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# Food security, genetically modified crops and environment

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**Abstract—At the dawn of agriculture, the population of the world was approximately 5 million. In beginning of the 19th century, when global population was less than 1 billion , it was easy to increase food production through expansion in area under cultivation. In beginning of 20th century, when world population was 1.6 billion, an increase in global food production was brought mainly through increased productivity per unit area. Green revolution came into play during 1960's and 1970's when the world went through a period of low productivity. The world produced enough food at beginning of 21st century when the world population was 6.1 billion but in the process caused damage to environment. Hunger and malnutrition is affecting over one billion people and world grain production is struggling due to problems of sustainability of input based agriculture, land and water shortages, erosion of biodiversity and climate change. The world population is now projected to grow to 8.2 billion by 2030 and 9.2 billion by 2050. Therefore, doubling production task by 2050 through traditional practices looks daunting itself in situations like frequent droughts, floods, cloud bursts, abrupt changes in temperature extremes and push to produce bio fuels. Therefore issue of food security need to be addressed through innovations in crop improvement effort and production technologies. The potential benefits of GM crops include increased tolerance to biotic and biotic stress, herbicides, and enhanced nutritional value while risks include allergies, gene flow, development of resistance to insects and unknown changes. But the global food security goal can best be achieved through judicial blending of traditional technologies with biotechnologies and making them available at affordable costs while winning public confidence.**

**Keywords: food security, GM crops, transgenic, environment, sustainable agriculture**

## I. FOOD SECURITY AND ENVIRONMENT

The World Food Summit of 1996 defined food security as existing when all people at all times have access to sufficient, safe , nutritious food to maintain a healthy and active life. In simple words, food and nutrition security mean that every individual has physical, social and economic access to balanced diet that includes macro and micronutrients, safe drinking water, environment hygiene, primary health care and education so as to lead healthy and productive life. The global weather changes are seriously affecting productions food crops, horticultural crops, pulses and oil seeds crops. The climate changes in India could result in (1) changing temperature patterns (2) Changing precipitation pattern, (3) Glacier - Snow melt and floods, (4) Increased carbon dioxide and reduced oxygen levels, (5) Rise in sea level, (6) Changed pest dynamics and so on. India witnessed several droughts (1982, 1986, 1987, 1988, 1999, 2002 and 2009) which seriously impacted farm productivity. The impact of climate change may have direct and indirect effects on field/ horticultural crops production, livestock, incidence of pests/diseases/weeds and soil health deterioration.

The 4th Assessment Report (2007) of IPCC projected that by 2100 earth's mean temperature will rise by 1.4 to 5.8 degree Celsius and precipitation will decrease in sub-tropical areas. In past 100 years global temperature has increased by 0.74 degree Celsius. Consequence of one degree Celsius rise in temperature will be a reduction in growing period of wheat and greater risk of diseases and pests in crops. Even one degree rise in mean temperature will affect wheat yield substantially. In country like India, annual yield loss in wheat may cross 4-5 million tons in absence of any adaptive mechanism. IPCC (2007) also reported likely increase in frequency of heavy precipitation incidence over most of the areas. These changes will threaten national food security and situation can be more alarming in northern plains (grain bowl of the country) and hill and mountainous regions. The scientists, agricultural experts and farmers must meet global appetite for both food and energy while conserving vital natural resources for future generations.

## II. FOOD SECURITY AND SUSTAINABLE AGRICULTURE

Man has domesticated plants and animals from wild about ten thousand years ago and selection over years resulted in genotypes suitable for human sustenance. Farmers have been engaged in traditional breeding for thousands of years ago. New crop varieties have been developed by cross-breeding closely-related species. Eventually genes passed from one generation to the next through sexual reproduction. Scientists have also adopted mutation breeding where a few mutants were found useful. Earlier, focus was primarily on the production of varieties for higher yield and tolerance/resistance against diseases and insect pests. More recent developments are directed to protection against multiple biotic stresses, the enhancement of tolerance towards drought and salinity, development of male sterile lines for generation of productive hybrids and improvement in nutritional quality. In reality, almost all the crop plants have been “genetically modified” from their original wild state by domestication, selection, and controlled breeding over long periods of time.

