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Genetically Modified (GM) Crops – Regulation, Perception and Challenges in India; Comparison of Modern-Day Responses with Previous Reports

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Abstract

Genetically Modified (GM) crops are promising tools to counter the ever expanding food requirement for the global human population. India is a major agricultural producer in the world and holds a key position in the propagation of GM crops into the commercial market. Despite being a pioneer in producing GM cotton, the Indian government has maintained a strict moratorium on the introduction of GM crops intended for human consumption, despite there being no conclusive proof regarding any negative impacts that these crops may have. The present work thus provides a comprehensive review of the status of GM crops in one of the largest agricultural countries in the world. The review investigates the current status of GM crops in India, along with the socio-economic impact the adoption of GM crops has had on Indian farmers. The review also looks into the regulatory government oversights that are currently in place in the country. A comprehensive review of literature is also presented based on investigations carried out to understand the perception of Indian consumers on GM crops. The review revealed major trends among Indian consumers and discusses future directions that may be adopted to better understand the scenario of GM crops in India.

Introduction

The human population is going through a phase of exponential growth, often referred to as a 'population boom'. Our numbers have been projected to grow from 1.6 billion in 19001 to almost 8.2 billion souls by the end of the year 2025. This trend is not likely to change any time soon, which puts an enormous pressure on our food generating abilities. Raising our agricultural productivity has thus become of utmost importance. Adoption of novel approaches for increasing productivity has gained economic and scientific attention. In this aspect, no other technology perhaps shows greater promise than the use of genetically modified (GM) crops. Any crop plants, whose DNA composition has been altered by using genetic engineering techniques are referred to as GM crops. The practice of modifying plants or animals for better agricultural yield is not a novel one. Historically, selective breeding over many generations has been used to generate modified organisms. Crop plants, dairy animals and even dog breeds have been modified to have desired traits. These conventional methods of selective breeding and cross-breeding are time consuming and can often lead to incorporation of mixed results, with unwanted characters appearing alongside desired ones.

In case of GM crops, these drawbacks do not appear as recombinant DNA technologies allow scientists to detect and target specific genes that are responsible for specific traits. This gives GM crops the potential to become the major tool behind ensuring global food security **[**2**]**. New developments like CRISPR/Cas9 have the potential to generate GM crops which have improved nutrition content, enhanced disease resistance and increased drought resistance **[**3**]**. GM crops have been also shown to increase abiotic stress tolerance and salinity tolerance, scenarios that become more and more possible with respect to climate change **[**4**]**.

GM crops are one of the fastest-adopted agricultural technologies in the world, increasing by 112 times compared to 1996, when the cultivated area was only 1.7 million hectares, and is currently cultivated on 191.7 million hectares across a total of 26 countries **[**5**]**. The most commonly cultivated GM crops are cotton, soybean, canola, and maize. There were 95.9 million hectares (50%) of transgenic soybean, 58.9 million hectares (31%) of transgenic maize, 24.9 million hectares (13%) of transgenic cotton, 10.1 million hectares (5.3%) of transgenic canola and 1.9 million hectares (< 1%) of other transgenic crops being cultivated at present. GM crop cultivation has been showing rapid expansion in Africa and Asia. Within the Asia – Pacific region, India, Japan, China, Pakistan, Australia, Philippines, Myanmar, Vietnam, Bangladesh, and Indonesia participate in the cultivation of GM crops, with China and India being two major producers of GM crops. India is currently the largest producer of GM cotton and is involved in actively promoting agricultural biotechnology research. Therefore in the present work a survey was undertaken to understand the perception of the Indian population with respect to GM crops, and there responses were compared with respect to the present status of GM crops in India, along with the regulatory oversight and challenges that exist in the country.

Methodology

A questionnaire survey was designed in order to understand the perspective, knowledge and preference of Indian population towards GM crops. The questionnaire was developed based on the review of available literature and by understanding the importance, pros and cons of GM crops based on the regulatory guidelines of various countries and experts opinions. The questionnaire was circulated on a digital platform for which a web portal was built, which helped in reaching the target faster and was an economical option. Simultaneously a review of available literature was undertaken to compare with responses observed in the survey.

Results and Discussion

Current status of GM Crops in India

With a population projected to go beyond 1.3 billion, the needs for high yielding crop variants for its internal use cannot be overstated. Apart from its own internal demand, India is also a major global food exporter, with ties to many Southeast Asian and Middle Eastern countries. To meet its food resource requirements, India has been continuously involved in agricultural research and development. Using traditional approaches, crop production in India had increased from 51 million tons in 1950 to 241 million tons in 2010–2011**[**6**]**. The agricultural sector has grown much during the time period, making India largely an agricultural economy, with approximately 70 % of the working population in India is directly or indirectly dependent on agricultural sector for income.

