The Genetically Modified (GM) Food Debate in India: A Critical Introspection

Kanaujia, Anurag (1,2); Bhattacharya, Sujit (1,2)

1: National Institute of Science, Technology and Development Studies (CSIR-NISTADS), India;
2: Academy of Scientific and Innovative Research (AcSIR), India

Abstract

In the past few years the government of India has taken a strong pro-active stance towards introduction of new technologies for improving agricultural productivity and sustainability. Genetically Modified (GM) crops is one such technology with high economic and social stakes, as evident from debates about the utility of technology after the introduction of Bt cotton in 2002. Strong positivistic approach underscores the potentiality that GM technology can help address for food security, agricultural productivity, sustainable agriculture, etc. On the other hand, opposition has ranged from extreme stance (a strong precautionary approach) of disallowing GM technology in India to calling for a long-gestation period before scientific evidence emerges to strengthen the regulatory process. Issues of high royalty of Bt cotton, seed unavailability for non-GM cotton growers, and field trials being too restricted to properly assess the impact of this technology on environment, health, and food supply have further complicated this debate. Due to extensive public criticism, Bt brinjal in spite of getting regulatory approval was finally not introduced. An episode of regulatory failure, which is visible again in the indigenously developed GM mustard recently.

This study has revisited the GM debate in India by examining some of these issues through the lens of systems approach, social constructionism, and strategic management. The examination was based on close reading of literature and a focused field study. India epitomizes to a large extent the emerging/developing country's challenges and thus the study has a larger relevance for innovation and policy. The study underscores that policy articulations should be made simultaneously with strong institutional changes in the regulatory process. This, the study argues can provide a useful platform for resolving the conflicting stance among the different stakeholders, including bench-level scientists for improved decision making, and helping address the information asymmetry in the regulatory process.

Introduction

India introduced genetically modified (GM) plants in 2002, when the government allowed Bt cotton in commercial agriculture. This had a wide impact on a key agriculture commodity, cotton, which was being produced in the country. India had become fourth largest producer of GM crops in the world, based solely on cotton production in which 93% of India's cotton is Bt cotton in 2013 [1]. The acceptance of GM cotton by farmers with government's proactive support was instrumental in large scale adoption of Bt cotton. However, various issues ranging from uneven productivity of Bt cotton across different regions, pest resistance, and drought tolerance etc. has led

to questioning of GM cotton in particular and GM intervention in agriculture in general. 'Developing countries are caught between the potentials of biotechnology for development, on one hand, and their perceived adverse socio-economic impacts, on the other'. This according to Chaturvedi et al. (2012) is one of the reasons why the issue of GM crops remains contentious in developing countries. The responses of different countries also vary in terms of adoption of GM technologies. For example, a clear divide can be seen between the US and European stance in GM food crops. While US has shown a positivist approach that focuses on increasing productivity and shows lower anticipation of risks associated with GMO. Europe is approaching the issue with precautionary principle[1] in its policy stance. It has placed ban on growing GM plants and started stringent screening of the imported food material [2]. This divide has created regulatory uncertainty at the global level about the safety and adoption of GM crops.

The introduction of GM crops in agriculture involves multiple issues. Along with scientific and technological challenges; there are ethical, legal and social issues which have to be addressed for successful translation of this innovation to market. The multidisciplinary nature of this issue is one reason for the ongoing dispute. Along with requirement to understand technology, various socio-economic factors, and the predisposed ideas about what constitutes "natural", and the barriers associated with acceptance of GM food crops are not easy to assess and contemplate. A lack of understanding of technology among policymakers makes them vulnerable to influence/ill-inform views; this particular dimension of the problem seems to be ultimately contributing to framing of incomplete laws and policies.

Conceptual Framework for the study

The study applies understanding from Innovation Systems literature, Social constructivist approach and emerging strategic management literature to develop a framework. Innovation system approach argues that it is very important to have interactions between various parts of a system, say national, regional or international systems. It calls for developing varied types of functional linkages among the different actors which helps in developing capability [3]. The learning capability of institutions developed through interaction between them drives the process of innovation. Learning is in important function of the system framework. The role of institutions becomes important in this as it helps in developing the linkages essential for innovation activities to occur [3]. In national systems the role of local actors that can influence social learning capabilities like education systems, technical and scientific institutions, government policies etc. is "fundamental" [4]. These

[1] The emergence of increasingly unpredictable, uncertain, and unquantifiable, but possibly catastrophic risks, such as those associated with GMOs, climate change etc., have confronted societies with the need to develop a third, anticipatory model to protect humans and the environment against uncertain risks of human action. The emergence of this perspective has marked a shift from *post-damage* control (civil liability as a curative tool) to the level of a *pre-damage* control (anticipatory measures) of risks. (COMEST, UNESCO, 2005)

institutions can also serve as drivers of restoring faith in regulatory framework. A strategic management activity known as forum shifting can bring in perspective the socio-cultural issues.

