Review Article

Green Biotechnology and Scope of Genetically modified Crops: Facts and Prejudices

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Abstract

Biotechnology is a modern science with old roots. It can be considered a game changer in many ways as it has inherent solutions for many hurdles modern society is facing today. One of the most important branches of Biotechnology is Green or Agro-biotechnology, which is the application of biotechnological tools and techniques to genetically improve organisms, crops for the betterment of ever burgeoning population. Green biotechnology holds promise in producing crops with high yields and nutritional content, insect resistance, longer shelf life, and various other traits like production of vaccines (edible vaccines), monoclonal antibodies phytoremediation and so on. Biotech crops are supposed to need lesser water, fertilizers, herbicides, almost nil tillage requirement, lesser need to spray so less fuel consumption, reduced CO_2 and N_2O emissions. Inspite of all these advantages, the acceptance of genetically modified plants have become mired in controversies regarding their safety, applicability and their effects on the environment. This review deals with various positive and negative aspects of green biotechnology, trying to shed an unbiased light on the actual scenario because this technology actually has the potential to feed millions of poverty stricken, undernourished people on the earth. How far this goal is reached, still remains to be seen.

Keywords: Green Biotechnology; Genetically Modified Organisms; Green Revolution; Golden Rice.

Introduction

Biotechnology, among all biological sciences, has emerged as the harbinger of almost all the relevant scientific discoveries that modern science could boast of. This century, undoubtedly, belongs to this discipline, as only it has the potential to bring unprecedented advances in human and animal health, agriculture and food production, manufacturing and sustainable environmental management. Broadly Biotechnology may be defined as Convention on Biodiversity that include molecular techniques for diagnosis, breeding, tissue culture, exploitation of naturally occurring microorganisms for fermentation and inoculums for crop (e.g., mycorrhizas). According to Organization for Economic Cooperation and Development, it is the appliance of science and technology to living organisms, as well as, parts, products and models thereof, to alter living or non living materials for the production of knowledge, goods and services. The term is believed to be stamped in 1919 by Hungarian agricultural economist Karl Ereky in his paper entitled "Biotechnology of meat, fat and milk production in large scale agricultural enterprises".

Whole rainbow code of 'domains' of

biotechnology have been developed of which , specifically agricultural (Green) biotechnologies, industrial (White) biotechnologies, aquaculture (Blue) biotechnologies, and healthcare (Red) biotechnologies are better recognized (AGRIFOR Consult, 2005). Apart from these, there is yellow biotechnology which deals with nutrition biotechnology, gray biotechnology concerning the problems of environment protection, Brown biotechnology for deserts and arid regions, gold one allied with bioinformatics, computer science and chip technology, violet concerning law, ethical and philosophical issues and dark biotechnology dealing with bioterrorism and biological weapons. (Kafarsky, 2012) Genetic modifications (GM) argue new characters or "traits" that are not naturally present in the organism. Encompassed manipulation in genetic modification includes; Transferring of genes, Modifying information in a gene i.e. gene editing, Moving, deleting, or multiplying genes within a living organism and grafting pieces of existing genes, or construction of new genes. The plants which are developed using these biotechnological techniques are generally called as genetically modified organisms or GMOs. The World Health Organization defines genetically modified organisms (GMOs) as "organisms in which the genetic material (DNA) has been altered in a way that does not appear naturally" (WHO 2002)

This review paper is mainly concerned with the green biotechnology which is maneuvering biotechnological processes in agriculture with the aim of improving nutritional quality, yield, economics and various other specifications useful while raising the crops. Likewise Genetic modifications also known as genetic engineering, genetic manipulation, gene technology or recombinant technology are considered to be the pillars of green biotechnology. Objective of green biotechnology is to produce more environment friendly farming solutions as an alternative to traditional agriculture and animal breeding systems. It includes various non-contentious technologies for remodeling food security such as molecular assisted breeding for desirable characteristics and tissue culture for mass proliferation of healthy planting material.

