 the Government of India approved the National Biotechnology Development Strategy which promoted the establishment of a National Biotechnology Regulatory Authority that would act as an "independent, autonomous and professionally led body to provide a single window mechanism for bio-safety clearance of genetically modified products and processes." Department of Biotechnology (DBT) has been given the responsibility to establish and operationalize this new regulatory authority, the Biotechnology Regulatory Authority of India (BRAI). Biotechnology regulation will continue under the existing regulatory framework until the BRAI is fully functional.

Bt brinjal has undergone rigorous scientific evaluation to assess its food safety, environmental safety, human, and animal health safety and biodiversity. It has successfully passed laboratory stages, green house trial stages, confined trial stages, multi-location research trial, large-stage field trial, seed production stage. The Ministry of Environment and Forests (MoEF) has a statutory body called the Genetic Engineering Approval Committee (GEAC) which has recommended the environmental release of Bt Brinjal in India based on the recommendations of the Review Committee on Genetic Manipulation (RCGM), a statutory body and two expert committees constituted by the GEAC between 2006 and 2009 (Abhishek and Dutta, 2011). But the last stage of commercial release is still pending in India (James, 2008).

Conclusions

Farmers and consumers have benefited from advances in agricultural technology for centuries, but the most recent

Table 3. Summary of the protocol followed for the regulatory approval of Bt brinjal

Time	Bt brinjal approval
2000–02 Transformation, backcrossing, event selection, green house experiment, and contained field trials	Applicant (Mahyco) (send his application to Institutional Bio-safety Committee IBSC)
2002–04 Green house experiment, confined field trials and initial bio-safety and environmental studies.	Review committee of genetic manipulation (RCGM) (Approval for the green house experiments contained field trials. Generation of data on field stability and expression confirmation of gene/event of Bt brinjal).
MLRTs2004–05 and 2005–06 Mahyco trials and ICAR trials.	Review committee of genetic manipulation (RCGM) (Approval for the conduct multi-location research trial of 8 Bt brinjal hybrid
Monitoring and Evaluation Committee (MEC) (Monitoring of multi-location research trials and large scale field trials data and recommendation of RCGM)	
LSTs 2007–08 and 2008–09 ICAR first year LSTs by IIVR.	Genetic Engineering Approval Committee (GEAC) (Approval of 7 Bt brinjal hybrid for large-scale field trial to the Indian Institute of Vegetable Research (IIVR)Indian Council of Agricultural Research (ICAR)
2008–09Experimental seed production by Mahyco	Genetic Engineering Approval Committee (GEAC) (Approval for the experimental seed production of 7 Bt brinjal hybrid on 0.1 acre per hybrid
In year 2011 Bt brinjal was under consideration for commercial release	

Source: Compiled by James (2008); Choudhary and Gaur (2009).

innovation transgenic modification of crops has generated enormous controversy. And the fact is that foods derived from GM crops have undergone more testing than any other food in history. Before entering the marketplace, they are assessed using guidelines issued by several international scientific agencies such as the WHO, FAO, and OECD. Before any GM food can enter the market, it has to be exhaustively tested by the developer and independently evaluated for safety by scientists or experts. The safety assessment is based on a comparison of the modified food to its traditional (non-GM) counterpart in terms of molecular, compositional, toxicological, and nutritional data. Even after these and other questions about the GM food are answered, there are still more steps in the approval process before the GM food can be commercialized. In fact, GM foods are the most studied food products ever produced.

Researchers routinely endorse the contributions that biotechnology, including transgenic crops, might make to agricultural productivity growth and poverty reduction in the years ahead. Yet most of India's actual policies toward GM crops are far from promotional. Precautionary bio-safety policies are keeping these crops out of the hands of farmers. Critics of GM crops have been able to work within India's open and democratic political system to secure a far more cautious approach. By filing law suits against RCGM for authorizing Bt cotton field trials in 1998, and by sponsoring physical attacks against those field trials, anti-GM activist groups in India have transformed the bio-safety approval process into a highly politicized and at times paralyzed policy struggle. RCGM and GEAC have moved slowly on bio-safety approvals, fearing criticism from anti-GM NGOs. Impact of all this has been precautionary approach towards GM crops. On the other hand, our neighbor China has embraced a more permissive bio-safety policy toward GM crops. One reason has been its greater insulation from the international influences that seem elsewhere to be promoting caution.

Policy Suggestions

Consumers in developing countries like India have more serious food safety risks to worry about than the still hypothetical consumer risks associated with GM food. Rich and well-fed countries can afford to invest policy resources to protect against this hypothetical risk; in the developing world priority must go to more clearly demonstrated safety risks such as unsanitary food processing or unrefrigerated storage, and also to more fundamental concerns such as the simple availability or affordability of food. As policy toward this new technology evolves in the years ahead, one may hope that the views of the real stakeholders, consumers, farmers, and rural communities will be heard as loudly as the various and conflicting opinions of GM crop advocates or opponents from the industrial world.

References

Abhishek,N. and Dutta, S. 2011. 'Bt Brinjal- Biological Terrorism or Agro-Biotechnology Invention (pdf)',Series of Crop Specific Biology Documents, Biology of Brinjal. Retrieved February 21, 2013, from http:// dbtbiosafety.nic.in/guidelines/ brinjal.pdf.

Advinus Theraputic. 2006. 'Sub chronic oral (90 days) toxicity study for transgenic Bt brinjal (*Solanum melangena L.*) containing Cry 1 A (c) gene in male rabbit' *www.envfor.nic.in/ divisions/csurv/geac/macho.doc*

Advinus Theraputic.'Sub chronic oral (90 days) toxicity study for transgenic Bt brinjal *(Solanum melangena L.) containing Cry 1 A (c) gene in* goat' *,ww.envfor.nic.in/divisions/csurv/ geac/macho.doc:*2006

Bandopadhyay, R., Sinha, P. and Chaudhary, B. 2012. 'Is Bt.brinjal ready for future crop?-A critical study', Indian Journal of Biotechnology, 11, 238-240

Brookes and Barfoot, 2012, Forthcoming

Central Insecticide Board and Registration committee, 2007. Ministry of Agriculture. India.

Chemical Industry 2007 'Cotton Market Comparison from 1996 to 2006', Mumbai. India.

Choudhary, B. and Gaur, K. 2009. 'The Development and Regulation of Bt Brinjal in India' (*Eggplant/Aubergine*). ISAAA Brief No. 38-2009.

Christoffoleti, P.J., Carvalho, S.J.P.D., Lopez-Ovejero, R.F., Nicolai, M., Hidalgoand, D.E.and Silva, J.E. 2007. 'Conservation of natural resources in Brazilian agriculture: implications on weed biology and management' *Crop Prot*, 26,383–389

Clewis S.B., Wilcut J.W. 2007. 'Economic assessment of weed management in strip- and conventional-tillage non-transgenic and transgenic cotton', *Weed Technology,* 21(1), 45-52.

Cohen, J.I., Quemada, H. and Frederick, R. 2003. 'Food Safety in Food Security and Food Trade, Food Safety and GM Crops: Implications For Developing – Country Research. International Food Policy Research Institute, Washington, D.C., U.S.A.

Department of Agriculture and Co-operation 'Cultivation of genetically modified food crops – prospects and effects', Fifteenth Lok Sabha, Thirty seventh report, Ministry of Agriculture, India:2012

ICAR 'Frontline demonstration of cotton 2002-09', Indian Council of Agricultural Research, New Delhi, India: 2009

IICT 'Chemical fingerprinting of Bt and Non-Bt Brinjal (alkaloids)', Indian Institute of Chemical Technology. http://*www.envfor.nic.in/divisions/csurv/geac/macho.doc:*2010

INTOX 'Acute Oral Toxicity Study of Transgenic eggplant-Brinjal (*Solanum Melongena L.*) in rat. Institute for toxicological studies. Pune, http:*//www.envfor.nic.in/divisions/csurv/geac/macho.doc:* 2003

INTOX 'Primary Skin Irritation Test of Transgenic egg plant-Brinjal *(Solennum Melongena L.* in Rabbit', Institute for toxicological studies. Pune. India. *www.envfor.nic.in/divisions/csurv/geac/macho.doc.* 2004.

James, C. 2008. 'Global Status of Commercialized Biotech/GM Crops: 2008', *ISAAA Brief No.39*. ISAAA: Ithaca, NY.

James, C. 2008. 'Global Status of Commercialized Biotech/GM Crops: 2008', *ISAAA Brief No.39*. ISAAA: Ithaca, NY.

MRC 'Substantial Equivalence Compositional Analysis Studies', 2004. Mahyco Research and Life Science Centre, Kallakal, Andhra Pradesh, http:*//www.envfor.nic.in/divisions/csurv/geac/macho.doc.*

MRC 'Food Cooking and Protein Estimation in Cooked Fruits' 2005. Mahyco Research Centre, Dawalwadi, Maharashtra, http:*//www.envfor.nic.in/divisions/csurv/geac/macho.doc.*

Novak, W. K., Haslberger, A. G. 2000 'Substantial equivalence and inherent plant toxins in genetically modified novel crops', *Crop and Chemical Toxicology,* 38 (6), 473-483.

OECD 'Report of the task force for the safety of novel foods and feeds', Organization for economic and Co-operative Development. C (2000)86/ADD1. Paris: 2000

Paarl berg, R. L. 'Governing the GM Crop Revolution Policy Choices for Developing Countries', International Food Policy Research Institute, 2033 K Street, N.W:2000

EC-II 'Report of the Expert Committee on Bt Brinjal Event EE-1', developed by M/s Maharashtra Hybrid Seeds Company Ltd. (Mahyco), Mumbai University of Agricultural Sciences (UAS), Dharwad and Tamil Nadu Agricultural University (TNAU), Coimbatore: 2009

Scoones, I. 'Regulatory Maneuvers: The Bt cotton controversy in India', Brighton. IDS. VIII, 44 S. Working Paper 197, ISBN 1 85864 511 5:2003

Food Safety and Standard Authority of India. Retrieved from, http:// www.fssai.gov.in

> *"If you keep your eye on the profit, you're going to skimp on the product. But if you focus on making really great products, then the profits will follow."*
>
> ***—Steve Jobs***

Focus

Biotechnological Applications of Microbial Xylanases

DIGVIJAY VERMA, VIKASH KUMAR AND T. SATYANARAYANA

Xylan is the second most abundant polysaccharide after cellulose in the plant organic matter, and it is a linear backbone of β-1, 4-linked D-xylopyranose residues with acetyl, arabinosyl, glucuronosyl, mannosyl, and uronosyl groups in the side chains. The complete hydrolysis of this heteropolymer, thus, requires the synergistic action of several enzymes, among which xylanases play a key role. A wide variety of microorganisms produce xylanolytic enzymes and most of the commercially available xylanases are from mesophiles. Immense interest in xylanases is due to their multiple applications in pulping and bleaching processes, textile processing and food and feed industries, saccharification of lignocellulosic materials to produce bioethanol, and waste treatment. Thermophilic bacteria and fungi are very important sources of thermostable xylanases.

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Plant cell walls are made up of cellulose, hemicelluloses, pectin, and lignin. Hemicellulose component is an integral part of lignocellulosic materials, and constitutes ~20–35% of total plant biomass. Hemicelluloses are made up of a relatively limited number of sugar residues like D-xylose, D-mannose, D-glucose, D-galactose, 4-O-methyl-D-glucuronic acid, D-galacturonic acid, D-glucuronic acid, and to a lesser extent, L-fucose. Xylan is the main constituent of hemicelluloses, which is composed of β-1,4-linked xylosyl residues. The backbone of xylan is attached with different groups (mannosyl, arabinosyl, acetyl, glucuronosyl, and uronyl residues) that make it a heteropolysaccharide. These substituent groups make covalent and non-covalent interactions with lignin and cellulosic fibers for maintaining the integrity of plant cell wall. A group of xylanolytic enzymes are, therefore, required for the complete hydrolysis of xylan. Endoxylanases (EC 3.2.1.8) are the most critical xylanases that directly cleave β-1,4 linked glycosidic bonds of xylan backbone. This review focuses on microbial xylanases and their potential biotechnological applications.

Xylanolytic Enzymes

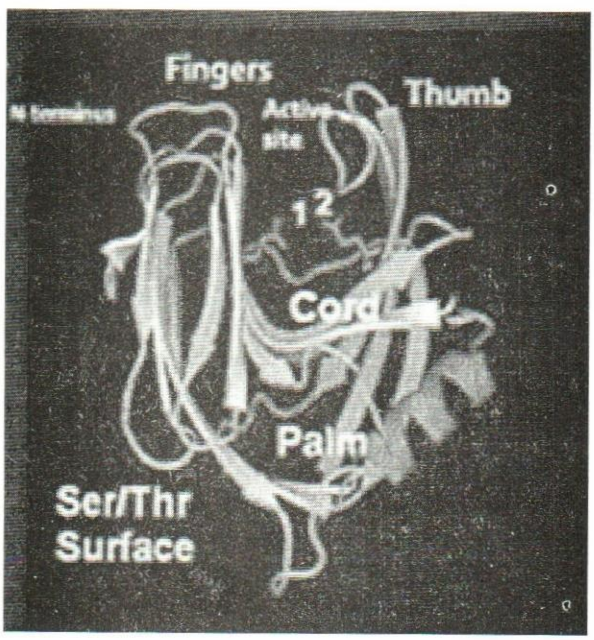
Xylanolytic enzymes represent a complex multi-enzyme system comprising β-1,4-xylanase, β-xylosidase, α-L-arabinofuranosidase, α-glucuro-nisidase, acetyl xylan esterase, and phenolic acid esterases. These enzymes act synergistically on xylan to release xylose and lower xylo-oligosaccharides from xylan and xylan containing lignocellulosic plant residues.

Classification of Xylanases

Due to emergence of several xylanases, a comprehensive classification system has been proposed based on amino acid sequence similarities of catalytic domain and hydrophobic cluster analysis. In the Carbohydrate Active enZYmes (CAZy) database (www.CAZy.org), xylanases are classified into nine different families (GH5, GH8, GH10, GH11, GH16, GH26, GH30, GH43, GH62). Families 16, 43, and 62 comprise two separate and distinct catalytic domains. This classification has been accepted widely. More stringent and true xylanases are included in GH5, 8, 10, 11, and 30. Among all xylanases, GH10 and GH11 xylanases are considered as true xylanases due to their high specificity towards substrates. GH11 xylanases are smallest xylanases having β-jelly-roll organization, while GH10 xylanase shows bowl shape structure (Figure 1). The xylanases of GH8 and GH10 are very close in their architecture and substrate specificity. The members of xylanolytic enzymes exist in monomeric, dimeric, tetrameric, hexameric and octameric forms, and therefore, their molecular weight may reach up to 495 kDa.

Microbial Source of Xylanases

A plethora of microorganisms have been reported to produce xylanase from bacteria as well as fungal sources. Microorganisms hydrolyse xylan not by the action of a xylanase alone, but by the combined action of more than one xylanase. Multiple forms of xylanases have been reported in several microorganisms such as *Bacillus subtilis*, *Thermotoga maritima* MSB8 and *Nocardiopsis dassonvillei*. Several xylanases have also been reported from the fungal sources. Fungal xylanases always produce a high titre of enzyme as compared to bacterial. *Trichoderma viride*, *T. reesei*, *Schizophillum commune*, *Aspergillus niger* and *Thermomyces lanuginosus* are well known examples of the fungi that produce xylanases (Satyanarayana et al., 1988). A very high titer of xylanase has been reported from *T. reesei* (960 Uml^{-1}), *T. viride* (188.1 Uml^{-1}) and *S. commune* (1244 Uml^{-1}). The enzyme preparation of *S. commune* also contains CMCase (65.3 UmL^{-1}) and FPase (5.0 Uml^{-1}) activities. Among yeasts, *Kloeckera, Candida* and *Pichia* produce xylanases. Majority of xylanases of fungal origin are optimally active below 50°C under acidic conditions. Fungal xylanases are, therefore, not considered as good candidates for paper and pulp industries.



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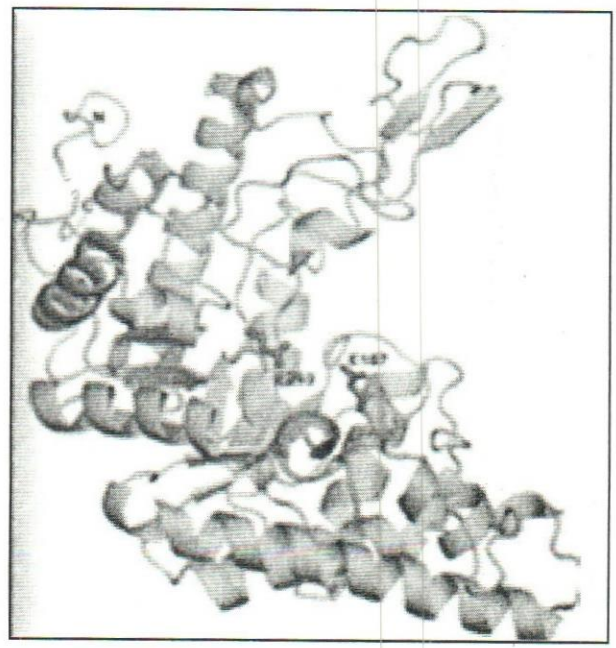

B

Figure 1. 3D structures of GH11 (β -jelly shape) (**A**), and GH10 (bowl shape) xylanases (**B**)

Thermoalkalistable Xylanases

Approximately 90% of the industrial enzymes are produced by submerged fermentation (SmF) technique as this provides several advantages over the other fermentation mode solid state fermentation (SSF). The production of high titers of any enzyme by optimizing the growth parameters is of prime importance in industrial enzymology. The optimization of various nutritional and physical parameters to which an organism is exposed is well known to increase production level significantly. The xylanase synthesis in *B. halodurans* TSEV1 is inducible. Most of the known microbial xylanases are optimally produced at pH 5.5-9.5. A high titre of xylanase has been reported by various *Geobacillus* and *Bacillus* spp. under alkaline conditions too (Satyanarayana et al., 2005, 2012). It is an established fact that thermophilic microbes produce high enzyme titres at their optimum growth temperature as seen in *B. halodurans* TSEV1. Carbon sources in the medium play a profound role in the enzyme production behavior of the microbes. Hemicellulosic substrates such as corn cobs, corn stover, wheat straw, rice bran, rice straw, and sugarcane bagasse have been used for xylanase production. In case of different *Bacillus* and *Geobacillus* strains, wheat bran supported a high enzyme titre, followed by corn-stover. The induction of similar levels of xylanase has been reported in the presence of crude fibrous biomaterials containing xylan. Nitrogen is crucial for proper growth of microorganisms as well as enzyme production. Tryptone, yeast extract, asparagines, casein, beef extract and peptone have extensively been used for the production of xylanase in cost effective way. Agitation and aeration are generally known to meet the oxygen demand, uniform mixing and distribution of nutrients during fermentation process. Increased agitation helps in overcoming resistance to the transfer of oxygen into the medium and then into the microbial cells. Under stationary conditions, lower enzyme titres are attained due to low dissolved oxygen in the medium. Agitation of 250 rpm supported higher xylanase production in *B. pumilus*, *Bacillus halodurans*, *Bacillus coagulans* and *Geobacillus thermoleovorans*. Inoculum concentration and its physiological status are well known to affect the fermentation profile of an organism. Inoculum levels between 1.0 and 5.0% have been reported to support optimal xylanase production. Generally at higher inoculum levels, enzyme production declines due to competition for nutrients among the bacterial populations. In a number of bacterial isolates, 12-18 h old cultures supported high xylanase titres. Xylanase from various sources are summarized in Table 1. The conventional method for optimizing enzyme production by "one-variable-at-a-time" approach involves varying a single independent variable, while maintaining the others at a constant level. The one-dimensional approach does not consider interactions between variables. To overcome this limitation, an alternative and a more efficient statistical approach, response surface methodology (RSM) has been developed. The use of statistical experimental designs in biotechnology is a widely accepted technique, and there are a few reports of optimization of enzyme production in submerged fermentation using statistical approach. Plackett-Burman (PB) design is a well-known technique for screening of significant parameters involved in fermentation and has been used successfully employed. By using statistical approach, 5.4-fold enhancement in xylanase production was reported in case of *Aspergillus niger* DFR-5; this could be attributed to optimum level of nutrients and favorable conditions that support good growth which results in high enzyme production. In the laboratory fermenter, a peak in xylanase production has been achieved in 36 h, which is 48 h in shake flasks; this reduction in fermentation time in the fermenter has been attributed to improved process conditions like aeration and mixing.

Table 1. Xylanase producing microorganisms

Microorganisms	pH (Opt.)	Temp (Opt.) °C	Production (Uml^{-1})
Bacillus amyloliquefaciens	7.0	80	10.5
Bacillus circulans b AB16	6.0	80	50
Bacillus circulans D1	5.0	60	9.18
Bacillus halodurans S7	9.5	70-75	0.4
Bacillus halodurans TSEV1	9.0	80	58
Bacillus halodurans TSPV1	11.0	90	16
Bacillus licheniforms A99	6.0-6.75	60	0.72
Bacillus pumilus B20	6.0-6.75	60	313.3
Bacillus pumilus MK001	7.5	60	4000
Bacillus pumilus SV-85S	6.0	50	2995
Bacillus sp. BP-/23	5.5	50	1.12
*Bacillus sp.*GRE7	7.0	70	5.0
Bacillus sp. SPS-0	6.0	70	–
Bacillus stearothermophilus	7.0	60	184
Bacillus subtilis ASH	7.0	60	410
Clostridium absonum CFR-7028.5	75	420	
*Bacillus halodurans*TSEV1	9.0	80	40
Geobacillus thermodenitrificans	7.0	70	8.5
Geobacillus thermoleovorans	8.5	80	25.8
Chaetomium thermophilum	6.0	70	–
Termitomyces sp.	5.6	65	–
Candida guilliermondii NRRL-17257	7.5	50-60	–

Production by SSF

SSF offers advantages over submerged fermentation (SmF) due to its similarity to the natural way of life for many microorganisms and its other advantages. Sugarcane bagasse, wheat bran, rice bran, and corn cobs are the agricultural residues that are abundant in several countries, and therefore, are used as raw materials for developing SSF processes.

The major factors that affect microbial growth and production of enzymes in SSF include selection of suitable microorganism and substrate, pretreatment of the substrate, particle size (inter particle space and surface area) of the substrate, water content and water activity (a_w), relative humidity, type and size of inoculum, and pH and temperature of the fermenting medium, removal of metabolic heat, period of cultivation, maintenance of uniformity in the environment of SSF, and the gaseous atmosphere (oxygen consumption rate and carbon dioxide evolution rate). There are many reports on the optimization of cultural variables for maximizing xylanase production.

The overall processing cost mainly depends on price of the substrate; cheap substrates such as agro-industrial residues are often used as carbon source in xylanase production. For enzyme production, various agro-wastes (the soya oil cake, wheat bran, corncob, rice straw, sugarcane and beet, banana waste, potato, tea, coccus, apple and citrus fruits, wheat straw, and corn stover) have been used as cheap carbon sources and enzyme productions were brought down.

Cloning and Expression of Xylanase Gene

Although several xylanases have been reported from plethora of microorganisms, the majority of xylanases do not tolerate the extreme conditions prevailing in the industrial processes. Furthermore, traditional fermentation technologies do not attain adequate titers of the enzymes with wild microbial strains. To overcome this problem and to generate an ideal xylanase for application in industrial processes, gene manipulation strategies are employed. The DNA manipulations have not only allowed improvement in production, but also permit alterations at gene level for modifying the properties of the enzymes and their expression in altered physiological conditions. Recombinant DNA technology (RDT) has successfully

Table 2. Cloning and expression of xylanase genes

Microorganism	Host	Vector	pH (Opt.)	Temp (Opt.)	Gene size	MW (kDa)
Bacillus subtilis strain R5	*E. coli* BL21(DE3)	PTZ57R/T	6.0	40-50	642	23.35
Bacillus strain 168	*B. subtilis*	pUB110				
Thermobifida fusca NTU22	*Pichia pastoris*	pPICZαA				
Streptomyces olivaceoviridis A1	*E.coli, P. pastoris*	—				
Streptomyces sp. SP27	*E. coli* BL21(DE3)	—				
Glaciecola mesophila KMM 241	*E. coli* BL21(DE3)	pET22b	7	30	1272	77
Geobacillus thermoleovorans	*E. coli* BL21(DE3)	pET28a	8.5	80	1224	
Bacillus halodurans TSEV1	*E. coli* BL21(DE3)	pET28a	9.0	80		
Geobacillus sp.71	*E. coli* BL21(DE3)	pET22b	8.0	75	1224	47
G. thermodenitrificans JK1	*E. coli* BL21(DE3)	pET28c	6.0	70	1224	45
Bacillus subtilis	*E. coli* JM109	pUC18	6.0	50	642	
Paenibacillus sp. DG22	*E. coli* BL21(DE3)	pQE60	6.0	60	630	20
Bacillus sp.	*P. pastoris* GS115	pHBM905A				
Geobacillus stearothermophilus	*E. coli* BL21(DE3)	pET28a	7.0	40	1047	45
Bacillus licheniformis MS5-14	*E. coli* BL21(DE3)	pET29b	5-7	40-50	639	23
*Bacillus halodurans*S7	*E. coli* BL21(DE3)	pET28b	9-10	75	1188	42.6
Bacillus subtilis AMX4	*E. coli* BL21(DE3)	pUC19	6-7	55-60	639	23

been used for cloning and expression of xylanases. Xylanase genes from *Bacillus licheniformis*, *Geobacillus thermoleovorans*, *Bacillus halodurans* TSEV1, and *G. thermodenitrificans* TSAA1 have been cloned and expressed.

The concept of cloning and expressing xylanase genes from extremophiles in mesophilic microorganisms like *E. coli*, *Bacillus megaterium*, *B. subtilis*, and *Pichia pastoris* is interesting because this offers rational strategy for not only enhancing the production of xylanase but also energy conservation. Xylanase is a widely reported enzyme from gram positive as well as gram negative microorganisms, but a majority of the potent xylanases has been reported from the genera *Bacillus* and *Geobacillus*. Cloning and expression of genes from gram positive to gram negative microorganisms is a routine strategy in gene manipulation (Table 2). In the very early reports, heterologous cloning has been attempted to improve the production of xylanases from the bacteria such as *Fibrobacter succinogenes*135, *Bacillus polymyxa* and *Bacillus circulans*. Besides *E. coli* and *Bacillus*, attempts have also been made in expressing xylanase genes from various microorganisms in the potent expression host *Pichia pastoris*. When the xylanase encoding gene of *Thermomonospora fusca* was cloned in *Pichia pastoris,* a three-fold higher expression was achieved with AOXI promoter. The recombinant xylanase is optimally active at pH 6.0 and 60°C. The endo-acting xylanase liberates xylobiose as the main hydrolysis product along with other lower xylooligosaccharides (X3, X4, X5, and X6).

Metagenomic Source of Thermostable Xylanase

Many available enzymes from cultured microorganisms do not withstand the industrial reaction conditions, and therefore, metagenomic approaches have received a great deal of attention in the last decade. Genes from the uncultured extremophiles could be valuable source of novel extremozymes. A range of extremozymes like esterases, xylanases and polyphenol oxidases have been obtained from cow rumen as well as deep-sea environments by metagenomic approaches. The xylanases obtained by metagenomic approaches have been shown to be optimally active above 50°C (Table 3). The recombinant DNA technology is a potent technique that empowers the researchers to achieve the production of thermostable xylanases in mesophiles, and also facilitate their over expression by coupling structural genes with the well-known strong promoters.

Table 3. Xylanases obtained using metagenomic approaches

Source of xylanase	Optimum pH	Optimum temp. (°C)	Family
Hot pool	6.0	100	GH10
Insect gut	5–6	–	GH11/GH8
Waste water	7.0	20	GH10
Straw stook	7.5	40	GH10
Horse/termite gut	–	–	GH10
Cow manure	7.0	40	GH10
Tundra soil	6.5	35	GH10
Compost soil	5.5–7.0	50–55	–
Hot spring	7.0	50	GH11
Compost soil	9.0	80	GH11

Biotechnological Applications of Thermostable Xylanases

Lignocellulose Bioconversions

Saccharification of lignocellulosic materials using xylanases liberates sugars, which could be employed for producing products like xylooligosaccharides, xylitol, ethanol, organic acids, SCP and hydrogen (Figure 2). Xylooligosaccarides have been shown to be useful as prebiotics and their product xylitol in preventing dental caries. Wheat bran was efficiently saccharified by the endoxylanase of *B. halodurans* TSEV1 as compared to the other agro-residues and industrial pulp. This could be attributed to the complexity of the structure of lignocellulosic substrates. The end products of xylan hydrolysis (xylobiose, xylotriose, xylotetraose, xylopentaose and other higher xylooligosaccharides) confirmed that the xylanase produced by *B. halodurans* TSEV1 is an endoxylanase and its mode of action is similar to that of family GH10 xylanases.

Textile Industry

Xylanases have been used in the pretreatment of low quality jute fibers, flex, hemp and ramie. Such fibers are rich in hemicellulosic content, and therefore, cause difficulties in proper spinning in the mill. The pretreatment of fibers with thermostable xylanases removes xylan without compromising the strength, and thereby, softening them to a significant level.

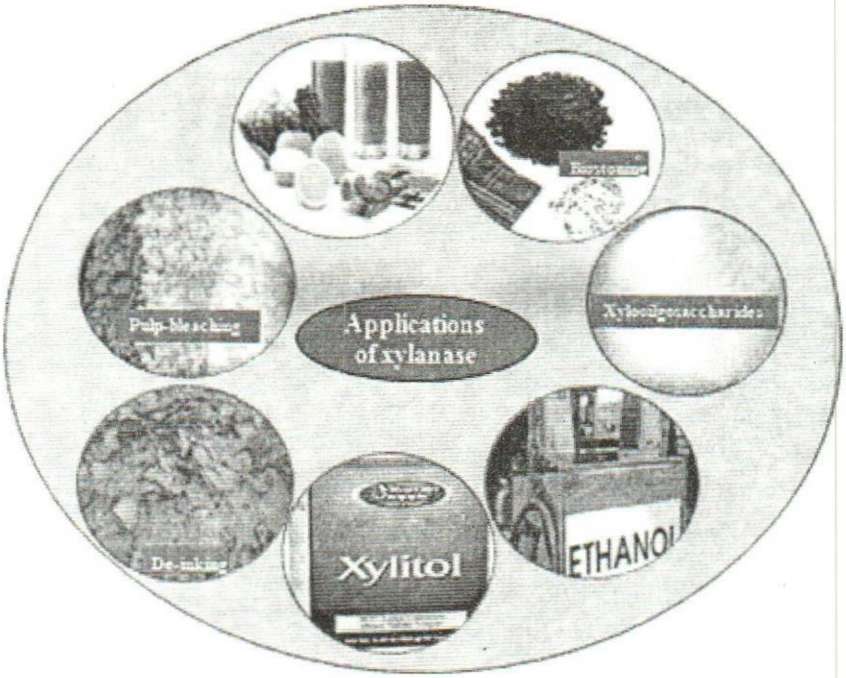

Figure 2. Applications of xylanases

Food Industry

There are several applications of xylanases in the food industry. The processing of cereals and millets with xylanases results in the reduction in processing time during fermentation of these food materials. The treatment of wheat flour with xylanases reduces the dough water absorption as well as significantly changes the texture of loaf. Xylanases are also used in clarifying fruit juices and wines, improving nutritional properties of silage and to achieve the desirable texture and loaf volume of bread in baking industry. The food industry does not require thermostable and alkalistable xylanases. The production of lower xylooligosaccharides (XOs) from agro-residues using xylanases significantly enhanced by the application of xylanases. There are several reports on liberation of XOs from agro-residues. An alkalistable and thermostable xylanase from *G. thermoleovorans*, *Bacillus halodurans* and *Streptomyces thermocyaneoviolaceus* have been employed in generating XOs from birchwood xylan as well as wheat bran. The lower XOs find application as prebiotics. The xylanase for food/feed and baking industries should be thermostable, but alklistability is not an issue.

Paper and Pulp Industry

The application of xylanases in paper and pulp industry came to light when Vikarii and her coworkers from Finland reported their applicability in pulp bleaching in 1986. Xylanases act on β-1,4 liked xylosyl residues and facilitates the release of xylan and lignin (polyphenolic compounds responsible for brown colour of paper) to make paper white and bright. In addition, xylanases improve water retention and pulp fibrillation. Xylanases have been shown to reduce the chlorine consumption up to 25–30%, making the process more eco-friendly. The industry demands for alkalistable and thermostable xylanases due to hot and alkaline nature of the pulp. Several microorganisms are known to produce thermostable xylanases that are active in a wide range of pH. Using xylanases of *Bacillus* sp., kappa number of the pulp was reduced by 27.4–75.3%. Furthermore, the brightness of pulp was enhanced by 1.0–3.0%. A thermostable and neutral xylanase from *Dictyoglomus* was successfully employed for enhancing the brightness of pulp by two ISO units.

Conclusions

The microbial xylanases have received undue attention in the last few decades because of their multiple applications in pulp processing, food and feed industries, production of bioethanol and xylo-oligosaccharides, baking, and oil-fruit juice extraction. Xylanases are produced from various fungi, yeasts and bacteria in submerged as well as solid state fermentations. Both native and recombinant xylanases are being produced on a large scale by several companies.

Further Reading

Adhikari, S. and Satyanaryana, T. "Biotechnological applications of thermostable and alkalistable microbial xylanolytic enzymes". In: Lignocellulosic Biotechnology, Future prospects (Eds. R.C. Kuhad and Ajay Singh). pp. 273-306, 2007.

Archana, A. and Satyanarayana, T. "Xylanase production by thermophilic *Bacillus licheniformis* A99 in solid state fermentation". Enz. *Microb. Technol.* 21: 12-17. 1997.

Archana, A. and Satyanarayana, T. Bacterial thermostable cellulase free xylanases in environmental friendly paper pulp bleaching technology. In: Advances in Microbial Biotechnology (Prof. K.G. Mukerji Festschrift Volume), APH Publ. Co., New Delhi, ., pp.131-140, 1999.

Coughlan, M.P., and Hazlewood, G.P. "â-1, 4 D-xylan-degrading enzyme systems: biochemistry, molecular biology and applications". *Biotechnol. Appl. Biochem.* 17: 259-289.1993.

Gilbert, H.J. and Hazlewood, G.P. "Bacterial cellulases and xylanases". *J. Gen. Microbiol.* 139: 187-94. 1993.