Forum-shifting is an important concept that comes from strategic management literature. Forum shifting refers to an activity focused to yield preferred results by changing the game. Activities under forum shifting can range from moving the agenda to a new forum or removing an agenda from an existing forum (*horizontal shifting*) or pursuing same agenda in multiple forums (*vertical shifting*) [2]. Peter Drahos describes it by saying that "some negotiations are never over" [5]. Climate change debate has various examples of such actions. For instance the introduction of polluter pays principle under the Reduced Emission by Decreased Deforestation (REDD) and REDD+ regimes where developed countries were supposed to help developing countries in adopting sustainable development practices to a more global and shared framework of Intended nationally determined contributions (INDCs). Another area where this can be extensively applied is in negotiations undertaken in IPRs [2]. USA in order to increase its market opportunities in medicine pushed for higher standards of IP at global level. The international agency overlooking medicine IP standards used to be World IP Organization (WIPO), this was shifted to General agreement on Trade and Tariffs (GATT) in 1980's before being put in the Trade Related Intellectual Property Rights (TRIPS) in the World Trade Organization (WTO) making the signatory parties legally bound to raise their IP standards. Along with this horizontal shift of regulatory forums at international level, it engaged in vertical shifting through trade agreements on bilateral level with other countries to maneuver them into accepting global trade standards [2].

Forum shifting exercise requires 1. Identifying actors, their goals and strategies, 2. Providing an institutional roadmap, 3. Identifying divergent discourses in discursive strategies that can bring institutions on/off-line. However, the context of forum shifting has been seen more in terms of articulating a position of a dominant group and make it acceptable by the community at large. We are looking at it as an activity for restoring the lost trust in government regulatory framework. According to Bjorn Johnson (1992) institutions are the source of technological and economic change [6]. Role of new institutions is critical in tackling situations of system failure, a critical implementation of the system of innovation approach [3]. System failure can be dealt with by creating institutional arrangements where the actors interact with each other [4].

Social constructionism emerged from sociology about thirty years ago. In the post-modern era it is a useful tool in qualitative research. According to social constructionist view, knowledge is constructed and not created or discovered to make sense of a social world [7]. Institutions with credibility can influence the objective reality of society and can thus alter individual attitude towards new technologies [8]. Berger and Luckmann (1991) maintain that conversation is the most important means of maintaining, modifying and reconstructing subjective reality which is comprised of concepts that can be shared with others without much problem [8]. This however is not easy when a field of science is not well established. The central concept of social constructionism, interpretive flexibility, is about this difficulty when same observation is interpreted in multiple ways.

Interpretive flexibility when applied to scientific facts plays a role in scientific controversies and debates in the social ecosystem [9]. It contributes to situations where truth, usefulness or relevance of a concept or idea is contested. Different situations of social construction of scientific facts and technological artefacts may exist, under which their meanings may change, and thus interpretive flexibility plays a crucial role in establishing scientific facts and technological artefacts [9]. GM technology is an example where controversy about truth 'i.e. its safety for health and environment' of scientific facts is affecting the social construction of this technological artefact.

The findings that emerge from this study is contextualized by the insights that emerge from the theoretical frameworks as highlighted above. The socio-economic conflicts that application of new technologies in agriculture bring in can be traced back to the introduction of hybrid corn in the early 20th century [10]. Issues of governance and regulation and public skepticism in adopting new verities have highlighted the role of social engagement and novel institutions. Agriculture Extension centers was one such organizational innovation created to promote hybrid seed verities and engagement with the actual users. Understanding how technology is socially shaped, policy cannot be designed only to address market failure, importance of developing networks and institutions built on trust (social capital) provides us to understand how to design effective interventions for confronting the challenges that are seen in the GM food crops.

Methodology

Close reading of literature was undertaken to capture the various dimensions of the debate on GM food crops in general with particular reference to India. The literature included research papers, policy documents of the government, reports of committees, newspaper clippings and websites. Newspaper reports served as important source while developing the timeline of events and shifting policy positions. Indian GMO research information system (IGMORIS) (igmoris.nic.in) maintained by department of biotechnology, is a very useful resource for accessing biotechnology regulations and GM crop field trial data. The website was consulted to develop illustrations and tables by the authors.

Focused primary study approach (semi-structured interviews) was undertaken to draw further the salient aspects of the debate and provide a stronger empirical basis to draw the arguments. The field study included interviews and interactions with farmers, scientists and public officials concerned with GM crops in agriculture. The interviews were conducted with subject experts at Indian Institute of Pulse Research (IACR-IIPR), Kanpur (2016); with farmer collective from Uttar Pradesh at Network on Rural and Agrarian studies (NRAS) workshop in Allahabad (2015); and government officials at Punjab agriculture department and Punjab Seed Corporation (2016).

The importance of social capital (trust), information asymmetry, different viewpoints among scientists and interpretations (interpretive flexibility), approach (positivistic, constructivist approach), regulation, governance were some of the key issues that were explored in the primary survey.

Findings

Policy Environment for GM crops in India: There is a strong rationale for Indian agriculture to shift from resource- or input-based growth[2] to knowledge- or science and technology-based growth,[3] as there is limited scope for land area expansion and exploitation of natural resources. This rationale has also driven the Indian policy stance in recent times. For instance, the Economic Survey of 2015-16 and committee appointed by NITI Aayog [11] have supported that adoption new technologies (including GM seeds, women friendly farm equipment, water sustainable irrigation techniques etc.) to overcome the current status of low productivity and overdependence of Indian agriculture on monsoon. Economic survey of 2015-16 points out that like Brazil and China, India too needs to open up to new GM technologies to increase agriculture productivity and address other pressing concerns. As evident from the directions issued by NITI Aayog to allow development of GM crops in light of the fact that the imported commodities may already be from GM produced in source countries [12].