History of Agriculture Biotechnology

Around 10000 years back, people in Middle east began to cultivate crops paving way for a settled sedentary life doing away with the nomadic life. To say that this event led to growth of various civilizations all around the world will not be an exaggeration. Settled life gave stability and time for people to think, innovate and invent. It is probable that cop improvement began as soon as farming did. Initially, it was unconscious selection of more vigorous individuals which slowly became more sustained and deliberate. The science of genetics was firmly established due to the works of Charles Darwin and Gregor John Mendel. Infact, Mendelian laws laid the foundation of modern plant breeding. The First green revolution occurred in 1960s and 70s when dwarf varieties of cereal crops along with increased mechanization and widespread use of nitrogen fertilizers, herbicides and pesticides led to remarkable raise in crop yield. Dr Norman Borlough is said to pioneer this green revolution by persuading the wheat breeders in Asia to use the technology and averting the critical food shortage in developing countries of Asia.

Now the world is again standing at similar juncture, where mouths to feed are becoming much more than the overall food production all over the world. The scenario is much graver in the developing and so called third world countries with over 95% of individuals being born in these countries. The world's population is predicted to double over the next 40 years, It is estimated that to meet these increased demands, food production must increase by at least 40% in the face of decreasing fertile lands and water resources. Shortage of enough resources to irrigate crops or purchase herbicides or pesticides, leading to a vicious circle of poor crop growth, falling yields and pest susceptibility (Christou et al., 2004). In short, we require another green revolution to mitigate this enormous difference between demand and supply of the food.

GM plant technology is an imperial approach that is being developed to combat such problems. The specific aspect of green biotechnology was reiterated by the European Commission in 2004: "Life science research can help European agriculture tackle its three main challenges: the shift in economic power away from primary producers (countries); the magnificent changes desired in agricultural infrastructure and systems; and the effect of trade globalization and liberalization that could lead to a 20% to 30% cut in EU agricultural output in the very near future (European Commission, 2002).

The current R&D emphasis is mainly on the development of varieties that show improved resistance to other biotic as well as abiotic stresses (e.g., drought and biofortified varieties), require lesser water, fertilizers, herbicides and pesticides, use lesser energy and are more environment and human friendly. Every now and then, companies involved in the development of such genetically modified plants have introduced something new to the market but how far these varieties succeed in fulfilling the requirements of being safe and cheap remains to be seen.

Advantages of Green Biotechnology

The benefits of green biotechnology to farmers, environment, consumers and society are many. Biotech crops are able to:

- Increase yields by 6% - 30% on the same amount of land by producing sturdier varieties that are more vigorous, softer shells and longer shelf life.
- Genetically modified crops are resistant to insect and viral damage thereby significantly reducing the need to spray crops.
- Reduction in fuel consumption and resultant CO_2 production because of less tillage.
- Claims are there that their usage have already reduced the global environmental 'foot print' of production agriculture by 14% including reductions of CO_2 emissions in 2004 equivalent to taking 5 million cars off the road for one year.
- Production of better, secure and nourishing food and feedstuffs, like healthier vegetable oils; produce containing less harmful natural toxins such as mycotoxins.
- Reduce production cost of raw material by increasing economic viability of biofuel
- Allow farmers to grow more food more reliably in harsher climatic conditions.
- Reduce water usage to meet the Millennium Development Goal.
- Protect soils from erosion and compaction through less ploughing.

Green biotechnology indulges choice for farmers to help them adopt sustainable agricultural practices that can tackle tomorrow's challenges. Agriculture is a major source of green house gas emissions, contributing to almost 48% of total methane emission and 52% of N_2O emission. Agricultural practices like deforestation, cattle feedlots, usage of fuel for spraying the crops, tilling of the soil and fertilizer use currently account for about 25% of all green house gas emissions and 14% of all CO_2 emissions. With the help of green biotechnology, there will be supposedly be lesser fuel consumption on farms through a reduced need to spray crops, carbon sequestration and reduced fertilizer use and N_2O emissions and sturdier crops . Studies have shown that maximum Green house gases are emitted during fuel usage for spraying of crops (Barfoot and Brookes, 2009) or powering water pumps. GM crops need much less or almost nil tillage thus aiding in soil carbon sequestration. GM rice and canola have increased Nitrogen use efficiency (NUE) thereby reducing the need of fertilizers and also decreasing the input cost of the farmers. The yields can be improved (Bt maize in Spain 2007; Brookes 2007) along with course to suffer with water scarcity by using water more sustainably, reducing water loss and by improving drought tolerance.