Henrissat, B. and Bairoch, A. "New families in the classification of glycosyl hydrolases based on amino acid sequence similarities". *Biochem.* J. 293: 781-788. 1993.

Kulkarni, N. Shendye, A. and Rao, M. "Molecular and biotechnological aspects of xylanases". *FEMS Microbiol. Rev.* 23: 411-56. 1999.

McCarthy, A.A., Morris, D.D., Bergquist, P.L. and Baker, E.N. Structure of XynB, a highly thermostable â-1,4-xylanase from *Dictyoglomus thermophilum* Rt46B.1, at 1.8 A° resolution. *Acta Crystallogr.* 56: 1367-1375. 2000.

Paes, G., Berrin, J.G. and Beaugrand, J. "GH11 xylanases: Structure/function/properties relationships and applications". *Biotechnol.* Adv._30: 564-592. 2012.

Satyanarayana, T., Jain, S. and Johri, B.N. 1988. Cellulases and xylanases of thermophilic moulds. In: Perspectives in Mycology and Pathology (Ed. V.P. Agnihotri, A.K. Sarbhoy and D. Kumar), Malhotra Publishing House, New Delhi), pp. 24-60.

Satyanarayana, T., Sharma, D., Rao, J.L.U.M., Ezhilvannan, M., Bharadwaj, M. and Adhikari, S. 2005. Potential applications of enzymes produced by the species of *Bacillus* and *Geobacillus.* In: Microbial Diversity: Current Perspectives and Potential Applications (Ed. T. Satyanarayana and B.N. Johri), I.K. International, New Delhi, pp. 741-768.

Satyanarayana, T., Sharma, A., Mehta, D., Puri, A.K., Kumar, V., Nlsha, M. and Joshi, S. 2012. Blotchnological applications of biocatalysts from the firmicutes *Bacillus* and *Geobacillus* species. In: Microorganisms in Sustainable Agriculture and Biotechnology (Ed. T. Satyanarayana and B.N. Johri), Springer, , pp. 343-379.

Subramaniyan, S. and Prema, P. "Biotechnology of microbial xylanases: molecular Biology and applications". *Crit. Rev. Biotechnol.* 22: 33-64. 2002.

Sunna, A., Moracci, M., Rossi, M. and Antranikian, G. "Glycosyl hydrolases from hyperthermophiles". *Extremophiles* 1: 2-13. 1997.

Verma, D. and Satyanarayana, T. "Molecular approaches for ameliorating microbial xylanases". *Biores. Technol.* 117: 360-367. 2012.

Vieira, D.S. and Degreve, L. "An insight into the thermostability of a pair of xylanases: the role of hydrogen bonds". *Mol. Phys.* 107: 59-69. 2009.

Viikari, L., Ranua, M., Kantelinen, A., Sundquist, J. and Linko, M. Bleaching with enzymes. Proc. 3rd Int. Conf. Biotechnol. Pulp and Paper Industry, Stockholm, pp. 67-69. 1986.

Voget, S., Leggewie, C., Uesbeck, A., Raasch, C., Jaeger, K.E. and Streit, W.R. Prospecting for novel biocatalysts in a soil metagenome. *Appl. Env. Microbiol.* 69: 6235-6242. 2003.

Kumar, V., Verma, D., Archana, A. and Satyanarayana, T. 2013. Thermostable bacterial xylanases. In: Thermophilic Microorganisms in Environmental and Industrial Biotechnology (Ed. T. Satyanarayana, T., J. Littlechild and Y. Kawarabayasi), Springer [In Press].

"I really do believe it is feasible to slow down the aging process, ... We call that a bridge to a bridge to a bridge -- to the full flowering of the biotechnology revolution."

—Ray Kurzweil

GM Crop Adoption and Marketing in India–An Empirical Survey

V.K. KAUL, ARADHNA AGGARWAL AND BHAVNEET KAUR

GM cotton has been cultivated across various countries of the world. Being a technology innovation, it involved a tremendous effort on the part of marketers/technology promotes to get it adopted by the targeted customers. The study is based on primary survey conducted in northern India. Personal factors which came out to be significantly related to adoption wereage and economic status of the farmer. The study also pinpoints toward the significance of word-of-mouth communication which comes out as the most effective way for spreading awareness and initiating trial. Private seed shops turned out to be the significant sources for seed procurement.

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Sustainability has been a growing concern amongst the developing and developed nations alike. Sustainability stands for the endurance of biological systems so that their present as well as future productivity is maintained. Sustainability creates conditions under which humans and nature coexist in productive harmony that permit the fulfillment of social, economic and other requirements of present and future generations. As our economy has been essentially a bio-based one, the introduction of new technologies to agriculture seems to be a rational path to attain sustainability. One of such technologies which promises/claims its way to sustainability is agro biotechnology. It is the application of biotechnology in the arena of agriculture so as to create renewable resources. GM crops are the products of agro biotechnology.GM crop technologyhas become one of the significant and widely available options to exploit and improve the agronomic traits of the crops though critics regard new technologies in agriculture implicitly as a threat to intergenerational equity and biodiversity (Aerni, 2010, p. 158–172). In addition to these, there are concerns related to the health, safety, and the religious ethics of the consumers. Despite all these concerns, commercial adoption by farmers of transgenic crops/GM crops has been one of the most rapid cases of technology diffusion in the history of agriculture (Borlaug, 2000, p. 2487–2490).

Objectives and significance

This article attempts to look into the reasons for the adoption of GM crops in Indian context. India has more than 10 years of experience with GM crops. But the only approved transgenic crop for commercial cultivation in the country is Bt cotton.This study looks at GM cotton (Bt cotton in Indian context) and explores the fact that how the individual farmer specific factors leading to the adoption of the technology was built into the marketing strategy used by its promoters.

Study contributes to the marketing literature by looking at the marketing strategy of the firm from the customer's perspective. The study uses responses of the customers to draw a picture of marketing strategy used by the firm. It looks at various marketing strategy elements as perceived by the customers instead of as formulated by the promoters of the technology. Specifically,it uses GM cotton as a building block to dwell into details and move from specific strategies to general framework for marketing of innovations.

Understanding the process of adoption of GM crops is of interest to policymakers, scientists, and agricultural stakeholdersbecause growing GM crops is considered as a technological change that can have an impact on several economic variables at both farm and aggregate level.

The article is divided into five sections—the first one lays down the objectives and contribution. Introduction to GM crops along with their benefits and concerns are detailed in the second section.This section also presents the review of the literature.The third section details out the research methodology involved.The fourth section dives into the various marketing, performance and farmer-specific factors affecting adoption. The fifth section gives conclusions and recommendations.

Background

Introduction to GM crops

GM technology involves the precise transfer of DNA with advantageous traits from one organism to another(Durham et al., 2011, p. 61–70). GM/transgenic cropscontain a gene or genes which have been artificially inserted through genetic engineering techniques instead of the plant acquiring them through pollination. The inserted gene sequence may come from another unrelated plant, or from a completely different species. Plants containing transgenes (other than naturally occurring original genes) are often called genetically modified or GM crops. GM crops carry the gene introduced in them to express desired beneficial, new, stable or inherited traits. These traits are generally agronomic in nature though they are expected to be consumer oriented in future too.

At present, several transgenic cotton (GM cotton) varieties are commercialized throughout the world. These are:

1. Bt or insect resistant (IR): It is also called Ingard cotton. It contains a gene from the soil bacteria Bacillus thuringiensis (Bt), which allows the plant to produce the Bt protein which kills cotton's major pest, heliothis or the cotton bollworm, when it eats the leaves. Bollgard II differs from Bt cotton in that it contains two, rather than one, genes from the soil bacteria Bacillus thuringiensis (Bt). The genes produce proteins in the leaves of the cotton plant and when cotton's major caterpillar pest eats the plant, it dies.
2. Herbicide Tolerant or Herbicide Resistant (HT or HR): It is called roundup ready cotton. The roundup ready characteristic makes the cotton plant resistant to the herbicide glyphosate. Herbicide tolerant crops are not harmed by the herbicides applied to the weeds around them, providing growers with greater flexibility in weed control options.
3. Stacked Gene cotton (SG): It is also called roundup ready Bt cotton. Roundup ready/Bt cotton was achieved through conventional breeding of the two GM varieties. It combines the traits of insect resistance with herbicide resistance.

Out of these only insect resistant Bt-1 and Bt-II are cultivated in India.

Benefits of GM crops

1. Benefits for the final consumer: Enhancement of the nutritional value, taste and quality and durability of foods (Nielsen et al., 2005). Products with unique nutritional combinations can be made. New products like golden rice (in which gene synthesizing beta carotene is introduced and hence its ability to provide Vitamin A) can provide the solution to the problem of malnutrition and world starvation. Moreover due to the improvement in yields and reduction in costs, the prices of the final products can also be reduced.
2. For the producers: There is an improvement in the agronomic traits like tolerance to specific herbicide and resistance to pest and diseases (Qaim, 2005, p. 3064–3070). This has led to the improved productivity for the producers in the form of savings in labor cost, factor cost, and time. Development of crops that can be cultivated in extreme environmental conditions. And crops with improved traits like higher yield, stress tolerance and decrease of maturation time of the plants (so they can be harvested sooner and more often during the year) also added to their profitability.

Increase in the shelf life of the perishable products has also helps in reducing the post-harvest losses. This provides for the better marketing opportunities for the resource poor farmers of the developing countries who have lack of proper transportation facilities and insufficient refrigeration system.

3. Environment: Reduction in application of pesticides and insecticides. This helps in conserving the environment and controlling the pollution hazard. Moreover, through genetic engineering, environmental friendly bioherbicides and insecticides can also be produced.

Efficient weed control helps in maintaining a sustainable cropping system through no or low tillage practices which leads to less soil erosion.

It is expected that GM crops can reduce the need for deforestation through efficient crop management.

Concerns surrounding GM crops

There are a number of debates related to the prospect and risks associated with the GM crops. These concerns equally apply to the GM cotton as well.

1. Environmental concerns relate to potential impact of GM crops on the environment. There is an issue of unintended transfer of genes through cross-pollination resulting in loss of flora and fauna biodiversity and threatening the natural ecosystem. The foreign genes might escape into the other varieties and non-target species leading to gene pollution and contamination of genetic resources. GM crops can develop resistance in the pests and may hasten their co-evolution.

   Cultivation of herbicide tolerant GM varieties can boost herbicide application in the field leading to environmental pollution. Moreover, large-scale cultivation of transgenic crops might bring the risk of reduction in biodiversity though squeeze in varietal and crop diversity. Moreover, there are unknown effects of GM crops on birds, insects, and other non-target species that come in contact with it or consume it.

2. There is a risk of potential human health impacts, including allergens, transfer of antibiotic resistance markers, etc. (Singh, 2010, p. 73–75).

   A key ethical concern about GM foods is their potential to trigger allergies or disease in humans. Given that a gene could be extracted from an allergenic organism and placed into another one that typically does not cause allergies; a person may unknowingly be exposed to an allergen. In turn, this could lead to an allergic reaction.

   Moreover, there could be new allergies occurring from the mixing of genes from two organisms. Disease is a major health worry with regards to GM foods. Given that some of the crops modified are done so with DNA from a bacterium or virus, there is concern that a new disease may occur in humans who consume the GM food. With some GM crops having antibiotic-resistant marker genes, there is also the worry that these genes could be passed on to microbes that cause disease and health problems in humans. With widespread antibiotic resistance currently already occurring, any new resistance could prove disastrous.

   These concerns relate to the GM cottonseed oil also as it is consumed in large quantities throughout the world.

3. The fact that GM technology involves mixing of the genes among species gives rise to the ethical questions related to the violation of natural organism's intrinsic values. It is propounded that this modification causes stress for the processed organism. Further there are ethical and societal issues related to the consumption of animal genes in plants.

4. Issues related to intellectual property-patenting living organisms are linked to fears that biotechnology will transfer resources from the public sphere to private ownership via the enforcement of intellectual property rights. This may lead to the domination of world food production by a few companies, increased dependence on industrialized nations, foreign exploitation of natural resources and theft of genetic materials by patent process (biopiracy).

5. Economic concerns: These are related to the affordability of GM seeds by the farmers worldwide. Due to the fact that the technology is patented, the cost of seeds is high compared to non transgenic varieties. Moreover, recycling of GM seeds is not profitable and hence repeated investment is needed each year in order to procure them.

6. Political and legal concerns: The government is concerned with the workplace health safety and wellbeing of the workers associated with this industry (biosafety). Another issue is of biosecurity that is the

state's preparedness against misuse of biological pathogens and toxins and prevention of biocriminal and premeditated bioterroristic activities. These chemicals could be used to instill fear in and to terrorize the population (Sliva, 2005, p. 1–6).

GM crops represent a typical case of technology innovations where in spite of a number of concerns, controversies and issues, the technology was adopted widely across the globe. According to ISAAA Brief No. 43, 2011, there is a 94-fold increase from 1.7 million hectares in 1996 to 160 million hectares in 2011 under GM crops. This makes biotech crops the fastest adopted crop technology in recent history. With the world population projected to reach 8 billion by 2025, declining crop yield and a poor growth of agricultural output, this technology promises to raise productivity, ensure food security and protect environment. This technology acts at basic sustenance level and promises to revolutionize the agriculture. In spite of a number of concerns and controversies around the GM crop technology, there are 29 countries cultivating 13 GM crops.

Out of these GM cotton is one of the principal Biotech crop which is being cultivated in 13 countries. Even in India, Bt cotton (a variant of GM cotton) has completed its 10 years of launch in year 2011–12. In fact it is the only crop legally permitted for commercial cultivation in the country. It occupies 88.4% of total area under cotton production in the country in 2010–11. This study is designed to look at the ways as to how the marketing strategies inhibited or propelled the adoption of GM cotton.

Review of literature

Studies on GM crops which specifically focus upon the effect of individual determinants and marketing strategy on the adoption have been exploredfor the purpose of this article. Literature survey has been carried out with a view to find gaps and dig out the relevant information which could be further verified through primary data research. The studies are grouped as follows.

Effect of various individual specific characteristics on adoption of GM crops

Demographic characteristics of the operator farmer like age and education have affected the adoption of GE crop technologies positively and significantly, according to a study by (Fernandez-Cornejo and McBride, 2002). According to the authors, these factors may also reflect management quality in the sense that more educated or experienced operators are more likely to understand that the economic benefits of new technologies usually accrue to early adopters. More experienced workers (age) got the optimum height of the Bt plant by applying more fertilizers. Hence the experience had an effect on the outcome of the technology. Arshad et al. (2007, pp. 121–124) found that the awareness regarding the availability of Bt cotton seeds was found to be more among the educated farmers. In the same study, level of the farmer's education was found to have positive impact on the satisfaction level. In contrast to this, Padaria et al. (2009, pp. 39–45) found the effect of education to be non significant. Study by Detre and Adhikari (2010, pp. 130–134), reported a negative influence of education. The authors conducted their study on a sub group of farmers-YBFR (Young and Beginning Farmers and Ranchers) in USA. Banerjee et al. (2009, pp. 218–225) found out that the effect of age and experience was not significant in determining the adoption of GM technologies in agriculture.

Psychographic characteristics of the farmers were studied by Padaria et al. (2009, pp. 39–45), Alexander et al. (2002, pp. 112–126), Detre and Adhikari (2010, pp. 130–134), Fernandez-Cornejo and McBride (2002), Kopainsky and Derwisch (2009) and Kopainsky, Derwischand Troeger (2011). One of the main traits is risk associated with the GM crops. It has been studied as the producer trait as well as the crop trait. Risk aversiveness of the YBFR was found to have an effect on adoption (Detre and Adhikari, 2010, pp. 130–134),risk return profile of the crops was found to have a significant influence by Alexander et al. (2002, pp. 112–126). In the wake of risk management by the adopting farms, GM crop adoption was found to be positively associated with contracting (marketing or production) by Fernandez-Cornejo and McBride (2002). Contracting ensures a market for GE crops, reducing price and any market access risk that could result from uncertain consumer acceptance.

Another trait is trust in the new crop technology (Kopainsky, Derwisch, and Troeger, 2011). Trust can even override or replace an empirical evaluation of the utility of improved seed (Kopainsky and Derwisch, 2009). Trust can be built through social exposure to improved seed, e.g. through marketing campaigns, free distribution of seed to key farmers and ensuing demonstration days. Maintaining trust can also be secured by branding. Branding can further stimulate demand in combination with strategies of pricing and new product supply. Other socio-psychological characteristics like scientific orientation, innovativeness, achievement motivation and positive perception were stressed upon by Padaria et al. (2009, pp. 39–45).

Other economic characteristics of the operators related to cultivation like size of holding, capital base etc were found to have a significant influence on adoption by Padaria et al. (2009, pp. 39–45). However, area under cotton, yield and gross farm income were not significant factors in determining adoption of GM technologies in cotton production in the study byBanerjee et al. (2009, pp. 218–225). According to Arshad et al. (2007, pp. 121–124), adoption was higher in case of large farmers with sufficient resources compared to the smaller farmers with limited resources.

Effect of various elements of marketing strategy on adoption of GM crops

Effect of price of GM technology on its adoption has been widely documented in the literature. Motivated by the relatively low adoption rates in Argentina, Qaim and Janvry (2003, pp. 815–828) analyzed farmers willingness to pay (WTP) for Bt cotton seeds and the expected level of demand for the new technology under different pricing regimes. They found the demand for GM seeds to be price responsive, and the WTP to be much lower than the current market price of Bt seeds in Argentina. Hence, they argued that reducing the Bt cotton seed prices would not only increase farmer's profits but would also be more profitable for the seed producing company. High price could result in the decline in the adoption rate for Bt cotton was concluded by Frisvold (2004). The study examined the role of economic factors in the diffusion of Bt cotton in USA and used dynamic diffusion model with multiple regression analysis. The study suggested that High price could result in the decline in the adoption rate for Bt cotton. Survey based analysis by Arshad et al. (2007, pp. 121–124) also quoted the high cost (price) of seed as a major reason for non adoption of Bt in Pakistan. Loganathan et al. (2009, pp.331–340), asked famers to rank the reasons for preferring a Bt cotton variety and the problems being faced by them in the cultivation of non-Bt and Bt cotton. The same were analyzed using Garret's ranking technique. High cost of Bt cotton seeds was the most important problem reported by the Bt cotton farmers. According to Alexander et al. (2002, pp.112–126), the adoption of Bt crops was also found to be negatively related to the prices of its substitutes (Alexander et al., 2002, pp.112–126).

Contrary to the above, the seed price interventions by the state (to reduce the prices of Bt cotton seeds) were found to have little impact on the aggregate Bt adoption in India in a study by Sadashivappa and Qaim (2009, pp.17–183), authors found a high WTP (close to the official market price) for Bt cotton seeds in India. According to them, the take-off phase for Bt cotton had already begun before 2006 and thus the government seed price interventions had little impact on aggregate Bt cotton adoption. Instead, seed price controls might reduce the incentive of the company to innovate in the future. Thus government interventions should be implemented after careful analysis of the long run implications of the policy on agricultural innovations. However, the results of this study were contrasted by Arora and Bansal (2011) concluding that the price controls by state governments contributed to the surge in adoption rates in the country.

The importance of Supply-side variables(place mix) such as initial availability of Bt seed adapted to local conditions and potential seed supplier profits on adoption was established for the first time through the study made by Frisvold (2004). Further, it was found that the availability of a wide variety of hybrids had a positive effect on adoption (Arora and Bansal, 2011). Emergence of new hybrids (technological development) extended the choice portfolio for the farmers and had a positive influence on the diffusion rate for Bt cotton in India. Arshad et al. (2007, pp. 121–124) also revealed the fact that pesticide sellers could affect the adoption as they were consulted by the farmers for pest problems.

The factors like higher yield, higher profitability and lower pest problems(related to the product element of the marketing mix) were also cited as important factors behind preferring Bt cotton (Loganathan et al., 2009). The same was supported by the studies made by Arshad et al. (2007, pp. 121–124) and Padaria et al. (2009, pp. 39–45). According to Arshad et al. (2007, pp. 121–124), the higher resource requirements like fertilizers and irrigation were found to have impacted adoption negatively. Farmers perceived high yield, less pesticide use, less labor requirement and easy picking of cotton as the major advantages of Bt cotton Padaria et al. (2009, pp. 39–45). According to Frisvold (2004) adoption was affected by higher pest damage in the area in the previous years. Moreover, relative utility of the improved seed that is its ability to multiply the gross margins from conventional seed also have an impact on adoption (Kopainsky and Derwisch, 2009). Thus the GM crop characteristics which had an impact on its performance affected their adoption and spread.

Some of the studies have accounted for the limited role played by popular media sources used for promotion such as television, radio and newspapers in creating awareness about Bt cotton (Loganathan et al., 2009, pp. 331–340). The authors further opine that non-economic benefits and bio-safety measures should be given adequate attention in the media coverage and campaigns to facilitate adoption of Bt cotton in India. Lack of knowledge and information as a constraint in adoption was reported by Arshad et al. (2007, pp. 121–124). A few studies identify the role of promotional strategies like- marketing campaigns, free distribution of seed to key farmers and social exposure to improved seeds through scheduled demonstrations and branding to build trust (Kopainsky and Derwisch, 2009; Kopainsky, Derwisch, and Troeger, 2011).

Some of the authors have also tried to uncover the need and content of training in order to facilitate adoption of GM crop technologies. According to Padaria et al. (2009, pp. 39–45), the socio-psychological characteristics like scientific orientation, innovativeness, achievement motivation and positive perception need to be stressed upon in the training programs to facilitate speedy adoption of technologies. Training in biosafety measures such as growing refugee crops so as to avoid building-up of the resistance by bollworms against the Bt toxin was pointed out by Loganathan et al. (2009, pp.331–340).

The literature review revealed there are a few studies which have tried to look into the strategies used by innovators/promoters for marketing of innovative products as influenced by individual factors. Moreover the basic reference to Indian context has been rarely found. Also, there exists a gap in the literature as to the linkage of marketing strategy elements and the adoption of GM crops (Bt cotton). Most of the studies have attempted to explore 4P's individually. The article attempts to fill these gaps by providing a comprehensive picture of the same in context of our country.

Methodology

The primary survey was conducted in three major cotton growing states of northern India–Haryana, Punjab, and Rajasthan. In all, 600 farmers were interviewed with 200 respondents from each of the three states. Farmers across these states were selected through convenience sampling. These farmers were majorly the cotton producing ones. Data cleaning process yielded response from approximately 384 farmers. Responses from the Punjab state were completely removed on the account of their questionable appearance. Pilot survey was carried for five days and questionnaire was improved to settle the issues and doubts that emerged. The survey started in the month of November 2007 and continued till the end of January 2008. The survey was based on fully structured questionnaire. Extensive consultations were made with the experts from academics and the government and corporate sectors. Their comments and suggestions provided inputs to the final version of questionnaire. The questionnaire was translated into Hindi language in order to increase its understandability for the target audience.

Tools for analysis

Percentage tabulation was made for every question in the questionnaire. By combining two or more questions and tabulating the data together, cross tabulations were carried out. In case of cross tabulations featuring two variables, a test of significance (Chi square test) was used. It was used to determine whether two variables are statistically associated with each other or not.

Chi square statistic has to be calculated from the numbers in cross tabulations. This is compared with the chi squared values from chi squared tables for given degree of freedom, at a given confidence level. Chi square test assumes that the expected value for each cell is five or higher. Hence fisher's exact test was used in cases when one or more of cells had an expected frequency of five or less.

Demographic, psychographic, and economic variables affecting target market characteristics been tested through this primary survey. Moreover, marketing strategy as affected by individual farmer characteristics resulting in the adoption of Bt crop also explored in this study.

The relationship of adoption with these variables is shown as:

Adoption=f(X)

Adoption is a function of X,

where X= age, experience, education, economic status of the farmer, dependence on agriculture and cotton, usage of inputs, availability of seeds, awareness of farmers and availability of finance.

Moreover, the qualitative factors like reasons for adoption, satisfaction and motivation for trial are also studied.

Definition of variables used is given by Table 1.

Table1: Definition and measurement of the variables used

Variable	Definition and measurement
Adoption	Adopters (who grew Bt cotton alone or in combination with Non Bt cotton)=1, Non-Bt growers=0
Age	Age of farmers, measured in years
Experience	Experience of cultivating cotton, measured in years
Education	Farmer's education level
Economic variables related to cultivation	Proportion of farmer's own land under cotton to total land area under cotton and Proportion total irrigated land to total area under cotton, measured as percentages
Dependence on agriculture	Proportion of yearly agricultural income to annual family income, measured as percentages
Dependence on cotton	Proportion of yearly income from cotton to yearly agricultural income, Proportion of total land under cotton to total land area under production, measured as percentages
Usage of inputs	Pesticides sprays made, measured in numbers and seeds/fertilizers used, measured in kilograms per acre
Availability of seeds	Various sources, worked out on a scale of 1–5
Awareness of the farmers	Various sources, worked out on a scale of 1–5
Availability of finance	Various sources, worked out on a scale of 1–5
Reasons for adoption	Worked out on a scale of 1–5
Reasons for Bt adoption	Worked out on a scale of 1–5
Reasons for non-adoption of Bt cotton seeds	Worked out on a scale of 1–5
Satisfaction from Bt	Worked out on a scale of 1–5
Satisfaction from Non-Bt crop	Worked out on a scale of 1–5
Motivation for trial	Worked out on a scale of 1–5

Source: Primary survey by the author

Results: GM crop adoption in India

General description of farmers surveyed

The farmers were classified as Bt and Non-Bt users. The sample had more population of Btrespondents (87%) than Non-Bt users. This points towards the trend to the growing adoption of Bt cotton across these states. Distribution of farmers surveyed into Bt and Non Bt users is given by Table 2.

The same is well supported by data. In 2010–11, there was 92.5% of adoption of Bt hybrids in Northern zone (ALCOSA newsletter, May2011) and 88.4% in the whole country (ISAAA Brief No. 43, 2011). Thus though

Table 2. Distribution of farmers surveyed into Bt and Non-Bt users

Variety	Number	Percentage
Bt	333	87
Non-Bt	51	13
Total	384	100

Source: Survey conducted by the author the sample is convenient one, it appears to represent the farmers (population) well.

Age and experience of farmers: A majority of farmers belong to the age group of 21–40. A high percentage of farmers also belong to the age group of 41–60. Moreover, the sample had around 81% of the farmers with up to 20 years of experience. The cross tabulation of age and experience of the farmers in Table 3 shows that maximum number of respondents fall in the category of 21–40 age group and 11–20 years of experience.

Table 3.Cross tabulation between age of the respondent farmers and their experience in cultivating cotton (number of years)

Experience ⟹ Age ⇩	0–10	11–20	21–30	61–above	Total
0–20	3	0	0	0	3
21–40	89	91	3	0	183
41–60	10	77	41	20	148
61 and above	2	2	3	2	9
Total	104	170	47	22	343

Source: Survey conducted by the author

This cross tabulation points to their level of maturity and lends an element of credibility to their responses.

Education status of the farmers: Education could have a bearing on their ability to understand and comprehend the promotional campaigns and susceptibility towards adopting innovations.

Sample constituted the farmers from all the levels of education but it was clustered around farmers who had 6–10 years of education. A majority of the respondent farmers were the highest educated members of the family. The cross tabulation of number of education years of the farmer with highest educated member of the farmer's family reveals that majority of the farmers are the highest educated members of the family and fall in the category of 6–10 years of education.

Cross tabulation between the numbers of education years of the respondents with the member with highest education in the family is given by Table 4.

Table 4.Cross tabulation between the numbers of education years of the respondents with the member with highest education in the family

Number of Education Years ⟹ Member with highest education ⇩	Up to 5	6–10	11–12	15	17	Total
Farmer's kids	0	48	12	2	0	62
His parents	0	2	4	0	0	6
His siblings	0	8	6	3	0	17
His nephews	0	5	2	0	1	8
Himself	28	142	54	34	8	266
Total	28	205	78	39	9	359

Source: Survey conducted by the author

Economic status of the respondent farmer: Variables like ownership of cultivated land area under cotton and the irrigation facilities point towards their ability to afford the resources for cultivation. Most of the respondents were the owners of the land on which they grew cotton.Percentage of Farmer's Own Land under Cotton to Total Land area under Cotton (OLC/TLC) is given by Table 5.

Table 5.Percentage of farmer's own land under cotton to total land area under cotton (OLC/TLC)

Percentage of Farmer's Own Land under Cotton to Total Land area under Cotton cultivated by him	Percentage of Farmers
0–20	2
30–40	8
50–60	13
70–80	4
90–100	73

Source: Survey conducted by the author

Most of the respondents said that the land under cotton was properly irrigated. This pinpoints the availability of water resources on the cultivated area under cotton. This also provides a hint towards the economic status and the ability of farmers to afford resources for cultivation. Percentage of total irrigated land to total land area under cotton cultivated by the farmer (TLI/TLC) is given in Table 6.

Table 6.Percentage of total irrigated land to total land area under cotton cultivated by the farmer (TLI/TLC)

Percentage of total irrigated land to total land area under cotton cultivated by the farmer	Percentage of Farmers
0–20	0
30–40	0
50–60	1
70–80	1
90–100	98

Source: Survey conducted by the author

Dependence on agriculture and cotton

This characteristic was explored through three variables-YAI/YFI, YCI/YAI, TLC/TLP.

1. **Percentage of Yearly Agricultural Income to Annual Family Income (YAI/YFI)**

   Majority of respondents in the sample had yearly agricultural income occupying 70–100% share of total family income. This means they had agriculture as the main occupation. This shows their dependence on agricultural income. The variable is shown in Table 7.

Table 7. Percentage of yearly agricultural income to annual family income (YAI/YFI)

Percentage of yearly agricultural income to annual family income	Percentage of Farmers
0–20	5
30–40	2
50–60	12
70–80	34
90–100	47

Source: Survey conducted by the author

2 **Percentage of yearly income from cotton to yearly agricultural income (YCI/YAI)**

The table 8 reveals that cotton income contributed a meagre portion of the total income of the farmers from agriculture. This was true for more than 50% of the cases.

3. **Percentage of total land under cotton to total land area under production (TLC/TLP)**

   For approx 50% of the farmers, cotton income contributed up to 20% of total agricultural income in the last cultivation cycle. Though most of the respondents said that they devoted more than 70% of their land to cotton(and a per the data classification, the majority of the farmers in the sample are adopters), the cotton income contributed a meager portion of their total income from agriculture. This means that in the same year, the productivity of cotton must have gone low. The reason for low productivity might be mealy bug which broke out on the last crop of 2007 across all the cotton producing states in the zone. The same is shown in tables 8 and 9.

Table 8: Percentage of yearly income from cotton to yearly agricultural income (YCI/YAI)

Percentage of yearly income from cotton to yearly agricultural income	Percentage of Farmers
0–20	52
30–40	21
50–60	18
70–80	6
90–100	2

Source: Survey conducted by the author

Table 9: Percentage of total land under cotton to total land area under production (TLC/TLP)

Percentage of total land under cotton to total land area under production	Percentage of Farmers
0–20	4
30–40	8
50–60	10
70–80	40
90–100	38

Source: Survey conducted by the author

Usage of inputs on sampled data

In this section, a comparison of Bt and Non Bt Cotton in terms of consumption of resources like pesticides, seeds and fertilizers was made. Table 10 shows the number of pesticides sprays made in current cultivation cycle.Around 55% of Bt users fail in 3–5 number of sprays category while for Non-Bt the maximum number of respondents occupy 9–11 number of sprays category.

Table 10: Number of pesticides sprays made in current cultivation cycle

Range (number)	Respondents: Bt (percentage)	Respondents: Non-Bt (percentage)
0–2	2	10
3–5	55	16
6–8	33	30
9–11	10	43
12–100	0	1

Source: Survey conducted by the author

This might be because of the reason that farmers are aware about less pesticide sprays to be made on Bt crop. The information might have come to them through Bt seed suppliers or other sources. The alternative explanation might be that pesticide sprays are able to control pests other than mealy bug. These pest attacked Non-Bt users the most and hence could be controlled by pesticide sprays so in spite of the fact that mealy bug couldn't be controlled by pesticide sprays Non-Bt users made a number of pesticide sprays. But in case of Bt only mealy bug caused the major havoc. Mealy bug was not even controlled by pesticide sprays while Btcotton crop was comparatively quite free from other bugs and hence pesticide sprays were made less.

99% of Bt users were reported to use 900 grams of seeds per acre. This corresponds with the fact that Bt seed packets come in a packaging of 450 grams each with some refuge Non-Bt seeds. So at the most Bt users bought 2 packets per acre of Bt seeds while 98% of Non-Bt farmers use 5–10 kg of cotton seeds per acre.

Tables 11a and 11b show the usage of Bt and non-Bt seeds per acre.

Table 11a. Bt seeds used per acre

Range(Kg)	Number of respondents	Percentage
0–0.9	321	99
1–3	2	1

Source: Survey conducted by the author

Table 11b. Non-Bt seeds used per acre

Range(Kg)	Number of respondents	Percentage
0–4	4	2
5–6	98	50
7–10	96	48

Source: Survey conducted by the author

Table 12. Usage of fertilizers per acre on Bt and Non Bt Cotton crops

Range(Kg)	Number of respondents: Bt	Number of respondents: Non-Bt	Percentage: Bt	Percentage: Non-Bt
0–50	2	2	1	1
5–100	23	61	10	31
101–150	140	136	59	68
151–500	71	1	30	1

Source: Survey conducted by the author

Again in case of fertilizer consumption, the whole numbers are coming due to the fact that the major fertilizers used are DAP(Di ammonia Phosphate) and urea which come in a packaging of a 50kg gunny bag. Though some of the farmers do use zinc also which comes in a package of 10kg bag.

Usage of fertilizers per acre on Bt and Non-Bt Cotton crops is shown in Table 12.

The table shows that Bt seed users are using more of fertilizers than Non Bt. The trend can be explained by highlighting the fact that according to the recommendation of fertilizer usage given by Haryana Agriculture University Hisar, Bt users can put up to 350 kg of fertilizer per acre while the recommendation for Non Bt is 160 kg the breakup for both is given as follows.

Bt: 150 kg Urea, 150 kg Superphosphate, 40 kg potash and 10 kg Zinc sulphate

Non-Bt: 75 kg urea, 75 kg Superphosphate and 10 kg Zinc

Most of the studies in the literature review too have not accounted for this input variable.

Relationship of various factors with adoption

The hypothesis testing is undertaken to find out the relationship of adoption with demographic, economic and marketing variables. Hypotheses 6, 7, and 8 are particularly focused upon exploring the relationship of adoption with marketing variables. These variables are derived from 4P's framework where all the elements of marketing mix—product, price, place and promotion work cohesively and persuade a customer to buy the product. It looks into these variables from the customer's (farmer's) angle as to how their purchase process has been affected due to the marketing strategies being used by the technology promoters.