The very first GM crop to become part of India's agricultural development happened with the introduction of GM cotton. Monsanto-Mahyco introduced Bollgard-I in 2002, India's first GM cotton hybrid containing Cry1Ac-producing Bacillus thuringiensis (Bt) genes for controlling the pink bollworm (P. gossypiella) pest7. Initially, only 36% of the farmers adopted the new crop however their participation rapidly increased to 46% in 2004, after the crop received nation-wide approval. This eventually led to the approval and introduction of Bollgard-II, which was two-toxin (Cry1Ac and Cry2Ab) producing strain conferring greater resistance to bollworm. Cultivation and production of Bt-cotton has grown exponentially since then. An estimate from 2012 substantiates how successful its introduction was, with approximately 7.2 million farmers cultivating Bt cotton on 10.8 million hectares of land, which was equivalent to 93 per cent of India's total 11.6 million hectares of land used for cotton cultivation8. Approximate 40 million bales of cotton was produced in 2014 in India, making the country the world's leading producer of cotton**[**7**]**.

Introduction of Bt-cotton played a positive role in the lives of Indian farmers and in India's agricultural economy. Bt-cotton has increased profits and yield by INR 1877 per acre (USD 38) and 126 kg/acre of farmland respectively. This is approximately 50% and 24% more than the profit and yield of conventional cotton strains. This translates to a net increase of Bt-cotton growers' annual consumption expenditures by 18% (INR 15,841/USD 321) when compared to non-adapters. This highlighted the improved living standards enjoyed by Bt-Cotton farmers**[**9**]**. Bt-cotton adoption has also lead to in a 22-fold surge in India's agri-biotech industry due to an unparalleled 212-fold rise in cultivation between the period of 2002 to 2011, which accounted for more than 30% of global cotton farmland, surpassing China and making it a world leading cultivator and exporter. 7 million out of the 8 million farmers (88%) are growing Bt-cotton annually. Cotton crop yields have also increased by 31% while

conversely the use of insecticides has been reduced to half (46% to 21%) enhancing India's cotton income by 11.9 billion US dollars. Therefore, it is safe to state that Bt-cotton has resulted in economic prosperity among Bt-cotton growers, with 2002–2011 often being called a white gold period for India's GM cotton industry.

The second GM crop for commercialization in India was Bt-brinjal, which was approved by the Genetic Engineering Approval Committee (GEAC) of Government of India in October 2009. As this was meant for human consumption, its introduction was marred with controversies. Concerns were raised by some farmers, anti-GM activists and scientists, and based on these issues the Government of India officially announced a moratorium stopping Bt brinjal on 9th of February 2010. This moratorium continues till date**[**10**]**. However, there do exists reports of illegal plantings of not only Bt brinjal**[**11**]**, but also of stacked insect resistant and herbicide tolerant cotton and virus-resistant papaya**[**12**]**. This has led to some hope the possibility of a bottom-up change to the moratorium policy.

Despite limited commercial introduction of GM crops, research and development continues to progress in India. The GEAC has given approval for limited experimental field trials of GM rice, brinjal, mustard, cotton and chickpea for the sole purpose of generating biosafety data. The GEAC has also recommended for commercial cultivation of GM mustard for clearance to the Environment Ministry. A number of GM crops or transgenic crops bearing novel traits have since been developed and approved for commercial agriculture production. Several other GM crops are in different stages of development across the many institutes in India. These include Cotton, Rice, Wheat, Maize, Brinjal, Potato, Sorghum, Mustard, Groundnut, Cauliflower, Okra, Chickpea, Pigeon pea, Castor, Sugarcane etc. The traits in focus are insect resistance, herbicide tolerance, drought tolerance, salinity tolerance, virus resistance, along with quantitative traits like increase in yield, nutrition improvement etc**[**13**]**.

Despite this efforts from the government the consumer attitude towards GM crops appeared to be mostly negative in our survey. When the participants were asked, 'In general, will you support if the government authorities allow genetically modified crops/food in commercial agriculture?'. In response to this, 47% (196 of 420) of participants stated that they were against this idea, and only 16% (67 of 420) of participants chose to support it (fig. 6). Remaining 37% (157 of 420) were neutral. When the participants were asked to point out their reasons for supporting and for not supporting GM crops respectively. The participants were allowed to highlight more than one reason for their positive and negative outlook towards the product. Regarding their positive outlook towards GM crops, 292 of 421 participants (69.3%) had stated that their main reason for supporting would be, "As environmental pollution is globally increasing, genetically modified technology may improve the resistance to pests

and viruses in the harvest and help minimize use of pesticides and chemical fertilizers". Alongside this, 224 participants (53.2%) stated that, "Compared with traditional hybrid crops, precision genetically modified technology may increase and maintain yield, improve food quality, and extend shelf life of food", was their reason for supporting GM crops (fig. 1).

