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Transgenics: A panacea or victims of their own success

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Abstract

The science of transgenics is one of the advanced and fastest emerging technology with a high adoption rate worldwide but the topic has always been a subject of acrimonious debate not only due to the versatile nature of Genetically modified (GM) crops with their exceptional abilities but also because of their power of modifying conventional plant breeding techniques in a major way. Concerns starting from religious, environmental to human health and confusion along with fear in the mind of people, have always created lots of obstacles in its path of success. Here we intend to present an overview about this technique, its global production and commercialization status (including India), marketing and food supply, scientific merits, biosafety and impact on environment as well as animal including human health.

Key Words: Commercialization, Food, India, Marketing, Supply, Transgenics

INTRODUCTION

The commercial cultivation of genetically modified crops began in 1996 and has been continuously expanding ever since, both in industrialized and developing countries. By 2009 it had reached a global area of 134 million hectares, cultivated by 14 million farmers in 25 countries(James, 2010). However, the acceptance of GM crop is heterogeneous.It has been estimated that by the year 2030, India will become the most populated country in the world with the population of about 1.5 billion. Thus it would be difficult to feed the country following only the traditional practices in agriculture. There is an urgent need to revolutionize Indian agriculture by bringing advanced practices or new varieties which are resistant not only to the insect pests but also have the potential to adapt to the changing environmental conditions into farming in order to produce surplus food. The food supply needs to be continuously increased with the ever increasing population of the world. This has necessitated the increased production of transgenic crops.The nextapprehension is economics and political concern which in due course influence their production and supply chain management. This economic and political aspect has seen a large volume of material regarding GMOs, much of which conflicting approaches, or fails to elucidate the category of physical/scientific questions.The economic/political dispute is habitually vary individual and debates at the local level, or with regard to specific introduction or proposals. Best conduct to understand as to how these issues happen and how they fit into the overall GMO controversy is by utilizing two primary organizing mechanisms,

[a] Risk management techniques, and [b] Risk benefit analysis

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The science of Transgenics refers to transferring of genes of interest across taxonomic boundaries (from related or even unrelated species) in to the plant. The genes of interest may come from any source like that of plant, animal, microbial organisms or any other recombinant. The gene (transgene) transformed into the plant is successfully integrated inside the plant genome and such type of plants are called as 'transgenic plants'. The progeny is similar to the parent except for some functional differences due to expressed transgene.Yield improvement for food security and nutrition enhancement to overcome the problem of malnutrition problem, include (i) Molecular farming, to reduce usage of chemical fertilizers, pesticides and chemicals, (ii) Decrease effect of environment (example biotic or abiotic stress, floods, drought conditions), (iii) Studying the behaviour and researching on more genes, (iv) Production of stable products, (v) Bioremediation, (vi) Detoxification of harmful compounds, and (vii) Improving livelihood and lifestyle of even small scale farmers, making more land available for cultivation, are some of the benefits of transgenics. Many advanced techniques are employed for successful transformation of foreign genes in almost all plant species. These techniques act as important tools and have made agriculture biotech modernized (Slater *et al.,* 2004).

GENE TRANSFER METHODS :

Gene transfer, methods of transformation are as follows:

(1) Vector mediated: The method uses vectors (plant gene based) for transferring gene of interest from organisms to plants for example: *Agrobacterium* mediated transformation, using virus vectors like Caulimoviruses (ds DNA), Gemini viruses (ss DNA) and Tobacco mosaic virus (RNA) (Gleba*et al.,* 2007).

(2) Direct Transfer Methods: transferring the gene using physical or chemical methods.

(a) Physical methods: transfer of naked DNA into the plant cells. It can be done by advance techniques like Biollistic method (which do not require protoplast cells and can be done with intact tissues (Kahl, 2004), microinjection (using microscopic control(Crossway *et al.*, 1986). Liposome mediated (for exogenous DNA delivery into protoplasts cells), Electroporation, Ultrasonication (for plant protoplasts, cells in suspension and plant tissue pieces(Zhang *et al.*, 1991). **(b) Chemical transfer:** transfer of DNA into the plant cells using chemical agents example: Calcium carbonate/phosphate, Magnesium chloride, PEG mediated etc. Note: Electroporation is the most widely used method which can be done both in monocots, dicots, example, rice, tobacco, wheat, maize, sorghum, carrot (Shillito*et al.*, 1985).

