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The necessity of transgenic technology in sustainable production

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Abstract

It has been more than half a century that plant geneticists and breeders have been trying to assemble a combination of genes in crop plants, in order to make them as suitable and productive as possible. Plant transformation technology in crop plants was first undertakenin the 1980s based on the ability of foreign gene integration into host plant genome and regeneration of transformed plant cells into whole plants. Soon after, transgenic plants were to be grown by farmers. Statistics show that farmers have started to cultivate genetically modified plants (GMPs) commercially since 1996. Between 1996 and 2012, the total surface area of land cultivated with GM crops has increased from 2 million hectares to more than 170 million hectares in 29 countries. To this extent, some concerns have been raised by ecologists and consumer organizations in West European countries based on the possibilities of horizontal and vertical gene flow of antibiotic or herbicide resistance from transgenic plants into human intestinal bacteria and some weeds via outcrossing, respectively. Due to consumer and ecologist concerns, different approaches have been developed to eliminate marker (and/or reporter) genes from the nuclear or chloroplast genome after selection. Some of these proposed methods are:
1. Replacing selectable markers with screenable ones.
2. Elimination of marker genes by co-transformartion followed by classic recombination and selection.
3. Excision of marker gene by some site-specific recombinases.
4. Separation of the transgene and selectable marker by transposable elements.
5. Avoiding gene pollution by chloroplasts genetic engineering followed by elimination of selectable marker.

Keywords: Gene flow; Sustainable production; Transformation; Transgene

1. Introduction and context

Sustainable production is now globally accepted but strongly needs to meet diverse parameters based on country-based facilities and agricultural systems. Nowadays, it has generally been proven that access to health and environmental indices is not simply reachable unless to follow alternative policies and routes. The biosphere is under unwanted forces and pressure due to uncontrolled human activities from developed and developing countries. Mono cropping cultivation system in the past century caused major pollution in soil, water and foods by agrichemicals. Although detoxification of these vital sources and industrially polluted atmosphere seems to be a major issue but there are still some opportunities to produce healthy food using modern technologies. These methods involve technologies of genetically modified organisms which are addressed in a cost effective and most importantly, eco-friendly manner. Diverse aspects and goals could be targeted in this context by integrating clean and green cis/transgenic technologies against problems. Unfortunately, some public opinions have got a narrow digestion of sustainability just in the form of classic production systems. The

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primary calculation of input and output of these systems shows that they could be adapted in small scale only and never useable on millions of hectares which are the main source of food and feed. It is well known that our lands and waters are already polluted with agrochemicals and need to be cleaned and detoxified. Although the first and second generations of transgenic plants could be produced without pesticides plus minimum amounts of herbicides, it is clear, reasonable and accepted that more progress and improvements still need to be committed to solve existing shortages and biosafety concerns as well. However, statistics show that farmers have started to cultivate genetically modified plants (GMPs) commercially since 1996. Between 1996 and 2012, the total surface area of lands cultivated with GM crops has increased from about 2 million hectares to more than 170 million hectares in 29 countries. Therefore more than 10% of the world's arable lands are cultivated with transgenic crops (1). To this extent, some concerns were raised by ecologists and consumer organizations in West European countries based on the possibilities of horizontal and vertical gene flow of antibiotic or herbicide resistance from transgenic plants into human intestinal bacteria and some weeds (via outcrossing), respectively. Although there is no evidence supporting these concerns so far, but the elimination of resistance genes from transgenic plants and management of isolation parameters could help to label the marketing of GM products (2,9). Despite the current uncertainty over GM crops, one thing remains clear, which is that this technology with its potential to create economically important crop varieties is simply too valuable to ignore. There are, however, some valid concerns. If these issues are to be resolved, decisions must be based on credible, science-based information (8). In addition, apart from any politics and conspiracy, to avoid any less developed ideas and useless challenges, it seems that a worldwide policy needs to be developed for defining modern sustainable systems. Usually, controversies that appear on a network have a negative charge to reach a stable and long life protocol. It has certainly be proven that the relationship between organisms in a sustainable biological/material/energetic cycling system must be considered rationally to save and oxygenize the biosphere.

Areas to be integrated for sustainable production systems

Today, different areas and objects that have emerged from transgenic technologies need to be considered and integrated in sustainable production systems. These include:

1. Bt Insect Resistant Technology
2. Herbicide Tolerance Technology (Glyphosate and Glufosinate)
3. Contribution of GM Technology to the Livestock Sector
4. Delayed Ripening Technology
5. Tissue Culture Technology
6. Molecular Breeding and Marker-Assisted Selection
7. Microbial Fermentation
8. Plant Disease Diagnostics
9. Bioinformatics
10. Green Energy: Biofuels
11. Plants for Bioremediation
12. Molecular Pharming and Biopharmaceuticals
13. Biofortification
14. Biotechnology for Salinity in Problem Soils
15. Biotechnology for the Development of Drought Tolerant Crops
16. Marker-Free GM Plants
17. Biotechnology for Biodiversity
18. Nitrogen Use Efficient Biotech Crops
19. …..