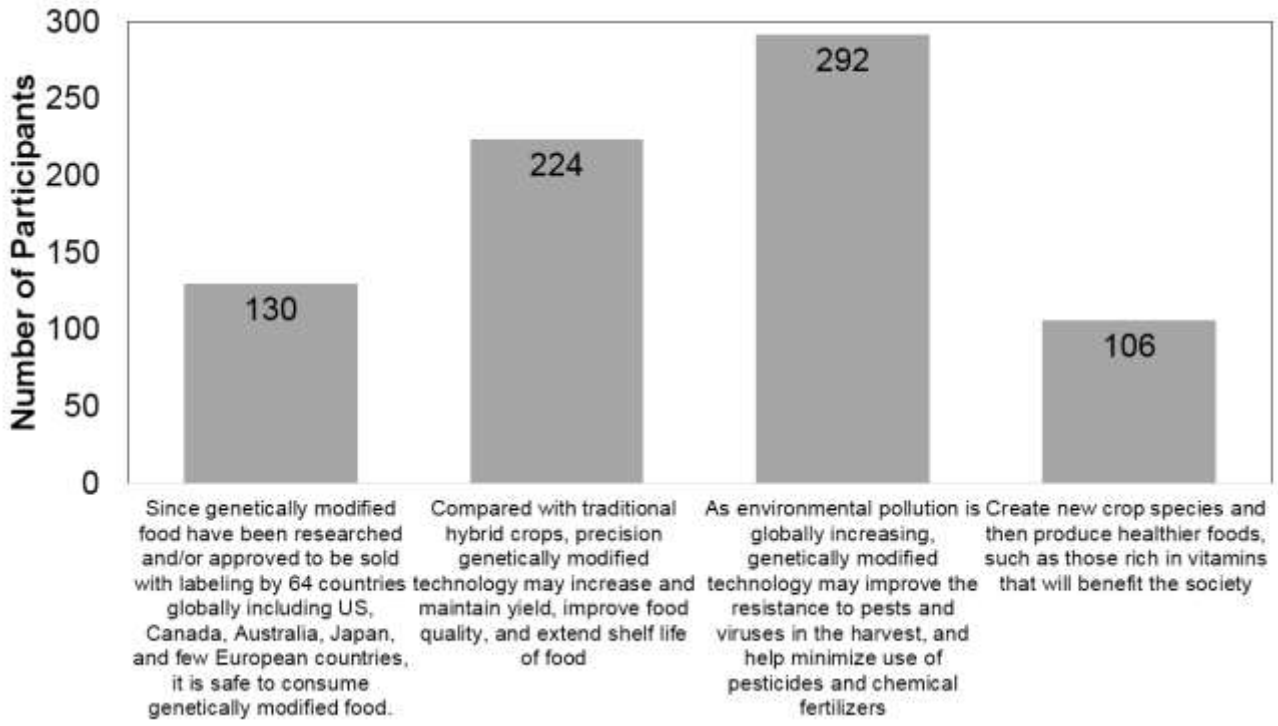

Figure 1: Response of participants to the question 'Which of the following reasons for supporting genetically modified food/crops seem reasonable to you?'

When the participants were inquired about their reason for negative sentiments towards GM crops, almost 50% of the participants (207 of 421) stated that, "Genetically modified organisms currently on the market do not show evidence of increased yield, enhanced nutrition, drought tolerance, or any other consumer benefit. It will take a long term scientific research to validate the safety of genetically modified foods". Other than the 'lack of evidence', 34.7% of the survey participants expressed their concern over "Generating new species against the law of nature may affect the Deoxyribonucleic acid (DNA) of natural crop species, threaten the biodiversity, and damage the environment" (fig. 2).