H1 There is a negative relationship between age of the target audience and the adoption of Bt cotton

H2 There is a positive relationship between experience of the farmers in cultivation and the adoption of Bt cotton.

H3 There is a positive relationship between number of education years of the farmer and the adoption of Bt crops

H4 There is a positive relationship between the ownership of land and adoption of Bt cotton

H5 There is a positive relationship between the dependence of farmer's family on income from cotton and adoption of Bt cotton

H6 There is a positive relationship between availability of Bt seeds and adoption

H7 There is a positive relationship between awareness and adoption

H8 There is a positive relationship between availability of finance used to fund the cultivation and adoption

These hypotheses can be tested by the use of various statistical techniques. Since the statistical techniques are data hungry and the information is patchy, the hypothesis has been tested in two stages.

Step1: The interdependence between adoption and the specified variable is determined through chi square and fisher exact test

Step2: Direction of the relationship is analyzed through the table.

Results

The sample shows a trend towards the adoption of Bt cotton seeds in northern zone. This is supported by the fact that in 2010–11, there is 92.5% of adoption of Bt hybrids in northern zone (ALCOSA newsletter, May 2011) and 88.4% in the whole country (ISAAA Brief No. 43, 2011). Summary of various observations made by the survey is:

- There is a negative relationship between age of the farmers/experience in cultivating cotton and adoption.
- The study shows that Bt seed users are using more of fertilizers than Non-Bt. The trend can be explained by highlighting the fact that this is in accordance of recommendation given by government agencies and universities.
- The relationship between the adoption and education is negative, and the overall education level of the farmers (in the sample) is low.
- There is a positive relationship between adoption and ownership of land area under cotton cultivation
- As the area under cotton cultivation as a proportion of total area under cotton rises, there is an increase in adoption which shows the confidence and expectation of farmers from Bt technology.
- Proportion of yearly income from cotton to total agricultural income appears to decrease with adoption. According to the factual data, outbreak of mealy bug pest caused heavy losses to the cotton crop in 2007. Since there was a widespread adoption of Bt cotton in that zone there seemed to be a negative relationship between adoption and this variable. The same is well supported by the low satisfaction score (compared to other factors) given to the crop yield from Bt seeds.
- Private seeds shops are the most important sources for seeds purchase for both adopters and non adopters.
- Important source of awareness for both the types of cultivars are—other farmers (word of mouth), company representatives and area development officer. These sources played important role in spreading the awareness regarding certification of Bt brands and initiating its trial.
- Income from last crop emerged as important source of financing the purchase of seeds.
- Though most of the farmers were concerned about the high price of seeds, they were convinced about the low overall cost of Bt cultivation. Moreover, the use of less number of sprays on Bt crop compared to its Non Bt counterpart is also evident from the analysis of this sample.
- Bt farmers are using lesser number of pesticides sprays and seeds per acre than Non Bt ones. The expectation of low requirement of pesticides was also quoted as the major reason for its adoption. This also

emerged as important satisfaction criteria from Bt crop. This must have contributed to the Word of mouth which emerged as the important source of awareness and trial.

- Low availability of seeds and lack of awareness were quoted as major reasons for non adoption of Bt cotton technology. Also, the farmers expressed a lower satisfaction score on the availability of Bt seeds. Hence the distribution channels for Bt seeds need to be strengthened in terms of reach.

Thus the survey explained target market characteristics and their relationship to the adoption of Bt Cotton in India. Marketing strategy elements and farmer specific characteristics (demographic, economic and psychographic) are related to the adoption of Bt cotton. The performance of Bt cotton seeds with Non-Bt was also compared in terms of resource consumption. The use of inputs like fertilizers and seeds was also found to be low in Bt as compared to Non-Bt.

Conclusions and recommendations

Primary survey revealed the importance of marketing strategy elements-product, price, place and promotion in determining the adoption of the technology in the country. Further, it pinpointed the effect of performance related variables like overall low costs of cultivation, the expectation of higher yield and low requirement of pesticides as the major motivators in adoption of Bt cotton. It also emphasized upon Word of Mouth, Agricultural area development officers and the Company Representatives in spreading awareness and initiating the trial for the technology. It highlighted the role of channel partners (dealers of seeds, fertilizers and pesticides, etc.) in providing loans for the cultivation.

Thus marketing strategy can facilitate the adoption of technology by building upon the factors which affect it. Marketing strategy elements need to be adapted according to the laws of countries, economic conditions of its potential adopters, geographic conditions of local areas inside the nations and the extent of competition and marketing avenues present there.

Marketing strategy should serve to educate the market about the new technology before they themselves render a judgment or intention to buy or not buy it. This is important because radical innovations resulting from new technology are complex products possessing attributes with which market is unfamiliar. Hence there is a severity of learning requirement in case of radical innovations. The market,which consists of all the stakeholders, lacks knowledge to evaluate and make judgments regarding these products. This gap is fulfilled by the promotional strategy for innovations.

Marketing strategy needs to be supported by the performance of the product because it is the Word of mouth which emerges out as the most important source for spreading awareness and generating trial by the potential market. Positive word of mouth can only be generated if the innovation confirms to the adopter's expectations. Moreover, by creating and promoting the differential advantage generated by the technology, marketing strategy can boost this word of mouth.

Marketing strategy is a must for the proliferation of the technology also. The developer of the technology should make it convenient for the other players to enter into the market keeping the profit margins and his sunk costs in the mind. It will help to increase the rate of adoption of the technology because as the number of players increases there is a greater market development due to pooling of resources. This pushes the demand in the market and aids in developing customized features and varieties of the product. The competition also helps in reducing overall cost of the market and the price of the product for the customer. This helps in better adoption and penetration of the technology amongst the masses. In this study, the high price of Bt cotton was seen as a major reason for its non adoption. However, the newer technological modifications helped in making the technology more acceptable to the masses in terms of lower price and customized features.

In short, all the elements of marketing strategy-product, price, place and promotion must act cohesively to spell success in the marketplace. The study also pointed towards the concerns made by the farmers regarding its high price and low availability. Hence the marketing strategy elements should be customized to provide-value for money, time and space utility for the customers in case of adoption of new technology like GM crops.

References

Aerni, P, 'Is agricultural biotechnology part of sustainable agriculture? Different views in Switzerland and New Zealand'. *AgBioForum, 13*, 2, 2010. Available on the World Wide Web: http://www.agbioforum.org.

ALCOSCA. (2011). Newsletter, May 2011, Accessed on: December 8, 2011, from http://www.webconnectindia.net/aicosca1/files/MAY%202011%20WEB.pdf

Alexander et al, 'Dynamic diffusion with disadoption: The case of crop biotechnology in the USA'. *Agricultural and Resource Economics Review,* 31, 1,2011.

Arora, A., and Bansal, S.,'Diffusion of Bt cotton in India: Impact of seed prices and technological development'. *Paper presented at 15th ICABR conference.* Frascati, Italy. 2011.

Arshad, M., Suhail, A., Ashgar, M., Tayyib, M. andHafeez, F. 'Factors influencing the adoption of Bt cotton in the Punjab, Pakistan'. *Journal of Agriculture and Social Sciences,* 3, 4, 2007.

Banerjee, S. and Martin, S.W., 'A binary logit analysis of factors impacting adoption of genetically modified cotton'. *AgBioForum,* 12, 2, 2009.

Borlaug, Norman E, 'Ending World Hunger. The Promise of Biotechnology and the Threat of AntiscienceZealotry'Plant Physiology, 12, 2000.Available on the World Wide Web:http://www.plantphysiol.org/content/124/2/487.full.

Detre, D. Ashok, K. and Adhikari, A., 'Factors affecting the adoption of genetically modified crops by Young and Beginning U.S. Farmers and Ranchers (YBFR)'. *Journal of the ASFMR,* 2010.

Durham, T., Doucet, J., and Snyder, L.U. 'Risk of regulation or regulation of risk?A *de minimus* framework for genetically modified crops'.AgBioForum, *14, 2,*2011. Available on the World Wide Web:http://www.agbioforum.org.

Fernandez-Cornejo, J. and McBride, W.D.).Adoption of bioengineered crops. Agricultural Economics Report No. 810,Washington, DC, 2002. Accessed on: December 18, 2011, from http://www.ers.usda.gov/publications/aer810/aer810.pdf

Frisvold, G. B., 'Diffusion of Bt cotton and insecticide use'.*Paper prepared for Presentation at Western Agricultural Economics Association Annual Meeting.* Honolulu, Hawaii.2004. Accessed on: April 9, 2010, from http://ageconsearch.umn.edu/bitstream/36223/1/sp04fr01.pdf

ISAAA .(2011*).* Global status of commercialized biotech/GM crops: 2011. ISAAA Brief No. 39 ISAAA: Ithaca, NY.

Kopainsky, B. and Derwisch S., 'Model-based exploration of strategies for fostering adoption of improved seed in West Africa'.Paper presented at the 27th International Conference of the System Dynamics Society.Albuquerque 2009.

Kopainsky, B., Derwisch S. and Troeger, K., 'The management of trust for stimulating the adoption of improved maize seed in Malawi'. *Paper prepared for presentation at the International Conference of the System Dynamics Society.* Washington DC. 2011.

Loganathan, R., Balasubramanian, R., Mani, K. and Gurunathan, S., 'Productivity and profitability impact of genetically modified crops – An economic analysis of Bt cotton cultivation in Tamil Nadu'. *Agricultural Economics Research Review,* 22,2009.

Nielsen, Chantal Pohl and Anderson, Kym, 'Genetically Modified Foods, Trade, and Developing Countries: Is Golden Rice Special?'AgBioWorld. 2005.Available on the World Wide Web:http://www.agbioworld.org/biotech-info/topics/goldenrice/specialgoldrice.html

Padaria R.N., Singh, B., Sivaramane, N., Yashwant, K. N., Ravi, M. and Surya S. 'A logit analysis of Bt cotton adoption and assessment of farmers' training need. *Indian Research Journal of Extension Education,* 9, 2, 2009.

Qaim, M. and Janvry. A., 'Genetically modified crops, corporate pricing strategies, and farmer's adoption: the case of Bt Cotton in Argentina'. *American Journal of Agricultural Economics,* 8,4, 2003.

Qaim, M.; 'Transgenic crops and developing countries.' *Economic and Political Weekly*, 2001.

Sadashivappa, P. and Qaim, M., 'Bt Cotton in India: Development of benefits and the role of government seed price interventions'. AgBioForum,12, 2, 2009.

Singh, B, 'Genetically Modified (GM) Crops and Controversies'' *Orissa review,* 2010

Sliva, E.J, 'Expanding frontier of biotechnology: issues in Biosecurity and Biosafety', *Asian Biotechnology and Development Review,* 8, 1, 2005.

> *"Biotechnology is not just about farming. It's about business; it's about our future, ... It doesn't affect just farmers; it affects everyone."*
>
> ***—Bob Stallman***

Focus

Performance of Bt Cotton in Gujarat: Is There an Evidence of Inclusive Agricultural Growth?

N. LALITHA AND P. K. VISWANATHAN

Ever since the introduction of Bt cotton in Gujarat, the area under Bt cotton has been increasing. Since Bt technology is a biological technology, the benefits of adoption could be scale neutral. A survey among the farmers in seven cotton growing districts of Gujarat shows that farmers with different socio economic background, including marginal as well as large farmers have equally adopted the new technology. The availability of more varieties at reduced prices facilitated increased adoption of Bt cotton among the small and marginal farmers in Gujarat. However, it is observed that while farmers allot larger share of land to those seed varieties that they have experimented with, a relatively smaller portion goes for those varieties which are adopted by the majority of farmers. A smaller percentage of farmers have realized lower cost of cultivation compared to others and the reduction seem to have come from lower use of pesticides on Bt cotton. Differences in yield levels were observed between early and late adopters of the technology, especially among the marginal farmers. Appropriate extension services regarding information on the nature of the variety, its suitability to the region and plant protection measures could reduce the costs for the marginal farmers by reducing their experimental costs and maximising the farm business income.

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The cotton sector in Gujarat has undergone significant transformation following the commercialization of Bt cotton in India in 2002. The increased adoption of Bt cotton has contributed significantly to Gujarat's agricultural growth in the recent years (Bhalla and Singh 2009; Shah et al., 2009; Gandhi and Namboodiri, 2010). Following the introduction of Bt cotton, the total area under hybrids and desi varieties, which occupied 99% of the total area in 2002–03 had declined to 28.9% in 2011–12 (Figure 1). By the time the approved Bt varieties were planted in Gujarat in 2002, it came to limelight that the farmers were also planting on a large scale another Bt variety that was not commercially approved by the Government of India. While the widespread adoption could not be prevented as farmers found the yield difference between the approved and unapproved variety to be negligible (Lalitha et al. 2007), it has nevertheless contributed to bringing in more area under Bt cotton cultivation which has increased from a mere 8000 hectares in 2002–03 to 21.3 lakh hectares in 2011–12.

Table 1. Compound growth rate of area, production and yield in Gujarat

Area, production, yield	Growth rate (CAGR, percentage)	
	Pre-Bt scenario (1990–2001)	Post-Bt scenario (2002–12)
1. Total cotton area	5.16	6.7
2. Bt area	–	86
3. Non-Bt area	0.86	6.9
4. Production	36.8	21.9
5. Yield	4.8	14.28

Source: Calculated from the data provided by Government of Gujarat, 2012.

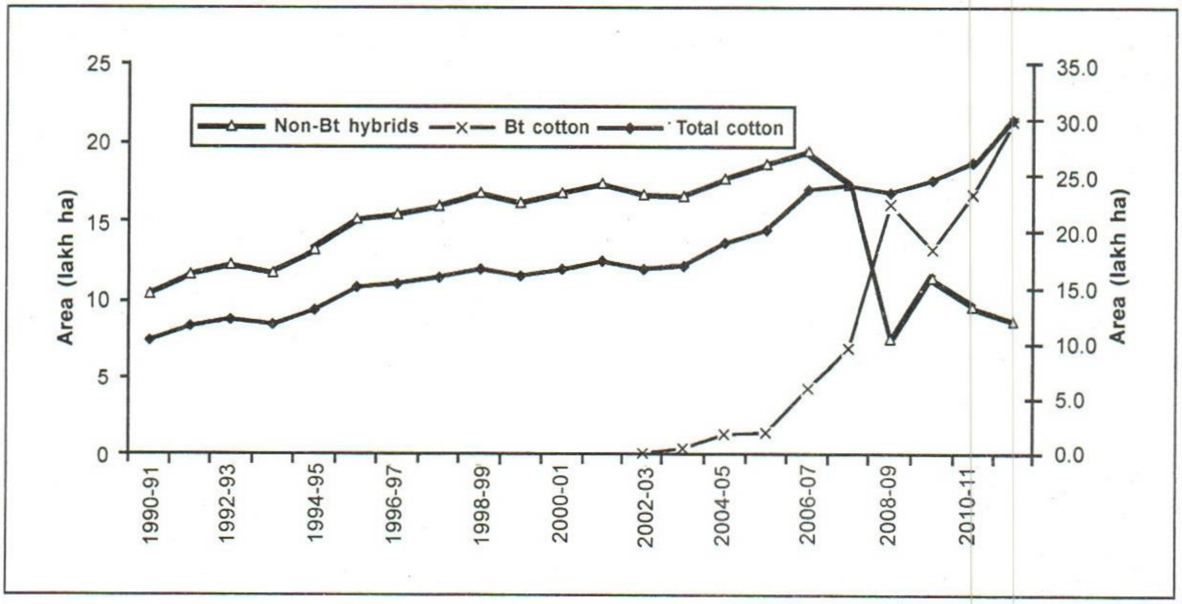


Figure 1: Trends in cotton area and expansion of Bt cotton area in Gujarat, 1990 to 2010–11

Source: Figure based on data provided by the Directorate of Cotton Development, Mumbai.

Figure 1 presents the long-term trends in area under cotton in Gujarat, characterized by the decline in area under Non-Bt hybrids in the event of increased adoption of Bt cotton varieties. Both production and productivity of cotton have made significant increase in the post-Bt scenario (Table 1) though there was a drop in both during later years, that is, 2008–09 and 2009–10 (Figure 2).

One question that the recent Bt cotton–led agricultural growth story in Gujarat unfolds is, "whether, Bt cotton adoption and its beneficial impacts have been inclusive or not." UNDP's, International Centre for Policy Research in Inclusive Growth defines inclusive growth as both an outcome and a process. On the one hand, it ensures that everyone can take part in the growth process,

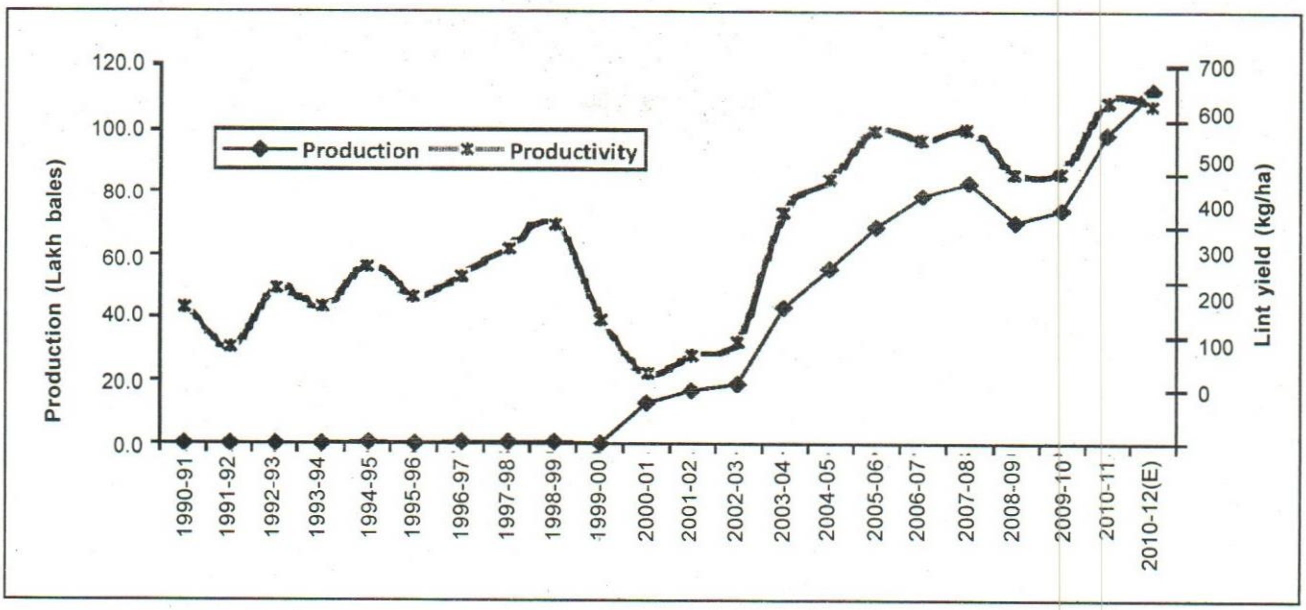


Figure 2: Long-term trends in production and productivity of cotton in Gujarat, including the post-Bt scenario

Source: Figure based on data provided by the Directorate of Cotton Development, Mumbai.

both in terms of decision making for organising the growth progression as well as in participating in the growth itself. On the other hand, it holds that everybody equitably shares the benefits of growth. Inclusive growth implies participation and benefit sharing. Participation without benefit sharing will make growth unjust and sharing benefits without participation will make it a welfare outcome. (http://www.ipc-undp.org/pages/newsite/menu/inclusive/whatisinclusivegrowth.jsp?active=1).

Based on this, some of the indicators of inclusiveness could be: (1) type of farmers (in terms of social background, size of land holding and regions of adoption) who adopt Bt technology; and (2) yield outcomes and cost of cultivation across different size groups.

Against this conceptual backdrop of agri-biotechnology led inclusive growth outcomes, this paper examines the trends in Bt cotton adoption among the farmers of different size groups based on a survey during 2007–08 covering 273 Bt cotton farmers drawn from seven cotton growing districts of Gujarat, viz., Rajkot, Bhavnagar, Surendranagar, Kutch, Sabarkantha, Vadodara and Bharuch. Tracing the adoption trends, the article addresses the question "whether adoption of Bt cotton has resulted in inclusive growth of cotton farmers in Gujarat." While understanding the rationale behind the seed choice made by farmers, it also analyses the cost and yield differences among the early and late adopters of technology across different size holdings. The article also presents a discussion on the overall performance of the technology based on different parameters, like the impact of Bt technology in reducing pesticide use, increasing the yield, quality of cotton and increased returns on the product.

The article is organised as follows. The second section examines the socio-economic profile of Bt cotton farmers in the study districts of Gujarat. It then discusses the adoption trends and the rationale of seed choice made by farmers. The third section looks at the performance of Bt cotton in terms of cost of production across farm size classes. The fourth section discusses the farm yield performance among the early and late adopters of Bt cotton. the fifth section examines the technological outcomes of well as the inclusive nature of Bt technology. The sixth section presents an analysis of overall performance of the technology, followed by conclusions in the last section.

Socio-economic characteristics of cotton farmers

Table 2 provides the baseline information about the socio-economic and demographic profile of the sample farm households covered in the study. Sabarkanta, Kutch, Surendranagar and Bhavnagar are relatively backward districts both agriculturally and industrially compared to other districts of Gujarat.

Average farm size of the sample farmers was 11.6 acres and the average size of cotton area was 6.5 acres (56% of the total area). Average age and average education of the farmers are 47.7 and 6.9, respectively. The Table indicates the predominance of agricultural dependence among the farmers, as only about 29% of them reported having income from non-farm sources, like animal

Table 2: Socio-economic characteristic of the sample farmers in Gujarat, district-wise

District	No. of farmers	Avg. holding size (acres)	Avg. cotton farm size (acres)	Mean age (years)	Mean education (years)	Farmers with non-agri. Income (percentage)
1. Rajkot	32	12.6	9.2	55.9	5.4	37.5
2. Bhavnagar	40	9.4	4.8	45.8	5.6	20.0
3. Surendranagar	40	18.6	11.7	45.8	6.1	15.0
4. Kutch	41	17.4	9.6	45.7	5.6	17.1
5. Sabarkantha	40	7.0	2.4	50.7	8.9	42.5
6. Vadodara	40	5.7	2.8	47.9	6.5	27.5
7. Bharuch	40	10.7	5.5	44.0	8.8	45.0
Total	273	11.6	6.5	47.7	6.9	28.9

Source: Farm household survey, 2007–08.

Table 3. Pattern of land ownership of the sample farmers

District	Total land (acres)	Cotton land (acres)	Percentage of cotton to total land	Cotton Irrigated land (acres)	Percentage of irrigated cotton to total cotton land
1. Rajkot	404.1	292.9	72.5	281.0	95.9
2. Bhavnagar	377.0	190.6	50.5	189.0	99.1
3. Surendranagar	743.4	466.3	62.7	314.3	67.4
4. Kutch	715	394	55.1	394.0	100.0
5. Sabarkantha	281.9	94.1	33.4	86.1	91.5
6. Vadodara	226.8	112.1	49.4	98.5	87.8
7. Bharuch	426.4	221.3	51.9	97.2	43.9
Total	3174.6	1771.3	55.8	1460.1	82.4

Source: Farm household survey, 2007–08.

husbandry, petty trade, private sector employment and the like.

Table 3 presents the profile of the sample farmers in terms of their land ownership status. Of the total 3174.6 acres of cultivable land reported by the sample farmers, 56% is grown with cotton. As is evident, highly irrigated lands are used for cotton cultivation in most of the districts, except in Bharuch where the percentage of irrigated land is 44%.

Analysis of Bt adoption in Gujarat and inclusiveness in seed choice

Since cotton is a major commercial crop of Gujarat, it is important to understand the adoption pattern of Bt in the state. Gujarat has the distinction of being home to the so called unapproved variety of Bt that has been widely cultivated since 2001–02, while the official approved varieties were introduced in 2002–03. However, since both approved and unapproved varieties are similar in traits, they are treated as Bt hybrids in this paper. Table 4 traces the history of farmer adoption of Bt cotton in the study districts. It shows disparate temporal pattern of adoption across the seven districts.

Few important observations emerge from Table 4. First, only Bharuch has adopted Bt cotton ever since its commercial release during 2001-02. Since approved Bt was introduced in 2002, it can be presumed that farmers in Bharuch have initially started with the unapproved Bt

Table 4. Trends in Adoption of Bt cotton by farmers, by districts

District	Year since Bt cotton was adopted (figures are %s to row total)							
	2007–08	2006–07	2005–06	2004–5	2003–04	2002–03	2001–02	Total
	1 year	2 year	3 year	4 year	5year	6 year	7year	
1. Rajkot	0.0	9.4	25.0	46.9	15.6	3.1	0.0	32 (100)
2. Bhavnagar	2.5	0.0	17.5	57.5	12.5	0.0	0.0	40 (100)
3. Surendranagar	2.5	12.5	50.0	17.5	15.0	2.5	0.0	40 (100)
4. Kutch	0.0	0.0	39.0	34.1	24.4	2.4	0.0	41(100)
5. Sabarkantha	12.5	47.5	32.5	2.5	5.0	0.0	0.0	40 (100)
6. Vadodara	2.5	35.0	37.5	22.5	0.0	2.5	0.0	40(100)
7. Bharuch	0.0	0.0	15.0	2.5	65.0	7.5	10.0	40(100)

Source: Farm household survey, 2007–08.

Table 5. Type of cotton cultivation by size holdings percentage share)

	Marginal	Small	Medium	Large	Total
2005–06 (n = 102)					
Bt cotton	27.4	20.5	31.3	2.0	81.2
Not classified	2.0	1.0	1.0	0.0	4.0
Desi	1.0	1.0	1.0	0.0	3.0
Others	2.9	2.0	6.9	0.0	11.8
Total	33.3	24.5	40.2	2.0	100.0
2006–07 (n = 252)					
Bt cotton	29.7	21.5	30.2	2.0	83.4
Not classified	5.2	0.0	2.8	0.0	8.0
Desi	0.4	0.0	0.0	0.0	0.4
Others	0.8	2.0	5.6	0.0	8.4
Total	36.1	23.3	38.6	2.0	100.0
2007–08 (n = 273)					
Bt cotton	29.3	21.6	31.5	2.6	85.0
Not classified	4.0	1.1	1.8	0.0	6.9
Desi	0.4	0.0	0.0	0.0	0.4
Others	0.4	2.2	5.1	0.0	7.7
Total	34.1	24.9	38.4	2.6	100.0

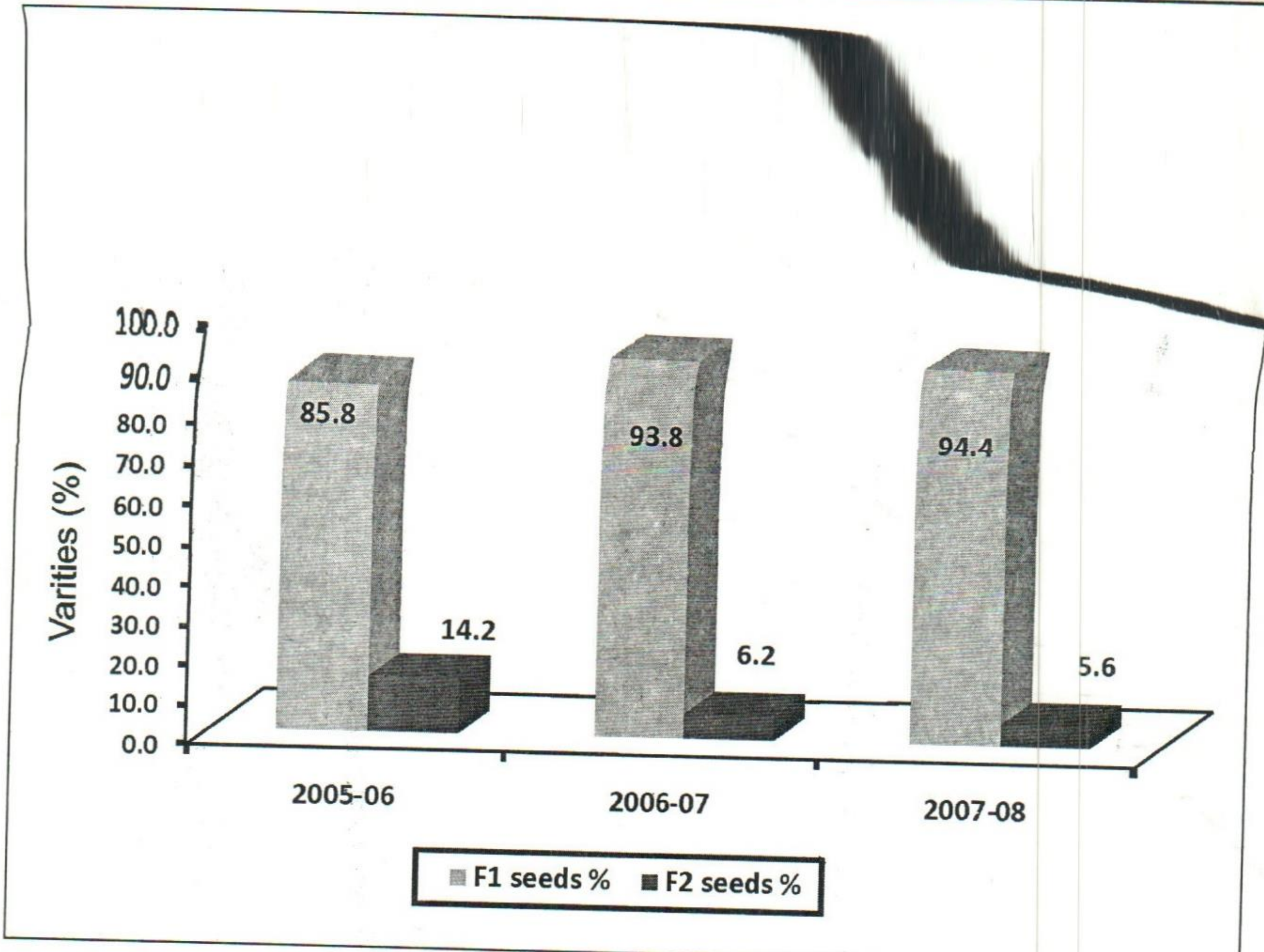
Source: Farm household survey, 2007–08.

cotton. Second, when three of the approved varieties were introduced in 2002–03, initial adoption has been slow. However, large number of farmers have started cultivating Bt from 2003–04 onwards. Third, while very few farmers from Vadodara have reported adoption of Bt before 2004–05, no new cases have been reported from Kutch and Bharuch since 2006–07. Four, none of the districts report continuous adoption of Bt. This is not abnormal in the sense as observed by Qaim (2003) [as quoted in Stone (2007)] that both adoption and non-adoption by farmers are not irreversible decisions and they are part of the normal process of learning.

All the districts here qualify as early adopters of the technology since they have more than four years of Bt cotton cultivation experience. The aggregate level scenario suggests that almost 77% of the farmers have been growing Bt cotton since the last 3–5 years.

In what follows, we try to contemplate the pattern of cultivation of cotton by farmers in terms of the trends in adoption of various cotton varieties. To understand whether there exist any differences between farmers on the varieta choices, the analysis considers farmers as a heterogeneous group with significant differences in their holding pattern.

Table 5 shows the trends in the pattern of cultivation of cotton varieties over the three year period, 2005–06, 2006–07 and 2007–08. Cultivation pattern by different size groups show that approved Bt is the most preferred choice among all size groups in all the three years (in the order of medium, marginal, and small) except for the large size holders. This obviously underscores the inclusiveness of the Bt technology in terms of its increased uptake even among the most resource poor farmers and this could be attributed more to the choice of seeds since the year 2004–05 and the reduction in Bt cotton seed prices since



Source: Farm household survey, 2007-08

Figure 3. Adoption of new (F1) versus farm saved (F2) seeds by farmers in Gujarat

2005. It may be noted here that initially, cotton seed prices were very high. But, due to government interventions, prices of the approved Bt varieties were reduced from Rs. 1600 to Rs. 750 per packet of 450 gram seeds. The price of the unapproved seeds matched this reduction with a drop in prices from Rs. 1200 to Rs. 400–600 during the same period. This ensured that small and marginal farmers are not excluded from realising the benefits of the Bt technology due to the price factor.

Note: Marginal, small, medium and large farmers are those with land holdings of 0.1–2.47, 2.48–4.94, 4.95–24.7 and 24.8 acres and above respectively.

Having adopted the Bt technology that now offers a wide variety of seeds at a standardised uniform price, it may be interesting to see how does the farmer select the seed that he wants to use? It should be noted here that F1 and F2 refer to seeds freshly sourced and farm saved seeds respectively.

Interestingly, the share of farm saved (F2) seeds which was at 14% in 2005–06 had declined to 5.6% in 2007–08. It indicates that the post-Bt period witnessed tremendous changes in seed use with majority of the farmers depending on the market for seed purchase every year. It is interesting to observe that farmers in Bhavnagar, Kutch and Sabarkantha entirely depend on the market for seed purchase. Whereas, farmers in Baroda, who were using F2 varieties by more than 50% in 2005–06, have now significantly switched on to F1 seeds to the extent of 87% by 2007–08. Overall scenario suggests that the proportion of F1 varieties used has increased from 86% (2005–06) to 94.4% during 2007–08 (Figure 3). Perhaps a reduction in the price of the F1 seeds in both the approved and unapproved varieties could have contributed to the progressive shift towards use of F1 seeds.

