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Biotechnology and its Impact on Food Security and Safety

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Abstract: A global recession, along with highly increased food prices in many countries in unregenerate manner, have caused some 100 million more people than last year suffering from silent hunger and poverty that would leave the world extremely vulnerable. The global food crisis potentially imposes a serious risk towards world peace and security.

The crop production however will have to be dramatically increased to meet the need. The ability of biotechnology to act as a tool to assist in solving the issue is far from being fully exploited.

Low crops production is considered to be the main reason for poverty and food insecurity in the world. High percentage of poor and food insecure people are living in developing countries and in rural aereas. Therefore, biotechnology can:1) increase the crops yield through introducing high-yielding varieties resistant to biotic and abiotic stresses; 2) reduce pest–associated losses; and 3) increase the nutritional values of foods which is a very important factor in rural areas or developing countries. Furthermore, in order to reduce or eliminate food insecurity, postharvest approach in wasting less is of a vital strategy to supplement increasing food productivity. Hence, the environmental issues in supplying safe and nutritious foods in a sustainable manner should be taken into account.

Biotechnology research and development have already produced significant products on the market, and will further have a pivotal role to play in encouraging and enhancing food production, considering the safety and environmental quality. Although the major concern being the safety and potential impact of genetically modified organisms (GMOs) on human health, the future of biotech crops looks encouraging as the global area of biotech crops continue to increase yearly and commercialization of drought tolerant maize and Golden Rice are expected in 2013/2014. Thus, biotech crops could possibly contribute in accomplishing the 2015 Millennium Development Goal particularly in reducing poverty by half through maximizing crop productivity.

Microorganisms play a vital role in sustaining soil health and productivity, in the process of plant biomass conversion to produce both food and fuel, and in the production of novel foods and feeds mainly by fermentation.

This review discussed the current trends and future perspectives on how biotechnology and genetic engineering can help us to provide safe and secure food and can act as a valuable tool to reduce poverty.

Keywords: Biotechnology, food security, poverty, economical issues.

INTRODUCTION

The world's current population in 2014 is 7.3 billion and will hit 10.9 billion by 2100, as a result of high birthrates in the developing world "www.worldpopulationstatistics. com" [1]. Undernourishment exists in 20% of developing countries and is the main cause of 50% of infant death. Hundred millions of infants and mothers have vitamin A and iodine deficiency and suffer from anemia. In Asia and Africa nearly 20% of maternal death is claimed by anemia, an unhealthy condition caused by lack of iron. Iron deficiency also causes more than 400 million women delivering stillborn and underweight babies. Undernourishment outbreak in Asia especially the East Asia has decreased due to the recent economical developments, but this region still locates about 66% of chronically under nourished people. In South Asia one from 5 is chronically under nourished. FAO believes that in 2015 half of the undernourished will live in Asia while 66% will be in South Asia. World Bank believes that, undernourishment originating from micronutrient deficiency decreases more than 5% of country GDP; meanwhile cost for its solutions is only 0.3% of country GDP. Undernourishment appears not only because of low food receiving, but also receiving foods with low macro and micronutrients which both are related to economical issues [2]. Poverty and food insecurity are the main causes of undernourishment. Population growth, dry and arid lands, drought, low yield crops, and economical imbalances are the main cause of low production in agriculture mostly in developing countries. Thus, agriculture as lifeblood should be developed to rescue the 740 plus million people going to bed hungry every day, but how is it possible? Will it be possible without application of new technologies and new methods which have the ability