Status of crop biotechnology and challenges ahead

Table 1 shows the pioneer countries in cultivation and cultivated GM crops (1). According to the above mentioned concerns, much of the GM crops grown in recent years are used for livestock feed (and non-human food), thus increased demand for meat will lead to increased demand for GM crops with which to feed livestock. Feed grain usage as a percentage of total crop production was 70% for corn and more than 90% for oil seed meals such as soybeans: about 70 million tons in 2010 (12). The end product of commercial grain from biotech maize, soybean grain and cotton was valued at approximately 160 billion US$ in 2011.

Table 1. Seven high ranked countries in GM crop cultivation in 2012 (1)

Country	Million hectares	Crops
USA	69.5	maize, soybean, cotton, sugar beet
Brazil	36.6	soybean, maize, cotton
Argentina	23.9	soybean, maize, cotton
Canada	11.6	canola, maize, soybean, sugar beet
India	10.8	cotton
China	4	cotton, papaya, tomato

Park and his colleagues in their review article argue that transgenic crops being grown in many parts of the world are either herbicide tolerant (HT) or insect resistant (Bt), although a number of novel transgenic crops for nutritional benefits, drought tolerant and higher yielding are under production (10).

In any biotechnological product, the three pillars of sustainability, i.e., economic, environmental and social factors have to be considered. From the economic dimension there are benefits on input savings and increase in crop yields and quality (10). The environmental dimension is quite important for sustainability, and transgenic crops have positive impacts on soil erosion, desertification, climate change and water quality due to lower levels of cultivation, lower levels of pesticide and herbicide use, and also less movement into ground water. The reduction of field operation can also lead to reduction in greenhouse gases (GHGs) emission and lower fuel requirements for machinery operations (10). Transgenic crops have health benefits too, as farmers use and handle less toxic pesticides. Increased income in developing countries leads to increased benefits in relation to nutrition, health and education (10).

Garcia and Altieri summarized the potential benefits of Bt and HT GM crops as: reduced pesticide and herbicide use, reduction of farming practices and more efficient short-term production. The potential impacts are monoculture paradigm, biodiversity reduction and increasing vulnerability of crops to environmental changes, new pests and diseases (5).

There is no evidence showing that transgenic markers used so far pose a health risk to humans or domestic animals. However, the risk of "vertical cross-species" can not be ruled out (3).

In a review paper, Tuteja and co-workers state that transgenes integrate at random positions in the genome of target species leading to possible unwanted side effects such as mutation and unpredictable expression patterns. Therefore, techniques for the removal of selection markers and the directed integration of transgenes at safe locations in the genome is desirable to biotech companies; although, at present there is no commercialization of marker free transgenic crops (13).

In general, there are two strategies to fight transgenic risks. One way is the use of markers not based on antibiotic or herbicide resistant genes, and the other is to excise or segregate marker genes from the host genome after regeneration of transgenic plants which include co-transformation (i.e., separate transformation of marker and transgene), recombinase-mediated marker deletion, transposon-based expelling systems, and transformation by marker genes are not based on herbicide or antibiotic selection (3, 7, 11).

Day and Goldschmidt-Clermont reviewed chloroplast transformation and argued that plastid transformation has several advantages over transformation of nuclear genome. One advantage is that plastid transgene expression can be very high and the desired recombinant protein may represent up to 70% of leaf protein. Another advantage is that the integration of transgene proceeds by homologous recombination and is therefore precise and predictable. There are also good selectable markers for plastid transformation such as aadA dominant gene that confers resistance to spectinomycin and streptomycin (4). They state that there are several strategies to isolate transgenic chloroplasts without foreign marker genes. Some of these are marker excision occur through homologous recombination, excision of marker genes by cite-specific recombinases, isolation of aadA-free plastid genomes using co-transformation and segregation, and isolation of marker-free plants using co-integration of the marker gene (4).

Status of agricultural biotechnology in Iran

Research areas of agricultural biotechnology in Iran are: crop biotech, horticultural biotech, soil biotechnology, food science biotech, plant breeding and genetic engineering, and biotechnology in animal and veterinary sciences. Altogether, 42 universities confer MS degrees and

9 presenting Ph.D. degrees in these fields of study in Iran. The number of graduated students from 2005 to 2009 were 637 with MS degree and 102 with Ph.D. degree. The number of students in 2010 were 1085 for MS and 177 for Ph.D. degrees. Since 2010, the number of graduated and graduate students have been on an increase in recent years. The number of specialists working in universities and research centers (public sector) with MS and Ph.D. degrees were 114 and 263 respectively, in 2010. The respective numbers of specialists in the private sector that same year were 19 and 16. The country's need for Ph.D. specialists have been estimated to be 375 for the Fifth Plan (2011 to 2015) and 417 for the Sixth Plan (2015-2020), in Iran (14).

The use of biotechnology and genetic engineering in plant breeding is quite active in Iranian universities and research institutes. However, no GM crop is grown in Iran due to environmental regulations, although Bt rice was temporarily commercialized in 2005 (6).

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