Implicitly, we wanted to understand the rationale behind the farmers' revealed preference for particular seeds or specific varieties that have been widely preferred by the farmers. The analysis of adoption of popular seed varieties helps us understand whether there is a clear pattern of varietal preferences as evinced by all the farmers irrespective of their farm size differences. Further, this also helps in verifying "whether the seed choice is influenced by the environmental or individual learning or social learning processes" as hypothesised by scholars, such as Stone (2007). Stone defines environmental learning as individual evaluations based on payoffs from various practices and social learning as adoption decision based on teaching or imitation. In fact, the processes of environmental or social learning about the Bt technology and its beneficial outcomes may also be seen as better indicators of *inclusiveness*, suggesting that there is no asymmetry in information across sections of farmers.

a planted with seeds sown in all 3 years to total area (n = 15 varieties)
ea planted with seeds sown in 2 years to total area (n = 16 varieties)
ea planted with seeds sown at least once to total area (n = 14 varieties)
area planted with unapproved seeds to total area

rm household survey, 2007–08.

s respect, a fundamental feature is that farmers nore than one variety. In our sample, on an farmer operated at least two plots planted with ce the farmers reported both the names of nd unapproved varieties, we had to group these rder to do this, since unapproved variety is one n different names, we have merged all the d varieties into one category and the individual arieties have been analysed. The results of this ted in Table 6.

y implication of the environmental learning is that growers maintain continuity in their ices over time while evaluating their payoffs. mplication of the environmental learning is that current area allocations to varieties the grower's experience with that variety (Lalitha 9). In order to understand which the popular e and which ones have continued to remain vourites, we have identified those (approved) at were cultivated in all the three years. It was 15 of the approved varieties were cultivated in e years. It is also evident that the area under eties had increased from 36% in 2005–06 to 06–07 and further to 61% in 2007–08. Out of varieties grown during two years, Rasi has as farmers' favourite seed and occupied the . It was also found that true to the environmental aracteristic, farmers had allotted 11% of the e Rasi seeds in 2005–06 which has almost 22% in 2007–08. This indicates that area grown cular variety increases with farmers experience tive pay offs with that variety.

lso tried to understand the Bt adoption that occurred due to social learning or demonstration do this, we have categorised those varieties ers have sown for two years. We observed that ies that were planted in the year 2005–06 were

discontinu 2007–08. cultivated in the thir the first tin year as w varieties h area. On t first time sample, 1 the share respective

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	2169 (37)	155
	364 (6)	56(
	833 (14)	96:
	5911 (100)	525:
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Table 8. Size-class differences in costs among late adopters (Rs./acre)

Costs	Marginal farmers	Small farmers	Medium farmers	Overall	Cost of marginal farmers in relation to (percentage)		
					Small farmers	Medium farmers	All farmers
1. Seed	036 (17)	922 (19)	761 (17)	928 (18)	11.0	26.6	10.4
2. Fertilizer	1342 (23)	1192 (25)	1052 (23)	1225 (24)	11.2	21.6	8.8
3. Pesticide	1454 (25)	1143 (24)	1229 (27)	1310 (26)	21.4	15.5	9.9
4. Weedicide	627 (11)	335 (7)	212 (5)	344 (7)	46.5	66.1	45.2
5. Irrigation	1463 (25)	1215 (25)	1292 (28)	1317 (26)	16.9	11.7	10.0
Paid out costs	5923 (100)	4807 (100)	4545 (100)	5123 (100)	18.8	23.3	13.5
Total cost (paid out + imputed values)	11554	9602	9936	10540	16.9	14.0	8.8
Paid out costs (percentage)	51.3	50.1	45.7	48.6	2.3	10.9	5.3

Note: Figures in parentheses indicate respective percentage shares.

as listed. For instance, late adopting marginal farmers spend 21% more than small farmers and 16% more than medium farmers on pesticides. The highest cost difference is noticed in the use of weedicides where marginal farmers spend 46% more than small farmers and 66% more than medium farmers. Seed cost incurred by marginal farmers has been 27% higher than medium farmers and 11% more than small farmers. Even in the case of irrigation, marginal farmers spend more, ie., Rs. 1463 per acre compared to Rs. 1215 per acre in case of small farmers and Rs. 1292 per acre as incurred by medium farmers.

From the aforementioned analysis it becomes evident that the marginal farmers incur more expenses on pesticides and fertilisers in particular as compared to rest of the farmers in case of both early and late adopter farmers.

More importantly, the more experience in Bt cotton as counted in terms 4–7 years of adoption does not have a significant influence on marginal farmers in particular in reducing the plant protection costs. This is because, early adopting marginal farmers are found to be taking much

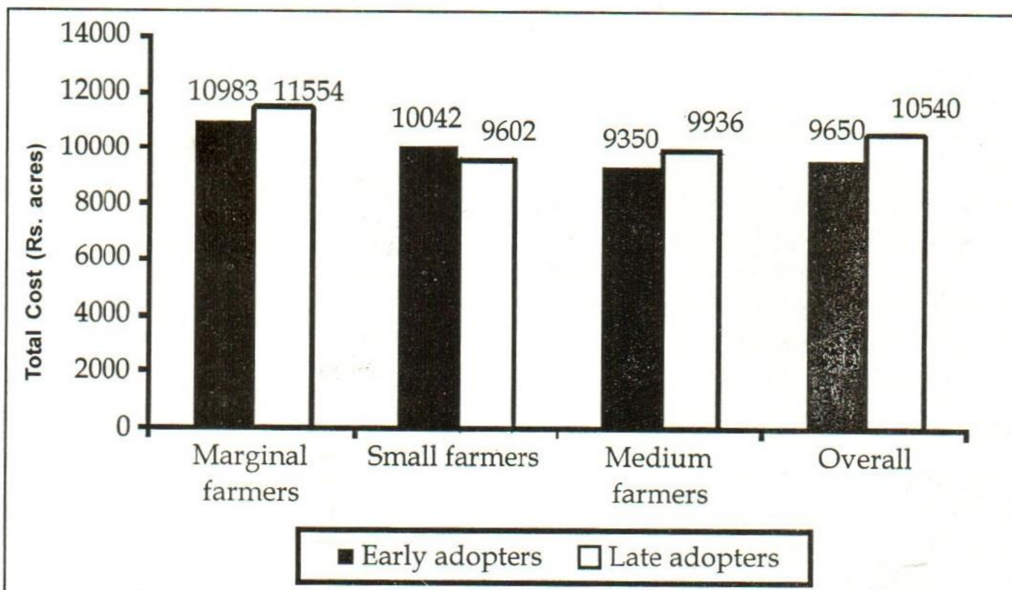

Figure 4. Comparative differences in paid out costs—early vs late Bt adopters

more care for plant protection compared to rest of the farmers. This can be further clarified by making a simple calculation taking the differences in absolute costs (per acre) between early and late adopters within similar categories as reported in tables 7 and 8. Accordingly, it may be seen that compared to late adopting marginal farmers, early adopting marginal farmers spend 33% more on pesticides and 12% more on fertilisers (Figure 4).

However, early adopting marginal farmers incur only 76% of the costs incurred by late adopting marginal farmers on irrigation. That is, early adopting marginal farmers spends Rs. 833 per acre compared to late adopting marginal farmers (Rs. 1463/acre) on irrigating their Bt cotton fields.

In the case of small farmers, early adopters spend 40% more on weedicides and 27% more on pesticides as compared to late adopters; while late adopters spend 26% more than early adopters for use of irrigation facilities. Similar trend has been noticed in the case of medium farmers also, as early adopters spend 23% more than late adopters on weedicides and 13% on pesticides and more than 12% on seeds.

Thus, from these analyses, it becomes evident that marginal farmers form a distinct category in terms of use of the technology by incurring higher cost of production. In this regard, their experience (environmental learning) in Bt cotton does not seem to exert any significant influence in reducing the costs on the critical inputs, especially, pesticides, seeds, fertilisers and irrigation.

Performance of Bt cotton with respect to yield

In this section, we examine the performance of Bt cotton in Gujarat with respect to yield realised by the farmers. We try to contemplate on the yield performance at the district level, followed by yield performance disaggregated with respect to farmers' experience in adoption of Bt cotton as well as yield differences between approved and unapproved Bt varieties. Finally, we also examine whether yield differs across size classes of farmers with respect to their experience in Bt adoption and growing approved and unapproved Bt varieties.

Bt yield performance at the aggregate level

The performance of Bt at the district level is presented in Table 9. It shows that the average yield at the aggregate level is 7.7 quintals per acre. Among the seven districts, the highest yield was reported from Kutch (12.4 Qtl/acre) (one of the backward districts) and the lowest yield reported from Bharuch (4.4 Qtl/acre) and Vadodara (4.5 Qtl/acre) districts. The Table shows an interesting point that the districts, Kutch and Bhavnagar which reported the highest yields (12.4 Qtl/acre and 11.4 Qtl/acre respectively) also reported the lowest variability in yield as evident from the coefficient of variation (CV) in yield (27.43% and 39.57% respectively). However, in rest of the districts, the variability in yield has been very high with CV in yield ranging from 119.25% in Surendranagar to 47.28% in Bharuch.

Table 9. Yield of Bt cotton across sample districts in Gujarat

District	Mean yield (Qtl/acre)	No. of farmers	Std. Deviation	Coefficient of Variation (percentage)
1. Rajkot	6.0	32	3.4	57.47
2. Bhavnagar	11.4	40	4.5	39.57
3. Surendranagar	8.6	40	10.3	119.25
4. Kutch	12.4	41	3.4	27.43
5. Sabarkantha	6.2	40	4.4	71.37
6. Vadodara	4.5	40	2.2	48.10
7. Bharuch	4.4	40	2.1	47.28
Total	7.7	273	5.9	76.05

Bt yield performance: Early vs late adopters

As we have discussed in the case of cost of cultivation analysis, it is also important to see whether experience in Bt cultivation influences the yield performance of Bt varieties. In this regard, we tried to look the yield differences with respect to early and late adopting farmers. Accordingly, the results are presented in Table 10.

As Table 10 shows, early adopters have reported a

Table 10. Bt yield performance according to experience in Bt cultivation

Experience in Bt cultivation	Mean yield (Qtl/acre)	No. of farmers	Std. Deviation	CV (percentage)
1. Early adopters (4 to 7 years)	8.0	135	5.1	63.6
2. Late adopters (1 to 3 years)	7.4	134	6.6	88.9
Total	7.7	269	5.9	76.3

mean yield of 8 Qtl/acre as compared to late adopters (7.4 Qtl/acre) which is about 8% higher than the yield reported by late adopters. Though the yield difference is not of very significant proportion, the higher yield reported by the early adopters also has shown lower variability (CV=63.6%) as compared to late adopters (CV=88.9%).

Bt yield performance: Differences by Size class

In this sub-section, we examine the size class differences in yield of Bt cotton as reported by the farmers. We limit the analysis to three farmer categories, viz., marginal, small and medium farmers. The results of the analysis are presented in Table 11.

Table 11. Size-class differences in yield of Bt cotton

Size class	Mean yield (Qtl/acre)	No. of farmers	Std. Deviation	Coefficient of Variation (percentage)
1. Marginal	7.2	93 (34)	5.1	70.3
2. Small	8.4	68 (25)	8.0	95.6
3. Medium	7.9	105 (38)	4.9	62.5
Total	7.7	273 (100)	5.9	76.1

Note: Figures in parentheses indicate the respective shares in total.

Table 11 indicates that the mean yield of Bt cotton at 7.2 Qtl/acre as reported by the marginal farmers has been the lowest among the three categories of farmers. In other words, the mean yield realised by marginal farmers has been 16% lower than that realised by small farmers (8.4 Qtl/acre) and 9% lower than that realised by medium farmers (7.9 Qtl/acre). The variability in yield as reported by the marginal farmers has been reasonably high (CV=70%) compared to small farmers (CV=62.5%). It may be observed that for majority of the farmers who belong to the medium category (38%), the mean yield was 7.9 Qtl/acre, which also indicated lowest variability across the three groups.

Thus, to sum up, the foregoing analyses on the differences in comparative performance of Bt cotton show some interesting points discussed as follows:

1. The sampled farmers have shown clear distinction in terms of choice of Bt varieties;
2. The analysis examining the influence of experience in Bt on cost of production indicated that compared to late adopters, early adopters incurred 5.4% less paid out costs (Rs. 4863/acre compared to Rs. 5123/acre). However, early adopters incurred 17% more expenses on pesticides (Rs. 1585/acre) compared to late adopters (Rs. 1310/acre). In comparison to early adopters, late adopters have spent more on irrigation (Rs. 1317/acre against Rs. 876/ acre). Late adopters incurred 9% more than early adopters in terms of total cost of cultivation, including paid out costs.
3. Cost of cultivation has been found to be differing across size groups of farmers. In this regard, an interesting observation was that marginal farmers incur more costs compared to small and medium farmers. The average costs incurred by marginal farmers (Rs. 6005/acre) was 16% more than small farmers (Rs. 5020/acre) and 25% more than medium farmers (Rs. 4520/acre). Though the proportion of different input costs remained the same across size classes, marginal farmers spent more than small and medium farmers in all the inputs used. For instance, marginal farmers spent 11% more on seeds compared to small farmers and 19% more than medium farmers on seeds. Marginal farmers also spent 22% more than small farmers and 56% more than medium farmers on pesticides. From this, it may be surmised that marginal farmers use the technology in a more input intensive regime compared to small and medium farmers.
4. The analysis of performance of Bt cotton measured in terms of yield across districts revealed that the highest yield was reported from Kutch (12.4 Qtl/acre) and the lowest yield was reported from Bharuch (4.4 Qtl/acre) and Vadodara (4.5 Qtl/acre) districts. Kutch and Bhavnagar which reported the highest yields (12.4 Qtl/acre and 11.4 Qtl/acre respectively) also had the highest consistency in yield across Bt farms.
5. The analysis to see whether yield of Bt varies with respect to farmer experience in cotton revealed that early Bt adopting farmers had relatively higher yield (8 Qtl/acre) compared to late adopters (7.4 Qtl/acre). The yield realised by the early adopters was also consistent across farmers as evident from lower variability in yield.
6. Though marginal farmers incurred more costs for producing Bt cotton, they reported lower yield per farm. They realised only 7.2 Qtl/acre as against 8.4 Qtl/acre in the case of small and 7.9 Qtl/acre in the case of medium farmers.

In all cases, marginal farmers have reported higher

Table 12: Farmer responses about the benefits of Bt cotton in Gujarat (percentage of farmers)

Benefits of Bt cotton	Rajkot	Bhav-nagar	Surend-ranagar	Kutch	Sabar-kanta	Vado-dara	Baruch	Total
1. Reduced pesticide usage	25.0	47.5	50.0	54.8	95.0	40.0	97.5	59.5
2. Reduced incidence of bollworm	59.4	42.5	55.0	61.9	100	62.5	95.0	68.2
3. Reduced cost of cultivation	25.0	40.0	42.5	54.8	82.5	22.5	97.5	52.9
4. Increased yields	53.1	60.0	65.0	76.2	97.5	50.0	85.0	70.8
5. Better market prices	59.4	52.5	62.5	71.4	97.5	27.5	92.5	66.4
6. Early maturing	40.6	37.5	77.5	83.3	95.0	55.0	95.0	70.1
7. Another crop cultivated after harvesting Bt cotton	25.0	15.0	37.5	66.7	95.0	17.5	7.5	38.3
8. Easier picking	53.1	42.5	67.5	73.8	95.0	45	92.5	67.5
9. Good quality of cotton	62.5	50.0	65.0	92.9	92.5	52.5	97.5	73.7
Overall average	44.8	43.1	58.1	70.6	94.4	41.4	84.4	63.0

Source: Farm household survey, 2007–08.

costs of producing Bt cotton and much of the cost was accounted for by the paid out costs for purchase of seeds, pesticides and fertilisers. Marginal farmers also spent more to access irrigation facilities wherever possible. However, despite such high input/ cost intensive farm management practices, marginal farmers realised lower returns per unit area.

Bt cotton and inclusive technological outcomes

Reduction in pesticide usage, incidence of bollworms and cost of cultivation

In this section, we try to reflect upon the various developmental outcomes emerging from the Bt technology as reported by the farmers. The various developmental outcomes as perceived here relate to the benefits realized by the farmers following their adoption of Bt cotton over the past six to seven years. We tried to capture the developmental outcomes of Bt adoption in terms of varied benefits, viz. a) a reduction in pesticide use, incidence of bollworms and cost of cultivation; b) an increase in yield, better market prices, early maturing, possibility of other cropping, easy picking, etc; and c) realisation of good quality cotton (see Table 12).

1. ***Pesticide use:*** Only about 60% of the farmers have reported that the adoption of Bt varieties has resulted in a reduction in pesticide usage. The responses varied between districts, ranging from as low as 25% in Rajkot district to as high as 98% in Bharuch and 95% in Sabarkantha districts. Modest responses were given by farmers in rest of the four districts, ranging between 40–55%.
2. ***Incidence of bollworm:*** As regards incidence of attack by bollworms, 68% farmers feel that adoption of Bt varieties has significantly reduced the casualty, though with inter-district variations in responses. In Bhavnagar, Surendranagar and Rajkot, the percentage of farmers reporting a reduction in the incidence of bollworm due to Bt cotton adoption has been in the lowest ranges of 42–59% compared to higher ranges of 62–100% in rest of the districts.
3. ***Cost advantages:*** At the aggregate level, about 53% of the farmers reported that they were benefited by a reduction in cost of production, with significant inter-district variations in the cost reduction due to adoption of Bt cotton varieties. For instance, only in two districts, viz. Bharuch and Sabarkantha that majority of the farmers (97.5 and 82.5% respectively) have reported a reduction in cost of cultivation following Bt adoption. Whereas, in five districts, the percentages of farmers responding in favour of Bt cotton have been in the lower ranges of 25 to 55% with a combined mean of 37%, suggesting that hardly 37% of the farmers have been benefited by a reduction in cost of cultivation as caused by their technological shift towards Bt cotton.

4. ***Yield advantages:*** Yield advantages due to Bt adoption has been reported by 71% farmers at the aggregate level. Farmer responses in this regard was higher in Sabarkantha (98%), Bharuch (85%) and Kutch (76.2%) districts compared to relatively lower proportions reported from other districts, the combined average of the proportions being 57%.

5. ***Price advantages:*** On the question whether adoption of Bt yielded better market prices, 66% of the farmers reported having realized better prices at the aggregate level with inter-district variations. However, this reporting of realisation of better market prices by the farmers needs to be taken with pinch of caution, as the prevailing cotton prices in the country do not correspond with the qualitative changes in output that may have been brought out by the adoption of Bt technology.

6. ***Early maturity and harvest:*** Another anticipated benefit from adoption of Bt cotton was the shortened crop cycle or early maturity or harvest of the crop as the trait has been introduced in hybrid varieties with early maturity. Against this question, about 70% of the farmers have reported that the crop could be harvested within a shortened time frame. However, significant differences observed across districts as regards the farmer response, as, in two districts, Rajkot and Bhavnagar, the proportion of farmers indicating a positive outcome (of early maturity) has been as low as 40% and below.

7. ***Other cropping possibilities:*** It emerges from the above point that a vast majority of the farmers felt that Bt adoption does not enable them to raise other crops after harvesting Bt cotton. For instance, only 38% of the farmers reported that they could grow other crops after harvesting Bt cotton. The responses varied across districts from as low as 7.5% in Bharuch to 15% in Bhavnagar to as high as 67% in Kutch to 95% in Sabarkantha.

8. ***Easy plucking:*** Yet another beneficial outcome of Bt adoption was anticipated in terms of easiness of picking of the crop during harvest. In this case, almost 68% of the farmers reported that easy picking was a positive outcome of the Bt technology. Among the districts, four districts have shown higher positive farmer responses in this regard with responses varying from 68 to 95%. In rest of the three districts farmer responses varied between 43 to 53%.

9. ***Good quality of cotton:*** One of the important beneficial outcomes of Bt cotton adoption was thought to be a qualitative shift in cotton output. The farmer responses have shown that a vast majority of them (74%) were very much impressed by the better quality of output realised from Bt cotton. The farmer responses were as high as 63 to 98% in five of the seven districts and compared to 50–52% in rest of the two districts.

Though the farmers accord greater credence to qualitative changes caused by increased adoption of Bt varieties, it still remains an issue needing further empirical probing on the qualitative dimensions of Bt cotton, especially to prove the inclusiveness of the technology with respect to its impact on the farm livelihoods and welfare gains. As shown in Figure 5, farmers from Bharuch,

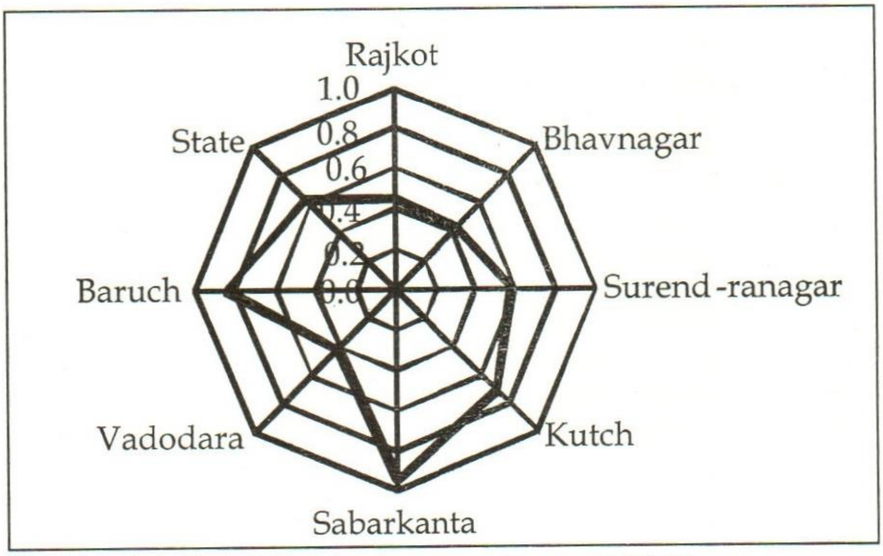

Figure 5: Overall performance of Bt cotton in Gujarat

Sabarkantha and Kutch have rated the overall performance of Bt cotton relatively higher than the farmers from other districts.

Does Bt cotton adoption bring forth inclusive farm growth?

The discussion in the earlier paragraphs showed that Bt cotton has been adopted by the medium, small and marginal farmers and in both developed and backward districts. To that extent, the technology has been inclusive in nature. Farmers have allocated mainly irrigated land for Bt cotton, the percentage of irrigated cotton being relatively lower only in two of the seven study districts. As, Bt cotton is a short duration crop and reaches harvesting stage early compared to the conventional long duration cotton, the yields are better in irrigated conditions (field observations based on interaction with farmers). Hence, farmers in predominantly rainfed conditions may not benefit more by adopting this technology. However, we restrain from saying so since our sample had consisted of farmers who had grown cotton mainly in irrigated conditions.

The cost analysis of the early and late adopters of the technology across size classes suggests that marginal farmers would be excluded from deriving the benefits of Bt technology if there is no state intervention in terms of providing extension services especially for rationalizing resource use for growing Bt cotton. Since Bt cotton is a biological technology rather than a mechanical technology, the productivity increase could be scale neutral implying that both marginal and small size holders could derive maximum benefits if the technology is adopted appropriately. Hence, extension services in the case of Bt technology is extremely important. As mentioned earlier, the Bt trait introduced in the plant offers resistance from bollworm, leading to reduction in pesticide use. However, farmers still need to spray pesticides for control of sucking pests. Here extension services are required to educate the farmers to identify the pest threshold limits and then resort to rational pesticide use instead of using a combination of chemicals that might not only turn to be ineffective on the pest complex but also lead to disastrous environmental outcomes. Bt technology yields better when adopted with IPM technologies (Tripp, 2009). However, the sample farmers are not aware of the IPM practices or other biosafety measures that need to be adopted along with the Bt technology.

Also, in India, the Bt trait has been introduced in the hybrids than in the varieties, which may be early maturing or long duration variety. Particularly in the early maturing variety, while the initial two or three pickings would be of very high quality, the later pickings tend to have lower quality output according to scientists. Hence, if the farmers have appropriate information about the varieties that they buy, then depending on the resource endowments of the farmer, they could decide on cultivating another crop to maximize farm income.

Conclusions

This article examines the inclusive nature of Bt cotton adoption among farmers in 7 cotton growing districts of Gujarat. It analysed (1) the rationale behind seed choice made by the farmers; (2) difference in the cost of production and the yield between early and late adopters of technology; and (3) the rating of the overall performance of Bt cotton by farmers across districts. The analysis revealed that Bt cotton adoption has been quite dramatic especially among the marginal and small farmers in the state. It reveals that farmers make rational choice regarding the seed by experimenting with a smaller plot of land for a newer variety and depending on the outcome, allocate larger plot of land for that variety. Though, the marginal farmers seemed to be incurring more costs towards other inputs such as pesticides, fertilisers and irrigation as compared to the other size holders, the yield reported by them is relatively less than the other adopters. Though no trend emerges regarding the cost of production for early and late adopters, early adopters realised a better yield as compared to the late adopters. More than 60% of the farmers have reported the overall performance of Bt cotton in terms of: (1) reduced pesticide use, incidence of bollworm, cost of cultivation; (2) increased yield and market prices; (3) early maturing; (4) easier picking and good quality of cotton. The overall trends with the experience of the marginal farmers who have incurred higher input costs compared to others, suggest that institutional interventions are imperative especially for providing extension services to help the farmers in choosing the right kind of varieties, chemical inputs and timing of the spraying. This intervention would ensure that the benefits from the technology are realised by the marginal farmers as well and they are not excluded from the agricultural growth process in Gujarat stimulated by the GM technology. Since the Bt technology in India has been dominantly propagated by the private sector which does not go beyond marketing of the seeds, the conventional state driven extension and support services will have to be strengthened to help the marginal farmers to internalise the benefits arising from the increased adoption of the Bt technology.

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References

Bhalla G S and Singh Gurmail (2009): *Economic Liberalisation and Indian Agriculture- A District Level Study*, Sage Publications New Delhi.

Gandhi Vasant and Namboodiri N V, (2010): "The Economics and Contribution of Cotton Biotechnology in the Agricultural Growth in Gujarat', in Dholakia Ravindra and Datta K Samar (eds.), *High Growth Trajectory and Structural Changes in Gujarat's Agriculture*, Centre for Monitoring Agriculture Publication no. 234, Indian Institute of Management, pp. 39-62.

Lalitha, N and Ramaswami Bharat (2007): "Pesticide Use Pattern among Cotton Cultivators in Gujarat', in Ravindra Dholakia (Ed.) *Frontiers of Agricultural Development in Gujarat*, Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad, pp. 77-98.

Lalitha N, Ramaswami Bharat and Viswanathan P K (2009): "India's Experience with Bt Cotton: Case Studies from Gujarat and Maharashtra', in Robert Tripp (ed), *Biotechnology and Agricultural Development Transgenic Cotton, Rural Institutions and Resource-poor Farmers*, Routledge, UK.

Qaim, M (2003): Bt cotton in India: Field trial results and economic projections', *World Development*, 31: 2115-27.

Shah, Tushaar; Ashok Gulati; Hemant P; Ganga Shreedhar and R C Jain (2009): "Secret of Gujarat's Agrarian Miracle after 2000', *Economic and Political Weekly*, 44 (52): 45-55 (December 26).

Stone, Glenn (2007): "Agricultural deskilling and the spread of genetically modified cotton in Warangal', *Current Anthropology*, 48: 67-103.

Tripp Robert (2009): "Biotechnology and Agricultural Development', in Tripp Robert (ed.), Biotechnology and Agricultural Development: Transgenic Cotton, Rural Institutions and Resource-poor Farmers. Oxon/ New York: Routledge, UK, pp. 1-22.

> *"Science cuts two ways, of course; its products can be used for both good and evil. But there's no turning back from science. The early warnings about technological dangers also come from science."*
>
> ***—Carl Sagan***

Technical Efficiency of Indian Pharmaceutical Firms: A Stochastic Frontier Function Approach

SANJA SAMIRANA PATTNAYAK AND ALKA CHADHA

Based on the framework of Battese and Coelli (1992), we estimate the stochastic frontier production function for 76 Indian pharmaceutical firms during 1991–2003. The stochastic frontier production function model with time-varying firm effects reveals that for the pharmaceutical industry as a whole, the technical efficiency has improved over the period 1991–2003. The patenting firms are found to be more technically efficient than their non-patenting counterparts.

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The pharmaceutical industry in India is going through a period of transition driven by a combination of external forces and internal productivity challenges. On the one hand, the Uruguay Round of Trade Negotiations of the General Agreement of Tariffs and Trade (GATT) has sought to strengthen the patent protection provided to pharmaceutical products in countries like India and on the other hand, economic reforms in India have sought to deregulate the pharmaceutical industry through lesser price controls. The Indian Patent Act, 1970, provided only for process patents in the field of pharmaceuticals, but with the World Trade Organization (WTO), India now provides for both product and process patents for pharmaceuticals since 2005. Thus, the Indian pharmaceutical firms have to gear up to the challenge of facing competition from pharmaceutical multinational companies (MNCs), because now these MNCs can launch new drugs in the domestic market without fear of being imitated and sold at cheaper rates by the Indian firms.

Further, the decade of the 1990s saw major policy changes for the pharmaceutical industry in India. These included greater liberalization of import policies, foreign equity participation, and price decontrol. In 1994, the New Drug Policy was announced which pruned the list of controlled drugs and allowed imports of bulk drugs. The greater competition heralded by deregulation and 100 percent foreign direct investment (FDI) in this sector led to a wave of mergers and acquisitions with a trend toward consolidation.

The Indian pharmaceutical industry ranks third worldwide in generic drugs, accounting for one-tenth of the world's production by volume. Indian pharmaceutical exports have risen sharply over the years by adopting stringent quality control in formulation manufacturing. The advantage of Indian firms lies in their ability to do low-cost reverse engineering and process innovation for generic drugs by employing skilled manpower in the fields of molecular biology, biotechnology, and chemistry. Moreover, the growth of the US and the EU generic markets over the past few years driven by patent expirations and concerns of rising health care costs, has also promoted Indian drug exports (Chadha, 2009).

Given the dynamic nature of the pharmaceutical sector coupled with the introduction of a new patent regime on January 1, 2005, we think it is important and appropriate to examine whether the internal efficiencies of individual pharmaceutical firms have undergone any change. This article attempts to estimate the technical efficiency of pharmaceutical firms using stochastic frontier production function for the industry as a whole and for sub-samples of patenting and non-patenting firms. We compare the efficiency of patenting and non-patenting pharmaceutical firms by using maximum likelihood estimates of the stochastic frontier production functions. The article contributes to the literature on technical efficiency by using an unbalanced firm-level panel data for Indian pharmaceutical firms and examines the impact of stronger patent protection and deregulation on their efficiency. The article is organized as follows: the second section outlines the literature review, the third section discusses the research methodology, the fourth section discusses the data sources, the fifth section analyzes the empirical results, and the sixth section concludes the discussion.

Literature Review

Technical efficiency can be studied using parametric and non-parametric methods. Stochastic Frontier Analysis (SFA) is a parametric method which measures technical efficiency and assumes a functional form. Data Envelopment Analysis (DEA), on the other hand, is a non-parametric method which uses linear programming model (Charnes et al., 1978).

The SFA and DEA methods have their own pros and cons. The SFA method can statistically test hypotheses and construct confidence intervals allowing for random errors. However, it may lose some flexibility in model specification (Hjalmarsson et al., 1996). The model, if misspecified, may give rise to the problem of multicollinearity and some theoretical restrictions may also be violated. It is possible to distinguish the effects of statistical noise from random errors when applying the SFA method to measure production inefficiency. But the DEA method cannot separate the statistical noise or the measurement errors from random errors. Thus, the relative efficiency scores obtained from DEA may be confused with effects from the uncontrollable factors. It is in fact a deficiency of the nonstochastic DEA. However, a regression analysis (Ray, 1991) and a Tobit model can be helpful to eliminate the effects of these uncontrollable factors (McCarty and Yaisawarng, 1993; Ruggiero and Vitaliano, 1999; Chakraborty *et al.*, 2001). Since the objective of our article is simply to estimate the technical efficiency of the Indian pharmaceutical firms and not many studies are found to have used SFA analysis in this context, it motivated us to use this analysis in our study.

The concept of technical efficiency dates back to the work of Debreu (1951) and Koopmans (1951), when both scholars addressed the issue of efficiency in the economics literature. Farrel (1957) built on earlier work to introduce the notion of efficiency measurement. Recognizing this, Aigner et al. (1977) and Meeusen and Van den Broeck (1977) introduced the stochastic production frontier model, which is an important contribution to the econometric modelling of production and estimation of technical efficiency of firms in an industry.

Researchers have used SFA to measure technical efficiency of the industrial firms in other sectors in India and other developing economies. Battese and Coelli (1992, 1995), using stochastic frontier production function model with time varying firm effects for Indian agricultural firms, find that technical efficiency of the farmers are not time invariant when year of observations are not included in the stochastic frontier. Pillai and Srinivasan (1992) and Majumdar (1997) examine the impact of age on technical efficiency of firms and find that older firms in the industrial sector in India are more efficient. Meanwhile, Huang and Liu (1994) find that older firms are less efficient compared to newer firms. Azizul et al. (2009) using SFA for Bangladesh manufacturing industry show that technical inefficiency declined over the period of study.

Technical efficiency may be defined in different ways (Fare et al., 1985). The present study defines technical efficiency of a given firm (at a given time period) as the ratio of its mean production to the corresponding mean production if the firm utilized its levels of inputs most efficiently (Battese and Coelli, 1989). In this study we have used a stochastic frontier production function model for panel data, in which technical efficiencies of firms may vary over time.

The advantage of using panel data is that it gives us the flexibility to examine the model behaviour of technical efficiency over time. The earlier models—Schmidt and Sickles (1984) and Kumbhakar (1987), among others—treated technical efficiency as time invariant. In later studies, researchers allowed technical efficiency to vary over time, but modelled efficiency as a systematic function of time (Kumbhakar, 1990; Cornwell et al., 1990; Battese and Coelli, 1992, 1995; Lee and Schmidt, 1993).

Methodology

This article uses the panel data model proposed by Battese and Coelli (1992, 1995). We have considered the following stochastic frontier production function with exponential specification of time-varying firm effects.

$$Y_{it} = f(X_{it}, \alpha, t) \exp(v_{it} - u_{it}) \tag{1}$$

$$u_{it} = \zeta_t u_i = \{\exp(-\eta(t - T))\} u_i \text{ where } \zeta_t = \exp(-\eta(t - T)) \tag{2}$$

where i and t are firm and time subscripts. Y_{it} is the output, X_{it} is a vector of inputs and α is a vector of parameters to be estimated. The error term v_{it} is distributed as $N(0, \sigma_v^2)$ and captures random variation in output due to factors not under the control of the firms. The term u_{it} is the technical inefficiency η and is an unknown scalar parameter. This model considers the non-negative firm effects and u_{it} increase, decrease or remain constant with time depending on $\eta < 0$, $\eta > 0$ or $\eta = 0$, respectively. $\eta < 0$, implies that firms improve their level of technical efficiency over time $\tau(i)$ is the set of T_i time period among the T period for which observations for the i^{th} firm are obtained. If observations are obtained at discrete intervals, then would be considered as a subset of the integers, 1, 2, ..., T denoting the periods of observations involved. In the present study, we expect technical efficiency to increase for those pharmaceutical firms that engage in R&D and patenting activities. Further, the parameters μ and σ^2 define the statistical properties of the firm effects associated with the terminal period for which we have observation since in the Tth time period for the firm, i^{th}, where $\mu_{it} = u_i$. The model assumption of firm effects as proposed by Stevenson (1980) is a generalization of the half-normal distribution. The exponential specification of the behaviour of the firm effects over time has a rigid parameterization such that technical efficiency must either increase at a decreasing rate ($\eta < 0$) or decrease at an increasing rate ($\eta > 0$), or remain constant ($\eta = 0$). We have used the composed error terms of the stochastic frontier model specified in equation 1 to estimate the total variation in output from the frontier level of output which is attributed to technical efficiency and is defined by the $\gamma = \sigma_u^2 / \sigma_s^2$, where $\sigma_s^2 = \sigma_u^2 + \sigma_v^2$. The ratio lies in the interval [1,0]. The positive ratio implies that firm-specific technical efficiency is important in explaining the total variability of output produced.