Sustainable agriculture mean successful management of resources for agriculture to satisfy changing needs of man while maintaining or enhancing the quality of the environment and conserving natural resources. Inappropriate soil and water management practices are hampering soil productivity. Hazardous chemicals (pesticides and fungicides) are also being released into the environment and becoming toxic to human and animal life. Improved seeds, chemical fertilizers, pesticides, tools and machinery are sometimes unavailable to resource-poor farmers due to high costs of inputs. But facts remain that the traditional plant breeding methods are time consuming and often not very specific. Emerging technologies such as biotechnology has the potential of enhancing production on a sustainable basis and can provide an alternative to technologies otherwise harmful to environment. GM technology has potential to create plants with the exact desired trait very rapidly and with great accuracy. It is now possible to increase yield by 50-100 % through judicial adoption of strategies like traditional breeding, hybrid technology, GM technology (genetic engineering) and improved crop production practices.

## III. WHAT ARE TRANSGENICS OR GMOS?

Transgenics (plants or animals) or GMOs are defined as those organisms that contain a gene(s) or genetic constructs of interest that has been artificially inserted by molecular or recombinant DNA techniques (genetic engineering) instead of the natural or conventional methods. The GMO, thus, carries ‘transgene(s) which when integrated and expressed stably and properly, confer a new trait to the organism, which was hitherto not present earlier or enhance an already existing trait. The term Genetically-modified foods or GM foods is most commonly used to refer to foods produced from transgenic plants or animals. The tools of recombinant DNA technology facilitated development of transgenic microorganisms in late 1970s and early 1980s, and transgenic plants and animals in 1980s. Till date, scientists have altered the characteristics of many organisms leading to increased yield and muscle bulk in farm animals and improved productivity, nutrition and tolerance to diseases/ insect pests or environmental stresses in crop plants and many other traits.

## IV. HOW ARE GM CROPS MADE?

GM crops are made through a process of genetic engineering where gene(s) or genetic constructs of interest genes are transferred from one organism to another artificially by molecular or recombinant DNA techniques. Based on advances made in last four decades in plant tissue culture and genetic engineering techniques, two major gene transfer techniques have been employed to transform various plant species. These are: (1) *Agrobacterium* -mediated approach, and (2) Biolistics approach. Two primary methods currently exist for introducing transgenes into plant genomes. Many other methods have also been developed. The first method uses a *Agrobacterium tumefaciens* to introduce the gene(s) of interest into the plant DNA. *Agrobacterium* has been successfully used to transform a wide variety of plant species including dicots, monocots, legumes, cereals, grasses and forest and tree species. The second method involves a device called a ‘gene gun.’ The DNA to be introduced into the plant cells is coated onto tiny particles of gold or tungsten. These particles are then physically shot onto plant cells. Some of the DNA comes off and is incorporated into the DNA of the recipient cells of host plant. The tissue explants are later cultured on media containing hormones and antibiotics to select transformed shoots. This method is followed mostly in those crops lacking host specificity of *Agrobacterium.*

## V. TRANSGENIC CROPS ACREAGE

Probably no discovery in plant sciences has had, in so short a time, such far reaching consequences on agriculture as the method reported in 1983 for the genetic modification of plants using gene technology. The first transgenic plant - a tobacco plant resistant to an antibiotic - was created in 1983. China was first country to grow a commercial transgenic crop (tobacco with viral resistance) in 1986. FlavrSavr- tomato developed by Calgene hit the market in the US as the first commercially available genetically modified crop in 1994. This tomato had a "deactivated" gene which was no longer able to produce an enzyme involved in fruit softening. That means, tomato can stay longer on plant to develop a fuller taste and has longer shelf life. Monsanto's Roundup Ready soya beans in foods for people and feed for animals, was approved in 1996. These beans have been modified to survive being sprayed with the Roundup herbicide that is applied to a field to kill weeds. The best known example of transgenics for insect resistance is the use of Bt genes in cotton, corn and other crops.