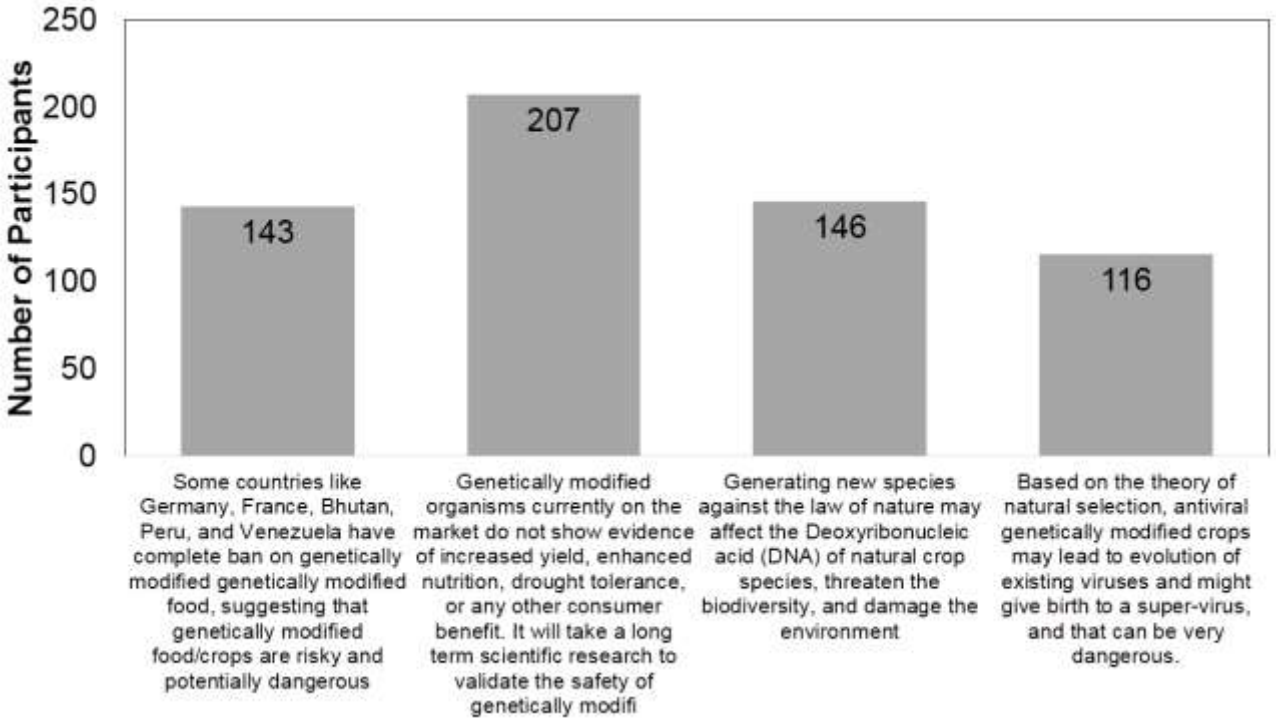

Figure 2: Response of participants to the question 'Which of the following reasons for opposing genetically modified food/crops seem reasonable to you?'

The negative sentiments observed in the present survey may have stemmed from lack of evidence towards promised benefits, as almost half of the participants choosing "Genetically modified organisms currently on the market do not show evidence of increased yield, enhanced nutrition, drought tolerance, or any other consumer benefit. It will take a long term scientific research to validate the safety of genetically modified foods", when inquired about it. This is not factual, as drought-resistant GM corn was first commercialized in the United States in 2013, and commercial cultivation is currently spreading to other countries such as Canada, Brazil, and South Africa. Recently, in the United States, GM corn that can control mold that produces aflatoxin, a carcinogen, has been developed and is receiving great responses from producers, farmers, and consumers. Various GM crops are presently being developed that provide benefits not only to producers, but also to the consumers.

GM regulations in India

India is a signatory country of the Cartagena Protocol on Biosafety, along with other institutions involved in the assessment of biosafety and other issues that may stem from GM crops. The Cartagena Protocol on Biosafety outlines the biosafety regulations for GM crops in detail, encompassing research,

commercialization and regulation of GM crops. India ratified the Cartagena Protocol in 2003. This required a setting up of a regulatory for monitoring of GMOs. However, the very first regulations for biotechnologically altered products was introduced as early as 1982, with the establishment of the National Biotechnology Board, with the goal of outlining biotechnology safety guidelines to undertake laboratory based biotech research[14]. The National Biotechnology Board later evolved into the currently functioning Department of Biotechnology (DBT), which was then placed under the stewardship of the Ministry of Science and Technology in 1986 [15].