Establishing an intent for introducing and exploiting GM technology from time-to-time by the Indian Government as a solution to agriculture problem is an important context in the whole debate. Genetic modification, for example is seen as a solution to address sustainability issues in water-intensive sugarcane varieties [13]. This exhibits the proactive stance toward the acceptance of genetic engineering technology in agriculture [14]. As we discuss later, this stance has not been reflected in popular opinion and consequently in actions of public representatives. Various NGOs, activists, scientists, and other leaders have expressed their worries about the effects of GM crops from time to time. Some NGOs held a public protest march in Bathinda, a city in Punjab, as they alleged that introduction of newly developed GM mustard is an attempt to destroy our food heritage by pushing GM food into our plates [15]. It is probably this stigma that has been attached to GM food that fuels the strong public opinion against introduction of GMO in India [16]. Their contention is supported by policy documents of the Government of India, Economic Survey (2016-17) and NITI Aayog. It also acknowledges the validity of apprehensions regarding the non-regulated use of technology and calls for policymakers and researchers to simultaneously work toward building public trust in the technology development, assessment, and approval mechanisms.

Traditionally in the Indian regulatory structure government appointed bodies take the final call on release of crops in the environment which reflects that people have faith on government taking fair

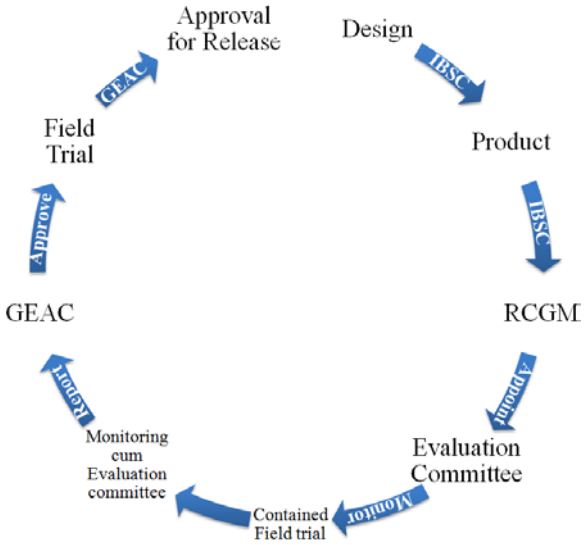
[2] An outlook based on staple theory of growth. It states in backward areas (as India was just after independence) development starts in core resource areas (such as oil, ore, natural gas, agriculture, etc.) and profits from this are used for value addition in other industries. It is a development focused on exploiting land, labour, capital, and natural resources to increase the output of an economy.

[3] The growth of service sector and the OPEC crisis of 1979, resulted in the new developmental economics point of view, which added technology as another factor of production. A paradigm shift in 2000-10s attributed availability of natural resources to crippled economic development; this they argue is due to overdependence of economy on resource sector industries.

decision. The GM debate however has shown us a new scenario where this system of regulation fails with rising trust deficit between the government and public at large. In such a situation new intermediaries can create a chance to push the debate toward closure helping in bridging the gap between different stakeholders [2].

Some Salient Features of biotechnology regulation in India

In India, application of biotechnology in agriculture is being dealt with by three different Ministries/Departments: (1) Ministry of Agriculture; (2) Ministry of Environment and Forests; and (3) Department of Biotechnology, Ministry of Science and Technology. GM introduction in agriculture is governed by the above three ministries. Stylized version of the regulatory process for GM approval in India is highlighted in figure 2.



Process followed during the development and Testing of a rDNA technology based or genetically modified organism, plant varieties for use in open fields. *(constructed based on GEAC website information, literature review and interview data)*

RCGM (Review Committee on Genetic Manipulations): This is one of the key regulatory bodies and ensures that any activity involving GMOs or r-DNA technology does not compromise environmental safety and human health in the country. The various powers it has include framing guidelines for GM research, reviewing high risk projects, and regulating import, export and sales of GMOs. Its responsibilities are also significantly high and are to guide applicants about preparation of bio safety data, approve the protocols for toxicity and allergenicity studies examining the data generated from laboratory experiments and field trials.

Monitoring cum Evaluation Committee: This committee undertakes field visits of experimental sites approved by RCGM and GEAC and prepares formats which are used for reporting the collected scientific information on transgenic crops under experimentation. It can be termed as the eyes and the ears of RCGM based on the nature of work it performs.

GEAC (Genetic Engineering Approval Committee): Under the Aegis of Ministry of Environment and Forests, GEAC is the principal authority for the approval of research, import-export, production and manufacturing of organisms as well as derivative products related to or involving recombinant DNA technology in the country. It is reconstituted every 4 years and has additional powers to appoint sub-committees and invite experts in their meeting to tender advice on important matters.

IBSC (Institutional Bio-Safety Committee): The Recombinant DNA safety guidelines, 1990 issued by the Ministry of Environment and Forests requires recognition of any facility using recombinant DNA technology based organisms to be recognized by the IBSC. IBSC also is the first body to be notified about the design, manufacturing and development of new GE organisms in the facility. It intimates the RCGM about any developments on GM research and is empowered to decide upon experiments until the bio safety level II.

