National Academy of Agricultural Sciences

Policy Brief to Accelerate Utilization of GE Technology for Food & Nutrition Security and Improving Farmers' Income

New Delhi
August 1, 2016

Policy Brief to Accelerate Utilization of GE Technology for Food & Nutrition Security and Improving Farmers' Income

National Academy of Agricultural Sciences

Policy Brief to Accelerate Utilization of GE Technology for Food & Nutrition Security and Improving Farmers' Income

Science-led agricultural growth has played a key role in the national progress in post-independence India. The Green Revolution (GR), propelled by the development and adoption of high yielding and disease resistant crop varieties in the 1960s, transformed the country from reliance on large scale imports of food-grains to a food-surplus country, maintaining a healthy buffer stock of food grains to provide access to food at affordable price. While these gains are outstanding, the country is still home to one-fourth of the world's undernourished, hungry and poor, and faces enormous challenges like the emerging and re-emerging biotic and abiotic stresses due to agricultural intensification and climate change. Added to these are serious concerns of dwindling natural resources – like arable land, water and biodiversity. To meet these challenges, **the country has no option but to use all the available and emerging tools and technologies to improve food production**. Genetic engineering (GE), also known as GMO technology, is one such technology, which has shown great promise in improving crop productivity, best exemplified by the outstanding success of *Bt*-cotton in India.

GE technology is a promising, relevant, safe and efficient technology for low-input high-output agriculture for crop improvement where conventional breeding tools have not been successful. It is an important tool to improve agricultural crops for their nutritional value, nutrient and water use efficiency, productivity, and tolerance/resistance to biotic and abiotic stresses[1]. The Academy has prepared and widely shared the science-informed policy options and actions for safe, intensive and judicious harnessing of the GE technology.

GE crops are developed by introducing genes or nucleic acid sequences of interest in the plant genome through the process of genetic engineering, to express a new useful trait or alter/check the expression of an undesirable existing trait, to enable the crop variety to resist stresses or develop new desired traits, which cannot be effectively incorporated through traditional crop breeding technologies. Thus GE has opened up uncommon opportunities for transferring genes across sexual barriers and thereby provides new genetic combinations to face the challenges of productivity decline, yield barriers, degradation of natural resources (soil and water) and climate change. Development of improved crop varieties by the integration of conventional breeding and molecular breeding and genetic engineering holds great promise.

In the last two decades (1996-2015), the global area under GE crops has increased over 100 folds, from 1.7 to 179.7 million hectares, benefitting nearly 18 million farmers. Of these 18 million farmers, 90% were small, resource-poor farmers in developing countries. In 2015, of the 28 countries[2] planting GE crops, 20, were developing countries, covering more than 50% global area under the GE crops. These

[1]**NAAS** (2011) Biosafety Assurance for GE Food Crops in India. Policy Paper 52, NAAS, New Delhi

[2]**The countries, which planted GE crops in 2015:** Argentina, Australia, Bangladesh, Bolivia, Brazil. Burkina Faso, Canada, Chile, China, Colombia, Costa Rica, Czech Republic, Honduras, India, Mexico, Myanmar, Pakistan, Paraguay, Philippines, Portugal, Romania, Slovakia, South Africa, Spain, Sudan, Uruguay, USA, Vietnam

crops have provided enormous environmental and economic benefits. A global meta-analysis has shown that ***"on average, GE technology adoption has reduced chemical pesticide use by 37%, increased crop yields by 22%, and increased farmer profits by 68%"***[3]. Between 1996 to 2014, GE crops have helped in increasing crop production valued at US$150 billion and improving environment, "by saving 584 million kg a.i. of pesticides; in 2014 alone, reducing CO_2 emissions by 27 billion kg, equivalent to taking 12 million cars off the road for one year; conserving biodiversity by saving 152 million hectares of land; and helped alleviate poverty for ~16.5 million small farmers and their families totaling ~65 million people, who are some of the poorest people in the world"[4].

GE crops have been developed for a variety of traits, such as longer shelf-life, improved nutrient contents, resistance to viruses, fungi, insects and herbicides (to help in the management of weeds) and tolerance to drought, floods and salinity. However, the GE crops developed for resistance to herbicides or/and insect pests, have been most widely commercialized. In 2015, cultivation of GE varieties carrying these traits individually or in combination covered nearly 12% of the world's crop hectarage. The most commonly grown GE crops in 2015 with one or both of the traits were soybean (covering 83% of the area under soybean production), cotton (covering 75% of the area under cotton production), maize (covering 29% of the area under maize production), and canola (covering 24% of the area under canola production)[5]. **High adoption of the first biotech drought-tolerant maize planted in the US** from 50,000 hectares in 2013 to 810,000 hectares in 2015 shows the power of GE technology[3].