Table 1 : Quick overview of reports on transgenic plants with improved nutritional status

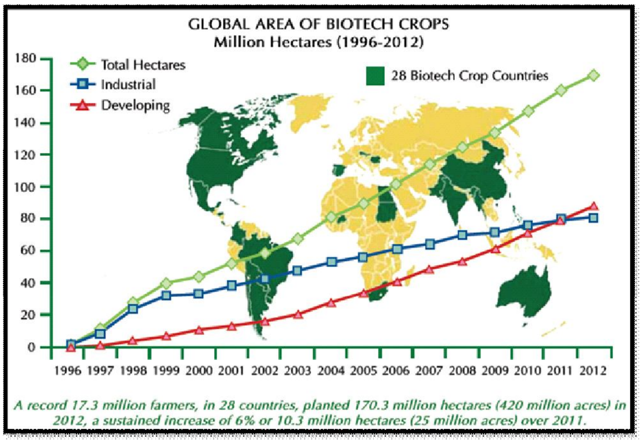
Transgenic plants with improved amino acid/protein content			
S.No	Transgenic plant	Description	Reference
1)	Transgenic canola and soybean seeds with increased Lysine	Feedback regulation system for lysine synthesis made insensitive	Falco *et al.*, 1995
2)	Transgenic lupins (*LupinusangustifoliusL.*) expressing a sunflower seed albumin gene	Enhanced methionine levels and increased nutritive value of seeds	Molvig*et al.*, 1997
3)	Transgenic potato plants withincreased protein content	Non-allergenic seed albumin gene*ama I* from *Amaranthushypochondriacus*	Chakraborty*et al.*, 2000
4)	Soybean seeds with enhanced methionine levels in seeds	Expresses feedback-insensitive cystathionine γ -synthase	Song *et al.*, 2013
	Transgenic plants with altered fatty acid composition		
5)	Transgenic canola having higher levels of 8:0 and 10:0 fatty acids	Overexpression of *FatB2 Cupheahookeriana*	Dehesh*et al.*, 1996
6)	Transgenic rice plants with improved seed oil quality	Soybean microsomal omega-3 fatty acid desaturase gene expressing rice plants	Anai*et al.*, 2003
	Transgenic plants with altered starch content		
7)	Potatoes with freeze-thaw stable starch containing tubers	An amylose-free starch with short-chain amylopectin was produced by simultaneous antisense down regulation of three starch synthase genes	Jobling*et al.*, 2002
8)	High-amylose potatoes	Antisense gene targeting of two branching enzymes coding genes *sbeI*and *sbeII*	Schwall*et al.*, 2000; Hofvander*et al.*, 2004; Andersson*et al.*, 2006
9)	Sweetpotato plants with increased amylose content in starch	RNA interference of the starch branching enzyme II gene (*IbSBEII*)	Shimada *et al.*, 2006
	Micronutrients and functional metabolites		
10)	Canola plants with increased Vitamin E content (α -Tocopherol)	Increased expression of expression of γ -tocopherolmethyltransferase	Shintani and DellaPenna, 1998

11)	Tomato fruits with increased β - carotene and lycopene	β -*Lcy*gene expression in tomato fruits modified	Rosati*et al.*, 2000
12)	Rice with increased iron content with increased bioavailability	Rice plants contained ferritin gene from *Phaseolus vulgaris* for increased iron content in rice grains, a thermotolerantphytase from *Aspergillus fumigatus* into the rice endosperm, for increased bioavailability and endogenous cysteine-rich metallothionein-like protein for increased absorption.	Lucca *et al.*, 2001
13)	Tomato fruits with enhanced aroma and flavor on engineering of terpenoidMetabolic pathway	Overexpression *of Clarkia breweri S*-linaloolsynthase (*LIS*) gene causesincreased accumulation of S-Linalool	Lewinsohn *et al.*, 2001
	Tomato fruits with increased flavonols	Overexpression of *Petunia chalcone*isomerase	Muir *et al.*, 2001
14)	Transgenic maize plants with increased Vitamin C	Wheat dehydroascorbatereductase (DHAR) gene over-expressed in maize	Chen *et al.*, 2003
15)	Enhanced zinc and iron accumulation in transgenic rice	Cloning and over-expression of soybean *ferritin* gene in rice	Vasconcelos *et al.*, 2003
16)	Corn plants with increased Vitamin E	Overexpression of barley homo gentisic acid gerany lgeranyl transferase (HGGT) resulted in increased tocotrienol and to copherol	Cahoon *et al.*, 2003
17)	Higher vitamin E in Soybean seeds	*Arabidopsis* genes *At-VTE3* and *At-VTE4* (γ-to copherolmethyl trans ferase) expressed in soybean seeds	Van Eennemaan*et al.*, 2003
18)	Transgenic multivitamin corn	Increased accumulation of ascorbate, folate and β-carotene in endosperm	Naqvi*et al.*, 2009
19)	Transgenic tomato plants with increased carotenoid, tocopherol, phenylpropanoids, flavonoids, and anthocyanidins	Fruit-specific downregulation of the *DE-ETIOLATED1* (*DET1*) gene	Enfissi*et al.*, 2010
	Genetic manipulation of fruit ripening		
20)	Transgenic tobacco with altered ethylene production and perception	Silencing of ACS gene Over expression of RTE1	Knoester*et al.*, 1997; Zhou *et al.*, 2007
21)	Transgenic tomato fruits with altered cell wall softening	Silencing of *LeExp1* gene Silencing of PG gene	Brummell *et al.*, 2002; Smith *et al.*, 1988
22)	Transgenic fruits with altered sweetening	Over expression of β-fructosidase&Invertase gene	Klann*et al.*, 1993; Xie*et al.*, 2007
23)	Transgenic fruits with altered volatile production	Over expression of Geraniol synthase gene	Davidovich-Rikanati*et al.*, 2007
	Genetic manipulation of fruit ripening		
24)	Parthenocarpic eggplants	*DefH9-iaaM* overexpression in eggplant	Acciarri*et al.*, 2002