There have been three important legislations enacted by the Parliament of India with the aim of regulating GM crops. These include the Environment Protection Act (EPA), 1986 administered by Ministry of Environment, Forest and Climate Change in India (MoEF&CC), the Seed Act 1966 and the Seeds (Control) Order by Ministry of Agriculture and the Food Safety and Standard Act 2006 framed under the Ministry of Health and Family Welfare[16]. The multilayered regulatory framework in place for the assessment and ensuring of biosafety of GM crops, is jointly placed under the MoEF&CC and the DBT. The system is further spread out between six competent authorities. These authorities are the Recombinant DNA Advisory Committee (RDAC), The Review Committee on Genetic Manipulation (RCGM), The Genetic Engineering Appraisal Committee (GEAC), Institutional Bio-safety Committees (IBSC), State Biotechnology Coordination Committees (SBCC) and District Level Committees (DLC)[13]. The roles and functions of each of these committees have been elaborated under the act of 1989. The Genetic GEAC is the highest governing body constituted by the MoEF&CC under 'Rules for Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms/ Genetically Engineered Organisms or Cells' under the 1989 act. The EPA, 1986 allows the GEAC to function as a statutory body in India for review and approval of GM crops from the environmental aspect. Additionally, the Government of India is in the process of establishing the Biotechnology Regulatory Authority of India (BRAI) for quicker processing of modern biotechnology products to the Indian agricultural sector. This new authority was meant to provide an efficient single window system for GM crops research, safety issues and regulatory measures. With this goal in mind, the Biotechnology Regulatory Authority of India (BRAI) bill was introduced in Lok Sabha in 2013 to establish an independent regulatory authority for regulation of organisms and products of modern biotechnology including GM crops. When it becomes functional, BRAI will regulate the research, transport, import, containment, environmental release, manufacture, and use of all biotechnology products and all the approval will be granted through a multilevel process of assessment undertaken by a panel of scientific experts.

In light of these existing regulations, the survey asked the participants, 'The Indian Ministry of Agriculture has exempted genetically modified crops and genetically modified food with certain kinds of genetic modifications that are 'natural' to the plant but that have not had any 'foreign' Deoxyribonucleic acid (DNA) added. What do you think about this?'. In response to this, 34% of participants (143 of 420) stated that, '"Foreign" can be interpreted in many ways and this non-specific exemption will hamper the research on many "beneficial" or "actually useful" genetically modified varieties'. 30% of participants chose, 'Seems scientifically valid and strong as a decision', while another 18% opted for 'This exemption does not seem to be scientifically strong' (fig. 3).

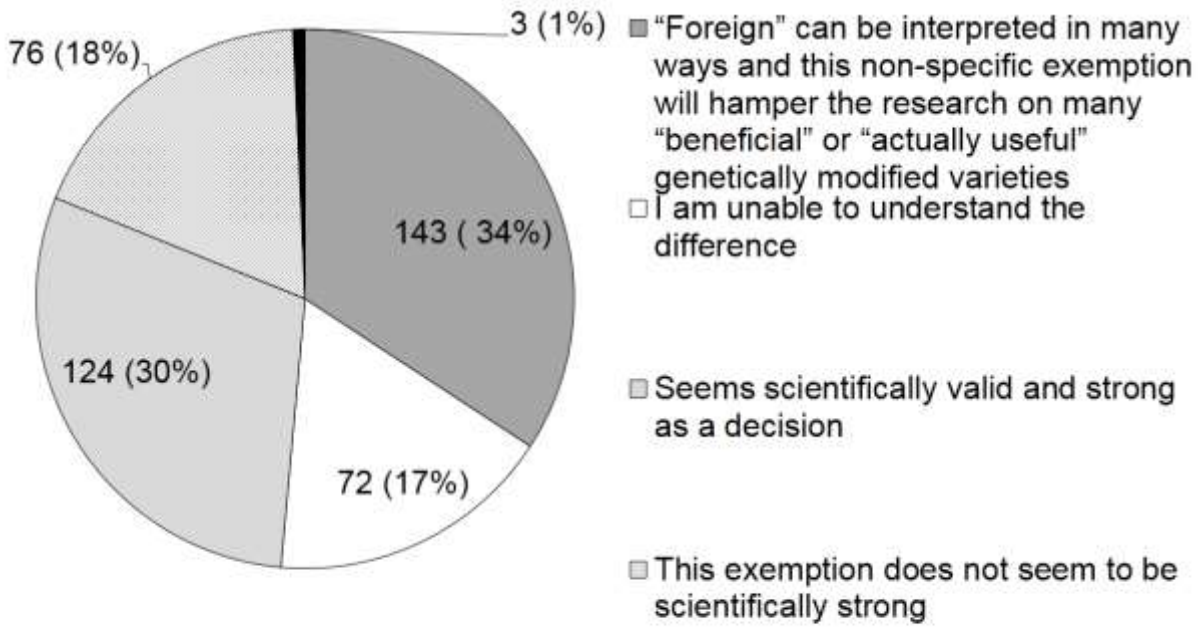

Figure 3: Response of participants to the question 'The Indian Ministry of Agriculture has exempted genetically modified crops and genetically modified food with certain kinds of genetic modifications that are 'natural' to the plant but that have not had any 'foreign' Deoxyribonucleic acid (DNA) added. What do you think about this?' (18)

The survey also asked the participants, 'India has a staggering history in terms of regulating the production and import of genetically modified food/crops. Do you think of the government supervision should be focused on restriction or propagation of research on genetically modified organisms?'. In response to this question, 39% of participants (166 of 420) stated that 'Considering the viewpoint of international authorities, Indian govt. should allow field trials for genetically modified foods'. 35% of participants (146 of 420) stated that 'the supervision should be more relaxed so that more genetically

modified organisms crops can reach the farmers directly', while another 25% (104 of 420) were of the opinion that 'restricted approach must be maintained regarding research and development or approval of genetically modified foods'(fig. 4).