Fig 2. *Regulatory Structure for Approval of GM Crops in India: A Stylized Version*
Source: constructed based on information from GEAC website, literature review and interview data

The process involves six different agencies which are arranged in a hierarchy of power. Institute Biosafety Committee (IBSC) is at the first layer and Genetic Engineering Appraisal Committee (GEAC) is at top. Other bodies Review committee on genetic manipulation (RCGM), State and Regional committees are in between with varying powers and functions in ensuring safety and quality standards of GMOs (GEAC Website, 2016).

The safety assessment of genetically engineered food products relies on the concept of 'substantial equivalence' [17]. The assessment involves the manufacturer and an independent regulatory body. Manufacturer is to perform testing of the engineered food product for toxins, nutrients or allergens found in the unmodified food and compare the two for any unexpected changes. The manufacturer's data is reviewed by the regulatory body. Based on these results regulatory body recommends for production or more tests on the food product.

A shortcoming of this method for which it has been criticized is that the level of similarity which makes something 'substantially equivalent" is not clear [17]. This approach of objective risk based assessment[4] seems incomplete to various scientist and civil society groups. They argue that the potential impact of the technology on human health includes allergens, transfer of antibiotic resistance markers and 'outcrossing' (*the movement of genes from GM plants into conventional crops or related species in the wild*) remain largely unassessed [18] [19] [20] [21].

Field tests and development of GM crops in India

Since the introduction of Bt cotton in India, multiple crops have gone through field trials. Between 2002 and 2012 a total of 212 events have been approved by Genetic Engineering Appraisal Committee (GEAC) for use in agricultural crops (Table 1). Field trial data is available from 2006 to 2013, where plants under trial include food crops, and non-food crops.

Table 1 also underscores that a substantial amount of public funding and research efforts have been invested for producing crops through GM technique. Indigenous competency has been developed as many field trials have shown promising results. Hence, the issue at stake is also on the indigenously developed crops through GM intervention. Table 2 highlights how the debate has shifted since the introduction of GM technology in India. Drawing further from Ramanna (2005) assessment of India's policy on GM crops, 2004-05, we have divided the time period into five phases which correspond to dominating socio-economic drivers in the research, development and adoption of GM technology in agriculture in India during the respective periods.

Phase I (India's introduction to genetically engineered crops): Fueled by success of biotechnology, alliances between large MNCs emerged (Monsanto, DuPont, Syngenta, Dow etc.), which started playing a crucial role in the development of agricultural technology. It is during this period that a profit-driven industry begun in agriculture, as companies invested significant capital and resources

[4] Objective risk based assessment: Quantitative data derived from experimental studies provide the sole standard for credibility and decision on risk and uncertainty. Assessment criteria for a valid knowledge claim is thus decided by quantitative parameters.

in biotechnology research. This contributed to the development of genetic modified crops. The potential market for these crops were in large developing countries like Brazil, China and India.

Table 1. *GM crops under field trials*

Year	Total number of crops	List of plants under field testing
2006	10	Brinjal, Cabbage, Castor, Cauliflower, Corn, Groundnut, Okra, Potato, Rice, Tomato
2007	4	Rice, Okra, Cotton, Brinjal
2008	5	Cauliflower, Cotton, Rice, Tomato, Corn
2009	11	Brinjal, Cabbage, Cauliflower, Potato, Cotton, Corn, Roundup ready (RRF) cotton, Rice, Groundnut. Chickpea, Sorghum
2010	16	Watermelon, Tomato, Papaya, Hybrid Rice, Rice, Cabbage, Cauliflower, Sugarcane, Sorghum, Maize, Groundnut, Glytol Cotton, Brinjal, Mustard, Rubber
2011	10	Rubber, Sorghum, Rice, Groundnut, Cotton (HT-Glytol Cotton, RRF Cotton), Corn, Mustard, Castor
2012	6	Cotton (RRF Cotton, Twinlink Cotton, Glytol Cotton), Corn, Rice
2013	5	Cotton (RRF Cotton, Twinlink Cotton, HT-Glytol Cotton), Corn (Corn, HT-Maize)

Source: (IGMORIS website http://igmoris.nic.in/)

Stagnation of agricultural productivity in growing India with frequent threats from pests and hybrid seeds requiring high input resources provided an opportunity for international biotechnology firm Monsanto to approach Indian authorities for license to import Bt cotton in India in early 1990's. Monsanto strategically formed a new subsidiary by inking memorandum of understanding (MoU) with Indian biotechnology firm Mahyco in India for this purpose [22].

Phase II (anti-GM networks and international networks): Threat of climate change and its implications need for sustainable development influenced the adoption of precautionary principle in policy making and the priorities of an economic model of agriculture improvement came under scrutiny [23]. Scientists in India expressed their willingness to compete with international MNCs and develop new varieties of crops that could match the claims of GM crops introduced in the US markets by Monsanto and Bayer, but at lower costs.