PRODUCTION (CURRENT STATUS)

The only genetically modified crop commercially cultivated for seed, fiber, feed in India is the Bt cotton which employs around 93% of the total land area, cultivating cotton only. It is responsible for production of a total of 96% of Indian cotton production in the year 2012. More than 1100 cotton hybrids (mostly came from Monsanto's Mon-531, Mon-15985) have been approved for cultivation in different climate regions in India. The success of Bt cotton in India has made the country emerged as the major producer and exporter (the second largest) in the world and have also placed Agri-biotech on top three place in biotechnology industry with a total revenue of 43.3 billion/$734 million (which as a whole accounts around 18% of the total revenue) in the year 2012-13. The year 2012 was marked as the 17th year of continuous increase in growth and commercialization of Biotech crops, with an annual growth rate of 6% and a record of 170.3 million hectares in transgenic crops area under cultivation. This clearly indicated the adoption of technology by millions of farmers worldwide which have also earn their trust by providing high standard results, quality and by being safe for consumers point of view and for environment. According to a recent study, Europe in the year 2011 declared the biotechnology crops to be safe. From a total of 28 countries planting biotech crops in the year 2012, number of developing countries (20) growing Biotech crops were found to be relatively much more than the industrial countries (8). As a result, it changed the idea and belief that transgenics are meant only for the developed nations. Out of the top ten countries in the list, the top nine countries (which comprises of a total of 60% of world population) grew biotech crops in more than 2 million hectares. Sudan and Cuba joined the group in the year 2012 by planting Bt cotton (in 20,000 hectares) and Bt maize (30,000 hectares), respectively for the very first time. It was found that 17.3 million farmers (out of which 15 million were small scale farmers of developing countries) in the year 2012 grew transgenic crops. Bt cotton demonstrated a significant increase of US$ 250 per hectare thereby benefitting the farmers directly and reducing the level of pesticides to half of their original amount. According to an executive summary highlighting the commercialization of biotech crops worldwide (Clive James, 2012; Figure 1), USA stands first (adoption rate of nearly 90%) in the list of countries growing biotech crops *viz* maize, soybean, cotton, canola, sugarbeet, alfalfa, papaya, squash by utilizing 69.5 million hectares of area under cultivation while India stands fifth growing Bt cotton utilizing 10.8 million hectare area and China with its 7.2 million small scale farmers, stand sixth in position with 4 million

Fig.1. Graph showing Global area of cultivation of Bt crops in million hectares from the year 1996-2012.



(Source: Clive James, 2012)

hectares area, 80% adoption rate, growing Bt cotton, papaya, tomato, sweet pepper and poplar. In the list of developing nations, the countries: India, china (Asia group), Argentina (Latin America) and South Africa (African continent) which together comprises of 40% of the total world population, grew 48% of the global (78.2 million hectares) transgenic crops. Brazil- with its fast approval system is emerging as another engine of growth with 21% increase rate of the transgenic crops, a total of 36.6 million hectares of cultivation area stands second to USA. The first insecticide resistant and herbicide tolerant stacked soybean has been approved to be available at commercial level in Brazil from the year 2013. In the list of European Union (EU), Spain, Portugal, Czechia, Slovakia and Romania planted Bt maize (129,071 hectares) where an increase of 13% was observed in 2011. European Union, in the upcoming year (2014) has planned to grow a new crop named "Fortuna" (Transgenic potato), resistant to the late blight disease in potato which is expected to decrease the production loss by about US $ 1.5 billion annually and applications of fungicides of course.