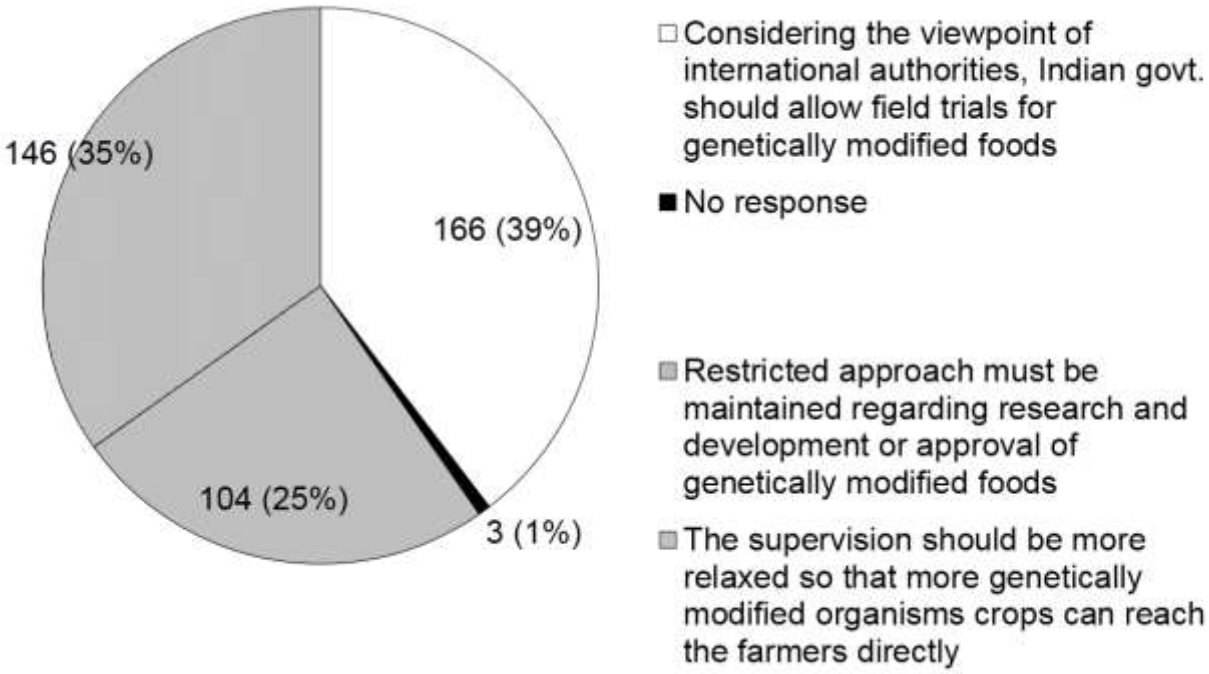

Figure 4: Response of participants to question 15 'India has a staggering history in terms of regulating the production and import of genetically modified food/crops. Do you think of the government supervision should be focused on restriction or propagation of research on genetically modified organisms?' (17)

Consumer perception of GM crops in India

In case of commercialized products, attitude towards the product, current knowledge of the product, and information about the product in the market are all major driving factors that go a long way in influencing a customer's perception, notion, and beliefs. Public perception on the matter has the ability to influence policy makers, therefore it is of utmost importance to understand where the Indian consumer mindset lies with respect to GM crops. Limited number of investigations have been carried out to assess consumer perception towards GM crops in India.

Anand et al. (2007) found out using a survey that the respondents were willing to pay a small premium for GM wheat when no information was provided to them. When the respondents were provided with positive "producer friendly" information, their willingness to pay for the GM wheat increased by a

small amount. However, there was significant decrease in willingness to pay when the respondents were provided with negative information. This showed how important it is to understand consumer sentiments towards GM foods and crops are a major factor in anticipating sales and development of new markets in this era of open market policies[17]. A similar investigative survey was undertaken by Mandal and Paul in 2012, to find out the factors that shape the perception of Indian consumers toward the consumption of GM food. The data was collected using self-administered online questionnaires from Indians spread across the three cities of Delhi, Hyderabad, and Kolkata, who were mostly young professionals. The study revealed that the four major factors which determined the perception of Indian consumers were their attitude towards GM foods, their concern for health, their preexisting knowledge of GM food and the information available about GM food[18].