Scientific studies during this period also identified many adverse effects of prolonged exposure to GM crops on human health, as well as on environmental sustainability [24] [18]. On the basis of these apprehensions, civil society groups around the globe have argued for more stringent checks on GM-based products [25]. Impact of these studies have been seen more in GM food crops resulting in many countries denying entry of GM crops in their food system or considering

withdrawal of GM crop based products from their markets. European Union has become an important point of reference for South countries

Phase III (Farmer-Industry Linkages): Soon after the first setback of the Indian Government's decision to not allow Bt cotton in Indian markets, biotechnology firms had re-engaged farmers through collaboration with local biotechnology firms and built confidence among farmers about the new technology and its potential to decrease the use of pesticides in cotton cultivation [22]. This, coupled with approval of commercial release of Bt cotton, meant a partnership between the farmer and the industry was developing.

Phase IV (Farmer Suicides and Precautionary Principle): Maintenance of vigor in the Bt cotton crops emerged as one of the issues, as over time the traditional bollworm pest population seems to be undergoing artificial selection with individuals having tolerance to Bt toxin; increasing in population and rendering the Bt cotton seeds susceptible to them. This situation of susceptibility was compounded by poor rainfall in selected regions of country, which are now thought to be the reason for farmer suicides in drought-hit regions. The opposition of GM crops as a result of apparent failure of Bt cotton technology prompted government setting up assessment committees. The Parliamentary committee on agriculture noted that in India, debate on GM crops centered on the regulatory structure for GM crop testing and their approval [26]. The subsequent committees for GM crop assessment and their views are as follows.

The first appraisal of regulatory scenario was conducted in 2009 when Jairam Ramesh, then Environment and Forest Minister ordered a moratorium on commercial release of *Bt* Brinjal and posed three preconditions (namely 1. setting up of independent regulator, 2. obtaining consensus of all states, and 3. consensus among scientists on the protocol for tests on safety of GM crops) for lifting the moratorium. GEAC had approved Bt brinjal for commercialization in 2009 in India and stepped out of The Indian Supreme Court (SC) placed moratorium on commercialization of all GM food crops in 2005. This move, however, received strong dissent from several non-governmental organizations and the Ministry of Environment and Forestry overruled the GEAC and called for the indefinite moratorium on the commercialization of GM crops to continue. Consequently SC appointed a technical experts committee (TEC) to look into risk assessment studies, to advice on proper evaluation of GE crops and to advise on feasibility of initiating open field trials [27].

S. K. Sopory committee set up to assess Bikaneri Bt cotton case reported that the appearance of a commercial variety in fields showed the presence of structural flaws in regulation and distribution systems [28]. It was stated that the lapse was a consequence of poor project planning and implementation of available rules for release and safeguarding of new varieties. This incident ended up questioning the capability of the national systems and their ability to come up with indigenous varieties of GM crops in future. Since 2009 attempts to revive the GM food crop initiative have been met with sharp resistance before being put off by local governments [29]. Most recently reports about protests against field trials of GM mustard in Punjab have surfaced with the

NGO: Coalition for GM free India and Kheti Virsat Mission (KVM) launching campaign against the promotion of GM food crops in Punjab [15].

One can observe precautionary principle underlying as the central thesis of each of the committee's report. This showed the existence of a larger barrier in acceptance of field-to-plate crops, such as brinjal and rice versus cotton, a fiber crop that is not cultivated for human consumption.

Phase V (Present: Environmental Activism, Sustainable development, and Food Security): After a decade long moratorium on GM field trials, concerns about food security and climate change seem to have again motivated government to examine the intervention of GM in agriculture [30]. One outcome of this was the government allowing states to regulate respective GM technology development in 2014 [29]. The increased activity on the climate change scenario has led to a spillover effect on other production-related sectors. Sustainable development has become one of the most cited philosophy of development and growth, especially after the adoption of Nationally Determined Contribution (NDC) framework of climate change mitigation and adoption in 2015. Groups which advocate more stringent checks on GM-based products have emerged and grown. However, the role of government in this situation of confusion has become even more important as a mediator and in directing the use of genetic manipulation technologies for the betterment of society. In addition to the problems (as pointed out by the Economic Survey 2015-16) that occupy most of the space for agricultural improvement through GM crops adoption, Sopory committee noted that they observed a general lack of capability [28]. In our case study we observed incomplete connections between farmers and agencies, absence of an easy to understand and follow mechanism in crop assessment, and ignorance of crop's environment and nutrition requirements as the issues that need to be addressed to allow for a better, efficient, and beneficial uptake of the GM technology.

Learnings from the different periods of GM in agriculture debate

We see that two blocks with divergent views have emerged in the debate, one supporting adoption with caution, which can be called as positivism (there is a divergence within this group also, with some even not stressing upon the caution) and other calling for rejection of technology, whose viewpoint seems to be based on the concept of precautionary principle [31]. Table 3 broadly captures concerns and credits of these two stances.

Growing Consensus among government and Scientists: The Positivistic Stance

Many agricultural scientists and the Government now share the view that with India, its growing population and shrinking arable land resource [25] [32] [33], they need to start investing in technologies that promise raising agricultural output [34]. Researchers working on development of new GM crops often cite high productivity with its GM crops on the strength of Bt cotton, (the only GM crop commercially cultivated in the country), and emphasize the potential of GM technology to take India to the frontline, among the agricultural producers of the world [29] [35] [23].

