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ENVIRONMENTAL SAFETY ISSUES ASSOCIATED WITH THE USE OF MODERN AGRICULTURAL BIOTECHNOLOGIES

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Background

Biotechnology can be defined as any technological application that uses biological systems, living organisms or their derivatives to make or modify products or processes for specific use (UN Convention on Biological Diversity). Biotechnology is applied in medicine, industrial procedures, environment and agriculture. Agricultural biotechnology is a collection of techniques used to improve crops, animals and microorganisms and is classified as traditional or modern. Traditional agricultural biotechnology involves the domestication of plants and animals for crop propagation and animal breeding. This is limited to one species or a few related species. On the other hand, modern biotechnology breaks the breeding barriers between species using genetic engineering to manually add traits into desired species. For example, bacterial wilt disease resistance gene has been moved from sweet pepper to banana. Other traits developed as a result of modern biotechnology include; drought, disease and weed resistance, ability to produce toxins for defence against pests and improved nutrient value.

We should know that the natural environment provides the core resources for agriculture and influences its overall productivity, while the agricultural systems in turn, impart a significant footprint on the environment through deforestation, soil degradation, water consumption, pesticide use and emission of greenhouse gases. Modern biotechnology uses non-traditional scientific means hence the need for a good management framework or system to maintain environmental safety. Environmental safety means maintenance of biodiversity, soil properties, a clean functional eco-system and health of organisms and people. This brief highlights the environmental safety aspects most threatened by modern agricultural technologies especially those involving genetically modified (GM) crops.

Highlights of environmental safety concerns

Potential to create new weeds through crossing with wild relatives

Horizontal gene transfer

Loss of genetic diversity

Development of pesticide/herbicide resistance

Impacts on agricultural practices and agro-ecosystems

Potential to create new weeds through crossing with wild relatives: 'Transfer' of genes from transgenic plants like herbicide resistant crops (e.g. 'roundup ready' soybean) to the wild or semi-domesticated relatives can lead to creation of 'super weeds'. There is also a potential for herbicide resistant varieties to become serious weeds in other crops. This may result into an increased amount of herbicides applied per hectare of land. However, current research shows that hybridization between GM crops and their compatible relatives does not have serious environmental consequences.

Horizontal gene transfer: Horizontal gene transfer is defined as the stable transfer of genetic material from one organism to another without reproduction or human intervention. This phenomenon is considered a significant source of genome variation. This issue has received a considerable attention from numerous expert panels such as National Agricultural Research Organisation (NARO), World Health Organization, Food and Agriculture Organisation (FAO), Organization for Economic Cooperation and Development (OECD), European Food Safety Authority (EFSA), and United States Department of Agriculture (USDA). Based on scientific evidence, they report that horizontal gene transfer from GM plants to other organisms is, at most, an extremely rare phenomenon and to date no environmental harm has been reported from it.



Loss of genetic diversity: The most often expressed concern relates to sexual hybridization between the transgenic crop and its relatives, and that the levels of biodiversity will be reduced from that interaction or even go extinct. However, in reality most crop progenitors are dispersed over a wide geographical range and their numbers are large, so the likelihood of their species extinction is minimal. Also in many cases, it is difficult to find single centres of crop diversity. Some crops like wheat, sorghum, barley, pearl millet, peas, lentil, flax, maize and lima beans have multiple centres of crop diversity. Some have no discernible centres of diversity at all (e.g. sorghum, pearl millet and bottle gourd). Paradoxically, hybridization between crops and wild species could actually result in high levels of genetic diversity in the wild relatives as the genes of the wild species and the crop are blended together. As a new taxon evolves, many alleles will be lost, but the hybrid population is likely to carry high levels of diversity for many generations.

Effect on Non-target organisms: These include pollinators, non-target herbivores, soil organisms and species which contribute to local biodiversity. The effects of GM crops to non-target organisms can be direct or indirect; direct effects are due to toxicity through ingestion by the non-target organism of a toxin produced by GM crops. Indirect effects occur via multi-trophic food chains, involving organisms not directly consuming the GM crop but feeding on other insects associated with the transgenic crop. In a consensus document on 'safety information on transgenic plants expressing Bt (*Bacillus thuriengiesis*) derived insect control protein' revealed that a few non-target organisms are negatively impacted by exposure to Bt proteins. For example poultry was not affected by feeding it on Bt maize, soil microbial organisms in Bt maize fields were negatively affected, as well as honey bee larvae and adults fed on pollen containing the Bt proteins. It is also worth noting that Bt substances have been safely used in organic farming since 1924 as a bio pesticide.

Development of pesticide/herbicide resistance: Insects or weeds exposed to insect tolerant or herbicide tolerant GM crops could evolve resistance, similar to how they develop resistance to synthetic insecticides or herbicides. This could result in increased reliance on other toxic insecticides or herbicides, or a return to prior pesticides or pest control strategies to manage target pests. The same strategies in place for pest resistance management in conventional agriculture, apply to biotech crops in order to delay or completely stop the occurrence of resistance.