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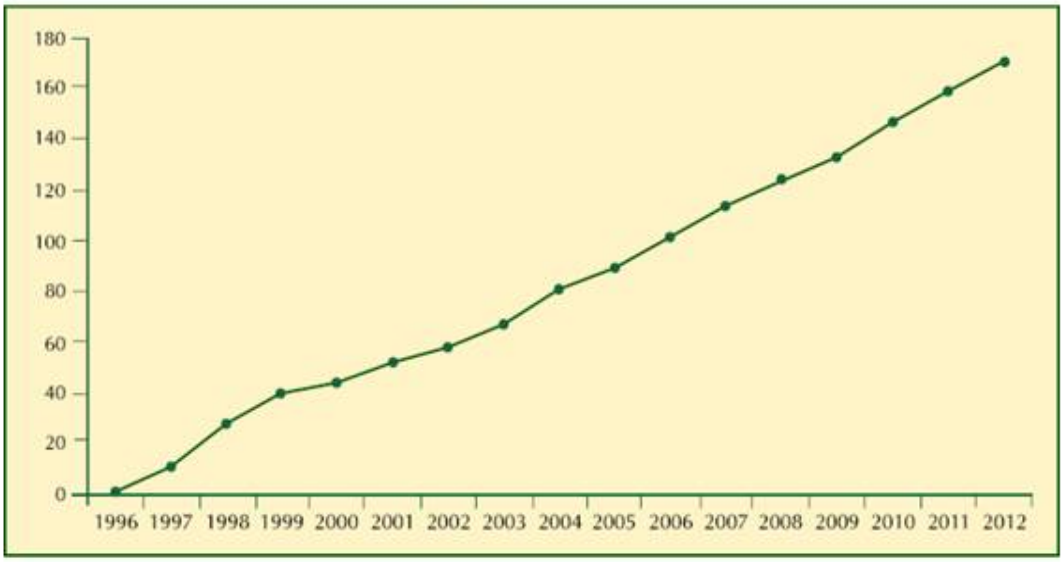

Fig. (1). Global area of biotech crops from 1996 to 2012 (million hectares). Source: Clive James, 2012 [25].

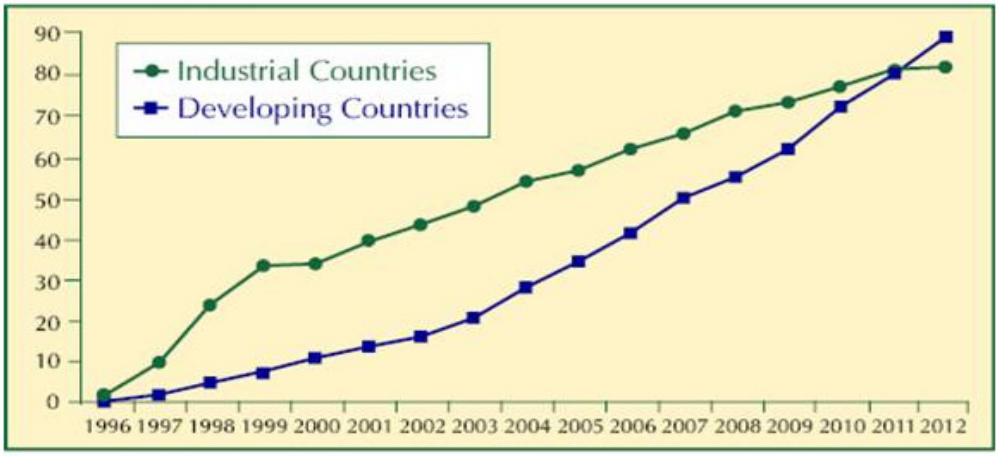

Fig. (2). Global area of biotech crops from industrial and developing countries (million hectares) Source: Clive James, 2012 [25].

to increase the crop yield AND minimize the crop loss due to pests, produce foods with high nutritional value, and finally resulting in sustainable agriculture and food safety and security? [3]. Will there be any alternative other than genetic engineering and biotechnology? Predicting the future will be difficult. Nonetheless, GMO industry has grown exponentially worldwide and many developing nations are looking to GM foods as the solution to increase food productivity and food security. In the west however it appears that corporations are exploiting this science to increase the aesthetics of crops at the expense of nutritional value and health concerns to the greater public. There are already few examples such as soybean, corn, canola, and cotton seed oil, *etc* on the market (Fig. **1**). About 1.6 billionth hectare planted in 2012 – same area as USA and GMO crops have increased from 25 to 29 countries with strong 10% growth rate (Fig. **2**) [25].

"By 2012, 88 % of corn (maize) and 94 % of soy grown in the United States were genetically modified (USDA) (Fig. **3**). The main players are US firms Monsanto, DuPont and Dow Chemical, as well as Germany's Bayer and Syngenta of Switzerland. Since their introduction in the 1990s, GM products have conquered agriculture in the US and hold a large share of the food on Americans' plates. Though most genetically modified organisms (GMOs) are not directly involved in human consumption, About 60-70 % of processed foods have ingredients derived from GMOs"phys.org/news/ 2013-06gmo -corn-soybeans-dominate.html [4].