Given the fact that much of India's consumer population are young, a consumer survey carried out among the youth, by Kajale and Becker (2014) found that 41% of participants were willing to buy GM foods. The study also found that female respondents were less willing to buy GM food than male respondents by 18.5%. Religion was also found to be a factor among the Indian youth, with a decrease to accept GM foods by 5.9% with an increase in religious concern about GM food[19]. Deodhar et al. (2008) investigated the factors which may impact the probability of consumption of non-GM and GM foods among Indian consumers. Additionally the study looked into the fact, whether or not consumers were willing to pay a premium for non-GM/GM foods. The investigation found that majority of the city survey respondents (72%) and about 28% of the web based survey respondents claimed that they were somewhat or extremely willing to consume foods produced with GM ingredients[20]. In another consumer survey carried out by Krishna and Qaim (2008), 68% of the participants supported the introduction of Bt vegetables, while 17% mildly or strongly oppose the new technology. The overall attitude toward GM foods was found to be quite positive in India, with 55% of all consumers willing to purchase Bt vegetables even if they were sold at current price levels for conventional vegetables[21].

In the present study, when the participants were asked, 'In general, will you support if the government authorities allow genetically modified crops/food in commercial agriculture?'. In response to this, 47% (196 of 420) of participants stated that they were against this idea, and only 16% (67 of 420) of participants chose to support it (fig. 5). Remaining 37% (157 of 420) were neutral. Next in a similar line, the participants were asked, 'Genetically modified technology is applied in the medical sector to produce medicine, such as genetically engineered insulin and recombinant hepatitis B vaccine. Do you think this benefits or harms the consumers?'. In response to this, 55% (229 of 420) of the participants stated that they did not know about this. 44% (185 of 420) of the participants stated that this would be beneficial (fig. 6).

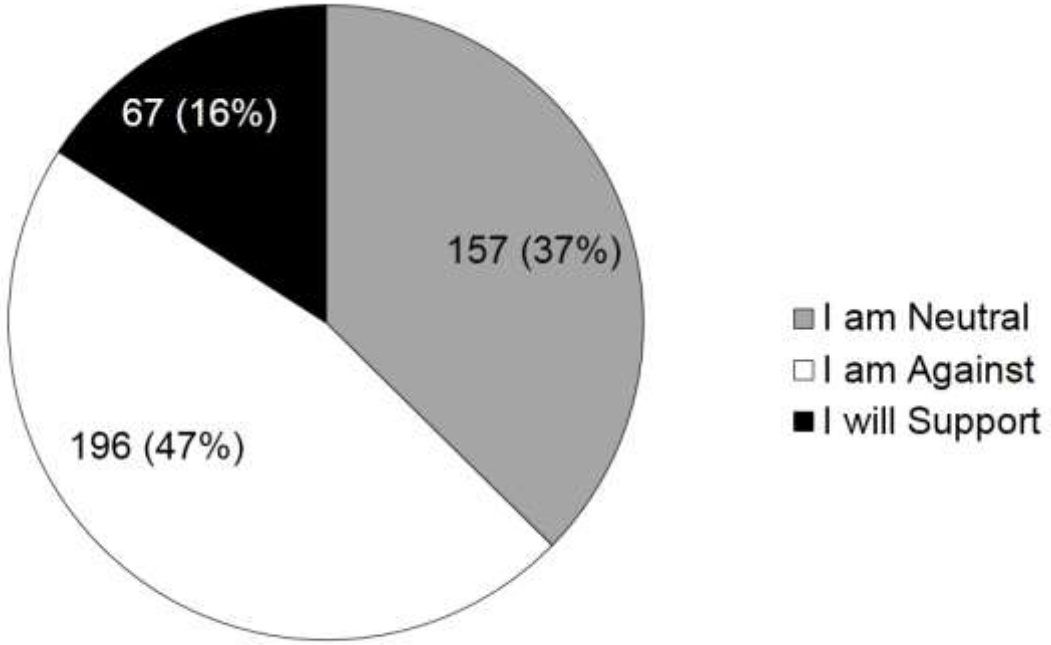

Figure 5: Response of participants to question 4 'In general, will you support if the government authorities allow genetically modified crops/food in commercial agriculture?'(6)