The other GE food crops, such as apple, sugar beet, papaya, potato, squash and eggplant, developed for varying traits covered smaller area across the world. Apart from the GE cotton, the non-food GE plants grown in 2015 included alfalfa, poplar, carnations and roses. In addition, GE varieties of a large number of other plant species are also at advanced stages for commercial release. These include several GE crops of interest to us, such as banana, bean, cassava, chickpea, citrus, cowpea, groundnut, mustard, pigeon pea, rice, safflower, sorghum and wheat.

Regulatory approval is an essential requirement for commercialization of GE crops, to ensure the biosafety of the GE crops, their products, and the associated technologies. India's multi-tier regulatory system is one of the most robust regulatory systems in the World, to address the biosafety and environmental issues, which are considered to be the main impediments in public acceptance of GE crops. Under the 'Rules for Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms/ Genetically Engineered Organisms or Cells 1989', of the Environment Protection Act, 1986, six competent authorities, i.e. the Recombinant DNA Advisory Committee (RDAC), Institutional Biosafety Committees (IBSC), Review Committee of Genetic Manipulation (RCGM), Genetic Engineering Appraisal Committee (GEAC)[6], State Biotechnology Coordination Committee (SBCC) and District Level Committee (DLC) have been established. While the RDAC has advisory role, the IBSC, RCGM and GEAC have functions

[3]**Klümper**, W. and Qaim, M. (2014) A meta-analysis of the impacts of genetically modified crops. PLoS ONE 9(11): e111629 doi:10.1371/journal.pone.0111629

[4]**James,** Clive (2015) Global status of Commercialized Biotech/GE Crops. *ISAAA Briefs* No 51, ISAAA, Ithaca, NY

[5]**Garcia-Alonso**, M (2013) Safety Assessment of Food and Feed Derived from GE Crops: Using Problem Formulation to Ensure "Fit for Purpose" Risk Assessments. *Collection of Biosafety Reviews.* 2013; 8:72-101

[6]The name was changed from Genetic Engineering Approval Committee to Genetic Engineering Appraisal Committee, in July, 2010

to regulate GE products, including the GE crops, the SBCC and DLC are involved in monitoring. The GEAC is the apex body constituted by the Ministry of Environment and Forests and Climate Change[7].

***Bt*-cotton is the only GE crop commercialized in India**. It was released for commercial cultivation in 2002. The area under *Bt*-cotton increased from 50,000 ha in 2002 to 11.6 million ha 2015 comprising nearly 95% of total cotton area under *Bt* trait (Fig. 1). *Bt*-cotton is cultivated by about 7.7 million small-scale farmers, across different cotton growing areas of the country. Comprehensive studies have shown positive and stable impact of *Bt*-cotton on socioeconomic development in small-farm-holder households in India[8, 9]. Since the adoption of *Bt*-cotton, chemical pesticide use in cotton in India has declined from 33% to 11% of the total pesticide used in the country – a certain gain for improving the environment. Productivity and production have almost doubled, making India No. 1 producer and exporter of cotton in the World. It is estimated that India enhanced farm income from *Bt*-cotton by US$1.6 billion (about IRs 11000 crores) in 2014 alone[10].