MARKETING

According to a business report, the transgenic market is expected to reach US$ 12billion by 2015. Apart from food shortage, less water supply other factors like costs, yield and nutritional advancement, pesticides free plants and climate changes are responsible for increasing demands for the development of resistant varieties. There is no doubt in the fact that the area of cultivation of biotech crops has increased from 311 in the year 2008 to 333 million in the year 2009 but inspite of this much demand, biotech crops are repeatedly facing difficulties in consumer's acceptance worldwide.According to the standards set by the worldwide nations, they are selling with a label in the market.United States (based on new market research reports), comprises the largest market for transgenics, but people even from developing countries like India, China, Japan, Philippines and South Korea are now becoming aware and an increasing interest has been developed for good quality of food becoming available directly from the genetically modified plants. Apart from these some countries from sub Saharan African continent with around 30% of undernourished population are also trying to bring the technology at their place too. A large amount of land is used for the cultivation of genetically modified insects and herbicides resistant soybean, cotton, maize and canola crop plants. The transgenic crops developed till date are banana, tomato, cabbage, cauliflower, cassava, cotton, rapeseed, eggplant, pigeon pea, papaya, chickpea, rice, potato, wheat and watermelon. The Seed companies belonging to the private sector have/are stressing more on vegetables like cauliflower, cabbage, rapeseed, corn, pigeon pea, okra, tomato and rice.

FOOD SUPPLY CHAIN

Hundreds and millions of people (in rural or urban area) are connected to the food chain supply for their livelihoods and plays a crucial role. Food processing sector and the food supply chains of transgenic crops in India are increasingly growing along with the capital to output ratio from past two decades. An increase in the number of cold storages has been found which are also acting as wholesale traders. The retail sales are growing by about 49% in both urban and rural food markets, the supply chains are shortening (by a reduction in village brokers) as the public wholesale markets *i.e.*Mandi's are buying the products directly from the farmers. The reduction in number of mediators in the food supply chain has no doubt benefitted the farmers but the irony is that only the private sector has played the lead role in bringing this revolution as the government participation both as buying and as seller is only 7%. The Indian retail markets have changed a lot since decades. It was started for the very first time by the Indian government in the year 1960s and 1970s which subsequently changed to co-operative retail chains in 1970s and 80s and further shifted to private in 1990s and 2000s. Later on it was again divided into two phases in which one phase (mid 1990s-2000) i.e. middle class centered, was kept alive on account of domestic and foreign venture, and the second phase (2000s – at present) proceeded by domestic capital is lower middle and upper working class centered.

The changes in the food supply chain in India over the past decades (Ablett *et al.*, 2007) are as follows:

(1)The expenditures on food in urban sector have tripled (from being one-quarter in 1971 to become more than 1/3 by 2006) since past 35 years and the supply chain has increased to three folds in three decades. This rise is due to the increasing interest in domestic production.

(2)Along with differences in the food consumption, a lot of diversity in the type of food taken by urban population was also found. According to the reports, a reduction of 13% (i.e. from 36% in the year 1972 to 23 % in 2006) was reported in consumption of cereals by people of urban areas while a difference from 52% to 32% was reported in case of rural population (IndiaStat). People are more focused on consuming the non grain food items *viz* fruits, vegetables, pulses, dairy, meat whose level of consumption have risen to 71% of total food consumption in India. The changing lifestyles, type of employment, fast life, modernization of food industry are the major reasons.

(3) Although with the government's initiatives the marketing of grains have found to be doubled from 12% in the year 1970s to 24% in 2000s over past three decades but the role played by the government in food supply chain, marketing has not shown any significant increase and been continuously limited to be nearly at a constant rate from 6% in 1970s to 7% in 2000s. Thus, the credit of overall food economy is shared by the private players like retailers, wholesalers, processors, private mills, logistic firms, traders, brokers, mediators, modern entrepreneurs, agribusiness managers and many private companies.

(4) The private sector has transformed themselves according to the consumers demand and changing needs and thus contributes a large share of 93% in food economy due to their increasing interests. As a result, the food retail market has been found to be increased from 2001 to 2010 by 49 percent (Reardon, Timmer, and Minten 2010; Reardon and Minten 2011a). The food processing sector from 2002-2006 has grown by 7 % (Ministry of Food Processing 2008) but the modernized food industry which includes cafes, neighbouring stores, restaurants, supermarkets, hypermarkets, bars, food *i.e.* especially those popular amongst the urban population plazas grow by 9% every year from the year 2001-2006 (Euromonitor International 2007).

