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Review Paper

Ecological Impact of Genetically Modified Crops

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Abstract

Despite the potential benefits of transgenic crops, they are also concerned regarding the possible environmental and agronomic impacts. The biosafety implications of the field release of transgenic crops have attracted global attention also.Research for analyzing the short and long term effects of transgenic crops on the environment is one of the major challenges for its safe release in developing countries which are rich sources of genetic biodiversity. Horizontal transfer of genes between soils microorganisms may be facilitated by vector DNA from genetically engineered plants resulting in disturbances in the functioning of organism that affects the soil ecology and fertility. There is a need of in depth study to address the effect of transgenic plant on non-target animals, plants and other organisms. Considering the potential impact of transgenic crops on genetic diversity, pragmatic decisions should be taken by the policy-makers not to release these crops into centers of origin, delicate ecological zones and the pockets rich in biodiversity. Therefore, the challenge will be to use scientific tools and knowledge to attempt to predict problems and solve them before they happen.

Keywords: Genetically modified crops, biodiversity, agriculture, non-target organisms.

Introduction

Advances in technologies enabling transfer of foreign gene in plants have overcome several barriers to crop improvement. These technologies offer immense benefits in terms of increased yield, better quality and resistance to biotic and abiotic factors. The transgenic crops can minimize crop damage through disease and pest-resistant varieties, reduce the use of chemicals and enhance stress tolerance in crops, thereby permitting economically productive farming on hitherto unproductive lands. Over the last two decades, transgenic plants were widely used in basics and applied studies. The first genetically engineered crop released in 1994 for commercial production was the *FlavrSavr* tomato in United States. Thereafter adoption of GM crops has been at very fast pace. The global area under transgenic crops has continued to grow over the last eight years, reaching 81 million hectares (m ha) in 2004, which represents a 47-fold increase from 1.7 m ha in 1996. Thus potential of this technology for enhancing crop productivity has been accepted worldwide[1].

Despite the potential benefits of transgenic crops, there are also concerns regarding the possible environmental and agronomic impacts if the transgenes escape and get established in natural or agricultural ecosystems. From an agronomic point of view, the transfer of novel genes from one crop to another may have many implications, including depletion in the quality of seeds leading to a change in their performance and marketability. Concerns over the ecological impacts of transgenic crops largely depend upon whether or not a crop has wild relatives and the ability to cross pollinate them. If crops hybridize with wild relatives and gene introgression occurs, wild populations could incorporate transgenes that change their behavior and they could present a serious threat as weeds or competitors in natural communities[1].

Risk assessment protocols of transgenic crops have largely been based on assumptions that genetic modifications of plants will not alter their behavior, or that of other organisms in the natural environment. These assumptions are made from limited information on the level of gene flow occurring between crops and wild species, and small scale experiments with transgenic plants and untransformed plants. However, there is a need to study the impact of transgenic crops on the environment on a long term basis. In addition, strategies have to be devised for minimizing crop to crop gene flow and environmental exposure to transgenes by developing transgenic plants, which can address biosafety concerns in proper perspective. This can be achieved by avoiding or minimizing cross pollination, avoiding antibiotic markers or switching on the expression of inserted genes only in the specific tissues and at specific developmental stages.

The biosafety implications of the field release of transgenic plants have attracted global attention. The potential environmental impacts of any transgenic crop will vary depending on the crop's characteristics, the ecological system where it is being grown, its management and the regulatory mechanism. In the initial years of transgenic technology a major role was played by molecular biologists which were soon transcended to the ecologists and environmentalists to address the perceived ecological risks. Research for analyzing the short and long term effects of transgenic crops on the environment is one of the major challenges for its safe release in the developing countries which are rich sources of genetic biodiversity. The field trials of transgenic crops occurred with a rapid pace not permitting to generate essential baseline ecological data. So far, the monitoring data on the perceived environmental effects of transgenics is very limited.

Risk to Environment

Although there are serious considerations about the environmental effects of transgenic crops, the knowledge on this area is still not enough. The knowledge on potentially significant environmental effects of transgenic crops raises three risks: First, there may be serious environmental damage from accumulating pressures that trigger threshold effects, such as depleting populations of certain non-target organisms. Second, without improved monitoring and science, the potential environmental benefits of some transgenic plants may be underestimated, making the technology vulnerable to inappropriate restrictions. Third, the long-term potential of transgenic crops or alternative agricultural technologies to reduce or solve genuine environmental problems will not be fully exploited[2].

According to NRC (2002) transgenic crops do not present new categories of environmental risks compared to conventional methods of crop improvement, but specific traits introduced by either approach can pose unique risks. The nature of the risks vary depending on the transgenic crops characteristics, the ecological system in which it is grown, the skill with which it is managed, and the private and public rules governing its application[2]. There is ample evidence that transgenic crops and their genes, through pollen dispersal, can spread[3] even between species that are mainly in breeders[4]. The effects of such "genetic pollution" on the environment are still uncertain[5] but the certain thing is the most probable dangerous effects of this new intense pollution on the complex ecological balances. Although there is some concern that transgenic crops themselves might become weeds, a major ecological risk is that large scale releases of transgenic crops may promote transfer of transgenes from crops to other plants, which may than become weeds[6].

Evidence indicates that such genetic exchanges among wild, weed and crop plants already occur. The incidence of shattercane (*Sorghumbicolor*), a weedy relative of *sorghum* and the gene flows between maize and teosinte demonstrates the potential for crop relatives to become serious weeds[7]. In this respect the most important thing is the potential transfer of genes from herbicide-resistant crops (HRCs) to wild or semi-domesticated relatives thus creating "superweeds". In actuality the use of herbicide-resistant transgenic crops is likely to increase herbicide use as well as production costs. It is also likely to cause serious environmental problems[7]. Total weed removal via the use of broad-spectrum herbicides may lead to undesirable ecological impacts, given that an acceptable level of weed diversity in and around crop fields has been documented to play important ecological roles such as enhancement of biological insect pest control, better soil cover reducing erosion[8].