The rapid adoption of transgenic crops during 1996 to 2009 reflects multiple benefits realized by large and small farmers both in industrial and developing countries. The global area of transgenic crops increased from 1.7 million hectares in 1996 to 52.6 million hectares in 2001 and then to 134 million hectares in 2009 (80 fold increase over 1996). During 2009, four principle transgenic crops of the world are soybean (77 % of 90 million hectares), maize (26% of 158 million hectares), cotton (49 % of 33 million hectares) and canola (21% of the 31 million hectares). During 2009, the number of farmers adopting biotech crops increased to 14.0 millions and 13.0 millions (90%) were small and resource poor. Twenty five biotech mega-countries in order of acreage are USA, Argentina, Brazil, India, Canada, China, Paraguay, South Africa, Uruguay, Bolivia, Philippines, Australia, Mexico, Spain, Chile, Colombia, Honduras, Burkina Faso, Czech Republic, Romania, Portugal, Germany, Poland, Slovakia, and Egypt (James, 2008).

In the developed world, there is clear evidence that the use of GM crops has resulted in significant benefits while developing countries have also started reaping benefits. Ensuring an adequate food supply to ever increasing population in the next 50 years is going to be a major challenge in the years to come. GM foods promise to meet this need in a number of ways.

## VI. POTENTIAL BENEFITS OF GM CROPS?

Genetically modified crops are important component of agricultural development since these allow adaptation of genotypes to change in environment and help reducing crop losses in developing countries where focus is on fighting hunger and poverty. Some of the benefits that have been widely accepted are briefly described as under.

## VII. RESISTANCE TO BIOTIC STRESS

The crops are under constant threat from attacks of pests and diseases. Huge yield losses often devastate financial position of farmers and many a times leads to starvation. Indiscriminate and extensive use of pesticides has affected human health and degraded environment in many parts of the world in past century. The run-off of wastes from excessive use of pesticides and fertilizers often poison the water supply and cause harm to the environment. Moreover, the consumers do not wish to eat food that has been treated with pesticides because of potential health hazards. There is also an urgent need to reduce use of chemicals e by adopting eco friendly measures such as IPM and biotechnological tools.

***Insect pest resistance:*** Most of insect –pests belonging to Lepidoptera (moths and butterflies), Diptera (flies) and Coleoptera (beetles and weevils) cause severe yield losses every year. *Bacillus thuringiensis* (Bt) is a naturally occurring bacterium which produces crystal proteins that are lethal to insect larvae. Tools of genetic engineering have facilitated introduction of genes encoding insecticidal proteins of Bt in cotton, corn and other crop plants, enabling them to produce its own pesticides against insects such as the bores. Growing GM foods such as Bt corn or cotton or other crops has helped reducing the application of chemical pesticides. Less dependency on conventional pesticides have benefited cotton growers with the use of Bt cotton in China and India. It may also help other developing countries where similar risks over excessive use of conventional pesticides exist.

***Herbicide tolerance:*** It is not economical to remove weeds by physical means, so farmers often spray large quantities of herbicides to kill weeds in crops. The manual weeding is labour intensive, time-consuming and expensive process. GM crops made resistant to one very powerful herbicide could help prevent environmental damage by reducing the amount of herbicides needed.

***Disease resistance:*** Many viruses, fungi, nematodes and bacteria cause plant diseases. Many transgenics have now been developed that carry resistance to these diseases. The viruses cause considerable losses and are difficult to control through chemicals. The coat protein gene has been successfully employed against viruses with positive sense RNA encapsidated by single type of protein, and single stranded DNA Gemini viruses and RNA Topso viruses. The commercial cultivation transgenic including squash and papaya having virus resistance is in progress in many developed countries. Fungal diseases also cause huge losses but have been controlled by fungicides while conventional breeding approaches have not proved much effective in many instances. Expression of chitnases, glucanases and other related genes has shown enhanced resistance to many fungal diseases in past. Progress has also been made in developing trangenics for resistance against many bacterial and nematode diseases

## VIII. TOLERANCE OF POOR ENVIRONMENTAL CONDITIONS

***Drought/salinity tolerance:*** With population pressure more productive land is being utilized for housing thereby leaving farmers to grow crops in rain fed or other unsuitable areas. Creating plants that withstand long periods of drought or high salt content in soil and groundwater will help people to grow crops in inhospitable areas. Indian scientists are working on the transfer of salinity tolerance genes from mangrove tree species to annual crops. BADH gene cloned from a highly salt tolerant mangrove species, *Avicennia marina* has been transferred in tobacco and *Brassica* and is expected to confer salinity tolerance. The work on other crops is also in progress.