DISTRIBUTION OF TECHNOLOGY GAINS: KEY DRIVER FOR FOOD SUPPLY CHAIN

This canbe assessed in terms of cost farmers pay for accessing GM technology concern with total traits benefit. Here the traits benefits can be measured in terms of the farm income gain plus cost of accessing the technology at the farm level.

Table 2. Cost of assessing technology (million $) relative to the total farm income benefits 2007[In US]

	Cost of technology: all farmers	Farm income gain: all farmers	Total benefit of technology to farmers and supply chain	Cost of technology: developing countries	Farm income gain: developing countries	Total benefits of technology to farmers & seed supply chain: developing countries
GM HT Soybeans	931	3,935	4,866	326	2,560	2,886
GM IR maize	714	2,075	2,789	79	302	381
GM HT maize	531	442	973	20	41	61
GM IR cotton	670	3,204	3,874	535	2,918	3,453
GM HT cotton	226	25	251	8	8	16
GM HT canola	102	346	448	N/A	N/A	N/A
Total	3,174	10,081	13,255	968	5,829	6,797

(Source: Brookers G. and Barfoot P, 2009)

where, N/A = not applicable.

Brooks and Barfoot (2009) examined this issue in term of above said methods. They just summarised their analysis across the four main biotech crops for the year 2007. Finally concluded that the total cost was equal to 24% of the total technology gains where they exempted the farm income gains in addition of coat of the technology payable to the seed chain (Table 2). For farmers in developing countries the total cost was equal to 14% of the total technology gains, whilst for farmers in developed countries the cost was 34% of the total technology gains. These circumstances depend on county basis. In the Table 2, cost of the accessing the technology is based on the seed premiumpaid by farmers for using GM technology relative to its conventional equivalents. Similarly in Argentina in the year 2001, Qaim and Traxler identified that the economic surplus in terms of aggregate welfare, associated with GM HT soybean was $335 million.Pray *et al.* (2002) in China examined the adoption of GM IR cotton and incorporated their analysis to consider consumer level inputs. In Mexico adoption of GM IRcotton was that 85% of the total benefits from adoption went to farmers with only 15% earned by the supplies and technology providers (Traxler *et al.*, 2001).

Table 3. Adoption rate of GM crops in the leading exporting countries of maize and soybean (2009)

GM Crops	Country	Adoption rate (%)
Soyabean	Brazil	78
	Argentina	98
	USA	91
Canola	Canada	93
Maize	USA	85
	Argentina	50
	Brazil	30-53

(Source: USDA, ISAAA, 2010)

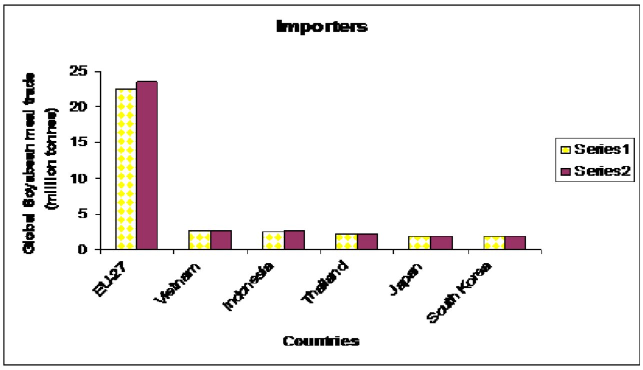
Table 4. Global soybean meal trade (Million tonnes)

	2009/2010	2010/2011
Global trade	56.0	56.63

(Source: USDA, ISAAA, 2010)

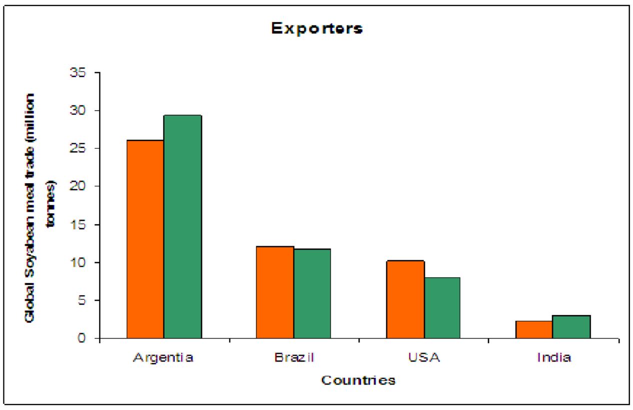
Soybean meal world trade is around 56 million tonnes, which is approximately one third of its total production. Argentina, Brazil and USA, the world's first, second and third largest meal exporters, account for 85 to 90% of total world soybean meal exports. Argentina exports around 98% of its soybean meal production. No real alternatives exist to imports from the three large producing and exporting countries since South East

Fig.2. Importers of Soybean meal trade (million tonnes)



(Source: USDA, ISAAA, 2010)

Fig.3. Exporters of Soybean meal trade (million tonnes)



(Source: USDA, ISAAA, 2010)

Asian countries are the major markets of Indian soybean meal. India has a freight advantage over American countries for supply to Asia (Table 4, Figure 2 and 3).