More recently, the first variety of Golden Rice using daffodil genes and bacteria was released, and a new variety of Golden Rice is released by Syngenta, replacing the daffodil gene with maize. This new variety, "Golden Rice 2″ produces up to 23 times more beta-carotene [5].

Golden Rice has undergone two years of field testing in the Philippines. Although Golden Rice was developed as a humanitarian tool to combat blindness in underdeveloped countries, it has met with significant opposition from environmental and anti-globalization activists.

In this review, we will discuss the ways which biotechnology and genetic engineering can help us to provide food security, and can act as a valuable tool to produce safe food and reduce poverty. Meanwhile we will have a glance at the GM food controversies surrounding and will suggest how to handle the challenges we are facing today.

Fig. (3). Commercially marketed GM crops in the US: 1 (most selling) 5: least selling (Source: NCSAP, USDA-ERS) [26].

BIOTECHNOLOGY - AN IDEAL OPTION

"Both conventional and genetically modified plant breeding change the genes of a plant so that a new and better variety is developed. Traditional breeding crosses only two closely related plants hat are sexually compatible, in which thousands of genes are being rearranged.

The aim is to combine the favorable traits from both parent plants and exclude their unwanted traits in a singular new and better plant variety. However, the progeny of this first cross inherit a mix of genes from both parent plants and so both positive and negative traits may be inherited" [3].

The selected positive progeny is breeded back to one of the original parent plants (back crossing) to try and transfer more of its positive traits into the following generation and takes place over a number of generations, which usually means a number of years, until the progeny have all the desirable traits with none of the negative ones of the original two parent plants that can take 10 years or more to select a good variety.

"Conventional breeding also crosses different species of plants to create hybrids. Plant hybrids are common in agriculture and horticulture and home gardeners would be familiar with hybrid flowers and vegetables.

The unique power of genetic engineering however lies in its ability to incorporate novel genes into new plants to develop plants with properties that would not be achievable through conventional breeding. This is a completely new technique.

This may mean using genes from unrelated organisms such as in the case of insect-resistant GM cotton" [3].

Today, supermarkets are flooded with GMO products and GM ingredients in all good items, but how safe is it to eat them? Regarding the economical issues, new biotechnology can help us to reduce poverty and food insecurity by: 1- producing high-yielding crops resistant to the biotic and abiotic stresses; 2- reducing pest associated losses; 3- increasing the nutritional values of foods.

PRODUCING HIGH-YIELDING CROPS RESISTANT TO THE BIOTIC & ABIOTIC STRESSES

Improving the ability of crops to withstand environmental stresses (*e.g.* extreme pH, salt, heat, *etc*) will enable growers to farm in those parts of the world currently unsuitable for crop production. This would lead to increase global food production by reducing crop loss and increasing yield, while conserving farmland and reducing pressure on irreplaceable natural resources like the rain forests. It will also provide more employment opportunities for people and increase productivity. Drought resistance in GM crops will reduce water use in irrigation. This will be very useful in some tropical or arid regions where water is scarce. "About 30% of arable land is characterized by the poor solubility of iron due to the alkaline soil. The resulting limitation of plant growth cannot be alleviated by fertilizers. The tolerance of rice to such low iron availability in alkaline soils could be improved by genetically engineering the crop to release more iron- stabilizing chelators" [6]. "Aluminum released by acid soil is toxic to crop roots. The world's arable land (30-40%) is affected by acid soils resulting in yield losses of up to 80%. Expression of bacterial citrate synthase in roots is one of the strategies presently being developed to overcome this problem" [7]. The irrigated land (40%) is affected by salinity. Genetic engineering can confront this problem, also, for example by introducing sodium pumps in the plants. Producing herbicide tolerant crops is another benefit of biotechnology application in agriculture which can increase the crop yield. It can be achieved by introducing a gene coding for a

target enzyme intensive to the herbicide or an enzyme detoxifying the herbicide. Apart from crops resistant to stresses, crop yield can be increased in several ways: Major cereal crops which are annuals may be converted by GM to perennials. This would reduce tillage and erosion, as well as leads to conservation of water and nutrients [8]. It will also increase crop yield during the year. Such perennial crops would decrease labor costs, improve labor allocation, and generally improve the sustainability of agriculture [2].