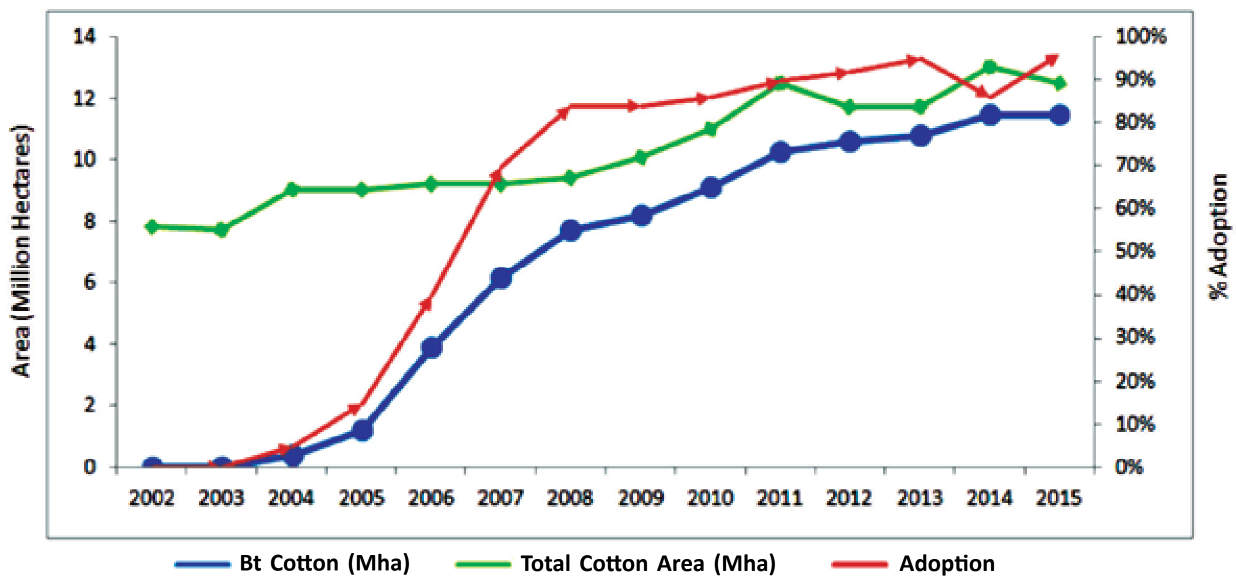

Fig. 1: Adoption of *Bt*-cotton in India. In 2015, India achieved adoption rate of nearly 95%, across the major cotton growing areas. The cotton production jumped from 13 million bales in 2002 to 39 million bales in 2014-15, becoming the largest producer of cotton, ahead of China and the US. It helped in transforming India's farm economy. (Adapted from James, 2015)

GE Crop Research in India

Indian labs are actively engaged in developing GE crops. Currently active GE research is being pursued to develop desirable traits in over 100 different plant species, which include plants used for food, livestock feed, fiber, fuel and dietary or medicinal purposes. The traits of interest vary from resistance

[7]**MoEF&CC** (2015). Regulatory framework for genetically engineered (GE) plants in India. MoEF&CC, Government of India

[8]**Kathage,** Jonas, Qaim, Martin (2012) Economic impacts and impact dynamics of *Bt* (*Bacillus thuringiensis*) cotton in India. PNAS 109 (29), 11652 – 11656. (www.pnas.org/cgi/doi/10.1073/pnas.1203647109)

[9]**Mayee,** CD and Chowdhary, Bhagirath (2013) Adoption and Uptake Pathways of *Bt*-cotton in India

[10]**James,** Clive (2015) Global status of Commercialized Biotech/GE Crops. *ISAAA Briefs* No 51, ISAAA, Ithaca, NY

to biotic stresses, tolerance to abiotic stresses (e.g., drought, salt, heavy metals, etc.), and development of novel nutritional[11] and medicinal properties[12]. Over 20 GE crop varieties[13] are at advanced stages of development in various public- and private-sector institutions of India, for a variety of important traits like resistance to biotic stresses (viral, fungal and insect pests), tolerance to herbicides, tolerance to abiotic stresses, improved nutrition, hybrid seed production, etc.

Major Regulatory Hurdles

Following the moratorium on *Bt* brinjal on 9th Feb. 2010, **there was a setback to GE research** and the country continues to debate on the relevance of GE crops in India, in spite of the success of *Bt*-cotton clearly showing environmental and socioeconomic advantage of growing GE crops. Recently, the environment for GE research has improved as the **Government of India has taken positive steps and allowed field trials** of several GE events (Table 1). Of these, GE varieties of three crops carrying

Table 1: GE events allowed field trials during 2014-16 (Source MoEF&CC, 2015).