COMMERCIALIZATION OF GM CROP AND BIOSAFETY

The commercialisation of GM crops is a regulated activity, and countries have different authorization procedures. New GM crops are not approved simultaneously. This asynchronous approval in combination with a zero-tolerance policy towards low-level presence of nationally unapproved GM material in crop imports is of growing concern for its potential economic impact on international trade. There is an obvious difference between traces of nationally unapproved GM material due to asynchronous approval and isolated foreign approval or due to the accidental presence of research events (Table 4 and Figure 2, 3).GM technology has always been a controversial topic as far as environmental, animal and human health hazards are concerned (Grumet and Gifford, 1998; Khetarpal, 2002; Philippe, 2007). This is because the method is different from traditional breeding in a major way and employs artificial introduction of genes which get incorporated into anywhere in the plant's genome. Thus the technology requires thorough assessment for confirmation of the results obtained, the risks they may pose and for their performance. The process although encourage diversity but poses threats by creating difficulty in the process of risk assessment (Conners *et al*., 2003; Nap *et al*., 2003) and may disturb the genetic diversity of wild plants leading to the production of weedy relatives, antibiotic resistant bacterial stains. In order to reduce the adverse effects by transgenic crops whenever may be used as feed or food, various strategies have been developed. The strategies are developed keeping into consideration the requirement for research and development in the respective countries, these are being issued and revised from time to time and employ extensive assessment, testing with efficient regulatory management system. Similar guidelines including extensive field trials are issued to test the products performance, stability or perform allergenic and toxicity related studies of the trait under different environmental conditions in the field conditions. Measures (as much as possible) are taken to restrict the gene flow completely or at least within the acceptable levels in field conditions. Labelling of food or food products is another concept being introduced in order to provide prior information to the costumers. Introduction of advanced instruments to monitor and regulate the trans-boundary movement of GMO may help a lot. Keeping in view the harmful or negative implication of transgenics, India signed United States Cartagena Protocol on Biosafety, according to which if there is no proof/result or any scientific consensus on any action responsible for causing risk to the public or the environment, people taking the proposed action will be the only one responsible for saying that it is not harmful. In India, the Environment Protection Act (1986) relates to the rules, management, improvement of environment and protection to living things including human beings from hazards while Environment (Protection) Rules (1986) employ storage, handling, manufacture, import, export, of hazardous organisms including transgenics. Both these significantly contribute to an efficient biosafety regulatory systems.

(Source: Stein and Rodriguez-Cerezo, 2009)

By 2015 there could be over 120 different transgenic events in commercialised GM crops worldwide compared with over 30 GM events in commercially cultivated GM crops in 2008 (Table 5). Although the commercialisation of the crops shown may be technically possible by 2015, the practical or rather regulatory-feasibility may be more questionable especially rice in particular, given that in some of the developing countries no GM (food) crops have been authorized so far.

Table 5. Events in commercial GM crops and in pipelines worldwide, crop-wise

Crops	Commercial in 2008	Commercial pipeline	Regulatory pipeline	Advanced development	Total by 2015
Potatoes	0	0	3	5	8
Rice	0	1	4	10	15
Cotton	12	1	5	9	27
Rapeseed	4	0	1	5	10
Maize	9	3	5	7	24
Soyabean	1	2	4	10	17
Other crops	7	0	2	14	23
All crops	33	7	24	61	124

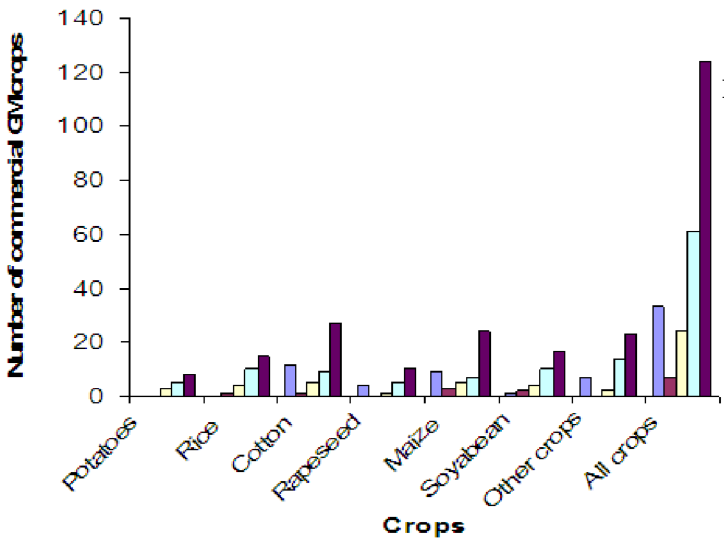


Fig.4. Commercial GM crops

(Source: Stein and Rodriguez-Cerezo, 2009)