Table 2. *Different phases of GM crop development with first attempts for its introduction in 1998.*

Phase I (1990-1995) Introduction of intervention in agriculture	**Phase II (1995-2001) Anti-GM Networks**	**Phase III (2001-2005) Farmer – Industry Linkages**	**Phase IV (2005-2012) Farmer Suicides and Precautionary Principle**	**Phase V (2012-Now)**
- Monsanto applies for Bt cotton introduction. Application rejected due to high technology fee (1990-1993) - Monsanto and Mahyco obtain license to import Bt cotton (1995)	- International opposition to GM-organisms, influence Indian groups. Anti-GM groups block approval by government agencies - Linked to Initial field tests on Bt cotton - Application for commercialization of Bt cotton rejected (2001)	- Alliances between farmers and industry built up confidence in the Bt technology - Gujarat episode: illegal Bt cotton found in farms growing traditional varieties (2001) - Application for commercialization of Bt cotton approved by GEAC (2002)	- Farmer suicides alter perceptions about the utility of Bt technology. The widening of anti-GM groups networks also widened - Renewal of commercialization license for Bt cotton rejected by the Andhra Pradesh Government (2005) - GEACs approval for commercial-ization of Bt brinjal blocked by the Environment Minister (2010)	- The threat of food security and climate change cited as reasons to look toward GM technology for yield and tolerance - GM mustard developed by Delhi University with Government funding (2012) - Parliamentary Standing Committee on Agriculture and Technical Expert Committee favor moratorium on GM trials (2012)

Sources: [27] [26] [17]

In the GM debate the claims that these crops facilitate or are hurdles in achieving sustainable development, millennium development goals (MDGs), and food requirements have been one points of contention. With the estimates of global population reaching 9 billion by 2050 and one of the pressing issues will be of food availability [36]. India becoming the largest contributor to the global population by 2050, the already pressing problem of poverty is set to assume the center stage.

The Precautionary approach: The precautionary principle restricts the introduction of a product or process with unknown or disputed effects on the society, environment etc. It is one of the main principle cited to prohibit the use of GM organisms and food. The principle banks upon the theory of risk management for placing the burden of proving the safety of GM technology before adoption. Arrow and Fisher (1974) introduced how risk neutral decisions can lead to sustainable development choices by providing more flexible choices in future. In India a call for stringent policy framework in regulating the application of biotechnology in the country has been there since the beginning of debate [23]. Government actions are in agreement with the views of providing safeguards as articulated by scientists. There was a need of a regulatory authority which would have functions of ensuring that adequate measures are taken to avoid issues like environmental, social, ethical, moral, health and hygiene, bio-warfare. National Biotechnology Regulatory Bill, 2008 had been proposed [37] [37]. The bill had argued for establishment of Biotechnology Regulatory Authority of India (BRAI) with a Chairperson, two full-time members and two part-time members; who will be people that have expertise in life sciences and biotechnology in agriculture, health care, environment and general biology. The bill also proposed setting up an inter-ministerial governing body, to oversee the performance of BRAI [37], and a National Biotechnology Advisory Council of stakeholders to provide feedback on the use of biotechnology products and organisms in the society [37]. The revised drafts renamed as Biotechnology Regulatory Authority of India Bill, 2012 propose this regulatory body to be an autonomous and statutory agency with functions to regulate the research, transport, import, and manufacture biotechnology products and organisms [37]. Food Safety and Standards Authority of India (FSSAI) has also been brought into the picture with it being assigned the role of overseeing safety of processed food products.

Points of Contention in marketing of technology: Findings from the Case Study: A criticism of green revolution that is being seen as applicable on GM technology is switching from traditional subsistence farming to industrial mono-cropping, which has negative effects on small farmers [26]. They found themselves trapped in the cycle of high interest rates on seeds, fertilizers, and pesticides, which they had to buy on credit [1]. As they were often working with only one dealer, there was no competition and prices remained very high [41]. The institutional and economic setups for using the new technology effectively and safely are still developing and, as a result the trickle down effects of technological advancements, are not easily reaching to small-scale producers. For example, Bt cotton seeds are expensive, farmers have to buy seeds every cropping season, which increases the factor cost for the farmers.

Post-facto policy interventions: Along with promoting application of GM technologies in agriculture, an intent for in safeguarding the interests of farmers can also be observed in some steps taken by the government. The introduction of more safeguards (see for example: center tightens rules for GM seed technologies providers, 2016), to ensure protection of farmer rights in market, support schemes in cases of crop failure etc. shows a protectionist[5] ideology.

[5] Trade Protectionism: In the current globalized economic setup, the movement of goods and services among countries are not free. There are a number of reasons for which countries put barriers on trade. Some of these motivations are protecting their own companies from foreign competition, or protecting consumers from dangerous or undesirable products. (Protectionism? Tariffs and Other Barriers to Trade, OECD, 2009)

Table 3. *The two stands on GM crop adoption: Key Issues in the GM crops debate and developments that have occurred over time. (Sources:* [38] [33] [14] [34] [22] [39]*)*