Scenario of Green Biotechnology

Since 1995, farmers have been growing GE crops. In 2003, 7 million farmers in 18 countries, more than 85 percent of them resource-poor farmers in the developing world were planting biotech crops. Relatively one third of the world biotech crop area was cultivated in developing countries. In 2013, GM implanted area in USA was 70.1 million hectares including maize, soybean, cotton, alfalfa, papaya, canola, sugarbeet and squash whereas in Brazil, it was 40.3 mha covering maize, soybean and cotton. In India, the total area under GM cops was around 24.4 mha and Bt cotton is the only GM crop cultivated.

In 1980, first GMO patent was issued to a bacterium with an appetite for crude oil, ready to gobble up spills and in 1982, FDA Approved First GMO Humulin, insulin produced by genetically engineered *E. coli* bacteria to be commercially available in markets. Flavr savr, a delayed ripening variety of tomato developed by a USA based company Calgene, was the first commercially available genetically modified food in 1994 (James, 1996; Weasel and Lisa 2009) but was withdrawn from the market after sometime due to anti-GM hostility. A soyabean variety by the name 'Roundup Ready' incorporated with trait of herbicide tolerance especially against broad range herbicide Glyphosate was refined by Monsanto (Padgette et al., 1995). In 1996, insect resistance was introduced in maize by incorporating Bt gene of the soil bacterium *Bacillus thuriengiensis* responsible for producing an insect resistant protein called the Cry (Crystal) protein. Such Bt crops have been successful in many parts of the world. Rather than food crops, genetically modified cash crops are gaining more importance worldwide. Bt cotton currently occupies the largest area in Africa for any GM crop (ISAAA, 2009). Traits are also being incorporated in plants for the enmasse production of recombinant medicines and industrial products, like monoclonal antibodies, vaccines (edible vaccines), plastics and biofuels.(Sticklen 2005; Conrad 2005; Ma et al., 2003; Lal et al., 2007) though the technology is still in its nascent stage and will take considerable time to be exploited commercially. First edible vaccine to show some promise in animal trials was against transmissible gastro enteritis (TGEV) in pigs (Lal et al., 2007). The first food product of biotechnology (an enzyme used in cheese production and yeast used for baking) appeared on the market in 1990. Ye et al. (2000) engineered rice that contained moderate levels of carotene and since then researchers have produced the much higher yielding 'Golden Rice 2' (Paine et al., 2005). In 2015, *Aqu Advantage salmon,* the first genetically modified animal to be approved for food use having the quality of growth all year round was introduced (Bunge 2015). GM plants are also being assessed for their role in selective removal of pollutants or phytoremediation. For example, plants have already been genetically engineered to grow on contaminated sites and accumulate heavy metal soil contaminants such as mercury and selenium to higher levels, thereby decontaminating the field and allowing recycling or removal of the accumulated heavy metals (Sasaki et al., 2006; Banuelos et al., 2007). Molecular farming to cultivate GM plant-derived pharmaceutical proteins (PDPs) is currently being pondered upon across the world (Ma et al., 2003). The first full-size native human recombinant PDP, human serum albumin, was demonstrated in 1990 (Sijmons et al., 1990). Hepatitis B vaccine are attempted to be produced in potatoes and lettuce, (Kapusta et al.,1999) vaccines for heat labile toxin produced by *E. coli* and Norwalk virus, 50, 51 human pro-insulin 52 and several monoclonal antibodies have already been tried but still commercial success is evading the companies involved.(Hiatt et al., 1998; During et al., 1990; Ma JK-C et al.,1995; Francisco et al.,1997; JA, Gawlak et al.,1997; Mayfield et al.,2003).

GMOs: The Controversy

Although much research and resources are being continuously drawn into the field of green biotechnology, the gains are not upto the expected level. There has always been a cloud of controversy over the acceptance of these GMOs. It can be rightly said that GM crop cultivation is the need of the hour but still it is regarded as the most misunderstood and controversial technology of this era. Although most governments support biotechnology as a strategic technique for the new millennium, the red-green contrast of biotechnology has been the result of long term cultivation approach by the media all over the world. Medical achievements have always been in positive light but advances in agri biotechnology were seen suspiciously (Morgan and Shanahan, 1996). In this light, it is imperative to assess the successes and failures of this branch of biotechnology and the prospects of new GM crop varieties reaching the market in upcoming decade. A survey in UK in 1999 showed that on average, there was a disliking towards green biotechnology and food and crop applications were considered hardly acceptable whereas medical (red) biotechnology was considered to be useful and to be encouraged (Bauer 2002). This feeling of distrust was more evident in Europeans as they see GMOs as risk to society and morally unacceptable (Gaskell et al., 2006)