SCENARIO OF BIOTECH CROPS IN INDIA

India with its 10.8 million hectare area and a high adoption rate of 93% has been marked as one of the major producers of Bt cotton and was benefitted with a total of US$12.6 billion in the year 2002 to 2011 (Table 6).

Table 6. Adoption of Bt Cotton in India, by Major States, from 2002 to 2010 (ha)

State	2002	2003	2004	2005	2006	2007	2008	2009	2010
Maharashtra	25	30	200	607	1,840	2,800	3,130	3,396	3,710
Andhra Pradesh	8	10	75	280	830	1,090	1,320	1,049	1,650
Gujarat	10	36	122	150	470	908	1,360	1,682	1,780
Madhya Pradesh	2	13	80	146	310	500	620	621	610
North Region	-	-	-	60	215	682	840	1,243	1,162
Karnataka	3	4	18	30	85	145	240	273	370
Tamil Nadu	2	7	5	27	45	70	90	109	110
Others	-	-	-	-	5	5	5	8	8
Total	50	100	500	1,300	3,800	6,200	7,605	8,381	9,400

(Source: Compiled by ISAAA, 2010)

RESEARCH FINDINGS ON IMPACT OF BT CROPS ON ECONOMY, ENVIRONMENT AND ANIMAL HEALTH

In a report by researchers from University of Warwick in the year 2010 on 'The Impact of Bt cotton on poor households in rural India' stated that the introduction of transgenic technology has contributed significantly in increasing the country's economy and the women employment status in the country (University of Warwick, 2010). Subramanium (2010) concluded that Bt cotton plantations has not only reduced the pesticide usage but have also increased the employment status especially for the female workers (with 424 million more employment opportunities and were found to be benefitted by 55% more than the male workers) (Figure 5). An increase in the total wage income by US$ 40 per hectare has also been observed when compared to the traditional farming practices.

Studies have shown that from the year 1996 to 2010, transgenics have decreased the usage of pesticides globally by 17.9% (*i.e.* 443 million kg) andless emission of green house gases from the farm lands. This can be compared by restricting around 9 million cars from moving on the roads (Brooks and Barfoot, 2005). In USA alone, a reduction in pesticides usage of about 46.4 million pounds was observed in the year 2003 (Sankula and Blumenthal, 2004). China planting Bt cotton, witnessed a reduction in pesticides usage of around 78000 tons in the year 2001, which is nearly equal to 1/4th of the total amount of pesticides sprayed in China in 1990s (Pray *et al*., 2002) thereby reducing the risks of pesticides exposure to the country's poor farmers (Hossain *et al*., 2004). In the transgenics cotton field of USA and Australia, Bt cottoninspite of having any negative effects, was described to be effective for beneficial insects in a positive way (Carpenter *et al*., 2002). Introducing herbicide tolerance crops in the United Sates, encouraged practices like conservation, no-till cultivation which as a result saved approximately 1 billion tons of soil per year (Fawcett and Towery, 2002) which were otherwise eroded.No report or data related to the harmful impacts of Bt corn on insect's abundance and diversity was reported in Philippines lands planted with Bt corn.

Fig.5. Graph comparing the returns from Transgenic with Conventional cotton to the male/female workers in Rural India.

(Source: Subramanian, 2010)

But the debate still goes on, although there is much evidence in favour of transgenic crops but unfavourable ones also cannot be neglected and no definite conclusion can be drawn without further research in detail. There are evidences which suggest the harmful nature of Bt toxins too. According to a study published in Nature in the year 1999 the Monarch butterflies caterpillars feed on milkweed plants but scientists fear that if any pollen gets transferred from Bt cotton crop plants to the milk weeds plants (grown in the nearby area), it may cause caterpillars to perish and result in death. The irony is that it is not possible to create a species sensitive toxin which may remain harmless to the non targeted insects. In India, death of thousands of cattle after feeding on the remnants of Bt cotton in the district of Andhra Pradesh was reported. The curse of toxins doesn't stick to the death of animals but the soil of the area also gets polluted. In a case, the soil after growing Bt cotton crop in Gujarat state of India was reported to become dehydrated, lost not only its micronutrients but also its capability to sustain any other crop.

