BIODIVERSITY AND ECOLOGICAL RISK ASSESSMENT FOR GM CROPS

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Abstract: Genetically modified (GM) crops have now been part of the agricultural landscape for 17 years and have become important tools in crop production and Integrated Pest Management (1PM) in many countries. Many researchers welcome and appreciate the positive impacts of this technology in terms of improved production and economic benefits while others pick out it as a threat to biodiversity. This GE crop and several others have continued to raise environmental concerns over their sustainable use and consequences for biodiversity and ecosystem services in agricultural land such as biological control, decomposition and pollination. There has been considerable research addressing many associated issues including environmental and food safety, as well as economic and social impacts. In particular, extensive laboratory and field research has been generated relative to the assessment of non-target effect in transgenic Bt crops. This body of evidence and the quantitative and qualitative syntheses of the data through meta-analysis and other compilations generally indicate a lack of direct impacts of Bt crops on non-target macro invertebrates. The data also clearly show that Bt crops are much safer to non-target organisms than the alternative use of traditional insecticides for control of the pests targeted by the Bt proteins. Some indirect effects on arthropod natural enemies associated with reduced abundance or quality of Bt target herbivores have been shown, but the consequences of these effects are unclear but on the other hand Bt crops have reduced the use of insecticides. To emphasize all the possible risks associated with transgenic crops, information has been gathered from a total of 76 articles, regarding non-target plant and animals, and summarized in the form of the current review article. No significant harmful impact has been reported in any case study related to approved GM crops, although critical risk assessments are still needed before commercialization of these crops.

Keywords: GMOs, Biodiversity, Gene Flow, Non-Target Organisms.

Introduction: The process of evolution has resulted to the diversity living organisms on Earth today with prevalent traits and characteristics. But to produce preferred agricultural products by natural selection or selective breeding can be very slow. But, now with genetic engineering technology it has become possible to avoid natural evolution by introducing desired genes into plants and animals. The survival of such new species is depending on its traits and adaptation to the new environment. More variation in genes leads to more individuals with positive traits to withstand harsh conditions. On the other hand, little genetic diversity can be challenging during ever changing environments. Therefore, researchers believed that genetically engineered modifications may affect the genetic diversity of a population through crossbreeding or uncontrolled growth. Hence this subject has become the topic of interest today.

Meeting future food, pharmaceutical drugs, vaccines, and fiber desires without compromising environmental integrity is a fundamental challenge for agriculture globally. With the reduction of natural resources and mounting demands for food worldwide, along with challenges by climate change, an increase in agricultural productivity is a mandatory requirement to solve the problem of food security. Man has domesticated plants and animals since ancient times using artificial selection breeding techniques with desired traits [1]. The progression of selective breeding, served as a precursor to the current concept of genetic alteration.[2] Further advancements in genetics permitted humans to alter the genes (DNA) of living organisms directly.
Human insulin was the first FDA approved product of genetic engineering by Genentech in 1978 and branded as humulin [3] Then after, in 1988 the first human antibodies were produced in plants and in 1987, *Pseudomonas syringae* (ice minus mutant) was the first genetically modified organism (GMO) to be released into the environment. [4]Later on many varieties of GMOs produced and are efficiently used in biological and medical research, production of pharmaceutical drugs including vaccines [5], [6], [7] and also agriculture (GM crops) [8], [9]. The aim of the production of genetically modified crops (GM crops, or biotech crops) is to launch a new trait to the plant which does not occur naturally in the species.

Worldwide farmers have widely adopted GM technology and growing day by day. The total area of land grown with GM crops increased by a factor of 100, from 17,000 square kilometers (4,200,000 acres) to 1,750,000 km^2 (432 million acres) between 1996 and 2013 [10]. In the US, 94% of the cultivated area of soybeans, 96% of cotton and 93% of corn were genetically modified varieties only [11]. At present GM crops are expanding rapidly in developing countries also. **According to a report of** International Service for the Acquisition (ISAAA) the present global Status of GM crops is approximately 185.1 million hectares (457.4 million acres) with an increase of 5.5 million hectares from the 179.7 million hectares planted in 2015 among which US was still a leader in GM crops[12]. So, the genetic engineering technology is very much valuable to resolve global food security, malnutrition and climate change issues.