REDUCING THE PEST ASSOCIATED LOSSES

More than 15% of the world's crops are lost by insect damage, this happens mostly in developing countries. Many food plants, such as soybean, potato, and corn have been engineered with Bt gene which produces Bt protein (an insecticide) derived from soil bacterium *Bacillus thuringiensis*. Bt is non-toxic to humans, but is toxic to insects such as the European corn borer, cotton boll-worms, and potato beetles. This toxic Bt protein eliminates the need for chemical pesticides against insects that transmit viruses and other harmful microorganisms. Alternative strategies to confer insect resistance to plants might become of practical importance in the future [9]. Crops such as tobacco, tomato, squash and corn have been genetically modified to become virus resistant [10, 11]. Resistance to fungi is conferred by GM –induced biosynthesis of phytoalexins. Resistance to fungi is beneficial not only from a commercial point of view (crop yield) but also the safety issue by considering the reduction in carcinogenic mycotoxin levels. Various strategies have also been described to confer the resistance to bacteria. Recently a gene switching technology was developed by Rohm & Haas (a food chemical company); the gene can be activated in a plant to simultaneously improve pest management, ripening and other genetically expressed traits [12]. Gene silencing could boost agricultural yields [13]. Biotechnology and Genetic engineering by producing virus, fungi and insect tolerant crops lead to increased productivity and cost reduction, due to reduction in the use of agro-chemicals, thereby making farming a more profitable and rewarding venture for farmers which is very important for the poor and food – insecure farmers in developing countries and rural areas.

INCREASING THE NUTRITIONAL VALUES OF FOODS

Macronutrients

"Genetic engineering can be used to modify oils to achieve a reduction in the levels of saturated fats and trans fatty acids which are responsible for cholesterol production in the body; GM can also be used to increase the levels of unsaturated fatty acids in some commonly used oils such as canola, soybean, sunflower, and peanuts" [14].

Improved protein quality may involve an increase in the methionine and lysine content of protein (two essential amino acids) [15]. It may also be able to remove the beany flavor in soybean to expand its consumption and usage in various food systems." Modern plant biotechnology has focused very early on the genetic modification of plant carbohydrate metabolism, influencing source-sink interactions, improving starch biosynthesis, changing starch composition or accumulating fructans (a prebiotic having health beneficial effects) in transgenic crops" [16, 17].

Micronutrients

" It has been estimated that about 1.3 billion people suffer from iron deficiency. In order to increase the iron content of rice, the major staple food in Asia, three approaches have been proposed: 1- Introduction of ferritin gene from *Phaseolus vulgaris* into rice; 2- Expression of a heat tolerant phytase from *Aspergillus fumigatus*; 3-Overexpression of endogenous cystein-rich metallothionein-like protein" [18].

"Biotechnology can be used to introduce or concentrate certain nutrients such as zinc and iodine, carotenoids, flavonoids, vitamins A, C and E into common dietary staple food plants as a way of delivering optimal levels of key nutrients or fighting some nutritional deficiencies endemic in some regions of the world, including Asia and Africa" [8, 11, 19].

GM FOOD CONTROVERSIES & CHALLENGES

In order to trade the GM food and it's consumption by people, it should publicly be accepted, but whenever a new technology emerges, the critics begin to find its potential risks, though most of the time try to make challenges by covering the benefits and alarming the associated health risks. This is very common in food and related industries, the first reason is "fear of the unknown" and the second is because of its low profitability for some countries and some special companies, which do not want to lose their global markets by the entrance of novel foods (mostly cheaper) and new technologies (mostly applicable in rural areas and developing countries). Biotechnology is one of these new technologies that have the highest number of critics among others, some of the reasons for this criticism are mentioned above, these critics declare the potential risks of genetically modified foods as below [20]:

- Antibiotic resistance.
- Potential toxicity from GM foods.
- Unintentional gene transfer to wild plants.
- Treat to crop genetic diversity.
- Religious /cultural /ethical concerns.
- Concerns for lack of labeling.
- Concerns for organic and traditional farmers.

WHAT ARE THE SOLUTIONS?

Despite the GMO being over two decades, the difficulty of debating this subject is that of course we still do not know how they affect our human body in the long run. The most North Americans are often unaware that the foods they chose contain GMO, as current laws do not require GM crops to be labeled or traced because U.S. regulators do not believe that GM crops pose any unique risks over conventional foods. To solve the GM food challenges, we can choose between two different policies: 1) Totally ban GMO products from being commercialized (no production or no consumption of GM food any more). 2) More research, study and regulations, before genetic modification and marketing. Considering the

economical issue and food security, the first policy is not logical and this technology cannot be halted because of the important potential benefits they offered to society, thus we have no option to go for the second policy. According to the second policy, genetic modification should be adopted under conditions that avoid potential risks. Time and effort must be devoted to field testing before the release of any new GMO or food.