Genetically modified (GM) crops are different from crop improvement by natural selection and breeding both technically and conceptually and pose different risks, conceptualized in various international laws. The Cartagena Protocol on Biosafety,(Secretariat of the Convention on Biological Diversity, 2000) an international agreement signed by 166 governments worldwide that seeks to protect biological diversity from the hazard stiffed by GM technology. The United Nations food safety body, Codex Alimentarius, acknowledged the importance of regular breeding and safety assessment (Codex Alimentarius, 2009; Codex Alimentarius, 2003). The fact that a GM crop is basically different from a natural crop is utilized by the industry in different ways. It acquires patent for the process and the product on the basis that the generation of a GM crop constitutes an "inventive process", thus making the GM crop patentable. On the other hand, GM foods are projected to be hardly different from non GM foods apart from the verity that they have more dietetics value and shelf life. The exchange of genetic material between unrelated species through a system apart from sexual reproduction is called horizontal gene transfer, or HGT. Genetic engineering involves intentional horizontal gene transfer. Reproduction, involves vertical gene transfer, as the genes are passed down through the generations from parent to offspring.

Genetic engineering blurs the natural barriers between species and kingdoms that have evolved over millennia inducing unpredictable changes in the DNA, proteins, and biochemical composition of the resulting GM crop, which might prove toxic or have other detrimental effects like allergies and nutritional disturbances, as well as unforeseen effects on the environmental balance (Wilson et al., 2006; Schubert 2002). Just a single transformation at the level of the DNA can produce multiple pleiotropic effects with unknown outcomes because genes interact with one another and are regulated by a highly complex, multi-layered network of genetic and epigenetic development within the organism (Wilson et al., 2006). Genes from humans or animals can be transferred to plants or vice versa, potentially creating unpredictable Frankenstein monsters. Moreover, genetic engineering can introduce purely synthetic genes, thus, expanding the range of possible genes, effects of which may be beyond human imagination, for better or worse.

Supporters of GMOs claim that the technologies used are very precise and targeted (Wood et al., 2011) and the products would be as safe as the natural products as gene transfer also takes place naturally. However, these GM transformation methods are not reliant. Pattanayak et al., 2011 and Gabriel et al., 2011, found that ZFNs caused unintended mutations in human cell lines. In another investigation using human cells, CRISPR was found to cause unintended mutations in many regions of the genome.(Fu et al., 2013). To deal with these accusations, attempts are being made to transfer genes from a related organism or the same organism (so-called “cisgenesis” or intragenesis). For example, a gene from one crop may be inserted into another variety. However, Cisgenesis also involves the same genetic methods and thus the results may not be entirely predictable as new GM gene unit may contain genetic elements from other organisms, including bacteria or viruses causing unexpected effects. Experiments confirm that Cisgenic GMOs pose almost the identical danger to health and the environment as transgenic GMOs and can cause unanticipated changes to a plant (Nestle 2007; Taylor 2013; USFDA 1995; Graff et al., 2003).

The biotechnology companies BASF and Cibus have developed oilseed rape and canola with a technique involving altering a targeted gene by utilizing the cell’s own gene repair system called as RTDS (Rapid Trait Development System) to specifically modify the gene sequence in situ, and does not involve inserting foreign genes or gene expression control sequences (Cibus.undated). Cibus markets its RTDS crops as natural and non-transgenic and as produced without the insertion of foreign DNA into plants (Cibus 2013; Cibus undated). Many detailed studies like whole genome sequencing of RTDS GMOs, analysis of targeted proteins produced by the RTDS developed plants and evaluation of functionality, utility, and safety will be required to assess the fidelity and efficacy of the RTDS process and the degree to which unexpected alterations take place at other locations in the genome during the entire process, as any new technology can’t be deemed safe enough to be used unless tested for efficacy. RTDS is although more targeted than the traditional recombinant technology has its own pros and cons.