Impacts on agricultural practices and agro-ecosystems: As is the case with the introduction of any new variety, deployment of GM crops may impact agricultural practices such as intercropping and mixed cropping. In addition, some think that because of superiority of GM crops, there may be a reduction in cultivation of landraces (local crop varieties). However, in reality, farmers have long been accumulating knowledge and experiences that allow them to successfully keep land race purity even while cultivating modern and improved varieties. Besides, national bodies such as NARO always keep a gene bank of threatened landraces. The same strategies will apply to cultivation of GM crops. It is also worth noting that landraces themselves, are evolving entities and not static standalone materials, farmers often share their best types and even interbreed them. Another fear is, since GM crops are developed for controlling specific major pests, secondary and minor pests can become a problem if the primary pests are removed from the cropping system. Use of integrated pest management and crop management approaches should be emphasized to address some of these agro ecological impacts, the same way it is done for conventionally bred crops.

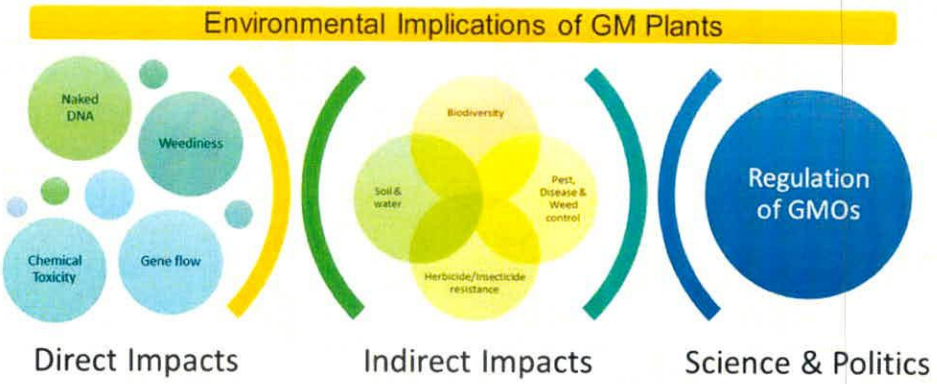


Figure 1 Source: Tsatsakis et al. 2017 https://doi.org/10.1016/j.envres.2017.03.011

As a result of the above concerns and controversies about commercially available crops made by using modern agricultural biotechnology, such crops have been subjected to stringent testing and regulations than any other agricultural product. This makes these

foods safer than traditional foods. Besides, modern agricultural biotechnology has offered remedy to environmental safety threats including phytoremediation (the use of green plants/microorganisms to remove pollutants from the environment). Also, research has been done on e.g. sorghum and wheat to get crops that can grow on marginal lands such as highly acidic soils hence increasing plant populations — and this is beneficial to the environment. It should also be noted that the higher yields obtained from GM crops could actually reduce the conversion of rich forests into farm lands and there by protect biodiversity. Also the specificity of certain GM proteins such as Bt has reduced the use of harsher pesticides that are toxic to more organisms. In fact, earth worms, bees and beetles have been found more abundant in Bt cotton fields than in conventional sprayed fields.

Recommendations

Uganda and the world is hindered from pursuing the promise of modern agricultural biotechnology by fear of the unknown! In Africa, commercial GM crop growing is currently legal in only Egypt, Sudan, and South Africa. Scientists cannot foresee all the potential mishaps and 'non-scientists' are scared of the dangers that may arise. Environmental safety issues are not unique to GM crops, thus these issues can potentially be addressed. In order to address safety issues, functional regulatory systems must be in place, with the competencies required to properly conduct an environmental risk assessment (Figure beside) and effectively manage any associated risks. The government of Uganda should therefore, aim at passing the Genetic Engineering Regulatory Bill and having stronger laws for environmental safety.

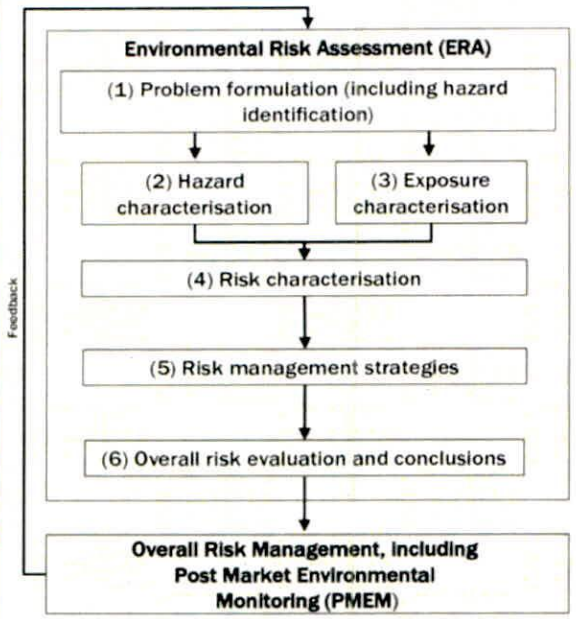


Figure 2 Source: EU Directive 2001/18/EC and Regulation (EC) No. 1829/2003

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