Methodology: This research review paper is based on information from the national and international data base like Web of Science, CAB Abstracts, Pro Quest Dissertations, Bielefeld Academic Search Engine (BASE) and BIOSIS. Special searches were conducted on various web-based and project databases containing information on environmental effects of GMOs. Information was also obtained from blogs, web sites and articles addressing the gene flow and gene pollution which can be found in the Appendices of the working document. Additionally, many press reports have been reviewed on a regular basis. Appropriate other published data have also been obtained from various local sources.

Results and Discussion: ***Pollution by Synthetic Fertilizers and Pesticides***: Synthetic fertilizers and pesticides both have ability to increase crop yields significantly and help to solve food security. Conversely, they both can cause severe aquatic [13] and soil pollution [14]. Besides the above risks, scientists expressed great concern that it not only affect to nontarget organisms [15], [16] but to humans health also [17] [18] [19]. Consequently, genetic engineering technology is believed as the sustainable, viable, and economical and can serve as an alternative to traditional pesticide methods. In transgenic agriculture, the advantages resulted from decreased use of herbicides and insecticides which hold massive potential for keeping natural environment unpolluted. It was estimated that the cultivation of GM crops reduced pesticide use by 22.3 million kg of formulated product [20].

Cisgenic Plants: Cisgenesis or intragenesis GMOs gene modification is based on the nature of introduced genotypical changes rather than the process of genetic engineering. Cisgenic plants contain genes of the host species or from other sexually compatible species whereas some genetically modified organisms (GMOs) are developed by the introduction of a gene originating from distant or sexually incompatible species into the host genome by using recombinant DNA technology (transgenic plants).

Concerns: Genetically modified (GM) crops are cultivated in grasslands much similar to normal crops. They interact directly with various organisms that feed on the crops and indirectly with other organisms through the food chain. The pollen from the plants is distributed like that of any other crop. This distribution pollen in the environment has led to concerns like gene flow and pesticide resistance [21].

Impact on Non-Target Organisms: GM crops are mainly resistant to insect due the expression of the *cry* (crystal delta-endotoxins) and *Vip* (vegetative insecticidal proteins) genes from *Bacillus thuringiensis* (Bt) [22]. Opponents argue that such toxins could affect insects and other non targeted pests like the European corn borer [23] .But Bt proteins applied as organic sprays for insect control with no harmful effects were reported [24] as *Cry* proteins are selective and target Lepidopterons only [25]. The *cry* proteins bind to specific receptors and rupture the epithelial cell membranes of mid-gut. So it affect only to those insects which have appropriate receptors in its gut. However, as non target organism lacks those particular appropriate receptors in its gut so consequently it is unaffected [26]. The policy makers and regulatory organizations evaluate the possible effects of transgenic plants to non-target organisms before approval [27].
A peer reviewed meta-analysis by Wolfenbarger; L.L et al [28] concluded that insecticide effects were much larger than those of transgenic crops. Another meta-analysis by Naranjo, S.E., [29] also indicates a lack of direct impacts of Bt crops on non-target organisms. The research reports also clearly show that Bt crops are much better than the substitute use of chemical insecticides.

In 2016, Meissle, M., et al [30] performed a comparative study between conventional and Bt maize on the effects of on non-target invertebrates, on abundance and diversity of soil inhabiting invertebrates, and on the abundance, activity and genetic diversity of microorganisms (bacteria and fungi). The meta-analyses data have shown treatments with common insecticides affected many significant effects on invertebrate populations while there were no noteworthy effects of Bt crops in general and on soil invertebrates.

The experiments of Lazebnik, J et al [31] on transgenic potato on non-target aphids confirmed the gene flow to non-target aphids for the first generation only. But later on these effects were no longer evident in the second generation.

One more a three year recent study of Héma, O.S., et al [32] could not find any adverse environmental impact on the abundance of non target organisms compared to traditional insecticide sprays. A study of Liu, Y., et al [33] on the effects of *Bt*-transgenic rice litter confirmed that *Bt*-transgenic rice had no effect on the aquatic community composition and *Bt* toxin was not detected in the experimental field water.

Biodiversity: The major debate about GM foods is the possibility of these products to affect biodiversity. This is a bit of a puzzling area as it is difficult to evaluate the long term because most of the consequences were observed and measured in the short-term. There is a possibility of transgenic crops to interact with other species and may potentially affect the fitness of other species of an agro-ecosystem and surrounding environment [34]. Hence, it is important to maintain the genetic diversity for both the environment and agriculture because the higher unevenness in DNA will offer a better chance for organisms to adapt to a changing environment.