***Cold tolerance:*** Frost destroys sensitive seedlings and damages the crops in many parts of the country. An antifreeze gene from cold water fish has been introduced into plants such as tobacco and potato and makes plants able to tolerate cold temperatures.

***Phytoremediation:*** Soil and groundwater pollution continues to be a problem in all parts of the world. Plants such as poplar trees have been genetically engineered to clean up heavy metal pollution from contaminated soil.

These "first generation" crops have proven their ability to lower farm-level production costs. Research is now focused on "second-generation" GM crops that will feature increased nutritional and/or industrial traits. These crops will have more direct benefits to consumers. Examples include (1) Rice enriched with iron, vitamin A,E and lysine, (2) Potatoes with higher starch content and proteins (3) Edible vaccines in maize, banana and potatoes, (4) Maize varieties with low phytic acid and increased essential amino acids, (5) Healthier oils from soybean and canola, and (6) Allergen-free foods

## IX. INCREASED NUTRITIONAL VALUE OF STAPLE FOODS

Malnutrition is common in third world countries. Vitamin A (VAD) deficiency causes millions of childhood deaths every year in world. It is also major cause of blindness in children in developing countries. In many parts of the world, most of people rely on a single crop such as rice for the main staple of their diet that needed to be made nutritionally rich. The two scientists Potrykus of the Swiss Federal Institute of Technology and Beyer of Germany inserted genes from a daffodil ( *Narcissus pseudonarcissus*) and a bacterium (*Erwina uvedovora*) into rice plants to produced modified rice popularly referred to as "golden" rice. It contains an unusually high content of beta-carotene (which body converts into vitamin A) and that cam meet a total Vitamin A requirement of an individual in a typical Asian Diet. Rice fortified with iron was also created through introduction of proteins from kidney beans (*Phaseolus vulgaris*). Scientist's claim that golden rice can address nutrition security problems of people including vulnerable children, nursing and pregnant mothers in the world.

Potato is another non-cereal staple food crop in many parts of the world. It has also been genetically modified using a seed albumin gene Ama 1 from *Amaranthus hypochondriacus*. Its composition corresponds to WHO standards for optional human nutrition. The Ama 1 protein is non allergenic and also rich in all essential amino acids. GM potato has potential of overcoming problems of protein-calorie malnutrition and mineral deficiencies.

Cassava is a staple for about 250 million people in sub-Saharan Africa. It is susceptible to diseases, not nutritious with a short shelf life. GM cassava has now been engineered which is more nutritious with longer shelf life, disease resistance and lower cyanide levels. GM cassava could save millions of lives from starvation in sub-Saharan Africa in years to come.

Quality protein maize (QPM) developed by scientists through conventional breeding efforts coupled with golden rice, designer potato- containing non allergenic protein and modified cassava developed through genetic modification can have far reaching implications in food industry in years to come especially in developing countries where hunger and malnutrition cripples life of millions of people every year.

## X. POTENTIAL RISKS OF GM PLANTS?

The forceful public questions are still being asked about negative effects of GM crops on human health and environment. Though no death or serious human health problem from use of GM foods have been documented till date, yet state of art knowledge is inadequate to predict with accuracy adverse effects from inserted transgenes. Therefore, careful biosafety assessment is must since every emerging technology has got risks also. The technology innovators (scientists), producers, and the government must assure the public of the safety of the novel foods that they offer as well as their benign effect on the environment. These risks, however, can be managed by developing technologies at affordable costs but tailor made to needs of the poor and hungry. Government also needs to frame suitable and transparent policy framework for bringing out comprehensive legislation for suitable safeguards to avoid the possible pitfalls. Where legislation and regulatory institutions are in place, there are elaborate steps to precisely avoid or mitigate these risks. The potential risks associated with this emerging technology are briefly discussed as under.