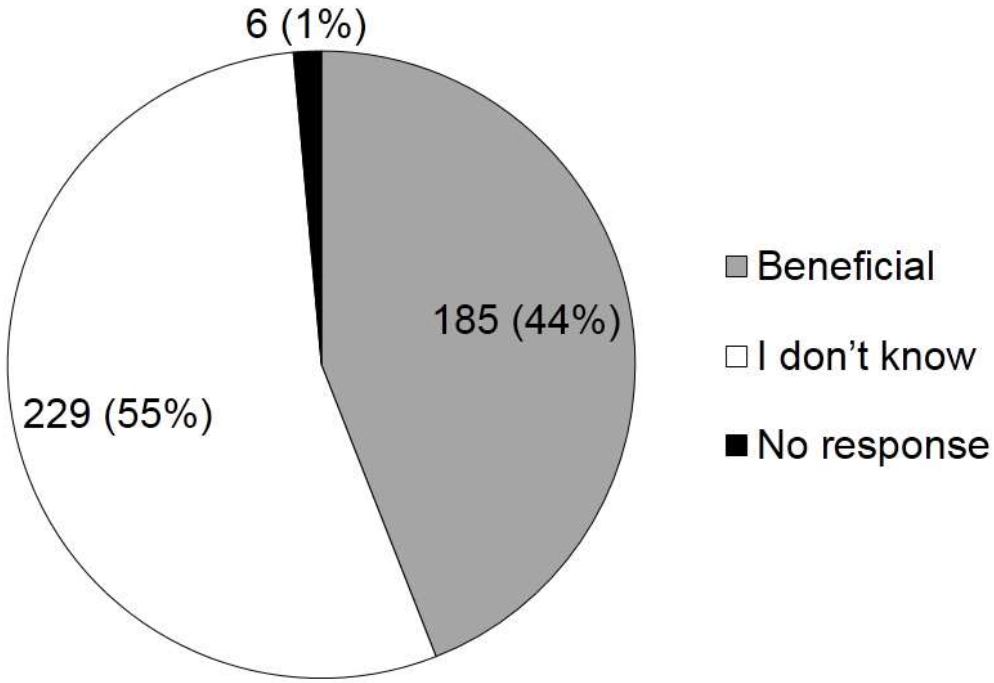

Figure 6: Response of participants to question 5 'In general, will you support if the government authorities allow genetically modified crops/food in commercial agriculture?'(7)

Challenges in India

Despite this apparent positive attitude present among Indian consumers, the government of India has adopted a cautious approach in introduction of GM crops. This has been partly due to the negative perception propagated by a section of the society. In 2006, environmental activists challenged the release of GM crops before the Supreme Court. An argument was put forward that planting GM crops contaminated nearby fields and was a danger to public health. The GEAC, at that time known as the Genetic Engineering Approval Committee, was very much operational and with a body to hear complaints. But, instead of directing the complaint to the GEAC, the Court ordered field trials to continue and when completed, share information on the extent of dangers posed by GM. This event had highlighted the fact that people were concerned about the unforeseen consequences of GM crop introduction. It is this kind of negative sentiment which has led to limited adoption of GM crops. In a major setback to the proponents of GM technology in farm crops, the Parliamentary Committee on Agriculture in 2012 asked the Indian government to stop all field trials and sought a ban on GM food crops such as Bt-brinjal. Raising the "ethical dimensions" of transgenics in agricultural crops, as well as studies of a long-term environmental and chronic toxicology impact, the panel noted that there were no significant socio-economic benefits to farmers.

Future direction

If we consider GM crops to be a commercial product intended to solve the possible high demand of food in coming times, then correct scientific information will play a major part in combating the negative sentiments that still exists in society. Information available of the product leads to the generation of either positive or negative outlook in the market. Therefore proper dissemination and promotion as well as spread of correct information in the right manner targeted to reach the intended customer pools play a beneficial role. This is more so in case of purchasing of food products as most consumers are sensitive to the conditions in which the food has been produced and whether it may result in any short-term as well as long-term side effects. Therefore it is of utmost importance for the food industry and other associated entities to disseminate health-specific information regarding the benefits that may be derived from specific varieties of GM crops. However, the increasing scope of negative propagandas regarding GM crops is gradually appearing to be a major challenge for management personnel involved in commercialization of products. This has led to timely and trustworthy promotion of the nutritional content of GM foods a necessity. Management personnel recognize the importance of product knowledge in shaping the deep-rooted perceptions within their

consumers. Influencing consumer knowledge and perception cannot be achieved solely through widespread campaigns but also require greater levels of management. People involved in this role may need to rethink and reshape the content for this purpose to make it more informative and engaging for the consumers. Packaging can be utilized as a very useful tool for providing health-conscious consumers with proper nutritional facts. Finally, as the consumer attitude toward GM products appears more and more to be the major factor in formulating overall perception in a market, legislators and manager must try to understand that just a widespread informative campaign may not be enough. They have to play major roles in carefully dealing with the already existing negative perceptions and must attempt to harness the positive contributions and other allied benefits of GM crops.

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