From equations (1) and (2), it can be shown that the minimum mean-squared-error predictor of the technical efficiency of the i^{th} firm at the i^{th} time period can be given as follows:

$$TE_{it} = \exp(-u_{it}) \tag{3}$$

$$= E\left[\exp(-u_{it}) \mid E_i\right] = \left\{ \frac{1 - \phi\left[\eta_{it}\sigma_i^* - \left(\mu_i^* / \sigma_i^*\right)\right]}{1 - \phi\left(-\mu_i^* / \sigma_i^*\right)} \right\} \exp\left[-\eta_{it}\mu_i + \frac{1}{2}\eta_{it}^2 \sigma_i^{*2}\right] \tag{4}$$

where $E_{it} = u_{it} - v_{it}$ and E_i represents the $(T_i \times 1)$ vector of E_{it}'s associated with the time periods observed for the ith firm.

$$\mu_i^* = \frac{\mu\sigma_v^2 - \eta_i' E_i \sigma^2}{\sigma_v^2 + \eta_i' \eta_i \sigma^2} \tag{5}$$

$$\sigma_i^{*2} = \frac{\sigma_v^2 \sigma^2}{\sigma_v^2 + \eta_i' \eta_i \sigma^2} \tag{6}$$

where, η_i represents the $(T_i \times 1)$ vector of η_{it}'s associated with the time periods observed for the i th firm,and $\phi(.)$is the distribution function for the standard normal random variable. The predictor of technical efficiency defined in equation (4) can be obtained by substituting the appropriate parameters by their maximum likelihood estimators (Coelli, 1991).

Data and Variables

The study is based on data for pharmaceutical firms including biotechnology firms provided by the Prowess database of the Centre for Monitoring Indian Economy (CMIE) over the period 1991–2003. Of the total firms, 30 are foreign-owned companies and the rest are Indian companies. For the econometric study, the dataset includes only those firms that report some R&D spending. This results in an unbalanced panel of 76 firms with 716 total observations. The data on patents granted is obtained from the *Gazette of India*, Part III, Section 2.

The capital variable is the value of net fixed assets deflated by capital stock deflator. The capital stock deflator uses base year 1995 and is a weighted average of the price index of construction and plant and machinery published by the Central Statistical Organization's (CSO) *Monthly Abstract of Statistics* for various years. The weights are derived as the relative shares of construction and plant and machinery given in the *National Income Accounts*, January 2004, published by CMIE.

The CMIE database does not report the number of employees in a firm. The series on labor was generated by dividing the data on firm-wise wages and salaries with the wage rate (total emoluments/number of employees) for the pharmaceutical industry obtained from various issues of the *Annual Survey of Industries, Summary Results Factory Sector* published by the CSO.

We used the perpetual inventory method to construct own technology stock of the firm, given as $RD_{it}(1-\delta) RD_{i,t-1} + R_{i,t}$; where $RD_{i,t-1}$ is the stock of R&D by firm i at time t – 1 and δ is the rate of depreciation to technical knowledge. And R_{it} is the new investment on R&D. Following earlier studies we take the depreciation rate of 15%. The R&D stock deflator (base year 1995) was constructed as a weighted average of the capital stock deflator and the consumer price index for urban non-manual employees obtained from the Government of India's *Economic Survey, 2003-04*. The weights for capital and labour were determined by wages/net sales and net fixed assets/net sales, respectively for each firm.

Empirical Results

The stochastic frontier production function for the panel data of Indian pharmaceutical firms is estimated as follows.

$$y_{it} = \beta_0 + \beta_1 k + \beta_2 l + \beta_3 rd + \beta_4 WTOD + \beta_5 PATD + v_{it} + u_{it} \quad (7)$$

The lowercase letter represents the logarithmic transformation of the variables. Gross value added is represented by y_{it}, k represents capital l for labor and represents the stock of R&D. To examine the impact of the setting up of the WTO and a stronger patent regime, we introduce a dummy that takes the value 1 for 1996 onwards and 0 otherwise. A dummy for patenting firms is also used to see the technical efficiency of firms that successfully engage in R&D and patenting activities, thus *PATD* takes the value 1 for the year that a patent is granted to a given firm and 0 otherwise. v_{it} and u_{it} are random variables whose distributional properties are previously explained in the third section. We have five different models and Maximum-likelihood estimates for these parameters are calculated for these models—Model 1: we estimate all parameters; Model 2: we assume $\mu = 0$; Model 3: we assume $\eta = 0$; Model 4: $\mu = \eta = 0$ and Model 5: $\gamma = \mu = \eta = 0$.

Model 1 is the stochastic frontier production function (7). In this model, the firm effects u_{it}, have the time varying structure. In Model 2, u_i's the have half normal-distribution ($\mu_i = 0$). Model 3 is the time invariant model (Battese et al., 1989). Model 4 is the time-invariant model and the firm effect μ_i in this model follows a half normal distribution. Finally, Model 5 is the average response function and firms in this model are assumed to be fully technically efficient. This means that firm effects μ_{it} are not present in the model.

The results for the aforementioned five models are presented in tables 1, 2, and 3 for three different cases namely, all firms, non-patenting firms, and patenting firms. In tables 4A, 4B, and 4C, we test the hypotheses for the parameters of the distributions of the random variable (firm effects). They are obtained by using the generalized likelihood ratio statistic. The null hypothesis, $H_0: \gamma = \mu = \eta = 0$, is rejected for both the full sample and the sub-sample of patenting and non-patenting firms. It implies that given the specifications of the stochastic frontier with time-varying firm effects, the usual production function is not an adequate representation of our data. We have also tested for the time-invariant models for firm effects. We reject both $H_0: \mu = \eta = 0$ and $H_0: \eta = 0$ to support the above hypothesis. This is also valid for both the full sample and the sub-samples.

We do not reject the hypothesis of the half normal distribution of u_{it}. Thus, given that the half normal distribution is an adequate representation of firm effects, we reject the hypothesis that the yearly firm effects are time invariant. Based on the results, it is evident that the hypothesis of time-invariant technical efficiencies for pharmaceutical firms would be rejected for the full sample. The estimated η from the exponential model in equation (2) is negative for both the full sample and the sub-sample of patenting firms, but positive for non-patenting firms. This means technical efficiency is increasing over time for the pharmaceutical industry as a whole and also for the firms engaged in patenting activities. However, efficiency for non-patenting firms shows a declining trend. Thus, it seems that increasing efficiency of the full sample is probably due to the predominant effect of patenting firms in the industry.

The estimated results of the stochastic production frontier given in equation (7) are reported for the full sample (Table 1), the sample of non-patenting firms (Table 2), and sample of patenting firms (Table 3). We notice that the coefficient estimates of all observable variables are of expected signs. The coefficients for the WTO dummy and

Table 1. Maximum-likelihood estimates of parameters of stochastic production functions for Indian pharmaceutical firms: Full sample

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
ln (R&D)	0.116*** (.020)	0.118*** (0.019)	0.120*** (0.018)	0.117*** (0.021)	0.115*** (0.024)
ln (capital)	0.092*** (0.023)	0.094*** (0.025)	0.094*** (0.023)	0.093*** (0.027)	0.091*** (0.029)
ln (labor)	0.536*** (0.035)	0.538*** (0.038)	0.545*** (0.039)	0.542*** (0.035)	0.535*** (0.037)
WTO Dummy	0.061** (0.031)	0.060*** (0.030)	0.061*** (0.031)	0.062** (0.032)	0.062*** (0.031)
Patent Dummy	0.013* (0.0075)	0.011 (0.0072)	0.012* (0.0079)	0.013* (0.0076)	0.014* (0.0081)
Constant	3.977*** (0.207)	3.976*** (0.206)	3.978*** (0.208)	3.980*** (0.212)	3.976*** (0.215)
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$	0.060*** (0.0088)	0.057*** (0.0084)	0.065*** (0.0087)	0.064*** (0.0079)	0.066*** (0.0089)
$\gamma = \frac{\sigma_u^2}{\sigma_s^2}$	0.623*** (0.058)	0.615*** (0.054)	0.568*** (0.059)	0.589*** (0.062)	0
μ	0.460*** (0.110)	0	0.462*** (0.129)	0	0
η	−0.034 (0.023)	−0.031 0 (0.027)	0	0	
Log likelihood	228.165	228.167	238.166	238.165	238.168

Notes: Standard errors are given in parenthesis

***, **, * denote significance levels at 1, 5 and 10%.

Table 2. Maximum-likelihood estimates of parameters of stochastic production functions for Indian pharmaceutical firms: Non-patenting firms

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
ln (R&D)	0.104*** (0.027)	0.106*** (0.029)	0.105*** (0.024)	0.107*** (0.024)	0.103*** (0.027)
ln (capital)	0.216*** (0.044)	0.103*** (0.046)	0.218*** (0.044)	0.216*** (0.045)	0.218*** (0.044)
ln (labor)	0.405*** (0.039)	0.382*** (0.033)	0.388*** (0.038)	0.400*** (0.037)	0.401*** (0.035)
WTO Dummy	0.031* (0.0171)	0.032* (0.0173)	0.030* (0.0170)	0.0312* (0.0172)	0.0313* (0.0174)
Constant	3.448*** (0.320)	3.442*** (0.319)	3.445*** (0.321)	3.452*** (0.341)	3.446*** (0.318)
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$	0.095*** (0.030)	0.098*** (0.031)	0.097*** (0.041)	0.092*** (0.032)	0.093*** (0.033)
$\gamma = \frac{\sigma_u^2}{\sigma_s^2}$	0.731*** (0.088)	0.752*** (0.085)	0.777*** (0.086)	0.735*** (0.076)	0
μ	0.290*** (0.126)	0	0.295*** (0.129)	0	0
η	0.017 (0.011)	0.019 (0.012)	0	0	0
Log likelihood	134.801	142.796	141.765	140.834	142.560

Notes: Standard errors are given in parenthesis

***, **, * denote significance levels at 1, 5 and 10%.

Table 3. Maximum-likelihood estimates of parameters of stochastic production functions for Indian pharmaceutical firms: Patenting firms

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
ln (R&D)	0.183*** (0.020)	0.134*** (0.021)	0.136*** (0.022)	0.131*** (0.021)	0.137*** (0.025)
ln (capital)	0.380*** (0.028)	0.371*** (0.026)	0.371*** (0.028)	0.376*** (0.029)	0.369*** (0.026)
ln (labor)	0.461*** (0.034)	0.446*** (0.032)	0.459*** (0.037)	0.459*** (0.032)	0.458*** (0.033)
WTO Dummy	0.051*** (0.0161)	0.0525*** (0.0183)	0.050*** (0.0150)	0.0543*** (0.0162)	0.0551*** (0.0164)
Constant	1.912*** (0.139)	1.908*** (0.137)	1.917*** (0.136)	1.915*** (0.136)	1.913*** (0.134)
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$	0.069*** (0.0089)	0.068*** (0.0085)	0.069*** (0.0088)	0.070*** (0.0087)	0.067*** (0.0085)
$\gamma = \frac{\sigma_u^2}{\sigma_s^2}$	0.621*** (0.058)	0.620*** (0.056)	0.621*** (0.054)	0.619*** (0.053)	0
μ	1.460*** (0.112)	0	1.452*** (0.115)	0	0
η	–0.068*** (0.023)	–0.068*** (0.021)	0	0	0
Log likelihood	131.965	132.987	131.884	132.564	132.432

Notes: Standard errors are given in parenthesis

***, **, * denote significance levels at 1, 5 and 10%.

Table 4A.Test of hypothesis for parameters of the distribution of the firm effects, μ_{it}, for all firms

Assumptions	Null Hypothesis	χ^2 - Statistic	$\chi^2_{0.95}$ - value	Decision
Model 1	$\gamma = \mu = \eta = 0$	15	8.67	Reject H_0
Model 2	$\mu = \eta = 0$	18.02	7.87	Reject H_0
Model 3	$\mu = 0$	0.03	6.69	Accept H_0
Model 4	$\gamma = \eta = 0$	17.23	7.87	Reject H_0
Model 5	$\eta = 0$	22.45	6.69	Reject H_0

Table 4B.Test of hypothesis for parameters of the distribution of the firm effects, μ_{it}, for patenting firms

Assumptions	Null Hypothesis	χ^2 - Statistic	$\chi^2_{0.95}$ - value	Decision
Model 1	$\gamma = \mu = \eta = 0$	13.00	7.76	Reject H_0
Model 2	$\mu = \eta = 0$	16.02	7.33	Reject H_0
Model 3	$\mu = 0$	0.02	5.65	Accept H_0
Model 4	$\gamma = \eta = 0$	15.22	6.87	Reject H_0
Model 5	$\eta = 0$	19.65	6.34	Reject H_0

Table 4C.Test of hypothesis for parameters of the distribution of the firm effects, μ_{it}, for non-patenting firms

Assumptions	Null Hypothesis	χ^2 - Statistic	$\chi^2_{0.95}$ - value	Decision
Model 1	$\gamma = \mu = \eta = 0$	12.00	7.25	Reject H_0
Model 2	$\mu = \eta = 0$	15.02	7.12	Reject H_0
Model 3	$\mu = 0$	0.01	5.77	Accept H_0
Model 4	$\gamma = \eta = 0$	14.35	6.57	Reject H_0
Model 5	$\eta = 0$	16.35	6.05	Reject H_0

the patent dummy in the full sample have a positive sign and are statistically significant. It should also be noted that the parameters γ and σ_S^2 of the ML estimation are statistically significant and the log-likelihood value is high enough to surpass the critical value. η is statistically different from zero and indicates a time-varying technical efficiency of the sample firms.

Technical efficiency

As stated above, a firm is said to be technically efficient if the estimated technical efficiency coefficient is 100% and technically inefficient otherwise. This means that if an inefficient firm utilizes its factors of production as effectively as an efficient firm does, it should be able to increase its current output to the level that the efficient firm could achieve using the same factor inputs without increasing its current factor inputs. Using the estimated parameter values for the frontier production function (7), predictions were obtained for the technical efficiencies (4) of individual firms. The average technical efficiencies for the full sample and sub-sample of patenting and non-patenting firms have been calculated and are presented in Table 5. We have divided the whole period (1991–2003) into three sub-periods to examine the gradual change in technical efficiency starting from the time of liberalization (1991) till the enforcement of the WTO provisions (2003), that is, 1991–94; 1995–98; 1999–2003, and 1991–2003.

Table 5. Average technical efficiency among all, patenting, and non-patenting firms 1991–2003

Types of Firms	Avg. 1991–94	Avg. 1995–98	Avg. 1999–03	Avg. 1991–03
All Firms	0.62	0.64	0.69	0.68
Patenting Firms	0.89	0.93	0.95	0.92
Non-patenting Firms	0.59	0.63	0.65	0.62

Note: We have taken the four yearly average of the estimated technical efficiency for individual firms.

We observe a gradual improvement in technical efficiency in all types of firms over the period under study. For the sub-period, 1999–2003, when the WTO provisions were enforced to strengthen patent rights for pharmaceuticals, the patenting firms almost reached the frontier, suggesting that stronger patent laws induce greater R&D efforts and improve efficiency. However, the average technical efficiency of all firms for the same period was 0.69, implying that the improvement in technical efficiency for patenting firms was unable to push the industry's output as a whole close to the potential output level. Further, the differences between technical efficiency of patenting and non-patenting firms should also be noted. While the technical efficiency for non-patenting firms are below average for all firms, that of patenting firms is above average for all firms. This is another indication of economies of scale in patenting firms, that is, patenting firms are able to achieve their potential efficient output by utilizing their production facilities more effectively than their non-patenting counterparts. Thus, we find that firms engaged in patenting activities are more efficient in a research-intensive industry like pharmaceuticals even in developing countries like India.

Conclusions

This article examines the technical efficiency of the Indian pharmaceutical industry in the light of policy changes in the international and domestic environment since 1995. We find that for the industry as a whole, there is evidence of time-varying technical efficiency for the sample firms.

The main hypothesis that the setting up of the WTO and the deregulation of the pharmaceutical industry in India has improved the efficiency of the industry is supported by the results of the study. The favourable impact of the WTO and liberalization of the industry on output is evident from the positive and significant sign of the WTO dummy. Moreover, the results on technical efficiency show that patenting firms are close to the frontier and utilize the factors inputs efficiently. Thus, the new WTO regime of stricter patent rights has provided a stimulus to patenting firms to undertake greater R&D activities in order to effectively compete with pharmaceutical MNCs (Jha, 2007) and are also collaborating with research laboratories (FICCI, 2005). It is likely that the stronger patent laws may stimulate even the non-patenting firms to become more research-oriented and efficient in the long run.

References

Aigner, D. J., C. A. K. Lovell, and P. Schmidt. 1977. Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics* 6: 21-37.

Azizul, B. Md., A. A. Kalim, and K. Fatima. 2009. Technical efficiency in stochastic frontier production model: An application to manufacturing industry in Bangladesh. *Australian Journal of Basic and Applied science* 3, no. 2: 1160-1169.

Battese, G. E., and T. J. Coelli. 1988. Prediction of firm-level technical efficiencies: with a generalized frontier production function and panel data. *Journal of Econometrics* 38: 387-399.

Battese, G. E., T. J. Coelli, and T. C. Colby. 1989. Estimation of frontier production functions and the efficiencies of Indian farms using panel data from ICRISAT's village level studies. *Journal of Quantitative Economics* 5: 327-348.

Battese, G. E., and T. J. Coelli. 1992. Frontier production functions, technical efficiency and panel data with application to paddy farmers in India. *Journal of Productivity Analysis* 3: 153-169.

Battese, G. E., and T. J. Coelli. 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics* 20: 325-332.

Chadha, A. 2009. Product Cycles, Innovation and Exports: A Study of Indian Pharmaceuticals. *World Development* 37, no. 9: 1478-1483.

Chakraborty, K., B. Biswas, and W. C. Lewis. 2001. Measurement of technical efficiency in public education: A stochastic and nonstochastic production function approach. *Southern Economic Journal* 67, no. 4: 889-905.

Charnes, A., W. W. Cooper, and E. Rhodes. 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research* 2: 429-444.

Coelli, T. J. 1991. Maximum-likelihood estimation of stochastic frontier production functions with time varying technical efficiency using the computer program, FRONTIER Version 2.0, *Working Papers in Econometrics and Applied Statistics* No. 57, Department of Econometrics, University of New England, Armidale, 45.

Cornwell, C., P. Schmidt and R. C. Sickles. 1990. Production frontiers with cross-sectional and time-series variation in efficiency levels. *Journal of Econometrics* 46: 185-200.

Debreu, G. 1951. The Coefficient of Resource Utilization. *Econometrica* 19, no. 3: 273-292.

Fare, R. E., S. Grosskopf, and C. A. K. Lovell. 1985. The measurement of efficiency of production. *Dordrecht: Kluwer-Nijhoff.*

Farrell, M.J. 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society Series A*, 120, no. III: 253-281.

Federation of Indian Chamber of Commerce and Industries (FICCI). 2005. Competitiveness of the Indian Pharmaceutical Industry in the New Product Patent Regime. *FICCI Report* for National Manufacturing Competitiveness Council, New Delhi.

Government of India, *Gazette of India, Part III, Section 2*, various years.

Government of India, Economic Survey, various years.

Hjalmarsson, L., S. C. Kumbhakar, and A. Heshmati. 1996. DEA, DFA and SFA: A comparison. *Journal of Productivity Analysis* 7, no. (2/3): 303-328.

Huang, C., and J. T. Liu. 1994. Analysis of a non-neutral stochastic frontier production function. *Journal of Productivity Analysis* 5: 171-80.

Jha, R. 2007. Options for Indian Pharmaceutical Industry in the Changing Environment. *Economic and Political Weekly* 42, no. 39: 3958-3967.

Koopmans, T.C. 1951. An analysis of production as an efficient combination of activities' T.C. Koopmans ed. Activity analysis of production and allocation, Cowles Commission for Research in Economics. Monograph no. 13, New York, Wiley.

Kumbhakar, S. C. 1987. The specification of technical and allocative efficiency in stochastic production and profit frontiers. *Journal of Econometrics* 34: 335-48.

Kumbhakar, S. C. 1990. Production frontiers, panel data, and time – varying technical inefficiency. *Journal of econometrics* 46: 201-12

Lee, Y. H. and P. Schmidt. 1993. A production frontier model with flexible temporal variation in technical inefficiency, in the measurement of productive efficiency: Techniques and applications', (Ed). H.O. Fried, C. A. K, Lovell and S.S. Schmidt, Oxford University Press, New York.

Majumdar, S. K. 1997. The impact of size and age on firm-level performance: some evidence from India. *Review of Industrial Organization* 12: 231-241.

McCarty, T. A., and S. Yaisawarng. 1993. Technical efficiency in New Jersey school districts. In: The Measurement of Productive Efficiency', Techniques and Applications. H. Fried, K.C.A. Lovell, and Schmidt, eds. Oxford Univ. Press, New York.

Meeusen, W. and J. Van den Broeck. 1977. Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review*18: 435-444.

Pillai, P. M. and J. Srinivasan. 1992. The age and productivity of machine tools in India'. In: Indian Industrialization', A. Ghosh, K.K. Subramanian, M. Eapen, H.A. Drabu (ed.), Delhi: Oxford University Press.

Ray, S. C. 1991. Resource-use efficiency in public schools: A study of Connecticut data. *Management Science* 37: 1621-1628.

Ruggiero, J. and D.F. Vitaliano. 1999. Assessing the efficiency of public schools using data envelopment analysis and frontier regression. *Contemporary Economic Policy* 17, no. 3: 321-331.

Schmidt, P. and R. C. Sickles. 1984. Production frontiers and panel data' *Journal of Business and Economic Statistics* 2: 367-74.

Stevenson, R. F. 1980. Likelihood functions for generalized stochastic frontier estimation. *Journal of Econometrics* 13: 57-66.

"Climate change, Urbanization, Biotechnology. Those three narratives, still taking shape, are developing a long arc likely to dominate this century."

—Stewart Brand

Feature

Micro, Small and Medium Enterprises in India: Trends, Composition, Issues and Challenges

KULDIP S. CHHIKARA AND ANAND S. KODAN

In this article we have analyzed the trends, composition, regional pattern, issues, and challenges of micro, small, and medium enterprises (MSMEs) in India with the help of appropriate statistical tools and techniques. The study clearly indicates that the Indian MSMEs are facing many challenges, such as technological gap, finance, marketing, government support, lack of infrastructure. On the basis of foregoing analysis we have made some viable suggestions for removal of problems faced by the enterprises are made to make them self-sufficient and effective for the development of the nation.

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The Small Scale Industries (SSIs),[1] including Khadi and Village/Rural Enterprises (KVI) [2] credited with generating the highest rates of employment growth, account for a major share of industrial production and exports[3]. They also play a key role in the development of economies with their effective, efficient, flexible, and innovative entrepreneurial spirit[4]. The socio-economic policies adopted by India since the Industries (Development and Regulation) Act 1951 have laid stress on Small Scale Industries (SSIs) as a means to improve the country's economic conditions. The primary responsibility of promotion and development of micro and small enterprises lies with the state governments. However, the Government of India, in recognition of the potential of these sectors in both creation of wealth and employment and of the need for a countrywide framework of policies and measures for their promotion and development, has always taken active interest in supplementing the efforts of the state governments in several ways. The Government of India set up the Small Industries Development Organization (SIDO) in 1954, as a public sector enterprise (PSE). Over the years, the government of India has formulated policy packages for the promotion and development of the sector and also implementing a large number of schemes and

[1]Small Scale Industry (SSI) includes cottage and handloom craft which employ traditional labour-incentive methods to produce traditional products, largely in village households.

[2]The Khadi & Village Industries Commission (KVIC), established under the Khadi and Village Industries Commission Act, 1956, is a statutory organization engaged in promoting and developing Khadi and village industries for providing employment opportunities in rural areas, thereby strengthening the rural economy. The KVIC has been identified as one of the major organizations in the decentralized sector for generating sustainable rural nonfarm employment opportunities at low per capita investment. This also helps in checking migration of rural population to urban areas in search of the employment opportunities.

[3]The contribution of MSMEs to total GDP and industrial production of India was 8 and 45 per cent respectively with Rs. 202017 crore or 40 per cent in total export of India (MSMEs:2010).

[4]As per the latest census (4th) of MSMEs (2006-07), there were 26 million MSEMs operating in the country, which provided employment to about 60 million persons. Of the total, 28 per cent were engaged in the manufacturing sector while remaining 72 per cent in the service sector (Economic Survey GOI-2010).

programmes. The policies and programmes implemented by the Ministry, span across different areas of operations of MSMEs, covering credit, marketing, technology, skill development, infrastructure development, fiscal matters and legal/regulatory framework. These programmes were implemented through various organizations under the Ministry, commercial banks, Small Industries Development Bank of India (SIDBI) and the State/UT Government, during 1990 when the economic condition of India was the worst. Therefore, GOI has been adopted modern strategy of economic growth i.e. LPG[5]. Due to this strategy, the economic environment of India has changed remarkably; the Indian economy was opened to foreign investments; quantitative and non-quantitative barriers on imports were removed; and the end of protective measures for small scale industries and others, are the main motives of new economic policy (NEP) which has brought the competitive growth in Indian industrial sector. In past NEP period the performance of SSIs of India has decreased due to high competition in the market, low technological base, high cost of production, removal of reserved items for SSIs, etc. Therefore, in 2000, the government of India has released a comprehensive policy package for the development of SSIs in India. The comprehensive policy package included financial, infrastructural, and technological support. However, the performance of SSIs was not significantly improved as compared to foreign firms. Therefore, the government of India took revolutionary step in this regard in 2006 by passing the MSMED Act 2006. The Act came into force from October 2, 2006, and fulfilled a long-cherished demand of the sector. The MSMED Act was notified to address the policy issues relating to Micro, Small and Medium Enterprises (MSMEs)[6] in India (Table 1). The salient features of the Micro, Small and Medium Enterprises Development (MSMED) Act, 2006 are:

- Setting up of a National Board for MSMEs.
- Classification of enterprises.
- Advisory Committees to support MSMEs.
- Measures for promotion, development and enhancement of MSMEs.
- Schemes to control delayed payments to MSMEs.
- Enactment of rules by State Governments to implement the Act in their respective States.

Review of literature

Many studies have been conducted on the issue of the development of MSMEs in India. The growth, development, issues, and challenges of MSMEs have also been studied by various scholars from different angles. In fact the area of MSMEs development offers a large scope to the scholars who may attempt to investigate various new issues. A review of a few important and relevant studies in this area has been made in this study.

Kumar et al. (2007) in their study "An Evaluation of the Impact of Economic Reforms on the Growth and Productivity of Indian Small Scale Industry" adjudged the impact of economic reforms on the growth and productivity of Indian Small Scale Sector. The results showed that economic reforms process initiated in the early nineties has had a downbeat impact on the growth and productivity of SSI. The Compound Annual Growth Rate (CAGR) of key growth parameters like number of units, production, employment and exports has been found to be tapered off in the post-reform period in relation to the pre-reform period. The analysis of total factor productivity (TFP) growth highlighted that TFP growth in SSI dragged after the

Table 1. Nature of Micro, Small and Medium Enterprises

Category	Micro Enterprises	Small Enterprises	Medium Enterprises
Manufacturing Enterprises in terms of Gross Investment in Plant and Machinery	Not Exceeding Rs. 2.5 Lakh	Above Rs. 2.5 Lakhs and Up to Rs. 5 Crore	Above Rs. 5 Crore and Up to Rs. 10 Crore
Services Enterprises in terms of Gross Investment in Equipment	Not Exceeding Rs. 1 Lakh	Above Rs. 1 lakhs and Up to Rs. 2 Crore	Above Rs. 2 Crore and Up to Rs. 5 Crore

Source: MSMEs Act, 2006

[5]It means liberalization, privatization and globalization. Liberalization means the government moves licensing policy to de-licensing and also removing all kinds of restrictions for industrial development. Privatization means the industrial development through private capital. The term globalization refers to the integration of economies of the world through uninhibited trade and financial flows, as also through mutual exchange of technology and knowledge. Ideally, it also contains free inter-country movement of labour.

[6]In 2006 all SSIs units were categorized into three groups i.e., Micro, Small and Medium Enterprises.

deregulatory and decontrol regime came into force. Also, the downward trend in TFP was completely driven by a technological regress during the post-reform years. On the whole, the study divulged that the recent thrust on the liberalization and globalization of Indian economy has failed to render any positive impact on the growth and productivity of SSI.

Sisodiya (2008) in his study examined the emerging challenges as well as future outlook of Indian SMEs, admitted increased deregulation, globalization of the Indian economy and repaid technology disruption. Some of the major challenges faced by SMEs include access to finance, low investment in research and development (R&D), and lack of access of technology, competition, credit, constraints, insufficient capacity and lack of proper training. After analyzing the previous studies, we found that the priority sector of India has been facing a large number of challenges i.e., market, credit, capacity, infrastructure etc., and these problems/challenges have increased after reform in Indian economy.

Chhikara and Kodan (2011) analyzed the various aspects of MSMEs of India and also measured the impact of globalization on the growth and performance of MSMEs in India with the help of appropriate statistical tool and techniques. The study clearly indicates that the growth of MSMEs in India has been hampered in all spheres. The study also indicates that the number of MSMEs units, production and globalization are positively and significantly associated to the import by MSMEs of India. The Chow Test clearly indicates that the labor productivity in MSMEs has increased significantly after globalization of Indian economy due to introduction of new technology. Thus, in future the demand of labor by MSMEs will be less due to technology advancement. Therefore, the researchers suggested that the government of India (GOI) should emphasize on establishment of more and more MSMEs units and also give special attention of the development of Khadi and Village industry in rural areas for the absorption of excess supply of labor force of rural areas.

Chhikara and Kodan (2011) found that the most of the banks have not achieved the priority sector lending targets and further found that there is significant difference in the total priority sectors NPAs of public and private sector banks. The paper also revealed that a large share (around 70%) of priority sector NPAs were caused by SSIs during the time under consideration. It suggested that, banking industry should consider financial inclusion as a moral responsibility as it is a need of time in capitalized world.

The above discussion clear indicates that the Micro, Small and Medium Enterprises in India have been facing many challenges on various fronts like marketing, finance, technology etc. Therefore, the present study is made to attempt the trends, growth, composition, issues, challenges of MSMEs in India in-depth with the help of appropriate statistical tools and techniques.

The present study has been divided into nine parts. The first part of the study is introductory. In second part, some important studies have been discussed in this context. The third part of the study represents the research methodology of the study in detail. Part four highlight the contribution of MSMEs in Indian economy. Part five of the study covers the growth trends of MSMEs in India. Part six represents the geographical pattern of MSMEs in India. In part seven, the composition of MSMEs in India has been presented. Part eight of the study highlights the issues and challenges in front of MSMEs in India. Findings, suggestions, and conclusion are contained in the last part of the study.

Objectives of the Study

1. To find out the growth trends of MSMEs in India.
2. To find out the regional pattern of MSMEs in India.
3. To examine the composition of MSMEs in India.
4. To highlight the issues and challenges in background of MSMEs in India.

Research methodology

The present study is based on secondary data, which were collected from following sources like, www.rbi.org, www.iba.org, report on trend and progress of banking in India, economic survey of India, related research work and magazines. The study covers the period from 1973/74 to 2006/07. The study analyzed various aspects of MSMEs of India with the help of appropriate statistical techniques. In this study, we have used time series data.

Compound Annual Growth Rate

The CAGR is compounded by employing formula:

$$Y = ab$$

By using logarithm, it may be written as:

$$\log y = \log a + t \log b$$

$$Y^* = a^* + t.b^* \text{ (where } \log y = y^*, \log a = a^* \text{ and } \log b = b^*)$$

The value of b* is computed by using OLS Method. Further, the value of CAGR can be calculated by followed method:

$$CAGR = (\text{Antilog } b^* - 1) \times 100$$

Contributions of Micro, Small and Medium Enterprises in India

Table 1 shows the contribution of MSMEs in aggregate gross domestic product (GDP), total export and total industrial production of India from 1999/2000 to 2007/08. The contribution of MSMEs in total GDP of India has increased from 13.08 to 16.84% and industrial production has increased from 39.74 to 45.00%. The export by MSMEs has increased from Rs. 54200 to 202017 crore, while the contribution of MSMEs has decreased from 33.96 to 30.80% during the period under consideration. It is interesting that the average compound growth rate (CAGR) of MSMEs production has been (14.19%) more than aggregate GDP (11.34%), while the CAGR of aggregate export of India has been (17.01%) more than export by MSMEs (15.74%) from 1999/2000 to 2008/09.