### XI. Health concerns

Major scientific and health organizations and regulatory bodies have endorsed the safety of approved GM crops to human health and environment. The critics think that this technology may be harmful to human health. They worry that the alterations could accidentally lead to substances that are poisonous or trigger allergies. Critics also argue that we do not know enough about the way how genes operate and interact and what will be the outcome of any modification.

At the same time, there are reports of allergies to many kinds of conventional foods, particularly nuts, fish and shellfish in many parts of the world. Environmental organizations, such as the European Green Party and Greenpeace, have suggested that GM food might trigger food allergies. On the contrary, most of the reviews about the results from allergen testing of current GM foods stated that "no biotech proteins in foods have been documented to cause allergic reactions. For example, GM plant that did not reach the market due to it producing an allergic reaction was a new form of soybean intended for animal feed. In 2005, a pest-resistant pea developed in Australia for use as a pasture crop was shown to cause an allergic reaction in mice. The work on this variety was immediately halted. A group of scientists and environmentalists believe that these products that failed safety testing can be viewed as evidence that genetic modification can produce unexpected and dangerous changes in foods. The immunologist who tested the pea noted that crops need to be evaluated case-by-case.

The anti-GM lobby is also critical of the use of DNA from plant viruses and bacteria in the modification of crops. They fear that these may also somehow trigger diseases. They have objected to the use of antibiotic-resistant marker genes in transgenic crops. The critics argue the antibiotic-resistant genes could be passed to the micro-organisms that make us ill. If this happens, we might not have the necessary drugs to fight back. The Scientists/genetic engineers counter these arguments with following explanations:

1. There is no evidence of GM food having caused any death or serious illness.
2. Technologies are now available for the removal of the marker genes.

3. Genetic modification can also be used to remove allergens from foods, for example, a hypo-allergenic strain of soybean fertile GM rye grass was produced that lacked the main pollen allergen.
4. Many of the conventional food got introduced in the world only after their undesirable or toxic substances were removed.
5. The regulatory structures that govern GM foods in US, EU and other countries are far stricter than for conventional food products.
6. The argument that genetic modification might result in the emergence of new allergens, needs case to case study since conventional plant breeding may also produce such allergens causing allergic reactions.
7. Extensive testing of GM foods could help to avoid the possibility of harm to consumers with food allergies.
8. The use of DNA from plant viruses and bacteria presents little risk. For instance many other crops being used in the laboratory are naturally infected with viruses for modification purposes, and millions of us eat them with no ill effects.
9. GMOs also allow improving nutritional aspects and can allowing incorporation of anti-cancer substances, and reducing our exposure to the less healthy oils and fats.
10. On the whole, with the exception of possible allergenicity, scientists believe that GM foods do not present a risk to human health

## XII. ENVIRONMENTAL CONCERNS

Some scientists and environmentalists fear that some of the genes engineered into crops such as herbicide and insect resistance could "escape" and be transferred to other species where they might have adverse effects. They believe leakage of these genes could result in the emergence of "super weeds" and in the disappearance of familiar species of insects. Scientists defend their claims with following arguments

1. This issue of gene flow that have relevance in cross pollinated crops could be addressed by creating GM plants that are male sterile (do not produce pollen) or their pollen does not contain the introduced gene or by creating buffer zones around fields of GM crops.
2. The concerns that pollens from GM crops may get transferred to other non-target organism like milk weed leading to killing of monarch butterfly caterpillars and development of resistance to pesticides still lack sound scientific data in its support. Scientists argue that GM crops will require a few chemicals to control pests.
3. Plants have also been modified plants to produce new plastics and bio-fuels that would be kinder to the environment than the products based on oil.
4. Field performance studies on drift of transgenes either to wild relatives of crops or to non transgenic varieties could help to ease problem if monitoring over a considerable period of time is done.