Concern	Pro Gm	Anti GM
Human Health	Address malnourishment among children with high protein GM food, for example Golden Rice to address Vitamin A deficiency [22]. Lower instances of pesticide in food and water among Bt farmers, and low levels of mycotoxins in Bt corn [35]	Reproductive, Immune system, Aging, organ damage, Gastro intestinal distress, dysfunctional regulation of cholesterol and insulin **[39] [24]**
Environment	Sustainable agriculture practices by lowering chemical fertilizers, pesticides, weedicide consumption. Adaptation to effects of climate change facilitated by technology.	Superpests being created by Bt technology use Superweeds being created by HT technology use **[22]**
Seed Supply	Seeds of varieties developed by public funded research can be made cheaper and easily available to the farmers.	Concentration of biotech firms over seed supply and farmers become dependent on market for their agriculture **[22]**
Manufactured Risk	Proper field tests with a uniform method under coordinator-ship of bio-safety experts will cultivate trust and confidence of public in procedures adopted for assessment of benefits and risks [32]	
Regulatory Issue		4 government committees and reports on GM crops **[40]** 1. Jairam Ramesh report, Feb 2010 2. Sopory committee report, Aug 2012 3. Parliamentary committee report on GM crops, Aug 2012 4. TEC final report, July-2013 [All the four committees have pointed out that it would be hasty to take a final call on release of GMO. The reports however differ on the reasons for taking this particular stand.]

This price of seeds on royalties being charged by the developer. This notification was brought after the demand for lowering of royalty charges for Bt cotton technology, with claims that domestic hybrid seed producers have paid over Rs. 5000 crore to Monsanto in the form of royalties. High royalties and license fee even after the efficacy of varieties have been lost are now under the purview of GM-licensing rules [42].

Trust Deficit: Despite its efforts government has been unable to develop trust among the general public and a section of scientists among other experts opposing the positivistic policy choice. To assess the barriers we have conducted case studies where farmers, scientists and

public officials concerned with GM crops in agriculture were interviewed and broad categories of factors involved were developed.

Confusion: There is involvement of multiple institutions leading to fragmentation of the regulatory process. Among the different players most notable are MoHFW (GEAC, RCGM, RDAC, FSSAI), DST, MoEF etc. which share regulatory and implementation responsibilities but there is a lack of concerted effort while deciding the final verdict on a particular event approval. High royalty payment to Monsanto and cotton seed price (control) order 2015 perhaps have created an unintended effect, and driven Monsanto into withdrawing their new technologies from the Indian market. But National Seed Association of India (NSAI) had urged government to reduce royalty as the Bt cotton technology according to them had become obsolete and also failed to stop pink bollworm [42]. Promotion of indigenous GM variety coming from public funded research can address these types of conflict.

Insufficient information and misleading perceptions: Our focused field study highlights that the whole process and particularly those aspects that a bench level scientist should be aware often do not have the needful awareness. Informal innovation becomes very important in crop development, however there is no mechanism by which this informal innovation can be incorporated in the formal innovation system in the indigenous development of GMOs. Farmers had the impression that GM seed could solve all their pest problems however new pests have emerged in Bt cotton showing that this belief was misplaced.

Discussion

Revisiting this debate on GM food crops in India has underscored some critical gaps that remain unresolved. A strong policy stance by the government can be seen over the years in promoting GM crops. This might have been a motivation behind large number of field trials till 2010. In spite of the positivistic policy stance and indigenous development of some GM crops, there have been strong impediments in commercialization of the different GM varieties. The GM cotton which was introduced and had been extensively cultivated has itself come under question due to various issues such as high royalty, secondary pest infestation. After the moratorium on Bt brinjal in 2009 and consequent shift in government policy, the number of field trials decreased progressively.

The close reading of various documents gives evidence of how divergent groups have emerged which have influenced the GM debate. These actors are generally distinguished by a strong positivistic stance vis-a-vis an approach of opposition based on precautionary principle. Various stakeholders who were outside the governance system played an instrumental role in the development of public opinion about this technological intervention. Various committees have examined the case of GM crops since 2002. Unlike the stated government stance of promotion of GM crops with a strong positivistic approach, the outcome of the reports demonstrate the reflexive attitude and precautionary principle based view towards the technology. The classical risk assessment approach is being challenged with this technology that falls into the grey area and challenges the very notion of ‘natural’ produce.

Through our re-introspection of the debate and based on the interviews conducted with farmers, experts and officials during the case studies, it emerged that there are divergent viewpoints

among the stakeholders. The case studies provide useful indications to why conflicts are emerging and calls attention to the need of a platform to bring these stakeholders together.

The policy landscape for GM crop adoption is shaped by group perspectives which is based on divergent views about GM technology. Scientific experts, government agencies, civil society etc. have their own understanding of the technology with their own set of beliefs and doubts. Scientific experts for instance look at available experimental evidence from animal testing and field trials. Farmers on the other hand have informal knowledge including understanding of risk factors which contest classical risk approach. There is no mechanism which allows them to participate in the governance system. Civil Society groups with their wide network and information campaigns act as agents for end users in constellation of actors for social negotiations [9]. This draws attention to the role of informal innovation in crop improvement and the absence of mechanisms to incorporate these activities in formal innovation system.

In figure 4, the factors influencing the GM crop debate are placed in a categorical visual representation for a more informed understanding of policy landscape. The framework can be a useful lens to look at the gaps in the regulatory landscape for biotechnology and distinguishing the issues that form the core of the debate.