Table 1. Contribution of MSMEs in Indian economy

Year	Aggregate GDP of India#	Total MSMEs production#	Aggregate Export of India#	Export by MSMEs#	Total industrial production
1999/00	1786526	233760 (13.08)*	159561	54200 (33.96)**	39.74
2000/01	1925017	261297 (13.57)	203571	69797 (34.28)	39.71
2001/02	2097726	282270 (34.28)	209018	71244 (34.08)	39.12
2002/03	2261415	314850 (13.92)	255137	86013 (33.71)	38.89
2003/04	2538170	364547 (14.36)	293367	97644 (33.28)	38.74
2004/05	2967599	429769 (14.48)	375340	124417 (33.14)	38.62
2005/06	3402316	497842 (14.63)	456418	150242x (14.63)	38.56
2006/07	3941865	709398 (17.99)	571779	182538 (31.92)	44.12
2007/08	4540987	790759 (17.41)	655864	202017 (30.80)	45.00
2008/09	5228650	880805 (16.84)	–	–	–
CAGR	11.34	14.19	17.01	15.74	–

Sources:

1. Annual Report 2010/2011 of Micro, Small and Medium Enterprises of India
2. Economic Survey of India: 2009/10

Notes:

1. * As per cent to aggregate GDP of India.
2. ** As per cent to aggregate export of India.
3. – Data is not available.
4. # Amount is Rs. In crore

Trends in growth of micro, small and medium enterprises in India

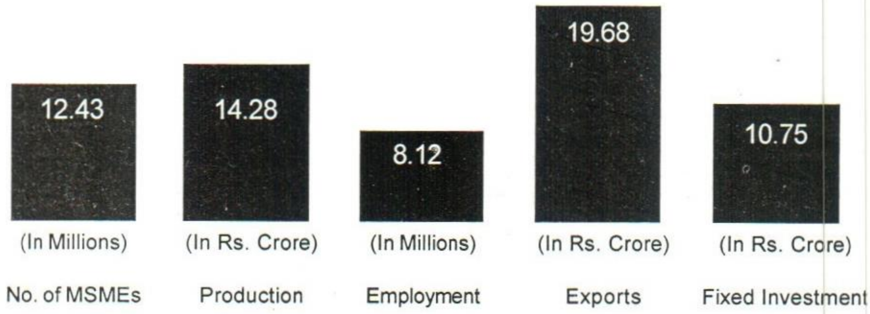
Table 2 expresses the number of MSME units were only 0.42 millions in 1973/74 which was increased to 6.79 million in 1990/1991 and further increased from 7.06 to 12.89 million from 1992/1993 to 2006/2007. The value of output by MSMEs has also increased from Rs. 7200 crore to 585112 crore during the same period. In 1973/74, 3.97 million people were employed in MSMEs which increased to 15.83 million in 1990/1991 and further, increased to 65.93 millions in 2008/09. The contribution of MSMEs in export of India has increased from Rs 500 to 9664 crore and

Table 2. Trends in growth of MSMEs in India

Year	No. of MSMEs (In Millions)	Production (In Rs. Crore)	Employment (In Millions)	Exports (In Rs. Crore)	Fixed Investment (In Rs. Crore)
1972–73	0.42	7200	3.97	400	**
1973–74	0.5	9200	4.04	500	**
1975–76	0.55	11000	4.59	500	**
1976–77	0.59	12400	4.98	800	**
1977–78	0.67	14300	5.40	800	**
1978–79	0.73	15800	6.38	1100	**
1979–80	0.81	21600	6.70	1200	**
1980–81	0.87	28100	7.10	1600	**
1981–82	0.96	32600	7.50	2100	**
1982–83	1.06	35000	7.90	2000	**
1983–84	1.16	41600	8.42	2200	**
1984–85	1.24	50500	9.00	2500	**
1985–86	1.35	61200	9.60	2800	**
1986–87	1.46	72300	10.14	3600	**
1987–88	1.58	87300	10.70	4400	**
1988–89	1.71	106400	11.30	5500	**
1989–90	1.82	132300	11.96	7600	
1990–91	6.79	78802	15.83	9664	**
1991–92	7.06	80615	16.60	13883	**
1992–93	7.35	84413	17.48	17784	109623
1993–94	7.65	98796	18.26	25307	115795
1994–95	7.96	122154	19.14	29068	123790
1995–96	8.28	147712	19.79	36470	125750
1996–97	8.62	167805	20.59	39248	130560
1997–98	8.97	187217	21.32	44442	133242
1998–99	9.34	210454	22.06	48979	135482
1999–00	9.72	233760	22.91	54200	139982
2000–01	10.11	261297	24.02	69797	146845
2001–02	10.52	282270	25.23	71244	154349
2002–03	10.95	314850	26.37	86013	162317
2003–04	11.4	364547	27.53	97644	170219
2004–05	11.86	429796	28.76	124417	178699
2005–06	12.34	497842	29.99	150242	188113
2006–07	26.10	709398	59.46	*	500758
2007–08	27.27	790759	62.63	*	558190
2008–09	28.51	880805	65.93	*	621753
ACGR	12.43	14.28	8.12	19.68	10.75

Source: Hand Book of Statistics of the Indian Economy (RBI: 2010) and Annual Report 2010/2011 of Micro, Small and Medium Enterprises of India.

13883 to 22017 crore respectively in 1973/74 to 1990/91 and 1990/91 to 2007/08. Figure 1 depicts that the average compound growth rate of number of MSMEs, production, employment, exports and fixed investment has been 12.43%, 14.28%, 8.12%, 19.68%, and 10.75% respectively during the period under consideration. It is



Source : Authors Calculations

Figure 1. Average Compound Growth Rate of MSME's in India

clear from table 1 that the value of fixed investment in MSMEs in india has increased from Rs. 109623 crore to Rs. 621753 crore with 10.75% CAGR from 1991/92 to 2008/09.

The 4th All India Census of MSMEs

The Quick results of 4thAll India Census of MSMEs (2006–07), which was launched in May 2008, were released during 2009–10. The results revealed that there were 2.61 crore MSMEs in 2006–07, providing employment to about 6 crore persons. Of the total MSMEs, 28% were in the manufacturing segment and 72% in the service segment. This was the first Census after the enactment of the Micro, Small and Medium Enterprises Development (MSMED) Act, 2006 (MSMED Act, 2006) and the medium enterprises were included for the first time.

Regional pattern of MSMEs in India in 2007

Table 2 reveals the number of units and employment in thousands, fixed investments in Rs. crore, employees per unit as well as fixed investment per MSMEs in different states of India in 2007. It is clear from table 3 that the maximum 211.791 (16.48%) MSMEs are in Uttar Pradesh, followed by Andhra Pradesh 1043.512 (8.12 per cent) and Sikkim is last in the list with 0.474 (1.774%). Further, it is also observed from Table 2, the MSMEs of Uttar Pradesh provided 16.48% employment vis-à-vis total employment provided by total MSMEs in India, followed by Tamil Nadu [9.09%], Maharashtra [8.65%] and Sikkim only 0.01% or 1774 employees. The Maharashtra topped in the list with 19.87% (Rs. 41197 crore), while Sikkim is again last with 0.01% (Rs. 14 crore) in making fixed investment as percentage to total fixed investment in MSMEs at aggregate level of India in 2007. Goa [98.80 lakh] is the leader in the maximum fixed investment per MSMEs, followed by Maharashtra (41.64 lakh), Nagaland (31.59 lakh), while Jharkhand is the last in this list with Rs. 5.14 lakh, while at aggregate level of India, the average fixed investment per MSMEs has been Rs. 16.14 lakh. It can be observed from table 3 that Nagaland ranked first [4.79 employees per MSMEs], followed by Sikkim [3.74], and Arunachal Pradesh is third with 3.28, while Himachal Pradesh ranked last with 1.80 employees per MSMEs in 2007. On the basis of level of employees per micro, small and medium enterprises (MSMEs) all States have been categorized into three broad groups i.e., high, moderate and low labour intensive States. It is clear from table 3 that five or 17.24% high labour incentive States [Arunachal Pradesh, Goa, Meghalaya, Nagaland and Sikkim] belong to high level[7], twenty one or 72.41% States [Andhra Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Maharashtra, Manipur, Mizoram, Orissa, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal] belong to moderate level[8], while only three or 10.34% States [Himachal Pradesh, Madhya Pradesh, Uttaranchal] belong to low level[9] labour intensive MSMEs States of India.

[7]Above 3 employees per micro, small and medium enterprises [MSMEs]
[8]Between 2 to 3 employees per micro, small and medium enterprises [MSMEs]
[9]Below 2 employees per micro, small and medium enterprises [MSMEs]

Table 3. Regional pattern of MSMEs in India

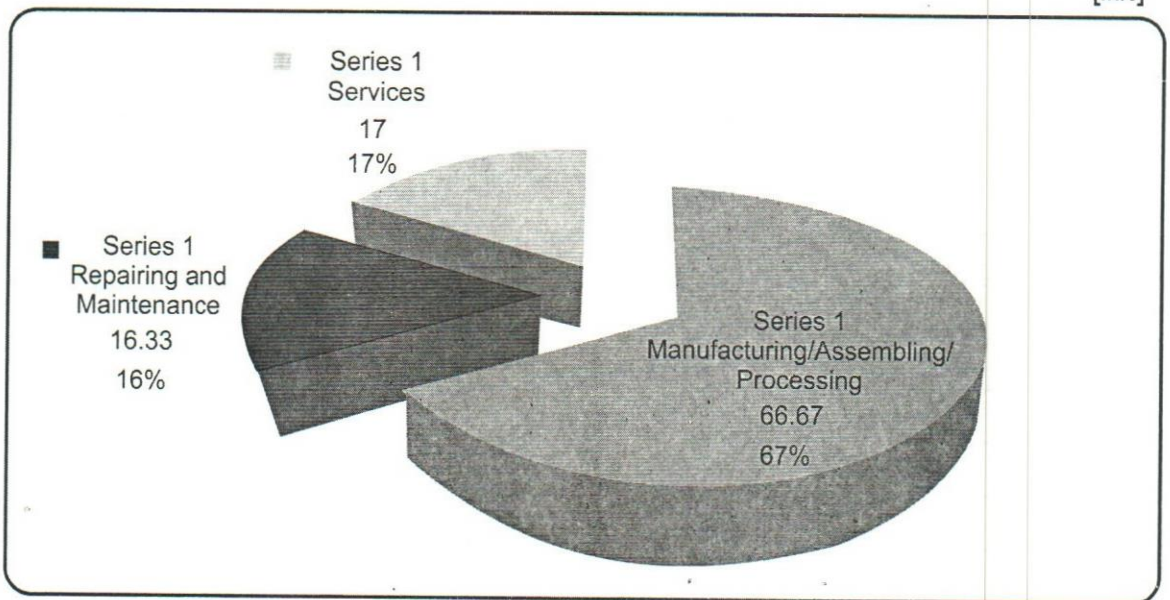
State	No. of Units (In Thousands)	Employment (In Thousands)	Fixed Investments (In Rs. Crore)	Employees per Unit	Fixed Investment per Unit
Andhra Pradesh	1043.512	2539.234	14480	2.43	13.88
Arunachal Pradesh	1.578	5.178	42	3.28	26.62
Assam	235.576	530.479	1451	2.25	6.16
Bihar	529.509	1319.395	3392	2.10	5.39
Chhattisgarh	315.118	635.522	2420	2.02	7.68
Goa	8.654	38.23	855	4.42	98.80
Gujarat	646.379	1585.675	14327	2.45	22.17
Haryana	263.308	640.564	9052	2.43	34.38
Himachal Pradesh	95.572	172.35	1104	1.80	11.55
Jammu and Kashmir	89.726	192.254	1738	2.14	19.37
Jharkhand	163.22	352.479	839	2.16	5.14
Karnataka	804.811	2056.678	11206	2.56	13.92
Kerala	542.61	1374.692	8998	2.53	16.58
Madhya Pradesh	976.981	1680.379	4723	1.72	4.83
Maharashtra	989.254	2704.767	41197	2.73	41.64
Manipur	57.171	162.667	428	2.85	7.49
Meghalaya	28.591	88.418	202	3.09	7.07
Mizoram	14.335	33.383	167	2.33	11.65
Nagaland	19.024	91.032	601	4.79	31.59
Orissa	468.468	1134.891	2640	2.42	5.64
Punjab	441.797	1042.995	13186	2.36	29.85
Rajasthan	538.728	1097.842	9254	2.04	17.18
Sikkim	0.474	1.774	14	3.74	29.54
Tamil Nadu	1006.684	2840.532	17252	2.82	17.14
Tripura	29.141	68.147	384	2.34	13.18
Uttar Pradesh	2116.791	5076.632	24852	2.40	11.74
Uttaranchal	137.618	262.737	2294	1.91	16.67
West Bengal	921.221	2586.716	6638	2.81	7.21
India	12843.80	31251.68	207307	2.43	16.14

Source: Indiastat.com

Composition of Micro, Small and Medium Enterprises (MSMEs) in India

It is clear from figure 2 that only 16% MSMEs have been engaged in repairing and maintenance, 17% in services and 67% in manufacturing during 2010/11. Figure 3 expresses the geographical composition of MSMEs in India in 2010/11. It is clear from figure 3 that only 45% MSMEs are located in rural areas and remaining in urban areas. Out of total micro, small and medium enterprises (MSMEs) 93% are micro enterprises, while remaning 7% are small

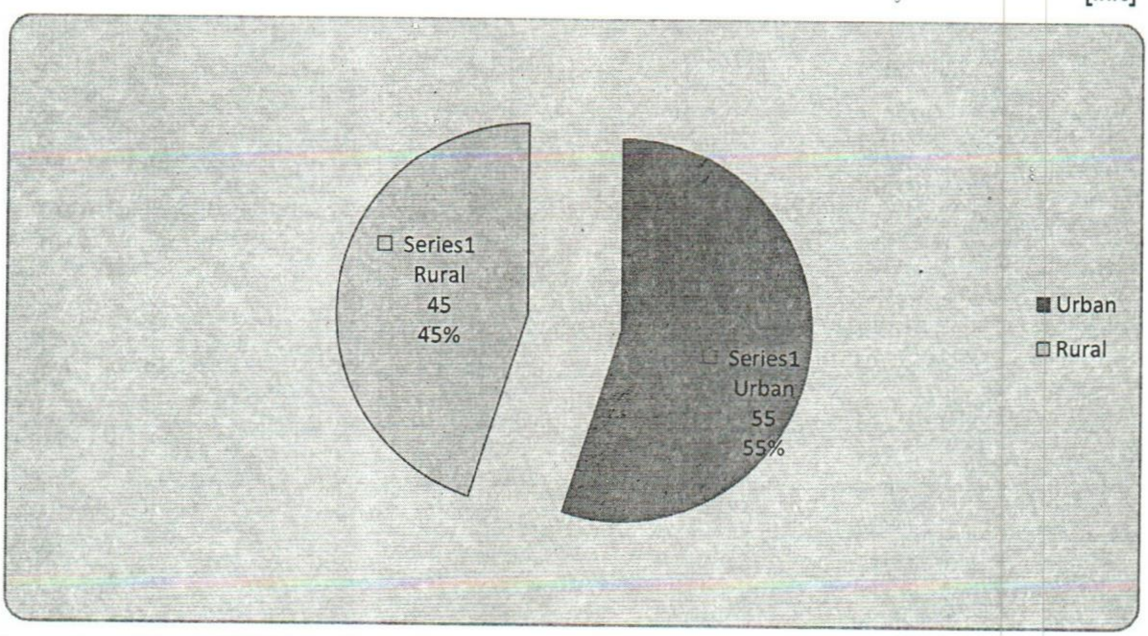
[In%]



Source: Annual Report 2010/2011 of Micro, Small and Medium Enterprises of India.

Figure 2. Composition of MSMEs on the Basis of Sectors

[In%]



Source: Annual Report 2010/2011 of Micro, Small and Medium Enterprises of India.

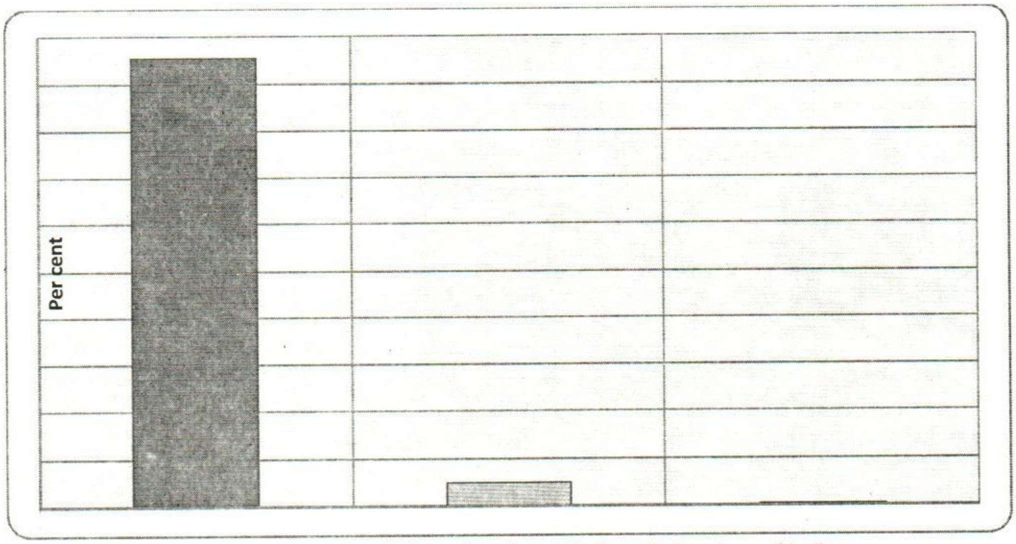
Figure 3. Composition of the MSMEs on the basis of Region

and medium enterprises in 2010/11 [see figure 4]. figure 5 depicts the composition of micro, small and medium enterprises on the basis of product. Figure 6 clearly indicates the male dominating in MSMEs as they share 86% ownership while only 14% MSMEs are run by women entrepreneur. The MSMEs in India are generally found in sole proprietorship [93%] followed by partnership [4%] and a negligible [3%] in other forms [cooperative and others].

Issues and Challenges of the Development of Micro, Small and Medium Enterprises (MSMEs) in India

The micro, small and medium enterprises (MSMEs) face problems at every stage of their operations, whether it is buying of raw materials, manufacturing of products, marketing of goods or raising of finance. These industries are therefore, not in a position to secure the internal and external economies of scale. Through this study we identified the following problems in development of MSMEs in India.

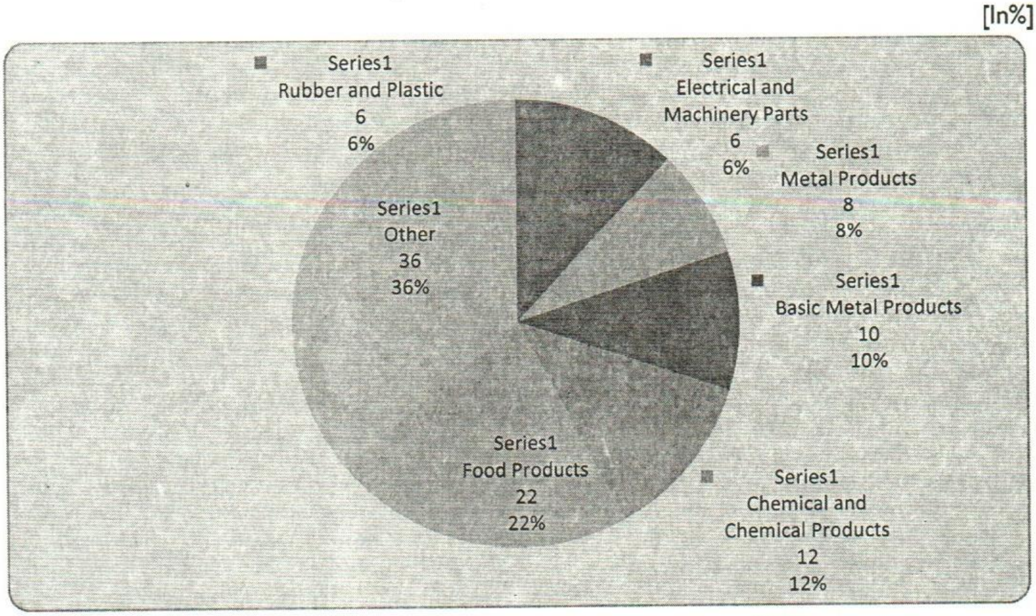
[In%]



Source: Annual Report 2010/2011 of Micro, Small and Medium Enterprises of India.

Figure 4. Composition of the MSMEs on the basis of Nature

[In%]



Source: Annual Report 2010/2011 of Micro, Small and Medium Enterprises of India.

Figure 5. Composition of the basis of Products

The Economic survey (GOI), 2010, showed that out of 27 public sector banks, only three were unable to achieve the overall priority sector lending targets[10] of 40% as on the last reporting Friday of March, 2009. Only 14 public sector banks achieved the agriculture credit target of 18% agriculture credit, in case of private sector banks, 5 out of 2, did not achieve the overall priority sector lending target and only 8 achieved the target of 18% for lending to agriculture. While the target for lending to the weaker section (10%) was achieved by 15 public sector banks, only 4 private sector banks achieved the same target in 2009. Out of total foreign banks, 27 did not achieve the overall priority sector lending targets of 32% in 2009. The number of foreign banks, which did not achieved the target of 10% and 12% for lending to the MSMEs and export sectors respectively, stood at six (see table 6.10). The disbursement by public sector banks to agriculture under the Special Agricultural Credit Plan (SACP) was Rs. 90,023 crore between April-September 2009, against the target of Rs. 2, 01,710 crore for the year, while disbursement by private sector banks was Rs. 30,092 crore, against the target of Rs. 62,352 crore (RBI: 2010).

Table 4. Banks' Failure in achieving the priority Sector Credit Targets

Target/ Sub-target	Public sector Banks	Private sector Banks	Total
Overall/agriculture/ weaker section	12	-	12
Only over all	12	15	27
Over all and agriculture	3	6	9
Over all and weaker section	3	-	3
Agriculture and weaker section	-	-	-
Only agriculture	-	-	-
Only weaker section	-	-	-
None	-	2	2

Source: report on trend and progress of banking in India 2007-08.

In line with Sarma, 2008, countries having Index of Financial Inclusion[11] [IFI] value between 0.5 and 1 are classified as high IFI countries, those having IFI values between 0.3 and 0.5 are termed as medium IFI countries and the rest having IFI values below 0.3 are classified as low IFI countries. By this classification, only 4 out of the 15 selected states are classified as high financial inclusion [FI][12] states. These include high-income states such as Punjab, Tamil Nadu, Kerala, and Karnataka. The medium

Table 5. Disparities of Financial Inclusion in India

Category	No. of State	Name of States
High Financial Inclusion	4	Punjab, Tamil Nadu, Kerala, and Karnataka
Medium Financial Inclusion	5	Haryana, Gujarat, Andhra Pradesh, and Maharashtra.
Low Financial Inclusion	7	Assam, Bihar, MP, Orissa, Rajasthan, UP and West Bengal.

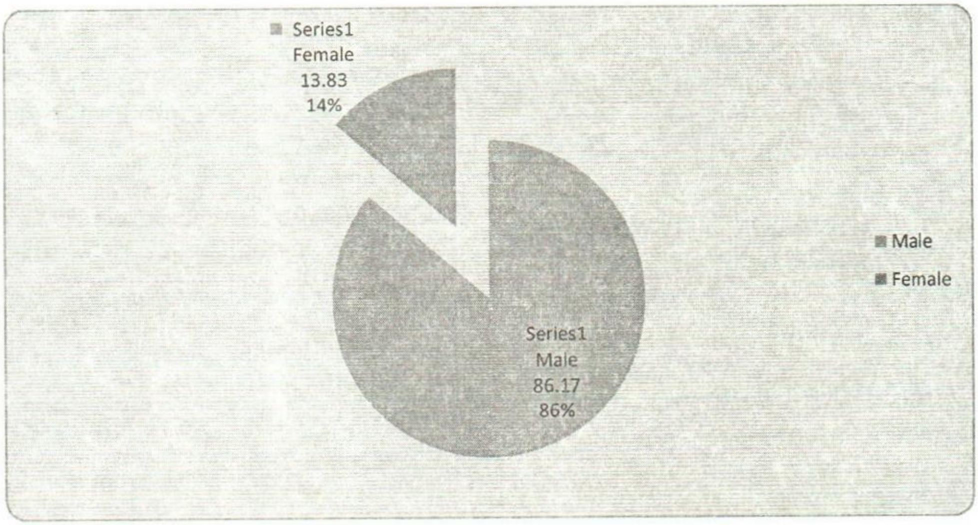
Source: Chhikara and Kodan: 2011

[10]Priority sector includes agriculture; small scale industries, other small business operators and weaker section of society who need finance in shape of loan. The description of the priority sector was formalized in 1972 on the recommendations of the informal study group on statistics relating to advances to the priority sector constituted by the RBI. Although initially there was no specific target fixed in report of priority sector lending, it reached a level of not less than 1/3rd of the outstanding credit by March 1979. In 1980, the target of priority sector lending was fixed and there was no target fixed for small scale industry under priority sector lending but, 40 per cent of the total small scale industry should belong to tinny sector and further export finance did not form the part of priority sector lending for domestic banks. In case of foreign sector banks, priority sector should get 32 per cent of net bank credit (NBC) and 12 per cent for export credit.

[11]The index of financial inclusion was developed by Sarma in 2008. According to this index, financial inclusion is a measure of inclusiveness of the financial sector of a country. It is constructed as a multidimensional index that captures information on various aspects of financial inclusion such as banking penetration, availability of banking services and usage of the banking system. The IFI incorporates information on these dimensions in one single number lying between 0 and 1, where 0 denotes complete financial exclusion and 1 indicates complete financial inclusion in an economy.

[12]Leyshon and Thrift (1995) defined financial exclusion as referring to those processes that serve to prevent certain social groups and individuals from gaining access to the formal financial system. Carbo, et al. (2005) defined financial exclusion as broadly the inability (however occasioned) of some societal groups to access the financial system. According to Conroy (2005), financial exclusion is a process that prevents poor and disadvantaged social groups from gaining access to the formal financial systems of their countries. According to Mohan (2006) financial exclusion signifies the lack of access by certain segments of the society to appropriate, low-cost, fair and safe financial products and services from mainstream providers. The Rangarajan Committee (2008) on financial inclusion in India defines financial inclusion as the process of ensuring access to financial services and timely and adequate credit needed by vulnerable groups such as the weaker sections and low income groups, at an affordable cost. Mandira Sarma and Jesim Pais (2008) defined financial inclusion as a process that ensures the ease of access, availability and usage of the formal financial system for all members of an economy. To conclude, it can be said that 'Financial Inclusion is the delivery of banking services at affordable costs to vast sections of disadvantaged and low income groups including households, enterprises, SMEs and traders'. Financial Inclusion Includes: [1] Transmission services: allowing receipt and transfer of money and cheques (banking services), [2] Protective services: offer long-term and medium-term financial security and protection against fluctuations in income and expenditure (life assurance, private pension provisions, home contents insurance, savings and credit) and [3] Promotional services: facilitate autonomy and enable individuals to promote them (e.g. loans for starting up micro-enterprises).

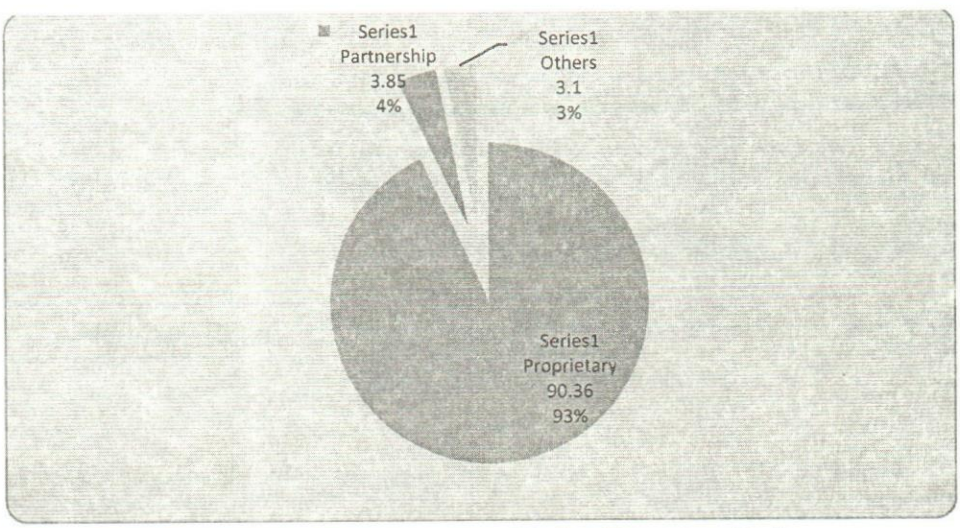
[In%]



Source: Annual Report 2010/2011 of Micro, Small and Medium Enterprises of India.

Figure 6. Composition of the MSMEs on the basis of Gender

[In%]



Source: Annual Report 2010/2011 of Micro, Small and Medium Enterprises of India.

Figure 7. Organization Structure of Micro, Small and Medium Enterprises (MSMEs) in India

IFI states are also 4 out of the 15 states in the list which includes, Haryana, Gujarat, Andhra Pradesh, and Maharashtra. It is surprising that the list of low IFI states like Assam, Bihar, MP, Orissa, Rajasthan, UP and West Bengal is dominated by low per capita income and low literately rate in comparison to other states of India.

Table 6 reveals the breakdown conditions of National and State highways of India in 2002. It is clear from table 6 that more than a quarter of the national highways are categorized as being in poor surface condition, while more than half of the state highways are listed as being in poor

Table 6. Indian highways condition breakdown

(In% of total)

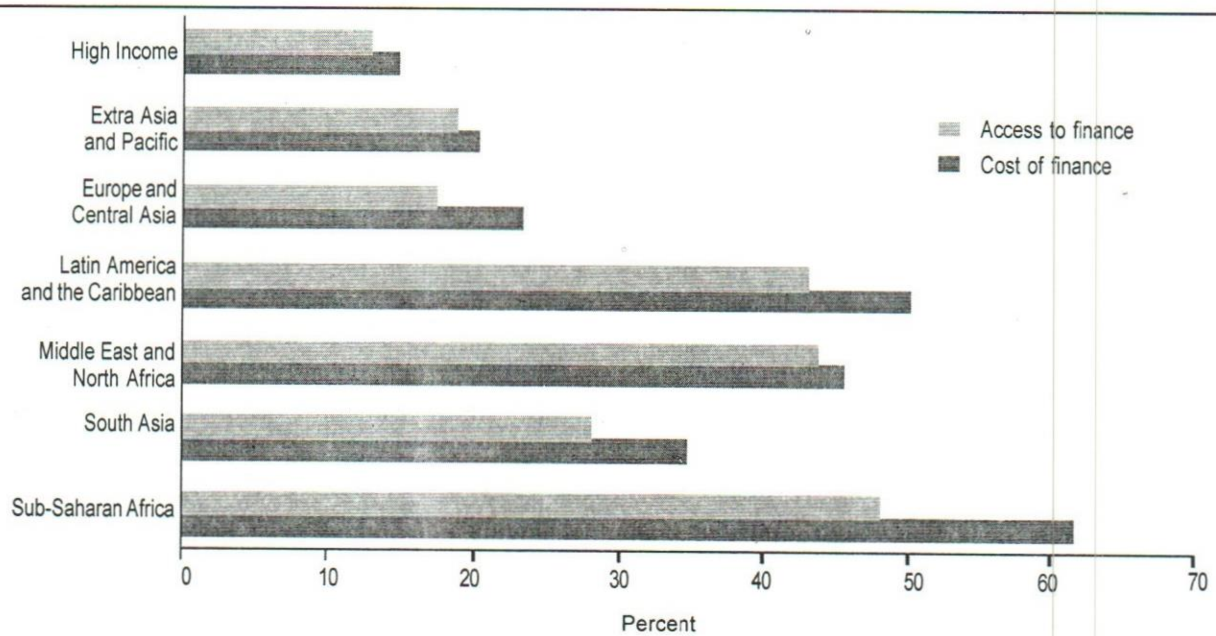
International Roughness Index(IRI)	National Highway	State Highway		
		Single Lane	Intermediate Lane	Two Lanes
Above 4(good)	50.70	11.00	10.80	11.20
4 to 6(fair)	23.70	23.40	31.80	48.40
6 to 8(poor)	25.70	35.30	34.60	35.50
Below 8(very poor)	0.00	30.40	22.70	4.90

Source: Bansal et al. (2002a).

or very poor shape. The specific breakdown is listed in table 6. In India, the length of National Highways is 58,000 KMs which represents only 1.7% of the total road network, yet they carry about 40% of aggregate traffic. Further, National and State highways clubbed together account for about 6% of the total road network, and carry close to 80% of aggregate traffic. Moreover, approximately 70% of India's inhabitants live in rural areas, comprising of 661,000 villages. Unfortunately, about 40% of these villages are not yet connected by all-weather roads to market centers and main road networks; this problem is particularly pronounced in the peripheral states in the north and northeast of the country, which are poorly connected with major economic centers (Bansal et al., 2002a).

Problems related to marketing

Most MSEs do not have money to invest in market research and are unable to carry out design and technical improvements to cope with market demands. Unlike big businesses, they cannot invest in advertising and packaging. This limits their ability to tap markets and attract consumers. Most people are unaware of Chamba Chugh, natural fibre purses and cushion covers, passion fruit pickles, Bhuvastra (garment of the Earth—made in coir), Chamba Chappals, Camel Hair Carpets (which do not burn) of Jodhpur, and the intricately carved tables of Ladakh. MSEs, especially those pertaining to traditional livelihoods, are therefore, increasingly being forced to rely on middlemen, petty traders, and big businesses to market their products. This has reduced many to the status of daily workers, earning less than the minimum wages (EPYP: 2007-12).



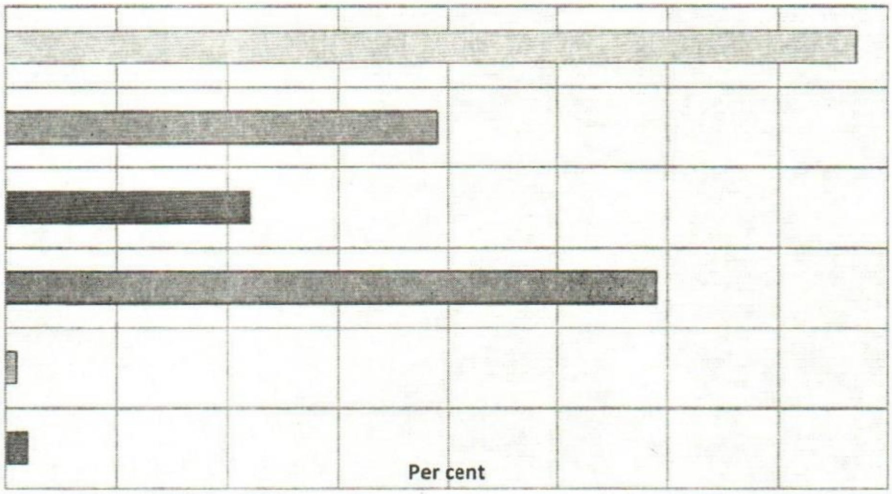
Source: Investment Climate Survey (ICS) responses by enterprises in 76 countries, grouped by region. Cited from theFinance For All? Policies and Pitfalls in Expanding Access

Note: Figure shows the percentage of firms reporting access to finance or cost of finance as a severe or major obstacle to firm growth.