## XIII. ECONOMIC CONCERNS

Bringing a GM food to market is a lengthy and costly process, and biotech companies wish to ensure a profitable return on their investment. Many new plant genetic engineering technologies have been patented, and patent infringement is a big concern of agribusiness. Yet consumer advocates are worried that patenting these new plant varieties will raise the price of seeds so high that small farmers and third world countries will not be able to afford seeds for GM crops, thus widening the gap between the wealthy and the poor. The critics also accuse the biotech companies of trying to "handcuff" agriculture by attempting to tie farmers into deals where they have little choice but to buy the GM seed and the designer chemicals to go with it. Scientists defend their claims with following argument. Scientists hope that in a humanitarian gesture, more companies and non-profits organizations will follow the lead of the Rockfeller Foundation and offer their products at reduced cost to needy. Ministry of Science & Technology and Ministry of Environment in India and many other public organizations in other countries are already funding research in area of crop biotechnology. It is also hoped that more public sector institution s will take up work.

## XIV. BIO-SAFETY REGULATIONS

All food products, novel or otherwise, are subject to a system of regulation which should ensure safety and consumer confidence. These regulations set standards or thresholds that must be met. Testing procedures are designed to pick up problems before products get on to the market. When we get ill as a result of eating food, it is usually because of poor practice somewhere along the line. Remember that we the consumers also have responsibilities. One of the reasons food poisoning cases have risen dramatically in recent years is because we have failed to store and cook food properly in our own kitchens.

Internationally, food security is addressed in the FAO/WHO Codex Alimentarius while effects of living modified organisms on biodiversity are addressed in the Cartagena Protocol. But regulations about biosafety of GMOs are relatively new in many countries and public trust is low. Regulatory mechanism for release of transgenics in India is now in place. The government of India is already implementing very strict and thorough evaluation criteria for transgenics. The release of transgenic crops for field cultivation is governed by the Indian Environment Protection Act (EPA)-1986. The current process of

Institutional Bio-safety Committee (IBSC), Review Committee on Genetic Manipulation (RCGM) and Genetic Engineering Approved Committee (GEAC) for approval of transgenic materials should be maintained. This regulatory system has to be followed strictly through close coordination among all the concerned departments, viz. Agriculture, Health, Science and Technology, Environment so as to reach an understanding on all the steps of evaluation and release. Results from all the studies should be hosted on the web to maintain transparency and win public confidence. It is the obligatory on part of scientists, producers and government to assure the public of the safety of the GM foods that they offer and benign effect of GM crops on the environment.

Proper labelling of food so that consumers know precisely what they are buying. But it would be difficult to label GM and non GM foods in countries where land holdings are small and food is processed by small scale industry. The GM labeling rules should satisfy those who wish to exercise a choice based on any perceived health threat, real or imagined. All this presupposes that the tests used to detect "foreign" DNA or protein is foolproof - some scientists argue they are not. That is why supermarkets in developed countries are now going to sources where the origin and purity of raw materials can be guaranteed.

## XV. CONCLUSIONS

Despite the uncertainty or controversies over risks of GM crops, its potential to develop new varieties in short time using valuable genes from diverse sources, makes this technology to valuable to ignore. And fact remains that by 2050 when world hunger will be on peak, climate change effects conspicuous, credible biosafety frameworks in place and comprehensive solutions available, resistance to GM will be subdued while social, cultural, economical and political support will continue to increase. The global food security goal can best be achieved through judicial blending of traditional technologies with biotechnologies. There are, however, some valid concerns. If these issues are to be resolved, decisions must be based on credible, science-based information. Finally, given the importance people place on the food they eat, policies regarding GM crops will have to be based on an open and honest debate involving a wide cross-section of society.

GM crops have potential role to play an important role in meeting food and nutrition security needs people in decades to come. They can also help in protecting and preserving environment by reducing dependence on chemical pesticides and herbicides. At global level, respective governments must ensure continued safe and effective testing of transgenic and implement biosafety regulations. The society must be well informed about the impact of transgenic on environment, food safety, health of producers and consumers, sustainability and global food security. These issues need resolved based on credible scientific information and public confidence has to be won based on an open and honest debate involving a wide cross-section of society. Adoption of GM technology could be made crop specific or deferred until all public apprehensions are cleared.

At the end, I sum up with words that developed nations must ensure that access to these emerging technologies at affordable costs is not denied or delayed in countries where hunger and malnutrition cripples the life of rpeople.