HRCs, through increased herbicide effectiveness, could further reduce plant diversity, causing shifts in weed community composition and abundance, favoring competitive species that adapt to these broad-spectrum, post emergence treatments[9]. Also some types of herbicides, for example glyphosate, has been reported to be toxic to some non target species in the soil- both to beneficial predators such as spiders, mites, carabid and coccinellid beetles and to detrivores such as earthworms, as well as to aquatic organisms, including fish[10]. At this point, it is very important to notice that at least 27 corporations have initiated herbicide-tolerant plant research, including the world's 8 largest pesticide companies Bayer, Novartis, Zeneca, Rhone-Poulenc, Dow/Elanco, Monsanto, Hoescht and DuPont, and virtually all seed companies, many of which have been acquired by chemical companies[11].

An additional area where serious considerations are relevant to a discussion of transgenic crops is that of genetic diversity and its possible erosion. Some argue that development of transgenic crops will enhance biodiversity by creating an increased need for exotic genes. On the contrary, it is obvious that transgenic crops promote monoculture for the reason of uniformity. Although a certain degree of crop uniformity may have certain economic advantages, it has two ecological drawbacks: First, history has shown that a huge area planted to a single cultivar is very vulnerable to a new, matching strain of a pathogen or pest. And, second, the widespread use of a single cultivar leads to a loss of genetic diversity[12]. Evidence from the Green Revolution leaves no doubt that the spread of modern transgenic varieties has been an important cause of genetic erosion[13].

Pest and disease resistance is a further area of transgenic crops that has to be considered carefully. The microbial insecticides most widely used since the 1960s are preparations of the bacterium *Bacillus thuringiensis* (Bt). The best known types of these insecticides are pathogenic and toxic only to larvae of the butterflies and moths (Lepidoptera). The promise of transgenic plants containing Bt genes is the replacement of synthetic insecticides now used to control insect pests[7]. Since most crops have a diversity of insect pests, insecticides will still have to be applied to control pests other than Lepidoptera not susceptible to the endotoxin expressed by the crop[14]. On the other hand, several Lepidoptera species have been reported to develop resistance to Bt toxin in both field and laboratory tests, suggesting that major resistance problems are likely to develop in Bt crops which through the continuous expression of the toxin create a strong selection pressure[15]. Given that a diversity of different Bt-toxin genes have been isolated, biotechnologists argue that if resistance develops alternative forms of Bt toxin can be used[16]. However, because insects are likely to develop multiple resistance or cross-resistance, such a strategy is also doomed to fail[17].

Impact on Non-Target Organisms

By keeping pest population at extremely low levels, Bt crops can starve natural enemies as these beneficial insects need a small amount of prey to survive in the agro-ecosystem. Parasites would be the most affected because they are dependent on live hosts for survival and development, whereas some predators thrive on dead or dying prey. Evidence from studies suggests that aphids were capable of sequestering the toxin from Bt crops and transferring it to its coccinellid predators, thus, in turn affecting reproduction and longevity of the beneficial beetles. The potential of Bt toxins moving through food chains poses serious implications for natural bio control in agro-ecosystems[18]. Bt toxins can be incorporated into the soil through leaf materials, where they may persist for 2-3 months, resisting degradation by binding to soy clay particles while maintaining toxin activity[19]. Such Bt toxins that end up in the soil and water from transgenic leaf litter may have negative impacts on soil and aquatic invertebrates and nutrient cycling process[20].

Pest resistant crops may produce toxin which will be harmful to non-target organisms including animals, plants, and microorganisms. Insect predators, soil biota and wildlife such as birds and invertebrates may also be affected. Laboratory research confirms that transgenic crops with insect resistance may have negative impact on beneficial insect predators including lacewings[21], ladybird beetles[18], monarch butterfly larvae[22], and soil biota[23].

The laboratory studies reported 44% mortality in monarch butterfly larvae fed on milkweed leaves dusted with Bt corn pollen, whereas mortality was nil in the case of larvae fed on leaves with non-Bt corn pollen. The results are still difficult to interpret to assess the degree of risk posed to monarch butterfly population in field conditions as the reported work was based on laboratory environment only[22]. It is reported higher rates of mortality in the monarch butterfly larvae feeding on milkweed leaves naturally dusted with pollen from Bt corn plants[24, 25]. Another study reported that a common type of Bt corn had no deleterious effect on black swallowtail butterflies. Studies on the effect of different types of Bt corn on different species of butterfly were also carried out in laboratory and field studies. These reports indicate the need to have more in depth research in this area both in laboratory and field conditions[10].

Conclusion

A major environmental consequence resulting from the massive use of Bt toxin in cotton or other crops occupying a larger area of the agricultural landscape, is that neighboring farmers who grow crops other than cotton, but sharing similar pest complexes, may end up with resistant insect populations colonizing their fields. This is because the lepidopteran pests that develop resistance to Bt cotton, move to adjacent fields where farmers use Bt as a microbial insecticide[14]. So emphasis has to be laid on studying the impact of transgenic crops on birds, mammals and soil biota. To study the impact of these crops on soil biota (bacteria and fungi etc.) is one of the important component of evaluation and risk assessment. As per the reports available so far, Bt crops may have adverse impact on soil-borne organisms and research in this area needs to be intensified.

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