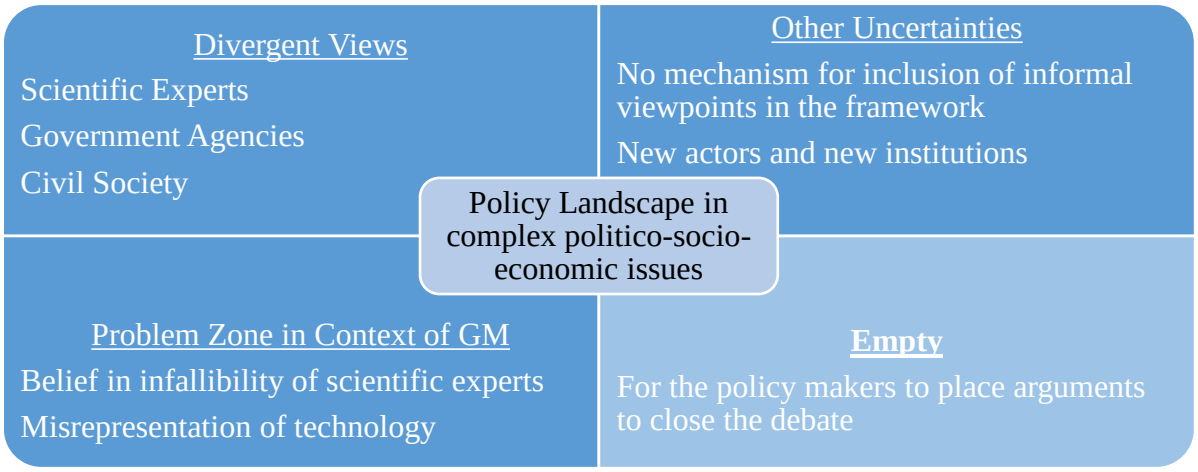


Fig 3. *Framework representing the policy landscape and balancing the concerns of stakeholders in GM technology.*

Towards a Closure of the Debate

The introduction of GM crops in India has associated with it multiple issues related to policy, regulation and technology. The government has been unclear about its position regarding the technology for over two decades. An imbalance created as a result of incomplete understanding of technology, which is treated as a product from the 'black box' of science and the absence of a systems approach involving all stakeholders from the three corners of society [25] [43]. It is difficult to place GM technology as solution or as a problem alone, as with any technology there are certain windows of opportunities and risks associated with the use of technology. Creativity during interpretation of these opportunities and risks is what will make the technology successful or a failure [44]. Influence of marketing strategies of MNCs in development of this technology is a crucial caveat in its adoption and is often balanced by protectionism based regulation. Regulation of the technology is also motivated by the effect of technology on environment and human health [45]. Management of local resources and

monitoring the efficiency of technology can make all the difference between success and failure of a technological intervention.

Due to the knowledge intensive nature of technology there is a need of development of institutions and intermediaries that can translate complex scientific advancement into simple understandable and usable forms for the end users i.e. farmers and consumers. Critical evaluation and assessment of the technology should underscore the whole process. Thus this institution also acts as a watchdog. This body can be instrumental in addressing the information asymmetry, serve as a channel for collection of user data on the success or failure of the technology. This data can be useful for identifying challenges for technology diffusion and its efficacy in different regions.

New agricultural research in biotechnology in principle should be supported by proponents of both positivist and precautionary approaches. As per R.B. Stewart (2002) non-preclusion based on precautionary principle approach requires new research in order to prove the ultimate effects of technology. Experimental development and field trials for GM crops are important to identify new varieties of transgenic plants and their effect on human health, environment etc. It is important to maintain a product database that allows regulatory authorities and other interested stakeholders to easily access and share basic information on products derived from the use of modern biotechnology [36]. A unique identifier of any new transgenic variety should be assigned so as to have a proper detailed information of crops being introduced in the country, food products containing GM should be in the public database. OECD's Unique Identification for transgenic plants is one such identifier. Available in the OECD bio-track product database this is a 9 digit alphanumeric code given to each transgenic plant that is approved for commercial use. Also this information should be made available in FAO GM food platform along with information about regions of their commercial application [46].

The problem and its resolution need to be seen in a much larger context. Influential theory of social constructionism, innovation systems and strategic management can help us in this exercise. Social construction of reality based on experiences in the real world [47] and its central concept of interpretive flexibility assume importance as in the environment with high scientific uncertainty various stakeholders with differing authority influence the public opinion differently [9], as can be seen from new studies which have identified other parameters that have not been addressed, and bring out new elements of concern.

Social Construction of Technology (SCOT) approach has been an influential theory and methodology in sociology and the history of technology. It emphasizes the role of social factors in development and acceptance of technology [48]. Scholars argue that the process of development of technology should be informed by human needs and desires. According to interpretive flexibility of scientific findings, scientific findings are open to more than one interpretation [9]. Social mechanisms play an important role in limiting interpretive flexibility towards resolution of scientific controversies [9]. Tom Andrews (2012) distinguishes constructivism as having individualistic mental constructs from social constructionism which has social context to the process of creation of knowledge [7]. In the case of GM debate this distinction is visible as the individual opinions are shifted to build a different social opinion. Popular opinion is shaped by institutions and intermediaries which project their perceived

realities about the world through communication channels [46]. Opposition to introduction of Bt Brinjal in India is a situation similar to system failure for the framework set up to promote use of new technologies and techniques in agriculture. Question of whether all modern biotechnology based agricultural practices are rooted in industrial monopolistic agendas [10] and how government is serving its mandate of social welfare in such a situation is the one that needs to be answered in order to resolve the current debate.

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