No.	Plant	Trait
1.	Banana	Antimicrobial peptide (AMP) gene
2.	Brinjal	Insect resistance
3.	Cabbage	Insect resistance
4.	Castor	Insect resistance
5.	Cauliflower	Insect resistance
6.	Chickpea	Abiotic stress tolerance, insect resistance
7.	Corn	Insect resistance, herbicide tolerance
8.	Cotton	Insect resistance, herbicide tolerance
9.	Groundnut	Virus resistance, abiotic stress tolerance
10.	Mustard	Hybrid seed production
11.	Okra	Insect resistance
12.	Papaya	Virus resistance
13.	Pigeonpea	Insect resistance
14.	Potato	Tuber Sweetening, fungal resistance
15.	Rice	Insect resistance, diseases resistance, hybrid seed production, nutritional enhancement
16.	Rubber	Abiotic stress tolerance
17.	Sorghum	Insect resistance, abiotic stress tolerance
18.	Sugarcane	Insect resistance
19.	Tomato	Insect resistance, virus resistance, fruit ripening
20.	Watermelon	Virus resistance
21.	Wheat	Effect of mutant strains Azotobacter

[11]**Datta**, A. (2012) GM Crops: Dream to bring science to society. *Agric Res* 1: 95-99. Doi:10.1007/s40003-012-0014-x

[12]**MoEF&CC** (2016). Genetically engineered plants in the product development pipeline in India. MoEF&CC, Government of India

[13]**MoEF&CC** (2015). Regulatory framework for genetically engineered (GE) plants in India. MoEF&CC, Government of India

important traits – mustard for hybrid seed production, cotton with stacked resistance to insect and tolerance to herbicide, and brinjal for insect resistance - are ready for commercial release[14]. However, introduction of the requirement of 'no-objection-certificate **(NOC)' from the State Governments, for conducting confined field trials, has emerged as a major hurdle** in moving forward.

It is high time to release and commercialize the GE varieties, which have been tested to be biosafe, to extend the benefit of growing these varieties to the farmers, consumers and the environment without further delay. This will also help in giving fresh push to the utilization of the available technology for improving our crops by introducing desirable traits for protecting environment and health of the consumers and extending economic gains to the farmers.

Since the introduction of *Bt*-cotton in 2002, the regulatory system in India has undergone changes necessitated by the experience of cultivation of *Bt*-cotton. Notably, the regulatory system has evolved in line with the improvements in biosafety and environmental safety as recommended in the guidelines of the WHO, FAO and OECD. However, **there is a strong need to provide enabling regulatory and policy framework to make the regulatory system efficient and effective to accelerate utilization of the GE technology** for the benefit and economic empowerment of resource-poor farmers. This can be achieved by –

(a) Renaming the GEAC again as a Genetic Engineering Approval Committee and authorizing it to approve multi-location testing of the biosafe GE varieties.

(b) The Indian Council of Agricultural Research (ICAR) should take the responsibility of multi-location testing of the GE varieties, approval for environmental release by the GEAC, on the pattern followed for multi-location trials of the non-GE varieties.

(c) There is an urgent need to establish the Biotechnology Regulatory Authority of India (BRAI) *to promote the safe use of modern biotechnology by enhancing the effectiveness and efficiency of regulatory procedures.* Until the time Parliament approves creation of autonomous BRAI, the RCGM and GEAC should have full time chairpersons as recommended by SAC to PM, and the GEAC should function like a statutory body and make final decision on approval of the GE event for environmental release.

(d) A policy decision may be taken by the MoEF&CC, through Gazette Notification, that the 'NOC' by the State Governments for 'confined field trials' is not required, particularly as there is no such provision in the biosafety guidelines.

(e) Apart from restructuring of the regulatory system, there is also a strong need to re-examine and harmonize biosafety requirements on case to case basis, to reduce the cost of regulation.

Emerging New Options

Application of emerging -omics technologies will further strengthen regulation in the country's multi-tier regulation system, of novelty, potential hazard, and environmental exposure to provide greater assurance that no unintended differences have been introduced by any breeding process used in the

---

[14]**James,** Clive (2015) Global status of Commercialized Biotech/GE Crops. *ISAAA Briefs* No 51, ISAAA, Ithaca, NY

development of GE crop varieties. Moreover, innovations in the future would be more effective, efficient and devoid of biosafety issues of any kind