However, criticizers expressed a big concern that if altered genes are introduced into wild plant populations and can develop a fitness advantage to survive better and able to reproduce. This benefit would lead to the engineered gene being preserved in the population but gradually reduce the genetic diversity and number of the native species [35]. Another study by Gibbons, D.W et al, [36] confirmed a decrease in avian biodiversity due to decrease in availability of weed seeds.

One more published farm trails data by Chamberlain, D.E., et al [37] showed that seed eating birds were more abundant on traditional maize even after spraying chemical herbicide. A 2013 study by Pleasants, J.M. and Oberhauser, K.S., [38] found a connection between the decrease of milkweed in farms that grew GM crops and the decline in adult monarch butterfly populations in Mexico. In a study by Relyea, R.A., (2005) [39] has examined the impact of four well known common pesticides namely, carbaryl, malathion, glyphosate [Roundup] and 2, 4-D on the biodiversity and species richness of 25 species of aquatic communities in artificial ecosystems. He found a reduction of 15% with sevin, 30% with malathion and 22% with Roundup in species richness while 2; 4-D had no effect on biodiversity.

Gene Flow: The gene flow or gene migration is the transfer of genetic variation from one population to another. Opponents argue that genes from a genetically engineered crop may pass to another organism by the process of outcrossing and it can occur in any fresh open pollinated crop variety. As a result the new traits potentially can cross into adjoining plants of the same or closely related species through crop to crop, crop to-weedy, and crop to-wild [40]. Scientists expressed few concerns that the transfer of genes from GMOs to native species could produce herbicide tolerant super weeds [41] which could pollute nearby traditional crops, or could interrupt the ecosystem [42] [43] Hence, the major concern is that if the GMOs have a considerable survival capacity and can increase in frequency and continue in natural populations. A study by Chilcutt and Tabashnik [44] reported that pollen mediated gene flow from Bt maize caused low to moderate Bt toxin levels in kernels of non-Bt maize refuge plants up to 31 m. Watrud LS, et al, [45] documented gene flow from creeping bentgrass (*Agrostis stolonifera* L.), to within a relatives of the same genus (*Agrostis*) as well as in native grasses.

Daniels, R et al [46] reported the first evidence of horizontal gene transfer (HGT) of pesticide resistance to weeds. They found an escape of transgene from GMOs to one or more interrelated wild crucifer species. However, the incidence of HGT from GM crops to other organisms is negligible hence GMOs poses no risks to human health or the environment [47].

A report of 2001 by Quist, D. and Chapela, I.H. [48] confirmed the presence of transgenic DNA in native maize grown in remote mountains in Oaxaca, Mexico. However their report has been dishonored on methodological grounds and described it as a manipulated data and Nature journal denied to publish [21] [49]. Ortiz-García, S.,et al, [50] performed a large scale systematic survey of 870 maize plants in 125 fields and 18 localities in the state of Oaxaca during 2003 and 2004 and found no evidence of gene flow in Oaxaca. However, other investigators confirmed presence of transgenes in non-GM maize varieties in a South Africa [51] in Columbia [52] and in Zambia [53] Sagers, C.L., et al [54] performed hybridization experiments on native canola (*Brassica napus*), transgenic canola, and a sexually compatible weed *B. rapa*, and their hybrids. They noticed that plants carrying the transgene were larger and produced more seeds than non-transgenic plants. Pollen mediated gene flow from transgenic canola to *B. rapa* was not significant. A recent study by Hu, J et al [55] indicate that pollen and seed mediated gene flow from the *Bt* poplar plantation was extremely low under natural conditions.

Conclusions: We conclude that while existing procedures are not entirely sufficient for accurate and exhaustive risk assessment, there exists a substantial knowledge base and expertise within the existing aquaculture, fermentation and (algal) biotechnology industries that can be combined and applied to ensure safe use in the future.

Even if gene flow exists, it can be solved by using genetic use restriction technology (GURT), or Terminator technology [56], [57], [58]. Further, using of sterile seeds can prevent the escape of GM traits.
We conclude that the risks of GMOs to environmental and human health are negligible. *The probable published harmful health effects of GM crops are very small and most of the concerns stated can also applied to traditional crops with equal strength. On the other hand, safety concerns cannot be ignored completely on the basis of current available information.* The new GE technology must be inspected for promising benefits and risks to human health and the environment. We also feel that there is no strong evidence to prove that GM foods are unsafe however we support and recommend for further research and observation to provide realistic evidence of safety and benefit. The present outcome of this review will provide upcoming researchers with updated information to design more vigorous experiments and will inform the decisions of different stakeholders regarding the safety of transgenic insecticidal crops.

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