Figure 8. Percentage of firms reporting finance as a problem

Problems Related to framing Business Policy

- It requires 13 procedures, takes 30 days, and costs 66.06 % GNI per capita to start a business in India.
- India is ranked 169 overall for Starting a Business.
- It requires 37 procedures, takes 195 days, and costs 2,394.86 % GNI per capita to build a warehouse in India.
- India is ranked 175 overall for Dealing with Construction Permits.
- India is ranked 104 overall for Employing Workers.
- It requires 5 procedures, takes 44 days, and costs 7.43 % of property value to register the property in India.



Source: Bansal et al. (2002a).

Figure 9. Indian Highway Characteristics (2002)

- India is ranked 93 overall for Registering Property.
- India is ranked 30 overall for Getting Credit.
- India is ranked 41 overall for Protecting Investors.
- India is ranked 169 overall for Paying Taxes.
- India is ranked 94 overall for Trading Across Borders.
- India is ranked 182 overall for Enforcing Contracts.
- India is ranked 138 overall for closing a Business.

Conclusion and Policy Recommendations

In this article we have analyzed the trends, composition, regional pattern, issues and challenges of micro, small and medium (MSMEs) in India with the help of appropriate tools and techniques. The study clearly indicates that:

- The MSMEs are playing an important role in economic development of India through employment generation, foreign earning, etc.
- The average compound growth rate of number of MSMEs, Production, Employment, Exports and Fixed Investment has been 12.43, 14.28, 8.12, 19.68 and 10.75% respectively during the period under consideration.
- Maximum 211.791 (16.48) MSMEs are located in Uttar Pradesh and minimum in Sikkim (1.774%).
- Arunachal Pradesh, Goa, Meghalaya, Nagaland and Sikkim belong to high level, Andhra Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Maharashtra, Manipur, Mizoram, Orissa, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal belong to moderate level, while Himachal Pradesh, Madhya Pradesh, Uttaranchal belong to low level of labour intensive MSMEs State of India.
- Only 16% MSMEs have been engaged in repairing and maintenance, 17% in services and 67% in manufacturing during 2010/11.
- Only 45% MSMEs are located in rural areas and remaining in urban areas.
- Out of total micro, small and medium enterprises (MSMEs) 93% are micro enterprises, while remaning 7% are small and medium enterprises.
- In india MSMEs have male domination, as they share 86% ownership, while only 14% MSMEs are run by women entrepreneurs.
- The MSMEs in India are generally found in sole proprietorship [93%] followed by partnership [4%] and a negligible [3%] in other forms [cooperative and others].
- Bank continuous failed to achieve the targets of priority sector credit in India.
- The contribution of non-institutional sources of credit has increased over the period in India.

Policy recommendations

- ✓ The state government is responsible for development of MSMEs, while central government also plays an important role in development of MSMEs. Therefore, coordination is must between central and state government policies.
- ✓ The GOI should take strict action against the banks and their employees responsible for non-attainment of the priority sector targets in general and the private banks in particular.
- ✓ Policies should be framed to boost the handicraft, particularly in rural areas, as most of the artisans live in villages and further it will help in halting the migration of the artisans to the cities.
- ✓ The plans and policies framed for the MSMEs must be hyped by the concerned authorities so as to make them success through the cooperation and work done by the related field persons and agencies.
- ✓ The self-help groups should not only be created rather they should be helped and strengthened to spread awareness among the masses by proving much needed help to them.
- ✓ Special incentives are needed to give to those units involving more and more workers as they contribute a lot towards the poverty alleviation through providing employment opportunities to the poor people.
- ✓ More and more business exhibitions cum village fares should be organized buy the GOI and the State governments with the help of rural people to provide ready markets for the products manufactured by these units and moreover for the protection of the cultural heritage of the nation.
- ✓ Special shields should be provided by the GOI these units against the proposed FDI in retail sector otherwise; their existence may be in danger and can be one of the major causes of the social unrest in the country.
- ✓ The effective training programmes should be initiated rather than the programmes just for the sake of formality to provide strong and capable management base for the units.
- ✓ Special attention is required to be given for the infrastructural development in India which is one of the major challenges before the industry for a free and fair development of the MSMEs.

References

Krishn A Goyal (2006) 'Impact of Globalization on Developing Countries (With Special Reference to India) *International Research Journal of Finance and Economics Issue* 5 (2006)

Globalization and Its Impacts, www.ilo.org

Thomas L. Friedman, The World is Flat, a Brief History of the Globalized World in the Twenty-First Century, Allen Lane, 2005

The African Economist. Vol.11, No. 35.2005

Damodar N. Gujarati (2005) 'Basic Econometric' Fifth Edition Published by Tata McGraw-Hall Publishing Company Limited-New Delhi

John E, Hanke and Dean W, Wichern (2007) 'Business Forecasting' Eight Edition Published by Pearson Prentice Hall New Delhi

Ramanatam, Ramu (2002) 'Introductory Econometrics with Application' Fifth Edition Published by Thomson Asia Pvt. Ltd., Singapore

Wayne W, Daniel (1990) 'Applied Non-Parametric Statistics' published by PWS-KENT Publishing Company, Boston

Mathew, M. (2004), "Small Industry and Globalization", *Economic and Political Weekly,* Vol. XXXIX, No. 20, 15 May 2004

Rajyalakshmi, N. (2004), "Productivity Awareness among SSI Units: A Case Study", *The Indian Journal of Commerce,* Vol. 57, No. 2, April- June 2004

Subrahmanya, M.H. (2004), "Small Industry and Globalization: Implications, Performance and Prospects", *Economic and Political Weekly,* Vol. XXXIX, No. 18, 1 May 2004

Gupta et al (2009) 'Performance, Challenges and Prospects of SMEs in Indian Economy', Vol. 2, No. 1, May-Oct, 2009, *KAIM Journal of Management and Research,* Charki Dadri (Haryana)

Sisodiya, Amit Singh (2008) 'Small and Medium Enterprises in India', ICFAI Press, Hyderabad

Aswathappa, K (2007) 'Business Environment and Strategic Management', Himalaya Publication House, New Delhi (India)

Chhikara, Kuldip S and Kodan, Anand S (2011) 'Priority Sector Credit by Commercial Banks: A Bank Group Wise Study',

Bansal, A., Bhandari, Bhandari, A., Liu, Z., Thompson, L., and Vickers, P, Executive Summary, in India's Transport Sector: The Challenges Ahead. The World Bank, May 10, 2002a.

Bansal, A., Bhandari, A., Gupta, D. P., & Vickers, P, Chapter 1: Highway, in India's Transport Sector: The Challenges Ahead, The World Bank, May 10, 2002b.

www.msme.gov.in

www.rbi.org.in

" Thinking is progress. Non-thinking is stagnation of the individual, organisation and the country. Thinking leads to action. Knowledge without action is useless and irrelevant. Knowledge with action, converts adversity into prosperity. "

—Dr. A. P. J. Abdul Kalam

Feature

Workforce Planning and Talent Acquisition: An Exploration

SUNITA PANDA AND CHANDAN KUMAR SAHOO

To perform better and to compete in highly dynamic environment, organizations these days have started focussing on acquiring the best talent. An effective workforce planning can help to focus on the dire needs of talent which will lead towards organizational success. Once those needs are known they can then be streamlined in order to fit into an effective talent acquisition strategy. This paper seeks to clarify the concepts of workforce planning and talent acquisition through a conceptual framework which shows the overall impact of talent acquisition strategies on attraction of talent. It helps in knowing the strategies which will lead to enhancement of organizational attractiveness and thus acquire the required talent.

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In today's competitive business environment alignment of human resource strategy with business strategy is of utmost importance. As a result of increase in competition, changing workforce demographics, talent shortages and increased globalization, talent need assessment, workforce planning and attracting superior talent has become a challenge for organizations. Organizations focal point has now centered upon crafting out strategies for developing irrefutable workforce plans and talent management processes for attracting suitable talent for the organization. As it is well known that for any organization 'people' are the most important asset that is irreplaceable. Achieving that asset and maintaining it has proved to be a challenge for organizations in the new millennium. If organizations have to succeed in the business front then they have to preserve the best talent for their organization. However, it's not only preserving that helps but to bring that talent in use at the right time is also a strategy. Perhaps, it is the competency of an organization on how it can create a talent inventory for itself which can be used when and where required. So the maiden step towards such an approach would be to attract and hire the best talent out of a pool of unrecognized prospective candidates. Acquisition of the best talent for an organization will contribute towards higher business performance which in turn will affect the organization's financial performance. Employees are the reflection of an organization's brand image. So talent acquisition should be aligned to the organization's strategic objectives which are imperative for the success of an organization. So recruitment of the key people who will help for improvement of the organization should be the focus of the recruiters. As a result of globalization it has been found that even Indian organizations are facing a change in their systems, management cultures and philosophy as far as talent acquisition is concerned.

The main purpose of this paper is to bring an insight into the concepts of workforce planning and talent acquisition. It is an exploration of various talent acquisition strategies and its impact in today's business environment. This paper focuses on the importance of a proper workforce planning which will lead to better talent attraction strategies and thus provide an organization with a talent inventory. This has been enumerated with the help of a model based on literature review done from past research work. The objective of this paper is to throw some light on the critical aspects of talent attraction which off late have been neglected by the organizations.

Workforce Planning

Ensuring the right number of people with the right competencies in the right job at right time is known as workforce planning. It has been defined variously in many ways one of which says it is a practice in which an organization tries to assess the demand for labour and calculate the various dimensions of supply which will be required to meet that demand (Reilly, 1996). Workforce planning is also known as human resource planning, succession planning and building bench strength. Earlier it was known as manpower planning but as it reflects inequality in gender and because it suggests a mechanistic quantitative approach towards workforce these days it is no more in use. It allows for a greater acknowledgement of qualitative issues especially regarding skills, and is applicable in a variety of organizational settings. The implementation of workforce planning has been considered to be one of the greatest challenges as practitioners continue to face difficulties (Laabs, 1996). As a result of intensified competition from home and abroad, labour market factors, recruitment and retention, the speed of information acquisition and dissemination, the globalization of economic activities, consumerism and the drive for quality at an acceptable price, organizations need to plan their own survival strategies (Reilly, 1996). In the competitive environment competitors are ready to grab the place in case the organization makes any errors. The uncertainty surrounding an organization compels it to think about the future as a result of lack of skilled workforce. Due to inflationary pressures and recession, the economy in the last couple of years has faced a downturn. In such a situation organizations need to adopt coping strategies and some of them from the human resource (HR) perspective are layoffs and downsizing. There is an increasing concern in industries towards losing competitive advantage during such period because of failure to prevent the brain drain from the industries. As advised by a renowned practitioner "even if the recession has forced you to cut back on projects you can use this time to assess your skill base, figure out what you'll need and get organized to hit the ground running when your budget loosens" (Melymuka, 2002).

Therefore, organizations need to focus on developing effective workforce strategies to redeploy their existing resources in order to create new positions. Top management professionals ignore the importance of workforce planning in most organizations as they are not able to perceive its value in the right sense (Vareta, 2010). It is a systematic analysis of the gap present in order to ensure the availability of the right number of employees with the essential skills in the organization in order to fulfil the needs when required (Vareta, 2010; Cherian, 2011). Both the internal as well as the external factors are responsible for the success of a workforce plan (James, 2006). It helps in shaping the future workforce requirement of an organization (James, 2006; Keel, 2006). It can be also used to craft out the strategic planning framework so that organizations are prepared to face any kind of shortage arising due to a shrinking labour pool (Cotten, 2007). Intense global competition, rapid technological changes, growth of the knowledge economy and the need for flexibility and expertise in the workplace are some of the challenges faced by the organizations these days (Catteeuw et al., 2007; Wickham and O'Donohue, 2009). Also due to a change in the demographic base the demand for highly skilled workforce, independent, internationally marketable and mobile individuals is exceeding the available supply (Ewing et al., 2002; Ployhart, 2006). Therefore in order to fill the gap arising out of the existing difference between demand and supply of the labor force, organizations need to acquire and form a talent pool for themselves.

Talent Acquisition

Organizations are increasingly trying to assess and enhance their attractiveness to prospective applicants which has critical consequences for the recruiting organizations as it leads to the most urging problem of talent acquisition i.e., attracting the right kind of people having the required skill sets and competencies to fit with the need and the culture of the organization (Highhouse et al., 1999; Rynes, 1991; Bhatnagar and Srivastava, 2008). Organizational attractiveness is a very important factor on which they need to focus in order to attract prospective job applicants towards them. This refers to the extent to which prospective job applicants have a positive attitude or perception towards the organization and the desirability of an individual to work in that place (Rynes et al., 1991; Aiman-Smith et al., 2001). It helps in attracting the right kind of job applicants with the right set of knowledge and skills to form a pool of talent which not only gives a competitive edge but also helps in matching up with the required organizational expectations (Cable and Turban, 2001). It has been found through an in depth analysis that a strong relationship exists between the organizational attractiveness and the job applicant's decision to accept a job (Chapman et al., 2005, Turban et al., 2001). The image of the organization, characteristics of the job and organization are the factors which are responsible for attracting talent as they all contribute towards enhancing the organizational attractiveness, while the characteristics of the recruiter such as friendliness and competence have an indirect effect on the intentions of the applicants (Turban et al., 1998). However, it's not necessary that all have the same characteristics and same factors for selecting or rejecting an organization for working there. The traits might differ from person to person. From the 'attraction-selection-attrition' model it has been inferred that people are attracted to different organizations based on their interests, personality and needs (e.g., for achievement, affiliation, power or stability) (Schneider's , 1987). The brand visibility of an organization has significantly influenced the degree to which talents have shown interest towards job openings.

Those organizations which can attract a larger applicant pool and more qualified applicants gain more effectiveness in their selection systems and a potential competitive advantage (Boudreau and Rynes, 1985; Lado and Wilson, 1994). Therefore it becomes imperative for organizations to consider and reconsider the various strategies that will attract potential talent. It depends on the organizations abilities to attract talent by presenting attractive job opportunities such as offering better pay packages, reward system, giving a realistic job preview etc. In order to make the talent pool wider organizations should consider a diverse group of male and female employees from different generations and from different cultural and ethnic backgrounds.

So the first and foremost step in an effective talent management programme is to plan the workforce which is needed to perform the various tasks in the organization and the second step is to acquire those talents which the organization lacks. During the former step the organization tries to find out the gap that exists in talent and in the later stage it tries to fill that gap through recruitment. Effective talent management is not only hiring the required talent but also integrating it. There are various pools of talent available from which an organization can select for itself like internal employees, external job applicants, part time workers etc. The organization which can expand its horizon and keep a holistic view of talent acquisition will always have an edge over its competitors. Talent acquisition doesn't only means the acquisition of external talent but also the integration of the internal employees in order to leverage the interest of the organization to its best. Superior talent management seeks to focus at all pools of talent and streamlines the planning stage to the talent acquisition stage.

Process of Talent Acquisition

In the current economic climate, short term retrenchment, growth in new markets, a constant line of innovative products and services, and high levels of operational excellence may help organizations in reaching their financial objectives. For most of the companies' talent represents an important driver of operating results and the labour cost associated with that is one of the largest elements of overhead expense. Effective talent management is a fundamental prerequisite to achieving these goals in any manufacturing concern.

Manufacturers are quite puzzled about managing talent due to a complex business environment. In developed markets, science and engineering graduation rates are not keeping pace with individual retirements, workforce outlooks of employment are changing dramatically, jobs require more complex skill sets, and the competition for talent from other industries is increasing. Manufacturers are inexperienced and novice in their approach towards managing talent as a result of which they are unable to keep pace with the rapidly growing market in various segments. Talent management has a critical role to play in manufacturing organizations. As a result of innovation in technology, globalization and changing demographics, the manufacturing sector is experiencing a rapid evolution.

Business strategy

Organizations with effective talent management practices have sustainable growth. In order to survive in this competitive world, organizations need to look out for ways which can enhance and fulfill their long term goals of the business. Organizations with a myopic vision are definitely going to be at a loss. Today the challenge is not only to invest resources in talent management but also to recognize what talent practices provide greater return, which can develop the best people in the organization and to align, integrate and streamline the talent practices with that of the business strategy.

HR strategy

It is well known that talent management is a main subset of the HR strategy. It is of prime importance that these two components should be in proper shape in order to achieve the common goal of acquiring talent which will drive sustainable growth.

Talent management

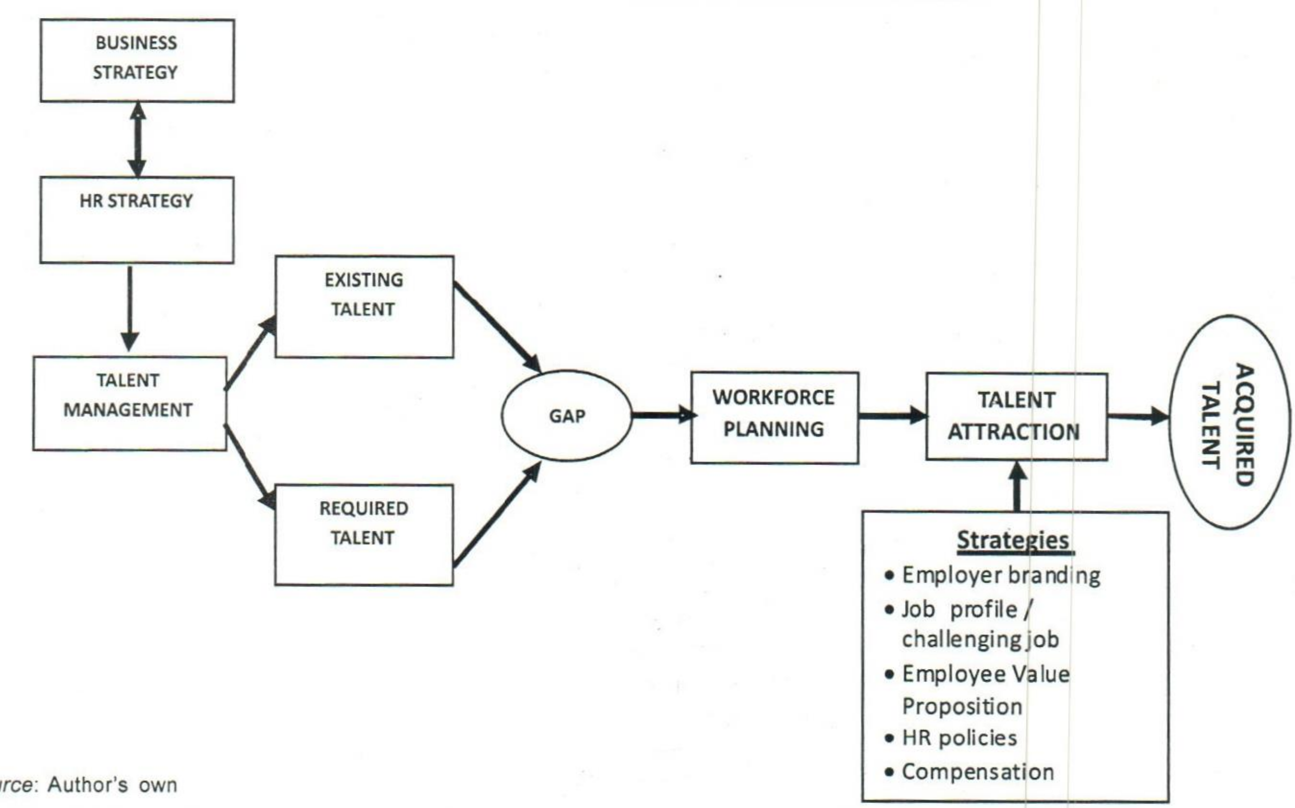
Talent management is something which adds value and broadens the horizon of research by offering business level and strategic viewpoint of managing talent in an organization (Jackson and Schuler, 1990; Walker, 1980). However, it has been seen that past research has failed to find a correlation between the two and how it can take place (Gubman, 2004). The human resource management practices that best support the types of strategies organizations may implement and the organizational structures i.e., functional, decentralized, etc. were the first initiative to tie the business strategy to human resource management (Tichy et al., 1982). So in order to be more strategic in their approach organizations must encourage HR professionals to understand the business strategy of the organization and streamline both the HR department and practices to support it.

Gap analysis

Gap in the context of the model given above is the difference between the existing talent which is already there in the organization and the talent which is required by the organization. Gap gives an idea about the number of talents to be recruited or acquired by the organization in order to fill the vacant positions as well as to plan future and present workforce required.

Strategic workforce planning

As it could be inferred from figure1 that workforce planning follows a simple path. However, it serves the greater organizational needs. It helps in knowing the present supply of labor and matching it up with the future demand of labor. It gives a quantitative idea about the talent required to form an effective and efficient workforce. It helps to ensure



Source: Author's own

Figure 1: Strategic Talent Acquisition

the alternatives available, it gives realistic staffing forecasts for the purpose of costing, and it gives a clear validation of the return on investment (ROI) made in training and development.

Talent attraction

Talent attraction is the process through which organizations attract talent as well as acquire them through recruitment and selection processes. It is the process of acquiring skilled workforce to cater the organizational needs. The workforce planning or human resource planning department in an organization plans the number and type of workforce required and accordingly the talent is acquired. Various talent acquisition strategies are used like employer branding, job profile, employee value proposition, HR policies and compensation to attract the right talent.

Acquired talent

A pool of talent is a sea of job seekers and potential candidates who are attracted through the talent acquisition process to the organization. The talent acquired from various sources that have potential and are capable but they are still novice and need training to hone their skills.

Talent Acquisition Strategies

- ***Employer branding:*** It is a way by which corporate identities are managed. The application of marketing principles to the field of human resource recruitment and attraction is known as branding (Maurer et al., 1992). Corporate identities can be maintained by creating an image of the organization both outside as well as inside the organization by being a distinct and desirable employer as well as a good place to work for (Ambler and Barrow, 1996; Backhaus and Tikoo, 2004). Therefore, initial perceptions are mostly based on the general view of the attractiveness of the organization (Rynes, 1991). So any information that the prospective candidates view forms a notion in their mind about the employer which acts as clues to know about the working style and environment (Turban et al., 1998). A high level employer brand helps the firms in attracting new talent (Bouchikhi and Kimberly, 2008; Lievens et al., 2007; Bhatnagar and Srivastava, 2008). The brand image of an organization not only ensures a continuous source of applicants but also increases the credibility of the organization by promoting organizational effectiveness and maintaining a high commitment and high performance environment (Holliday, 1997; Burack et al., 1994; Ployhart, 2006). Employer brand gives an edge to the organization over the others as it distinguishes it on the basis of certain unique and distinct features as opposed to the competitors and thus gives the applicants a clear picture of the employment value proposition.
- ***Job profile/challenging job:*** New recruits in an organization anticipate a high job profile as a result of brand image or goodwill of the organization. But it may not turn out to be the same and this may cause dissatisfaction and turnover among the employees. In order to tackle this problem the new recruits must be given a realistic job preview which will explain both the attractive as well as the unattractive part of the job and the organization (Wanous, 1975). It is obvious that the candidates only after knowing about the job as well as the organization can consider applying for the post. Hence giving a reflection of the job that they are going to do will help them in knowing about the responsibilities and duties. If a potential candidate is confused by an ambiguous job description, they won't apply. Also a challenging job profile has been seen to be one of the motivating factors for candidates to apply in an organization.
- ***Creating an employee value proposition (EVP):*** The creation of a strong and effective employee value proposition acts as a magnet to attract talent towards it. An EVP gives a competitive edge to the organization and a unique identity in the market. Job applicants get to know how it might be to work in that organization. It is that unique strategy which helps employers,tells the job applicants about the various opportunities that will be provided within the organization(Harchandani, 2009). This could be even made better by extending it to keeping in view the needs of various generational segments of applicants.
- ***HR policies:*** It has been seen that some companies are more successful than others in attracting talent due to their robust and effective HR policies. Organizations need to create HR policies which will not only attract talent but also enhance the brand image of the organization. The perceived value of an organization is increased for the applicants as a consequence of such practice. Hence creating policies which will enhance the organization's attractiveness in the labor market is of utmost importance (Hiltrop, 1999). Some of the policies which enhance the

attractiveness of the organization are continuously recruiting, specifying the kind of person required for the post mentioned, creating a challenging job profile, providing the employees with effective training and development.

- ***Compensation:*** The applicants seek job not only for career opportunities but also to earn money. Therefore in order to attract talent organizations should have a good pay package, it should be offering better benefits and incentives as compared to other industries. To attract talent which will take the organization to new heights the salary offered should also exceed the current standards set by other organizations. In today's competitive market where skilled payroll professionals are in strong demand, competitive compensation plan must be developed to get an edge over other organizations. Different and innovative compensation plans can be framed like providing the anticipated benefits with pay, compensating indirectly, and reevaluating salaries frequently etc.

Professional Implications

Workforce planning and talent acquisition is one of the most vital issues in which HR professionals/practitioners are involved. As a result of the dynamic nature of work, changing demographic patterns, the rapidly advancing technology, the shift to knowledge-based economies and the need for innovation, productivity of the job, to plan and acquire workforce for the organization has become even more difficult for managers. This article provides a practical and rational view of the strategic talent acquisition which will provide support to the practitioners in the following ways:

- It will help in clearing the concepts of workforce planning and talent acquisition in the present scenario.
- It also emphasizes on the importance of organizational attractiveness to acquire right talent.
- Gives the most important talent acquisition strategies which will lead to attraction as well as acquisition of talent.
- This will help the practitioners to bring in at least some changes in their old and traditional planning and acquisition processes.
- Finally, the whole process of talent acquisition in the form of a model which gives the steps through which the formation of an acquired talent pool takes place.

Conclusion

Indian businesses have started giving importance to talent deficits by chalking out strategies to eliminate it from the root of the talent spectrum. Organizations are working cooperatively with bodies like National Skills Development Corporation in the manufacturing sector. Visionary managers, executives, CEO's and entrepreneurs are also developed by working in collaboration with the National Manufacturing Competitiveness Council through the 'visionary leaders for manufacturing programme'. There is a need for developing workforce and talent acquisition strategies which will allow organizations to attract talent which will let the organization grow and compete with the other industries. Therefore, it's seen that both workforce planning and talent acquisition are important to streamline the organization's talent supply chain. As a part of a strategic business planning process organizations are increasingly using highly advanced approaches to attract talent. A workforce planning strategy well-made will always serve both the long term as well as the short term needs of the organization. It is the development of the effective workforce plan which will lead to successful talent acquisition and consequently talent management. Moreover there are organizations that do not focus on the long-term needs of talent while they only plan for the present. Most of them have their own recruitment programmes. However, in most of the cases it is found that the workforce planning and talent acquisition processes are not well structured and the technology is underutilized. Nonetheless, it is found that the organizations somehow fulfil their talent needs of the present. But for an organization to be competitive and have an edge over others it is necessary that they should not only focus on the current needs but also think what it takes to be better in the future. Their sourcing efforts can be improved by matching up the future demand of talent to that of the current supply.

References

Ambler, T. and Barrow, S. (1996), "The employer brand," *Journal of Brand Management*, Vol.4, No.3, pp.185-206.

Aiman-Smith, L., Bauer, T.N. and Cable, D.M. (2001), "Are you attracted? Do you intend to pursue? A recruiting policy-capturing study", *Journal of Business and Psychology*, Vol. 16, No. 2, pp. 219-37.

Backhaus, K. and Tikoo, S. (2004), "Conceptualising and researching employer branding," *Career Development International*, Vol.9, No.5, pp. 501-517.

Bhatnagar, J. and Srivastava, P. (2008), "Strategy for staffing: employer branding and person-organization Fit," *Indian Journal of Industrial Relations*, Vol.44, No.3, pp.35-48.

Boudreau J.W. and Rynes, S.L. (1985), "Role of recruitment in staffing utility analysis" *Journal of Applied Psychology*, Vol.70, No.2, pp. 354-366.

Bouchikhi, H and Kimberly, J.R. (2008), *The soul of the corporation: how to manage the identity of your company*, Pearson Education Inc, New Delhi.

Burack, E.H., Burack, M.D., Miller, D.M. and Morgan, K. (1994), "New paradigm approaches in strategic human resource management," *Group and Organization Management*, Vol.19, No.2, pp. 141-59.

Cable, D.M. and Turban, D.B. (2001), "Establishing the dimensions, sources and value of job seekers employer knowledge during recruitment," in Ferris, G.E. (eds.), *Research in Personnel and Human Resources Management*, Elsevier Science, New York, NY, pp. 115-63.

Catteeuw, F., Flynn, E. and Vonderhorst, J. (2007), "Employee engagement: boosting productivity in turbulent times," *Organization Development Journal*, Vol.25, No.2, pp.151-157.

Chapman, D., Uggerlev, K., Carroll, S., Piasentin, K. and Jones, D. (2005), "Applicant attraction to organizations and job choice: a meta-analytic review of the correlates of recruiting outcomes," *Journal of Applied Psychology*, Vol. 90, No. 5, pp. 928-44.

Cherian, K.T. (2011), "Human resource planning is a systematic analysis of HR needs," available at: www.oppapers.com/essays/Hr-Planning-Is-A-Systamatic-Analisis/563664.

Cotten, P.A.(2007), *Seven step of effective workforce planning*, West Tower, Washington, DC.

Ewing, M.T., Pitt, L.F., De Bussy, N.M. and Berthon, P. (2002), "Employment branding in the knowledge economy," *International Journal of Advertising*, Vol.21, No.1, pp.3 - 22.

Gubman, E. (2004), "HR strategy and planning: from birth to business results," *Human Resource Planning*, Vol.27, No. 1, pp. 113"123.

Harchandani, S. (2009), "Tap in the right talent," available at:www.humancapitalonline.com , pp.32-26

Highhouse, S., Zickar, M., Thorsteinson, T., Stierwalt, S. and Slaughter, J. (1999), "Assessing company employment image: an example in the fast food industry," *Personnel Psychology*, Vol.52, No.1, pp. 151-169.

Hiltrop, Jean-Marie (1999), "The quest for the best: human resource practices to attract and retain talent," *European Management Journal*, Vol. 17, No. 4, pp. 422–430.

Holliday, K.K. (1997), "Putting brands to the test," *U.S. Banker*, Vol.107, No.12, pp.58-60.

Jackson, S.E. and Schuler, R.S. (1990), "Human resource planning: challenges for industrial/organizational psychologists," *American Psychologist*, Vol.45, No.2, pp. 223"239.

James, W.M. (2006), *Forecasting manpower demands in the construction industry of Hong Kong*, The Hong Kong Polytechnic University, Hong Kong.

Keel, J. (2006), *Workforce planning guide*, State Auditor's Office (SAO) Report, Austin, TX.

Laabs, J. (1996), "Duke's newest power tool," *Personnel Journal*, Vol. 75, No.6, pp.44-52.

Lado, A.A. and Wilson, M.C. (1994), "Human resource systems and sustained competitive advantage: a competency-based perspective," *Academy of Management Review*, Vol.19, No.4, pp. 699-727.

Lievens, F., Van Hoye, G. and Anseel, F. (2007), "Organizational identity and employer image: towards a unifying framework," *British Journal of Management*, Vol.18, No.1, pp. 45-59.

Maurer, S.D., Howe, V. and Lee, T.W. (1992), "Organizational recruiting as marketing management: an interdisciplinary study of engineering graduates," *Personnel Psychology*, Vol.45, No.4, pp. 807-833.

Melymuka, K. (2002), "Don't just stand there – get ready," *Computer World*, Vol. 36, No.26 pp. 48-49.

Ployhart, R.E. (2006), "Staffing in the 21st century: challenges and strategic opportunities," *Journal of Management*, Vol. 32, No. 6, pp. 868-897.

Reilly, P. (1996), *Human Resource Planning: An Introduction*, IES Report, 312.

Rynes, S.L. (1991), "Recruitment, job choice, and post-hire consequences," In M.D. Dunnette, and L.M. Hough, (eds.), *Handbook of Industrial and Organizational Psychology (2nd Ed.)*, Consulting Psychologists Press, Palo Alto, CA, Vol.2, pp. 399-444.

Rynes, S., Bretz, R., and Gerhart, B. (1991), "The importance of recruitment in job choice: a different way of looking," *Personnel Psychology*, Vol. 44, No.3, pp. 487-521.

Schneider, B. (1987), "The people make the place," *Personnel Psychology*, Vol.40, No.3, pp.437-453.

Tichy, N.M., Fombrun, C.J. and Devanna, M.A. (1982), "Strategic human resource management," *Sloan Management Review*, Vol. 23, No. 2, pp.47"61.

Turban, D., Forret, M. and Hendrickson, C. (1998), "Applicant attraction to firms: influences of organization reputation and organizational attributes, and recruiter behaviors," *Journal of Vocational Behavior*, Vol. 52, No.1, pp. 24-44.

Turban, D.B., Lau, C.M., Ngo, H.Y., Chow, H.I.S. and Si, S.X. (2001), "Organizational attractiveness of firms in the peoples' republic of China: a person-organization fit perspective," *Journal of Applied Psychology*, Vol. 86, No.2, pp. 194-206.

Vareta, N. (2010), "Importance of human resource planning in organizations," available at: www. oppapers.com/essays/ Hr-Planning/427456.

Walker, J.W. (1980), *Human resource planning*, McGraw-Hill Book Company, New York.

Wanous, J.P. (1975), "Organizational entry: newcomers moving from outside to inside", *Psychology Bulletin*, Vol.84, No.4, pp. 601–618.

Wickham, M. and O'Donohue, W. (2009), "Developing 'employer of choice' status: exploring an employment marketing mix," *Organization Development Journal*, Vol. 27, No. 3, pp. 77-95.

It has become appallingly obvious that our technology has exceeded our humanity.

— Albert Einstein

Feature

Production and Productivity of Indian Indigenous Livestock Breeds

D. K. SADANA

Productivity of Indian breeds of livestock is superior when we consider the output based on low-grade inputs available to them. Indian breeds have the capacity to survive the vagaries of low feed/fodder regime, drought and heat-load, yet these produce reasonable volumes of output and also save on account of less food-miles and less pollution. In addition to the capacity to survive, indigenous breeds have special quality features like A-2 milk protein and therapeutic milk from cattle and camel. Utilizing the meager available local bio-mass in efficient manner, indigenous breeds have low input costs which raises the output to input ratio and hence the productivity.

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Indian livestock are often blamed for low production, but these cannot be blamed for low productivity for very simple reason: the available input levels are low, the climate is antagonistic, and health support is insufficient. In spite of these shortcomings, the Indian livestock maintain their capacity to survive, reproduce, and produce. Production levels are low, e.g., milk yield of Indian breed cow is 3000 kg vs. 8000 kg in Holstein. However, the difference in production has to be seen jointly with the environment in which the animal is performing. Productivity is an expression of the output to input ratio. Hence, the input levels and the ambient environment in which the animal is performing must also be accounted for. If the environments of the above two breeds are exchanged the ratio of 3:8 will break drastically. With heat-load, disease-load, even the basic survival of the exotic breed will become difficult. Matching of the indigenous breeds against their environment is necessary to assess the productivity and to question the myth that Indian livestock has low productivity.