GE Crops are as safe as their non-GE counterparts

During the two decades of the use of GE crops for food and other purposes, no risks, related to human health and environment as well as the related issues have been encountered[15] [16]. This view has also been supported by the **107 Nobel Laureates** in their letter to the Governments around the world, saying that the GE **crops are "… as safe as, if not safer than those derived from any other method of production**"[17] A recent extensive study by the three science academies in the US[18] examined the positive and negative claims on the effect of GE crops to environment and human health. The study found "little evidence to connect GE crops and their associated technologies with adverse agronomic or environmental problems." For example, there is a general perception that the use of GE crops leads to loss of biodiversity. The US study found no 'substantial' reduction in on-farm biodiversity, and to the contrary, 'sometimes their (GE crops) use resulted in increased biodiversity'. The study also found clear association of the use of *Bt* crops with a decrease in the use of insecticides by the farmers. In an extensive study in India, an average of 82.8% decrease in insecticide sprays on *Bt* cotton was found in the three major cotton growing states – Andhra Pradesh, Maharashtra and Punjab[19]. Development of resistance in pests resulting from use of sub-lethal doses of pesticides or over use of single pesticide is a natural phenomenon. Similarly the evolution of resistance to *Bt* toxin has been found to be associated with the use of GE crop varieties expressing low doses of *Bt* toxin or non-planting of refuges. Evolution of resistance to herbicide in weeds was also found to be associated with the overuse of a single herbicide (US Study, 2016). Such resistances can be easily checked by appropriate regulations and monitoring of the GE crops, and encouraging farmers to use integrated and sustainable pest management approaches.

A decade of EU-funded GE research did not find any adverse effect of the GE crops on health and environment as compared to traditionally bred varieties [20]. Similarly, the US study (2016) found no evidence that would suggest a higher risk to human health from consuming GE foods compared to consuming the non-GE counterparts. On the contrary, the US study found some evidence that GE insect-resistant crops have had beneficial effects on human health by reducing insecticide poisonings and decreasing exposure to mycotoxins.

Overall, the US study found no evidence of cause-and-effect relationships between GE crops and environmental problems. However, the complexities involved in the assessment of long-term environmental

[15]**NAAS** (2011) Biosafety Assurance for GE Food Crops in India. Policy Paper 52, NAAS, New Delhi

[16]**The Royal Society, UK (2016)** GM plants: Questions and answers. Issued: May 2016 DES3710

[17]**The Nobel Laureates** (2016) Laureates Letter Supporting Precision Agriculture (GMOs). http:// supportprecision agriculture. org/nobel-laureate-gmo-letter_rjr.html

[18]**US Study** (2016) **: National Academies of Sciences, Engineering, and Medicine** (2016) *Genetically Engineered Crops: Experiences and Prospects.* Washington, DC: The National Academies Press. doi: 10.17226/23395.

[19]**Mayee,** CD and Chowdhary, Bhagirath (2013) Adoption and Uptake Pathways of *Bt*-cotton in India

[20]**Economidis**, Ioannis, Cichocka, Danuta, and Högel ,Jens (2010) A decade of EU funded GE research. Publications Office of the European Union, 2010 ISBN 978-92-79-16344-9 .doi 10.2777/97784

changes often made it difficult to reach definitive conclusions. That is illustrated by the case of the decline in monarch butterfly populations. Detailed studies of the population dynamics of monarch butterfly carried out as of 2015 did not demonstrate an adverse effect related to the increased use of glyphosate, although there was still no consensus among researchers that the use of glyphosate on milkweed did not cause a reduction in monarch populations. The studies in India have shown that the activity of honey bees is not hindered by *Bt*-cotton[21].

GE Crops for the small-scale farmers

The GE crops have been found equally useful for both the large- and small-scale farmers but the small-scale farmers are more likely to be successful with GE crops when they have 'access to credit, extension services, and markets and to government assistance in ensuring an accessible seed price'[22]. The **success of *Bt*-cotton in India** can also be attributed to the extension services, availability of inputs at reasonable cost, credit and markets.

Initial push for the development of GE crops was driven by large investments in research and technology development by the private sector institutions, but **in the future, public-sector institutions have to play a much greater role**, particularly for developing GE crops of interest to small-scale farmers. This change is expected, as the returns from investments in research will not be sufficiently attractive for private-sector investment.

Need to promote GE technologies for improving farm incomes

The 2010 moratorium on the release of *Bt* brinjal and subsequent hurdles for field testing of GE crops adversely affected the morale of scientific community in the country and decelerated research on GE crops, and students intake in biotechnology. The trend must change, by **creating an environment and improved funding**, **to support GE technologies** for the development of crop varieties in sync with traditionally bread varieties for resistance to biotic and abiotic stresses and to improve their nutritional content and productivity. Such varieties **will help in hunger alleviation and improving farm incomes.**

Need to Create Public Awareness

One of the non-scientific barriers in the way of promoting GE technology is the erroneous public perception that - the GE technologies are the monopoly of multinational companies. A survey conducted under the auspices of the Phase II Capacity Building of Project on Biosafety of the Ministry of Environment, Forest and Climate Change[23], has shown that the public sector institutions – research institutes, general universities and agricultural universities - in the country are playing important role in the technology and product development of over 100 economically important plants.