In case of humans, the GM crops supporters suggests there is no harmful impact on human health as they believe that the GM products gets degraded inside the body due to pH differences, activity of enzymes like nuclease (DNA degrading enzymes) or other enzymes present in the gut (David Beever and Richard Phipps, 2003). They emphasize that no report, which can state the detection of GM product or plant chloroplast DNA in food (e.g. milk, meat, eggs),is available (Phipps *et al*., 2003, Chowdhury *et al*., 2004, Einspanier *et al*., 2001 and Phillips *et al*., 2002). Mosanto in the year 2009, stated Bt brinjal unfit for consumption (Mahyco, 2009). They explained that the reason is due to the abnormal increase in the concentration of one of the alkaloids (which is already toxic naturally) by 30%. In a 90 days experiment by Dr. Lou Gallagher (an epidemiologist in New Zealand) on lab rats fed with Bt brinjal reported organs system failure, enlarged spleen with changed immune defense mechanism (number of eosinophils, WBC count exceptionally higher than the normal) and reduced size ovaries. The article was published in India Today Jan, 2011.

LATEST UPDATES

It is of a view that drought tolerance is an important trait in order to increase the crop productivity and this will be commercialized soon. Monsanto set target to launch drought resistant transgenic Maize in USA in 2013. They have also disclosed the technology to WEMA (in a private or public partnership) with an aim to release this biotech crop by 2017 in Sub Saharan Africa which needs it the most. The latest attempts of gene transformation to develop transgenics are – Incorporation of *HVA1* gene through Biolistic method of gene transfer from barley to develop drought and salt stress tolerant genetically modified maize crop plants (Nguyen and Sticklen, 2013), *SGTL1* through *Agrobacterium tumeifaciens* mediated transformation from *Withania somnifera* to *Arabidopsis thaliana* to render the crop salt, heat tolerant and cold acclimating (Mishra *et al*., 2013). *NHX1* genethrough the same method from *Arabidopsis thaliana* was incorporated to develop salt tolerance *Brasica napus* plants(Dorani-Uliaie *et al*., 2012), Synthetic promoters through *Agrobacterium*-mediated transformation for the development of transgenic tobacco and *Arabidopsis* plants (Liu *et al*., 2013), Acetyl-transferases through *Agrobacterium*-mediated transformation from *Aspergillus nidulans* to develop Transgenic plants with decreased polysachharide acetylation and increased pathogen resistance against pathogens (Pogorelko*et al*., 2013), *Cry1Ab gene through Agrobacterium*-mediated transformation to develop Insect resistant transgenic rice (Qi *et al*., 2013), *ß-Glucuronidase gene through* Biolistics method for deveopment of Transgenic triticale (Karadag*et al*., 2013), Ribosome inactivating protein through *Agrobacterium*-mediated transformation from barley to transgenic potato with enhanced resistance to *Rhizoctoniasolani* (M hamdi *et al*., 2013), ß-fructofuranosidase gene from *Aspergillus niger via Agrobacterium*-mediated transformation to develop transgenic tobacco plants with Fructo-oligosaccharide production (Fukutomi *et al*., 2013), *bar* and the *gus-intron* genes through *Agrobacterium*-mediated transformation to develop transgenic peach (Soliman, 2013).

FUTURE PROSPECTS

Transgenics is a subject of acrimonious debate. As every coin has two faces, there are pros and cons here too but keeping in view their versatile nature and the exceptional abilities, the future of transgenic crops is expected to be brighter. The increasing interests of developing countries in growing these crops are an advantage. Their number (especially from Asia and Africa continent) is expected to increase more by the year 2015. Africa is planning to release its first drought resistant transgenic maize in the year 2017. Philippines Golden rice rich in vitamin A is expected to be released by 2013/14. Other upcoming Crops comprise sugar (drought resistant), Bt maize to be released shortly in Indonesia and china. Although, some of the research results, data, tests, findings and confirmations have reached to the field trials stage but many are still in laboratory stage. Extensive researches have been done in the past but more needs to be done while following the rules and regulations, policies and taking proper biosafety measures related to transgenics in order to make any transgenic crop available commercially by any country. Biotech crops with their significant contribution in increasing the crop yield have demonstrated their potentialand their developers' contribution (directly or indirectly) towards the 2015 Millennium Development Goals (MDG-2015) which aim to achieve food security, employment for all, reduce the problem of poverty and malnutrition.

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