Facts and Findings

Various studies show that GM crops are safe (Wendel 2013) but these claims are not found to be totally unbiased as industry itself is involved in funding of these researches (Diels et al., 2011). Independent researches are few and far in between as these do not get the required financial support nor they gain access to GM cops who are protected by various patent based controls (Waltz, 2009). Usually the companies retain the right to block any publication which they deem a threat to their reputation (Scientific American 2009). Although a few scientists have claimed that acquiring the GM crop seeds has become easy as GM companies have entered research agreements with Universities (Johnson 2013), these claims are found to be controversial by many researchers who were faced with various legal formalities and hurdles while doing so (Carman 2013). Inspite of these challenges, scant studies have been conducted that clearly show the harmful effects of feeding GM seeds to rats (Séralini et al., 2007; GM Free Cymru, 2011; Robin, 2008). Workers involved in these trials had to face vicious defamation campaigns and loss of careers upon publishing their research findings proving that GM companies and Universities work hand in glove while dealing with the controversies and research studies regarding GM crops (Bittman 2011 ; US FDA, 2013). Toxicities and detrimental effects seen in lab and farm animals feeding studies clearly indicate the harms of long term feeding of GM crops. There have been reports of severe organ damage and increased rate of large tumor formation (Séralini et al., 2012; EndScience, 2014) altered blood biochemistry, multiple organ damage and potential effects on male fertility (Gab-Alla et al., 2012; El-Shamei et al., 2012), unexplained mortality (Pusztai 2002), sustained immune response against GM proteins and allergic reactions (Prescott et al., 2005; Lee et al., 2013), disturbed liver , pancreas and testes function (Malatesta et al., 2003; Malatesta et al., 2002; Vecchioet al., 2004), liver ageing (Malatesta et al., 2008),liver and kidney toxicity (De Vendomois et al., 2009), intestinal abnormality (Fares et al., 1998) and various other deleterious effects. There is no evidence that commercialized GM food are safe to eat over the long term. Few studies that have been conducted on humans show problems but they were not followed up (Netherwood et al., 2004; T, Martin-Orue et al., 2004; Heritage, 2004 ; Yum et al., 2005). All GM crops should be commercialized only after conducting long term studies based on their response on human volunteers (American Association for the Advancement of Science (AAAS), Board of Directors (2012). As of 2015, 64 countries require labeling of GMO products in the marketplace (International Labeling Laws" Center for Food Safety).

In May 2014, Vermont in the US became the first state to pass a law to crave the labeling of foods that contain genetically modified organisms (GMO). Foods derived from GM crops have been consumed by hundreds of millions of people across the world for more than 15 years, with no reported ill effects. To stop the horizontal gene transfer between GM and non GM plants, physical isolation and genetic containment can be done. Physical isolation means that the crop must be bred in isolation at every stage of production. Whereas, genetic containment means building sterility and incompatibility systems to limit the transfer of pollen like, Genetic Use Restriction Technologies (GURTS) which interfere with fertility or seed formation. (Mascia and Flovell, 2004). In 2001, a highly publicized study showed that GM genes from GM maize had, by cross-pollination, contaminated wild maize in Mexico, the global centre for biodiversity of this species.(Quist and Chapela (2001) Similarly, Losey et al. (1999) claimed that Bt maize was harming the lifecycle of Monarch butterfly, an iconic species in American culture.

Conclusion

Agri biotechnology or the Green biotechnology is a branch of science we all love to hate but also can't do without. Much has been written to write off the technology which clearly has the potential to do wonders in the field of crop sustenance and reproducibility. It is undoubtedly the most promising branch which has the potential to feed the millions mouths which are added to the total world population every passing moment while the size of land under agriculture goes on shrinking. Green biotechnology is commonly considered as the next phase of green revolution. Some of the doubts regarding the safety and efficacy of GM crops are not unfounded. GM crops have been grown and used for decades now without any visible side effects as of now. The technologies involved in developing these GM crops are becoming more targeted day by day. GMOs have a great potential in not only increasing the crop yield or shelf life and reducing the carbon foot print of the cosmos but also can help in mitigating the effects of diseases (edible vaccine, pharmaceutical proteins, antibiotics), increase the nutritional value of food (Golden rice) Use of genetically modified food grade organisms as recombinant vaccine expression hosts and delivery vehicles creating new avenues for vaccinology is very promising. Various studies have shown that GM technology involves highly targeted gene transfer which is unlikely to cause unpredictable effects on the environment. Extensive safety testing of GM crops developed, and thorough risk assessment has shown that there are no varieties in use that pose risk to consumers (Wieczorek and Wright, 2012). Usually the GM cash crops are processed in such a manner that the formed product doesn't contain intact DNA or GM proteins. Proper labeling laws, stringent field trials of long duration and a positive public opinion is necessary to develop this promising branch so that we can harvest its benefit in the welfare of mankind meanwhile sustaining our environment.

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