---

[21]**Naik, A., Viraktamath, S., Vastrad, A. S., Udikeri, S. S. and Megeri, S. N.** (2011) Pollinator fauna and foraging activity of honey bees in two genotypes of Bt cotton. *Karnataka J. Agric. Sci.,*24 (3) : 400 - 403

[22]**US Study** (2016) **: National Academies of Sciences, Engineering, and Medicine** (2016) *Genetically Engineered Crops: Experiences and Prospects.* Washington, DC: The National Academies Press. doi: 10.17226/23395.

[23]**MoEF&CC** (2016). Genetically engineered plants in the product development pipeline in India. MoEF&CC, Government of India

The main target crops of these institutions are rice, cotton, tomato, brinjal, maize, tobacco, banana, chickpea, pigeon pea and wheat. The first five of these crops are also the target crops of the Indian private sector, mostly in collaboration with the public sector institutions. A number of GE events for insect resistance and drought tolerance have reached the stage of field testing. These R&D efforts are being directed not only to develop GE plant varieties of current relevance to Indian agriculture but also to address the emerging challenges, particularly the adverse impact of climate change, to ensure sustainable agricultural growth. Productivity constraints in crops, that are of particular relevance to small farm holders, such as pulses and millets are also receiving significant attention, to help in achieving food and nutrition security.

The points repeatedly raised by the opponents of GE technology include, (i) food safety of GE crops, (ii) loss of biodiversity, (iii) development of resistance in pests, (iv) development of super weeds, and (v) farmers' suicides. The studies reported above clearly show that the GE foods are safe, that there is no adverse effect of GE crops on biodiversity, that development of resistance in pests is no different from the normal natural phenomenon, and there is no evidence of development of super weeds. The problem of farmer's suicide is complex[24], and there is no direct evidence that GE crops lead to farmer's suicides.

The other issue that has been debated and discussed greatly in India **is the use of herbicide tolerance (HT) trait in GE crops**. This issue has also been a matter of concern in countries where HT has been commercialized for over two decades, such as the USA. Analysis made by the US Study[25] noted the change in the classification of glyphosate from Group 2B (possibly carcinogenic to humans) to Group 2A (probably carcinogenic to humans) by the IARC of WHO, but concluded on the basis of the European Food Safety Authority's evaluation that "glyphosate is unlikely to pose a carcinogenic risk to humans". Similar conclusion was arrived at by the Canadian Health Agency and the Environmental Protection Agency, that glyphosate does not interact with human systems related to estrogen, androgen, or thyroid. While acknowledging the existence of "disagreement among expert committees on the potential health harm that could be caused by the use of glyphosate on GE crops and in other applications", the US Study concluded, based on the available evidences, that "no differences have been found that implicate a higher risk to human health safety from these GE foods than from their non-GE counterparts"

Weeds are a major 'pest' of crops in India (www.nrcws.org). Since **HT technology** is shown to be safe to human beings as well as environment, use of this technology **is an unavoidable agronomic requirement in rain fed crops** like maize, soybean, chickpea, mustard, cotton, wheat, etc., to help in improving productivity of such crops.

Recent initiative of the Government of India to develop "Guidelines" to make GE products available to the farmers expeditiously and at a reasonable price is an important step, but it needs careful planning to ensure that in the long term the licensing system would not be detrimental to GE

---

[24]**Chand,** Ramesh (2016) Addressing agrarian distress: sops versus development. BP Pal Lecture, IARI, New Delhi, 2016

[25]**US Study** (2016) **: National Academies of Sciences, Engineering, and Medicine** (2016) *Genetically Engineered Crops: Experiences and Prospects.* Washington, DC: The National Academies Press. doi: 10.17226/23395.

research and development. Development of GE crops requires much greater investments compared to the investments for developing new varieties of plants through conventional breeding. No organization would be able to invest such resources under conditions restricting appropriate returns due to the proposed compulsory licensing system. Moreover, it is difficult to assess accurately and fairly the "trait value" before the GE variety is grown on a large scale on farmers' fields. Unless individuals and organizations which invest in achieving this goal are fairly rewarded our efforts to improve agricultural productivity may get seriously jeopardised in the long run.