GM products should be evaluated over a long period of time to establish their effects on health, agricultural pests, environment, and suitable regulations are necessary to avoid possible environmental and safety problems.

Antibiotic resistance marker genes used in GM crops should be evaluated to see if they can be substituted with other equally effective selection methods (when available) to prevent potential risks of antibiotic resistance in human and animals. To prevent movement of transgene from pollens to relatives of GM crops or to weeds in nearby farms, cautions must be taken, for example locating the field test facilities far away from nearby wild relative or non- GM farms.

Regulatory agencies should set up public health surveillance network that will quickly flag any problems (such as allergens, toxins), that may arise among people eating GM foods. Researchers and regulators should consider and assess the treat to crop diversity before any genetic modification" [3, 8]. By efficient regulations, we can perform a reliable labeling which can decrease the ethical, cultural and religious concerns by giving complete information about the GM food, thus giving the choice to consumers. Traditional farmers should be educated to understand this critical situation (over population and the need for more food) and the emergency need for a new technique to provide food security.

The public need to be sufficiently educated on genetic engineering of any product to enhance acceptability of such a food, this is because biotechnology is a new technology and unfamiliar to many people.

Therefore, we can simply solve the challenges by spending more time and effort and educating the public. All scientific consensuses confirm that "food on the market derived from GM crops pose no greater risk than conventional food" [21]. "No reports of ill effects have been documented in the human population from GM food" [22].

Foods containing ingredients from GM crops pose no greater risk than the same foods made from crops modified by conventional plant breeding techniques (American Association for the Advancement of Science, Board of Directors, 2012).

The American Medical Association, the National Academies of Sciences and the Royal Society of Medicine have also stated that no adverse health effects on the human population related to GM food have been reported and/or substantiated in peer-reviewed literature to date. European Union also spent $ 425 million over 25 years and concluded that genetic engineering per se is no more dangerous than other plant-breeding methods (www.gmo-safety.eu/news/ 1262. eu-genetic- engineering.html) [23].

Many European consumers and Americans are similarly asking for food regulation, demanding labels that identify which food has been genetically modified.

"Transgenesis is less disruptive of composition compared with traditional breeding techniques which routinely involve genetic mutations, deletions, insertions, and rearrangements" [24], thus the compositional equivalence between conventional and GM foods may no longer be justified. For labeling of GMO foods, the cost of labeling is not just ink and stamps. Huge costs associated with keeping label off from auditing from beginning to end of production. The US and Canada studies estimate that cost would be 9-10% of retail price of processed food products. The approval of the GM salmon, which can grow faster and is more economical is in near future (http://www.digitaljournal.com/article/ 349660#ixzz2eSPmEWHi) [27] and this GM fish could be destined for American supermarkets soon.

CONCLUSION

Genetic engineering and biotechnology are the only logical way of feeding an over populated world which is estimated to double by 2050.

GM has the potential to enhance the quality, nutritional value and variety of food available for human consumption, and to increase the efficiency of food production, food distribution, and waste management. It would lead to the development of new crop varieties that offer increased yields and reduced inputs.

Genes inserted into plants can give biological defenses against diseases and pests thus reducing the need for expensive chemical pesticides and convey genetic traits that enable crops to better withstand drought, pH, frost and salt condition. Use of herbicide resistance seeds will enable farmers to selectively eradicate weeds with herbicide, without damaging farm crops.

Adequate regulation, constant monitoring, and research are essential to avoid possible harmful effects from GM food technology and to give assurance to those concerned about this technology.

GM foods are safe. Careful application of biotechnology and genetic engineering will make life better, improve human health and welfare and save time and money. GM will also create jobs and yield sizeable foreign exchange. Overall, the benefits of GM foods far outweigh the consequences. Risk of producing and consuming new GM foods should be weighed against potential benefits, and when benefits outweigh the risks, such foods should be adopted to reduce the public concerns, and labeling should be performed with more accuracy. Finally we can say that biotechnology is a reliable way towards food security. Future of biotech crops looks encouraging as the global area of biotech crops continue to increase yearly and commercialization of drought tolerant maize and Golden Rice are expected in 2013 / 2014.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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