Productivity

Productivity basically is the overall output against the sum result of the available inputs. Indigenous breeds of livestock have, over the ages, developed the capacities and the qualities that make them sound in terms of productivity and highly capable to meet the local requirements. An Indian breed in its own habitat, for example, accepts whatever little is available and produces quality milk with therapeutic value, renewed draught power that is locally available, meat & wool and strengthens the local livelihoods. These livestock help in several aspects: reducing food-miles as the food is locally produced and locally consumed, reducing pollution by saving petro-fuel energy (through the use of draught power) or by generating energy from bio-gas. Use of manure also saves production of fertilizers and hence saves from increased pollution. These features are hardly ever considered, but have a direct relevance with productivity. Of special relevance are the locally adapted breeds.

Livestock vs. Breeds

Breed animals are just a part of the total livestock, indeed. In view of production and productivity, however, breed animals need to be distinguished from the remaining population. Take, for example, cattle. There are 37 recognized breeds plus 27 defined populations. These together make around 25% of the total cattle population in the country. Without going into the nitty-gritty of the definition of a breed, or exact numbers of each breed animals in the country, some statements can be safely made to examine the productivity.

A breed in its own tract (where it developed, or habitat of the breed) along with the surrounding environment makes the best production combination. The environment includes the ambient climate, the available nutrition, health support, and whatever available management level. In its attempt to adjust with the ambient conditions, the breed, in fact, has developed itself at gene level over centuries. Climate can be harsh; nutrition can be short of what is desirable; disease load may be high and persistent. Such situations are rampant in the country. If the breed continues to survive in spite of the shortcomings, it definitely has the necessary gene combinations. The interactions of existing genes themselves, and the interactions with the environment are such that the breed in question and the environment surrounding it makes a valuable combination of high output from the breed for the given input levels. Input levels are low; output cannot be expected to be huge. The breed is locally adapted. It survives, reproduces well, produces reasonably enough, and has the potential to improve, if properly attended to.

Basically, an adapted breed has to spend energy for getting and then maintaining its adaptableness to the shortages of inputs and harsh conditions. Take the instance of heat tolerance and production/productivity as an illustration.

Heat Tolerance vs. Production

A breed having adapted to tolerate high heat has the desired gene combination (genome) having been developed over centuries of exposure to high ambient temperatures. At any moment, the body system has to choose between survival and production. Both cannot come together. "Ability-to-Survive" comes before "Ability-to-Produce" as, in nature, survival is more important than production. The process of high production also generates higher metabolic heat. This has an antagonism: the body is unable to throw off extra heat due to high ambient temperature. Hence the body chooses to reduce its metabolic rate so that it can still survive. With lower metabolic rate the production lowers. This is the cost to be paid for letting the animal continue to survive in the face of high ambient temperature.

Production is less in the animals that are able to tolerate high heat. In high heat, a high milk producing breed (like Holstein) has to be provided artificial means of cooling like continuously sprinkling water or air-conditioners. Physiological anomalies have been noted among the crossbreds in spite of good management and input levels e.g. high male infertility among Frieswal bulls and drastic reduction in population size among Karan-Swiss strain of cattle. Due to high involuntary culling, crossbreds are often unable to replace themselves.

Feed and input levels vs. Production

Indigenous breeds have gained the ability to survive in spite of the shortages of feed and fodder. Availability of feed/fodder hovers around half of the demand of the existing livestock population in the country. An animal receiving half of what it needs will barely be able to survive; yet, sustained survivability of the breed in spite of the shortage of feed/fodder is another important trait of the indigenous breeds. This trait is missing in the high producing breeds (like Holstein) or crossbreds. Furthermore, if only low level feed/fodder is permitted to Holstein (or its crossbreds), it develops physiological and pathological disorders affecting their very survival. Drought situations (e.g., three consecutive droughts from 2001 to 2004) in Karnataka and Maharashtra have revealed high percentage loss of pure exotic breeds, medium loss of crossbreds and only low level loss of the local indigenous cattle.

By virtue of their genetic make-up, indigenous cattle/livestock have the capacity to digest low grade feed and can survive drastic shortages of feed/fodder. After the shortage period when the feed/fodder starts becoming available, the indigenous breeds have the capacity to come back to normal production/reproduction cycles. This is not true for the exotic breeds or their crosses. For this reason also the indigenous breeds score higher in respect of productivity. Even though the production per animal is low, productivity of the group is more due to better survivability, as explained next.

Survivability vs. Production

Productivity must also consider another important aspect: Production per animal or production per live animal?

The representative figures of 3000 kg yield by indigenous breed (e.g., Gir) and 8000 kg yield from exotic breed (e.g., Holstein) are expressed to be average production per animal to create the impression of low and high production or "disparity in productivity." This value (production per animal) actually is *production per live animal*. Animals are there to perform; their production is recorded and averaged. This, in other words, is the production of the live animals. There is no adjustment for the animals that were lost in the chain from sire being infertile leading to lost conception, from a successful conception to abnormal birth, and from a normal birth to not reaching the stage of first calving leading to lost milk production. All these losses are much higher in exotic animals (and their crosses) under the Indian input levels and far low among the Indian Indigenous livestock. Better survivability, hence, leads to better productivity. Just like survivability and longevity, there are more features at the species and the breed level which need to be considered.

Special Features of the Indigenous Breeds of Livestock that Raise their Productivity

Indian breeds of livestock (37 of Cattle, 12 Buffalo, 42 Sheep, 20 Goat, 9 Camel, 6 Horse, 2 Pig, 1 Donkey, 18 Poultry) have their innate features that make them more suitable in their own habitat compared to any other breed from other region brought into this habitat. Through interactions with the environment (especially and notably, the limitations in the environment), these breeds have developed unique features that, on the one hand, enhance their survivability, and, on the other, provide unique outputs of utility to man.

Survivability features include heat-tolerance, disease-resistance, and conversion efficiency of low-grade feed. It makes the indigenous breeds less dependent on external inputs and enhances productivity. This increased productivity is, in a way, ingrained in their genes—most of such genes are yet to be deciphered, yet the phenotypic expressions are evident through comparative studies. There is no doubt that several of such expressions are yet to be quantified. But, at the same time, lack of quantification should not be the reason to ignore the innate and evident values of the indigenous resources expressed through better survivability. Indigenous breeds have expressed better survivability through longer life, higher calf-crop, more number of lactations in the lifetime, and, as a result, better overall productivity.

Utility features are the beneficial output traits from the livestock, e.g., increased and dependable draught-power, flavored meat in sheep, etc. These utility features, besides providing revenue and livelihoods, also become the basis of selection. Over the ages man-made natural selection has favored such traits/features and, in many cases, these features have strengthened leading to additional gains from the livestock. All such favored features have together raised the productivity of the breed (for the same input received). These features in many cases have become the synonyms for the breed and the breed is better known from the typical feature for instance Kalamansi chicken. Kalamansi is the other name for Kadaknath breed of poultry found in Madhya Pradesh. The breed has black colored chicken that is known to have aphrodisiac properties. A study has concluded that black exterior and interior of this unique cock are due to specific climate, altitude and surroundings of the Jhabua tribal region in the state. Efforts at breeding this fowl elsewhere have invariably failed; appreciating the importance of the breed well integrated in the surrounding environment, the breed and the surrounding environment jointly raises the productivity of the system. Several of the other breeds of poultry as well as other species of livestock have typical features which imparts higher productivity to the breed.

Cattle

Indian indigenous breeds of cattle produce the healthier A2 type of milk which is superior to A1 type largely produced by Holstein and Jersey cows. A1 kind has been reported to cause 5 diseases: autism, atherosclerosis, heart disease, blood pressure and Sudden Child Death Syndrome (SCDS). Further, milk from indigenous cattle has been reported to produce proportionately more amount of omega-3-fatty-acid and conjugated linoleic acid (CLA), known to have a positive impact on human health, and, coming in milk, are easily digestible. In addition to milk, productivity from cattle also depends on the use of other products like dung and cow-urine. Quality of dung is superior for its use as manure, vermicompost, bio-fertilizer and production of bio-gas, methane and CNG. Quality of cow-urine is superior for its use as bio-pesticide. Recently certain US patents (e.g., # 6410-059, 7297-659 and 7718-360) have been obtained on the quality and use of Indian indigenous cow-urine, notably on its use as immunopotent and DNA repairing agent. Unlike production, the productivity should not depend only on the amount of milk produced. Indigenous cattle, hence, should score higher productivity based on the quality features narrated above. Productivity should depend on amount of milk as well as its quality.

Other Livestock

Indian indigenous breeds of sheep have special features viz. (i) capacity to migrate and help utilize remotely located pastures (e.g., Gaddi breed) (ii) wool with high luster (e.g., Magra breed) (iii) meat flavor (Mandya breed) (iv) palatability (several Indian breeds) (v) high fecundity (e.g., Garole breed) and (vi) capability to walk long distances (e.g., Marwari breed). These features are largely added outcomes for the same or similar inputs that make the breeds more productive in their own region. Indigenous goat breeds have marked specialties such as (i) high milk yield of more than 3.5 kg a day from Jakhrana breed (ii) ghee from Ganjam breed used for Asthmatic problems (iii) superior fiber like "pashmina" from Changthangi breed, and (iv) very high growth rate (e.g., Sirohi breed). Similarly, milk from camel breeds has been in use for diabetes as it has higher level of immunoglobulins, Vitamin C, Potassium, etc. In horse subgroup, Manipuri ponies are known for polo and racing purpose, which adds to their special usefulness and productivity. Increased productivity from Indian breeds of buffalo is directly from their higher feed conversion efficiency. Pigs do not have many defined breeds in the country; two breeds have recently been identified: Ghoongroo and Niang-Megha. The breeds have higher productivity by virtue of better local adaptability including efficient conversion of locally available feed resources.

Conclusions

Productivity is an expression of output to input ratio in comparison to *production* which only expresses the volume of output. Indian indigenous breeds of livestock are known to produce lower volumes but better quality of outputs in spite of having access to meager available lower grade inputs under the situations where the crossbreds or exotic breeds are unable even to survive. Ability to withstand tropical heat, insufficient and low-grade feed/fodder and drought situations takes a part of the energies of these breeds, leaving much less for producing higher volumes. Looking at the inputs and the outputs, the Indian indigenous breeds must be complemented for their higher productivity and for providing sustainable local production systems with secured nutrition and livelihood support to the large masses of the country that depend on marginal areas.

> *Almost everybody is enthusiastic about the promise of biotechnology to cure disease and to relieve suffering.*
>
> ***—Leon Kass***

Feature

Land Use Dynamics in Kerala: An Analysis of Issues and Policies for the Future

A. R. DURGA AND D. SURESH KUMAR

The land-use changes in Kerala represent an intricate pattern especially in view of the wide variations in physical settings and the complex development patterns adopted in the past. Hence, a study was taken up to examine the land use dynamics. Compound growth rate and Markov chain analysis were employed to analyze the change in land use pattern. The study showed that there is a significant positive growth in area under permanent pastures and other grazing lands and fallow lands other than current fallow. Markov chain analysis showed high instability in permanent pasture and other grazing lands. The present study also revealed that there is stagnation, large scale commercialization and instability in agricultural sector of Kerala. So it is imperative for the government to implement suitable policies such as promotion of group farming ensuring remunerative prices to bring area under cultivable waste under cultivation. Concerted efforts also need to be done to modernize method of agriculture through GALASA- "Samagra Krishi Vikasana Padhathi" (Complete Agricultural Development Project). In this regard fallow land other than the current fallows can be brought under cultivation.

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During the past three decades the agriculture sector of Kerala has undergone wide-ranging changes in terms of ownership of land, cropping pattern, cultivation practices, productivity, and intensity of cultivation. Unlike the other regions in India, the farm front of Kerala is characterized by extreme diversity in its bio-physical resource base and agro-climatic endowments. In earlier periods, the choice of cropping pattern was guided by agronomic considerations and consumption needs of farmers. The methods of land use in Kerala have changed over the past half century or so. Agricultural income in Kerala which showed a steady growth up to the mid-seventies began to decline thereafter and showed a wavering trend in the eighties. This change is mainly attributed to the shift in area from seasonal/annual crops to high-value-yielding perennial cash crops having a long gestation period. By the end of the eighties, cash crops started generating higher income to the farm sector. George and Chattopadhyay (2001) observed that such shifts in land-use may have profound implications for the food security of the state, which already depends on "outside supplies" to meet more than half of its food grain requirements. In addition to the conversion to upland crops owing to socio-economic and/or technological commercial reasons, population growth and urbanization have led to a marked increase in clay mining (for brick making) and other non-agricultural uses of land, which further deepened the situation. There is also a clear shift away from food crops, mainly rice and cassava, in favour of tree crops such as rubber and coconut.

Both climatic and institutional factors are crucial in determining land use pattern. The extent of land use is also influenced by technological changes over a period of time. The technological changes resulted in conversion of marginal lands into productive agricultural lands through capital-intensive cultivation. Nadkarni and Deshpande (1979) highlight the importance of institutional factors leading to underutilization of agricultural lands especially when people employed in urban areas keep lands idle for using it after retirement or for speculative motive. Their study also revealed that an increase in the size of operational holdings has a positive impact on current fallows.

Increase in population pressure and other factors can lead to expansion of agricultural land and intensification of cultivation and after a stage, it can cause conversion of agricultural land into residential and industrial area. Therefore a study of how land is used and trends in land use would help us in indicating how land is managed to evolve a better policy. Keeping these issues in view, the present paper aimed to (i) study the temporal land use pattern in Kerala, (ii) analyze the shift in the land use pattern, and (iii) suggest suitable policy measures for sustainable land use in the state.

Data and Methodology

Data

The present study is based on analysis of secondary data on land use pattern at state level. The time series data on land use pattern of Kerala was obtained from Season and Crops Reports, Agricultural Statistics at a Glance published by the Government of Kerala, for the period from 1980-81 to 2009-2010 .

Growth rates

Growth of any variable indicates its past performance. The analysis of growth is usually used in economic studies to find out the trend of a particular variable over a period of time. It clearly indicates the performance of the variable under consideration and hence it can be very well used for making policy decisions. To study the temporal land use pattern of Kerala compound growth rate was used. Following Goswami and Challa (2006), the growth in the area of different land use categories was estimated using the exponential growth function of the form:

$$Y_t = ab^T u_t \qquad (1)$$

where,

Y_t = Dependent variable for which growth rate was estimated (area)

a = Intercept

b = Regression coefficient

T = Years which takes values, 1, 2 ...n

u_t = Disturbance term for the year t

Equation (1) can be transformed into log linear form as follows.

$$\text{Ln } Y_t = \ln a + T \ln b + \ln u_t \qquad (2)$$

This equation was estimated using ordinary least square (OLS) technique. The compound growth rate (CGR) in percentage was then computed from the relationship,

$$\text{CGR} = (\text{Antilog of } (\ln b) - 1) * 100 \qquad (3)$$

Markov chain analysis

The Markov chain analysis is an application of dynamic programming to the solution of a stochastic decision process that can be described by a finite number of states. The Markov process was used to study the shifts in the land use categories thereby gain an understanding about the dynamics of the changes in land use pattern. Markov chain models are concerned with the problems of movement, both in terms of movement from one location to another and in terms of movement from one "state" to another. These models are used for describing and analysing the nature of changes generated by the movement of such variables, in some cases these models may also be used to forecast future changes (Collins, 1975). Following Suresh Kumar and Palanisami (2010) the changing land use pattern was worked out assuming that it follows a first order Markov chain as explained below.

A first order Markov chain is characterized by the transition probability matrix, given by expression (4):

$$p = \begin{bmatrix} p_{11} & p_{12} \cdots\cdots & p_{1n} \\ p_{21} & p_{22} \cdots\cdots & p_{2n} \\ \cdots\cdot & & \cdots\cdot \\ p_{n1} & p_{n2} \cdots\cdots & p_{nn} \end{bmatrix} \qquad (4)$$

where, p_{ij} is the probability that an area under the classification "i" during the current year changes into the classification "j" next year and "n" is the number of states. That is,

$$p_{ij} = Pr\,[X\,(t+1) = j / X(t) = i] \qquad (5)$$

where,

X(t) = State of the system at the year "t". It is clear that

$$p_{ij} \geq 0 \qquad i,j = 1,2,....,n \qquad (6)$$

$$\sum_{j=1}^{j=n} p_{ij} = 1, \qquad i= 1,2,.......,n \qquad (7)$$

In this paper, the structural change in land use pattern was examined by using the Markov chain approach. The estimation of the transitional probability matrix (P) was central to this analysis. The data for the study were the proportion of area under land use categories. The proportions change from year to year as a result of different factors. It is reasonable to assume that the combined influence of these individually systematic forces approximates a stochastic process and the propensity to move from one land use category to another category differs according to the land use category involved. If these assumptions are acceptable, then the process of land use dynamics may be described in the form of a matrix P of first order transition probabilities. The element P_{ij} of the matrix indicates the probability to move from the land use category i in one period to land use category j during the following period. The diagonal element P_{ij} measures the probability that the proportion share of ith category of land use will be retained. The elements P_{ij} of the matrix are the conditional probabilities of the area under a particular land use category in time t given its share in time t-1. The diagonal elements P_{ij} (i=j) indicate the extent of stability of land use categories. Hence, as the diagonal elements approach zero, area under a particular land use become less and less stable, and as they approach one, the land use categories tend to exhibit more and more stable over time. The off-diagonal elements P_{ij} (ij) are the probabilities of switching over between different land use categories. If P_{ij} is the diagonal element corresponding to the ith land use category, the other elements in the ith row give the proportions of previous period"s area of i-th land use category it is likely to loose to other categories in the current period. The elements of the i-th column give the proportions of areas of other land use categories in the previous period, the i-th land use category is likely to gain in the current period.

Projections

After estimating transition probability matrix (P), proportion of area under land use categories can be predicted using the following equation:

$$Y''(t) = Y''(0)\, P_t \qquad (8)$$

where,

Y_t = (r x 1) vector of proportion of area under land use categories in year t,

Y_0 = (r x 1) vector of proportion of area under land use categories in year 0,

P_t = (r x r) transition probability matrix to the power of time (t) and Y"(t) and Y"(0) are transpose of vector Y(t) and Y(0) respectively.

RESULTS AND DISCUSSION

Growth rates for area under different land use categories

The decadal trends in area under different land use categories reveal that there was no increase in area under forests between 1980s and 2000s (Table 1). The forest land in Kerala forms only 28 percent of the total land area, less than the national goal of having forest cover of at least one-third of the total land area. However, as for the share of forest area in the state remaining constant, there are differences of opinion. While the Government maintain that there is no change in the forest area in the state over the years, differing views are heard from scholars. It is said that "the absence of recurrent surveys of the area classified as forest" is the reason for the Government"s view. Field-level observations also indicate the conversion of forestland to cropland (George and Chattopadhyay, 2001). But according to the reports of the Kerala Forests and Wildlife Department, "the actual forest area in the State during 2003-04 was 9,400 sq. km which forms 24.19 percent of the total geographic area of the State" (Radha Devi and Ajith, 2011). The annual rate of deforestation in Kerala is said to be at the rate of 1.4 percent of the total forest cover (Kumar, 2005). This gives the impression that extent of area covered by forests is not yet clear. Several categories of lands such as barren and uncultivable lands, land under miscellaneous crops not included in net area sown, permanent pastures and grazing lands have all shown declining trend. Their total share in geographical area of the state has declined from 5.37 percent to 2.68 percent during the last three decades. A major part of these lands have gone into non-agricultural uses, the share of which has increased from 7.12 percent to 18.37 percent during the same period. The share of current fallows and other fallows increased from about 1.14 percent to 1.9 percent and 0.71 to 1.08 percent respectively. The net sown area has decreased to 55.15 percent.

Table1. Decadal averages of Different Land Use Categories in Kerala

Classification	1980s	1990s	2000s
Forests	10,81,500 (27.83)	10,81,500 (27.83)	10,81,500 (27.83)
Land put to non agricultural uses	2,76,530 (7.12)	3,19,900 (8.26)	3,79,520 (18.37)
Barren & uncultivable land	80,500 (2.07)	44,870 (1.08)	27,020 (0.70)
Permanent pastures and other grazing lands	4270 (0.11)	1,240 (0.03)	260 (0.01)
Land under miscellaneous crops not included in net area sown	49,650 (1.28)	27,9509, (0.65)	840 (0.25)
Cultivable waste	1,24,210 (3.20)	78,37076, (1.91)	980 (1.98)
Follow land other than current fallow	27,520 (0.71)	28,830 (0.75)	42,050 (1.08)
Current fallow	44,500 (1.15)	53,140 (1.44)	74,540 (1.92)
Net area sown	21,96,800 (56.54)	22,53,880 (58.13)	21,42,690 (55.15)
Area sown more than once	7,03,980 (18.12)	7,60,460 (19.10)	7,62,070 (19.61)
Total cropped area	29,00,780 (74.66)	30,12,160 (77.15)	29,04,820 (67.57)

Note: Figures in parentheses indicate percentage to total geographical area

There was about 32 percent drop in area under barren and uncultivable lands from 850 lakh ha to 270 lakh ha between 1980s and 2010s. This sharp decline in barren and uncultivable lands is probably due to the increasing pressure on land caused by increase in population and increasing demand for land for non-agricultural purposes. As a result of the increasing demand for land for industrial, housing and infrastructure developments, the land put to non-agricultural uses has shown a sharp increase of about 72.5 percent from 2765 lakh ha to 3965 lakh ha during this period. On the other hand the increasing demand for land for agricultural purposes has largely been met by bringing in cultivable wastes under plough. As a result of such extensive agricultural practices, the area under cultivable wastes decreased by about 75.96 percent from 1242 lakh ha to 769 lakh ha over the last 30 years. The decline in the land under miscellaneous tree crops is the result of construction purposes.

Growth rates were worked out to get a detailed picture on the dynamics of land use pattern in the state (Table 2). The decade-wise growth rate analysis for the period 1980-2010 reveal that the decline in permanent

Table 2. Compound growth rate of different land use categories

Classification	1980s	1990s	2000s
Land put to non agricultural uses	1.32	4.69	-1.59
Barren & uncultivable land	-6.33	-17.24	-16.34
Permanent pastures and other grazing lands	-16.29	-33.23	1.16
Land under miscellaneous crops	-11.37	-18.66	-2.91
not included in net area sown			
Cultivable waste	-4.24	-11.81	14.52
Fallow land other than current fallow	0.81	4.45	8.47
Current fallow	1.79	14.05	0.16
Net area sown	0.55	0.23	-1.71
Area sown more than once	1.79	-3.33	-8.39
Total cropped area	0.88	-0.75	-3.44

pastures and other grazing lands, land under miscellaneous crops not included in net area sown and cultivable waste was the highest during previous two decades. It might be due to population pressure and increasing demand for land for non agricultural purposes. Increase in fallow land is due to large proportions of land left uncultivated as people have moved to the city for jobs and are unable to take care of the land. The growth in cultivable waste during the last three decades was the highest among the growth rates of all the land use categories, followed by the growth rate in fallow land other than the current fallow. The increase in other fallow lands is a major challenge to the growth of Kerala agriculture. Massive conversion of paddy fields for building houses, destruction of hillocks and filling up of low lying lands, paddy fields, water bodies and real estate boom have resulted in decrease in net sown area to 1.71 percent in the last decade.

Shift in land use pattern

The Markov Chain analysis was carried out to study shift in the land use pattern. The stability of the acreage share of the different land use categories considered for analysis and the transition probability matrix captured their direction and volume of changes over time. The results of the transition probability matrix for different land use categories are presented in Table 3 and Table 4.

It can be inferred from the Table 3 that permanent pastures had shown high instability during 1980s. It had retained zero percent of previous period's area during the current period. It gave away cent percent of its previous share to barren and uncultivated land. But it gained 8 percent from miscellaneous tree crops. The land put to non agricultural uses retained 29 percent of the previous share and diverted about 3 percent to forest, 16 percent to cultivable waste and 52 percent to net sown area. However, it gained 28 percent from fallow land, 8 percent from net area sown. Forests retained 97 percent of the previous share and gained 3 percent from land put to non agricultural use. But 3 percent were diverted to net sown area.

Table 3. Transitional probability matrix for land use categories during 1980s

	FOR	LPNAU	BAUL	PP	MTC	CW	FL	NSA
FOR	**0.97**	0.00	0.00	0.00	0.00	0.00	0.00	0.03
LPNAU	0.03	**0.29**	0.00	0.00	0.00	0.16	0.00	0.52
BAUL	0.00	0.00	**0.92**	0.00	0.00	0.08	0.00	0.00
PP	0.00	0.00	1.00	**0.00**	0.00	0.00	0.00	0.00
MTC	0.00	0.00	0.00	0.08	**0.48**	0.44	0.00	0.00
CW	0.09	0.00	0.00	0.00	0.19	**0.40**	0.11	0.21
FL	0.16	0.28	0.00	0.00	0.00	0.00	**0.56**	0.00
NSA	0.00	0.08	0.00	0.00	0.00	0.00	0.01	**0.91**

FOR : Forest;
BAUL : Barren and uncultivable land
MTC : Land under miscellaneous tree crops and groves
CW : Cultivable waste
a) Current fallow (CF)
b) Fallow other than current fallow (FOTCF)
NAS : Net area sown
LPNAU : Land put to non-agricultural use
PP : Permanent pastures and other grazing lands
FL : Fallow lands

Table 4 and 5 present the results of the transition probability matrix for land use categories for the decades 1990s and 2000s. The results indicated that forests have become more stable in the second decade. This is because forest area retained much of its area from cultivable waste or fallow land. While permanent pastures showed more stability in the third decade. The use to which NSA is put has changed. This may be attributed to the fact that there is a reduction in the area under paddy production. The percent share of area under paddy production in total area under food crops has declined indicating a shift in cultivation. Unabated massive conversion of paddy fields for building houses, destruction of hillocks and the filling

Table 4. Transitional probability matrix for land use categories during 1990s

	FOR	LPNAU	BAUL	PP	MTC	CW	FL	NSA
FOR	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPNAU	0.00	**0.97**	0.00	0.00	0.00	0.00	0.03	0.00
BAUL	0.00	0.00	**0.79**	0.00	0.21	0.00	0.00	0.00
PP	0.00	0.00	0.00	**0.20**	0.80	0.00	0.00	0.00
MTC	0.00	0.00	0.06	0.03	**0.55**	0.06	0.00	0.29
CW	0.00	0.00	0.05	0.00	0.00	**0.95**	0.00	0.00
FL	0.00	0.08	0.00	0.00	0.00	0.00	**0.92**	0.00
NSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**

Table 5. Transitional probability matrix for land use categories during 2000s

	FOR	LPNAU	BAUL	PP	MTC	CW	FL	NSA
FOR	**0.96**	0.00	0.00	0.00	0.00	0.00	0.04	0.00
LPNAU	0.11	**0.17**	0.00	0.00	0.00	0.00	0.00	0.72
BAUL	0.00	0.00	**0.56**	0.00	0.03	0.00	0.00	0.41
PP	1.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00
MTC	0.00	0.00	0.19	0.00	**0.81**	0.00	0.00	0.00
CW	0.05	0.00	0.00	0.00	0.00	**0.90**	0.05	0.00
FL	0.00	0.00	0.00	0.00	0.00	0.09	**0.58**	0.33
NSA	0.00	0.15	0.00	0.00	0.00	0.00	0.00	**0.85**

up of low-lying lands, paddy fields, water bodies and deforestation has been widespread in the state causing serious ecological and environmental problems and complex feedback effects on agricultural production. The recent spurt in real estate prices began taking its toll on paddy fields in Kerala, which forced the state government to pass a bill banning any other commercial activity on the paddy fields (Radha Devi and Ajith, 2011).

The shares of different land use categories were predicted for next five years (2010- 2015) using transition probabilities and are presented in Table 6. It is evident from the table that the permanent pastures and land under miscellaneous tree crops are likely to retain their share in coming years. Area under forest, net area sown and fallow land are likely to remain same in the future.

Table 6. Projected shares of land use categories

Land use classification	2012-13	2013-14	2014-15
Forest	10893.0	10910.7	10927.5
Land put to non-agricultural use	3688.2	3683.5	3679.1
Barren and uncultivable land	228.9	228.9	228.7
Permanent pastures and other grazing lands	3.7	3.7	3.7
Land under miscellaneous tree crops and groves	41.3	41.0	40.7
Fallow land other than current fallow	0.81	4.45	8.47
Cultivable waste	1024.0	1032.8	1041.1
Fallow lands	1232.7	1235.6	1238.4
Net sown area	20678.2	20653.8	20630.7

Summary and Conclusion

Growth rates estimated for area under different land use categories showed a significant positive growth in area under permanent pastures and other grazing lands and fallow lands other than current fallow of 1.16 and 8.47 percent respectively. Net area sown registered a significant negative growth of about 1.71 percent. Dynamics of land use pattern was studied by Markov chain analysis and the results showed that permanent pasture and other grazing lands with high instability during the first and second decade. Decline in the number of persons engaged in farm-related activities, increasing specialization in livelihoods, migration of rural labour in search of work affect the transformation. The present study revealed the stagnation, large scale commercialization and instability in agricultural sector. There is a great scope for further extension of area of land under cultivation, as the existence of 3.8 percent of total geographical area is under fallow and cultivable wastes which can be brought under cultivation. The area under cultivable waste is increasing. Hence government need to implement suitable policies such as promotion of group farming ensuring remunerative prices to bring these land under cultivation. The forest cover in the district showed absolute stagnation in area. The forest area was about 27 percent which is well below the required level of 33 percent of the total geographical area. Hence the forest department may have to take steps to implement the afforestation programmes and protect the available forest from deforestation and other illegal activities. Concerted efforts need to be done to modernize method of agriculture through GALASA- "*Samagra Krishi Vikasana Padhathi*" (Complete Agricultural Development Project). In this regard fallow land other than the current fallows can be brought under cultivation.

References

Collins, L. (1975) "An Introduction to Markov Chain Analysis, Concepts and Techniques in Modern Geography". University of Edinburg.

Goswami, S.N. and O. Challa.(2006). "Land Use Scenario in Meghalaya- An Exploratory Analysis". *Agricultural Situation in India*. Vol.7. pp 531-536.

George, P.S. and S. Chattopadhyay.(2001). Population and Land Use in Kerala. In: Growing Populations, Changing Landscapes: Studies from India, China and the United States. National Academy Press, Washington DC. pp 79-106.

Kumar B.M. "Land use in Kerala: changing scenarios and shifting paradigms". *Journal of Tropical Agriculture*. 2005. 42(1-2), p.1-12.

Nadkarni, M.V. and R.S.Dheshpande. (1979) "Under-utilization of Land- Climatic or Institutional Factors?" *Indian Journal of Agri. Economics*.

Radha Devi, R. and N. Ajith Kumar. (2011)Population pressure on land in Kerala. Working Paper No.24.

Suresh Kumar, D., and K. Palanisami. Impact of drip irrigation on farming system: evidence from Southern India. *Agricultural Economics Research Review*. 23. 2010. pp 265-272.

"Learn from yesterday, live for today, hope for tomorrow. The important thing is to not stop questioning."

—Albert Einstein

Union Movement of Government Employees

*CHINNU MARIAM CHACKO

The book is an attempt to bring out the various dimensions of the union movements and how they influence in determining the pay structure of employees specifically that of the Non-Gazetted Officers (NGOs) in the government. The common goal of unions is to demand for the revision of salary and allowances including the promotional benefits to the members. It is clear that the union movement of government employees got rooted very quickly than the general trade unions though the wages of government employees are not determined by the method of collective bargaining. The author brings a brief study on public service unionism, in which government employees emerged as an important class. The main factor the author tries to bring out is the influence that the trade unions put in for the determination of pay of government employees and the author also sums up the evolution and growth of NGO's unions in Kerala.

The first chapter discusses how the unions are recognized as legitimate social organizations and how they have become an integral part of the contemporary business and industry and is emerging as a formidable socioeconomic force. In order to understand the emergence and structure of trade unions, the author points out certain theoretical frameworks, such as revolutionary approach of Karl Marx and the economic approach put up by the Webb and also the theories raised by writers such as Chamberlin and A.M. Ross. All these reveal that the union movements in the public sector and the private sector are different. A major contributor to the growth of public sector unionisation is the rapid spread of legislation granting state and local government employees the right to organize and bargain collectively.

In the second chapter, the author takes up a close look at the evolution and growth of the unions. During the Second World War period too, the unions of NGOs had to struggle a lot to get recognition. In the pre-independence period, the role played by the unions of NGOs was meagre. In the post-independent period, with the political support, the unions began to grow. In Kerala, after the general election of 1957, the communist party of India supported and recognized the unions of NGOs and accepted many of the demands raised by them. The first strike initiated by the union after the formation of the state of Kerala was for the revision of pay scales, dearness allowance, and for the rights for organization of unions. The communist party abundantly supported the unions of non-gazetted officers in Kerala.

The third chapter of the book comments on the different issues in the growth of the unions of NGOs. Studies conducted by the author revealed that majority of the members of NGOs have not changed their union since their joining. The reasons for changing their membership in the union are due to inability of the leaders to protect the interests of its members. Some members are reluctant to favour with the political ideology followed by the union. With regard to the continuation in the membership the security aspect of job is the prime concern. Preferences such as strength, popularity, and leadership style also attracted the members to the unions of NGOs. The activity of the unions largely depends on the source of income. The major sources of income are from subscription and donations, but it is stated that those funds are sufficient to meet their expenditure and if there is excess fund, the money is deposited in bank or invested in fixed assets, such as land and property. This shows that the unions of NGOs in the state are financially very sound.

The book gives us an insight into the evolution of NGO unions in Kerala. It has been seen that among the seven NGO unions in Kerala, four union leaders are of the opinion that the bargaining power of the unions has been decreased compared to previous periods though some members opine that the bargaining power of the unions has increased considerably. However, there is a positive correlation between the political connection and the bargaining power as stated in the book. The author also stated that the major defect of the NGO unions is their political bias, which will make impossible for them to take a firm stand against the ruling party. The book has developed an exploratory framework for analysing the union activities of NGOs in Kerala.

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The price of success is hard work, dedication to the job at hand, and the determination that whether we win or lose, we have applied the best of ourselves to the task at hand.

—Vince Lombardi

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