Recommendations

We, the Fellows of the NAAS, representing the scientists of the national agricultural research system of India seek Government of India's urgent intervention to promote research and development of GE crops, so that this useful technology is successfully harnessed for addressing the current and emerging challenges of Indian agriculture. To achieve this objective we recommend the following policy interventions by the Government of India:

1. We must double the productivity of our farms to meet the zero hunger challenge of the United Nations by 2025. Such an increase will be possible only through the judicious use of all the available farm technologies, including the GE technologies. It is high time to **approve environmental release of the GE varieties**, **which have been tested to be bio-safe**, to extend the benefit of growing these varieties to the farmers and consumers without further delay.

2. Recent approvals by the GEAC (MoEF&CC) allowing confined field trials (CFTs) of some GE crop varieties is a positive step showing intent of the Government to promote GE technologies. **However, the hindrance continues due to** the introduction of an extra step of obtaining **NOC from the States** for conducting CFTs of GE crop varieties. **This provision is counterproductive for GE research, and it must be dropped** as the GEAC examines the biosafety issues from a national perspective, and there is no provision of such a step in the regulation of CFTs of GE plants in India.

3. **There is a strong need to strengthen the regulatory system for improving efficiency** to accelerate utilization of the GE technology. (a)The **GEAC should be renamed** back as 'Genetic Engineering Approval Committee'. (b) The **GEAC should function like a statutory body** vested with the authority to take final decision on approval of the GE event for environmental release. (c) The Indian Council of Agricultural Research **(ICAR) should take the responsibility of multi-location testing** of the GE varieties, approval for environmental release by the GEAC, on the pattern followed for multi-location trials of the non-GE varieties. An efficient regulatory system, is essential so that the fruits of creative work of our young scientists reach the end users – the farmers, at a fast pace, and the objective of the Government's 'lab-to-land' is attained for the biotechnology sector.

4. **There is an urgent need for greater investment** to develop well trained quality human resource for basic and applied research and infrastructure development to **give push to GE technology in active partnership with the public and private sector institutions**, to ensure inclusive access

to improved technologies among all the farmers - small or large. Increased investment and a forward-looking and efficient regulatory system will also ensure harnessing the full potential of the emerging GE technologies, which show the promise to substantially change the future crop production because of the precision in genetic transformation. For example, **application of the gene-editing technology, named CRISPR, is** expected to be a **powerful tool for developing precision crops at a fast rate.**

5. We must develop a strong public awareness programme on the issues related to GE technology, to put restrain on creation of erroneous public perception, based on unsubstantiated information. For example, the recent epidemic of white fly in North India has no connection with the commercialization of *Bt*-cotton.
6. Recent initiative of the Government of India to develop "Guidelines" to make GE products available to the farmers expeditiously and at a reasonable price is an important step, but it needs careful planning to ensure that in the long term the licensing system would not be detrimental to GE research and development, and promotion of public-private partnership.

Acknowledgement

The National Academy of Agricultural Sciences extends warm thanks to the Committee Members and other colleagues for their efforts and inputs in developing the Policy Brief.

Committee:

Prof. Anupam Varma
Dr. K.V. Prabhu
Dr. T.R. Sharma
Dr. Ashok K. Singh
Dr. C.D. Mayee
Dr. N.K. Singh
Dr. K.C. Bansal

Other Colleagues:

Dr. R.S. Paroda
Dr. M. Mahadevappa
Prof. S.P. Adhikary
Dr. K.M. Bujarbaruah
Dr. B.S. Dwivedi
Dr. J.K. Jena
Dr. J.L. Karihaloo
Dr. N.H. Rao
Dr. Balram Sharma
Dr. K.K. Singh
Dr. K.K. Vass
Prof. M.P. Yadav
Prof. R.B. Singh
Dr. T. Mohapatra
Dr. Vibha Ahuja
Dr. Bhagirath Choudhary
Dr. V.K. Gupta
Dr. P.K. Joshi
Dr. C.S. Prasad
Dr. D.P. Ray
Dr. Anil K. Singh
Dr. (Ms) Chandrika Varadachari
Dr. B. Venkateswarlu
Dr. S. Ayyappan