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# Biosafety management for designer crop production

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**Introduction:**

With the ever-increasing threat of global population, there has been an urgent need for enhancement of productivity in crop plants by infusion of new genetic variability and improvement of the nutritional and industrial utility of the crop species. Effective utilization of genetic diversity remains a pivotal factor in designing crop varieties with better agronomic attributes and adaptability to challenging environmental conditions. Biotechnology is emerging as one of the most innovative tool in life sciences and is influencing almost every aspect of human life. The feasibility of mobilizing and expressing foreign genes into plants has opened up a new era of genetically engineered (transgenic) crops. With limited natural resources available to improve agricultural production, genetically engineered crops provide a promising alternative for improving and enhancing crop productivity. Last few years have witnessed a remarkable progress in the production and cultivation of transgenic crops.

Organisms whose genomes have been altered by the insertion of a foreign gene or genes from another species or unrelated organism are known as **transgenics** or genetically engineered organisms (GEOs). They have detectable fragments of expected size and acceptable values of foreign/ transgene protein. They carry the transgene which when integrated and expressed stably and properly, confers either a new trait to the organism or enhances or suppresses an already existing trait. Intensive research over the past few decades has resulted in the development of effective gene transfer procedures with subsequent recovery of genetically modified plants. Today's commercialized transgenic plants have been produced using Agrobacterium-mediated transformation or gene gun-mediated transformation/ microprojectile bombardment. Novel techniques allow precise manipulation of transgene incorporation and can help to secure stable expression of the transgenics in a wide range of environmental conditions (Tsaftaris, *et al.*, 2000)

Insertion of foreign gene into plants has made them capable of defending against

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natural stresses (biotic and abiotic) with enhanced survival, persistence and competitive capabilities, producing biofuels, vaccines and antibodies and better quality products and novel compounds of commercial value and improving the nutritional quality of food products. To date, various transgenes have been successfully introduced into the nuclear genomes of various plant species. Major crops where transgenics are commercially available include rice, soybean, maize, cotton, canola, potato, cassava, squash, papaya, groundnut, oilseeds and various vegetables and fruits (Asif et al., 2011; Chakraborty et al., 2010; Hutchison et al., 2010). Significant improvements in the commercially available crops including herbicide resistance, insect and virus resistance and nutritional quality enhancement have been achieved (Table 1). The role of genetic engineering in generating transgenic lines/cultivars of different crops with improved nutritional quality, biofuel production, enhanced production of vaccines and antibodies, herbicides, and increased resistance to biotic and abiotic stresses has also received attention (Ahmad et al., 2012). The world's leading producers of transgenic crops are USA, Brazil, Argentina, India, China, Paraguay and South Africa.

**Biosafety:**

The safe application of biotechnology in agriculture for minimizing risks to the environment and human health from the handling and transfer of transgenics is termed as biosafety.

**Table 1**
Commercialized transgenic food crops and the significant improvements achieved.

| Transgenic crops | Significant improvements |
|---|---|
| Corn, soybean, rice, corn and sugar beet | Herbicide resistance |
| Corn, rice, tomato and potato | Insect Pest resistance |
| Papaya, squash and potato | Virus resistance |
| Tomato and melon | Delayed ripening, increased shelf-life |
| Canola and soybean | Improved oil quality |
| Canola and corn | Male sterility |

Biosafety has similarly been defined as "the avoidance of risk to human health and safety, and to the conservation of the environment, as a result of the use for research and commerce of infectious or genetically modified organisms"

**Biosafety concerns:**

- **Risks for animal and human health:** toxicity &food/feed quality/safety; allergies; pathogen drug resistance
- **Risks for the environment:** gene flow; invasiveness of GMOs might become predominant; susceptibility of non-target organisms, changes to biodiversity.
- **Horizontal gene transfer:** genetic pollution through pollen or seed dispersal & transfer of foreign gene to micro-organisms (DNA uptake) or generation of new live viruses by recombination (transcapsidation, complementation, etc.)

**Biosafety issues in transgenic crops:**

**Main Concerns:-**

- Development of **aggressive weeds**/ wild relatives by transfer of transgenic traits
- **Erosion of land races**/wild relatives by genetic pollution in centres of origin/ diversity
- Harm to the **non-target organisms**
- Development of **pest resistance** by prolonged use
- **Monoculture** and limitations to farmers's choice in crop management
- Hazard to human and animal health by transfer of **toxins and allergens** and by creation of new toxins and allergenic compounds

**Concerns Associated with Transgenic crops**

- **Human health risks:**
  i. Risk of possible allergies
  ii. Extensive testing required.
  iii. Labeling of GM food required.
  iv. Fear of danger to human health from foreign gene.
- **Environmental risks:**
  i. Unintended harm to other organisms
  ii. Pests develop resistance to transgenics.
  iii. Gene transfer to non-target species.

**Food safety:**

Food biosafety research focuses on the assessment of novel foods produced from transgenic crops which is performed by comparing them with the conventional analog with an established history of safe use in a study called substantial equivalence, which is done through evaluation of agronomic, morphological and chemical composition, including macro and micro-nutrients, toxins, and potential changes in the levels of endogenous plant constituents (comparative compositional analysis), allowing the identification of differences between transgenic crops and conventional analogs (Carli et al., 2009; Ridley et al., 2004). The transgenic-derived food should be "substantially equivalent" to its natural counterpart.

- The potential hazards of transgenics to human and animal health may be associated with toxicity, allergenicity, intolerance, nutritional quality and microbiological safety of the food, and the possible side effects due to disruption of the metabolic pathways (Costa et al., 2011). There are various assertions that transgenic maize expressing PATprotein, potato expressing the snowdrop lectin gene, Monsanto's transgenic soya; and the Flavr Savr tomatoes also pose unacceptable health risks but they have not yet been scientifically proved (Pusztai, 2001).

- Recently, a new MS-based technology, 'Foodomics' has been introduced which includes the genomic, transcriptomic, proteomic, and metabolomic studies of transgenic-derived foods for compound profiling, authenticity, and/or biomarker-detection related to food quality or safety; the development of new transgenic foods, food contaminants, and whole toxicity studies; and new investigations on food bioactivity, and food effects on human health

**Environment safety:**

- Ecological biosafety research has identified potential risks associated with certain crop/transgene combinations, such as intra- and interspecific transgene flow, persistence and the consequences of transgenes in unintended hosts.

- Concerns have been raised that transgenic crops themselves could become weeds and invade agricultural or natural ecosystems, and the engineered traits could be introduced into nontransgenic counterparts and wild relatives leading to further undesired consequences (Lu, 2008; Raybould and Gray, 1993).

- Concerns have also been raised that the wide spread of transgenic crops could adversely affect the levels of natural diversity and genetic variability through replacement of traditional varieties (land races), hybridizations between transgenic crops and land races or wild relatives and interactions with non-target organisms.

- The widespread cultivation of pest-resistant transgenic crops might lead to resistance developing in the targeted pests (Tabashnik et al., 2008). Glyphosate resistant weeds have also been reported in some countries

- The risks of transgenic crops may be direct/indirect/immediate or delayed (Conner et al., 2003; Hilbeck et al., 2011). 'Direct effects' are primary effects on human health and the environment which are the result of the transgenic crop itself. Direct effects can be due to toxicity through ingestion by the non-target organisms of a toxin produced by the transgenic plant. Indirect effects' occur through a causal chain of events like multitrophic food chains, through mechanisms such as interactions with other organisms, transfer of genetic material, or changes in use or management of the crop. 'Immediate effects' refer to the effects which are observed during the period of the release of the transgenic crops. Delayed effects' may not be observed during the period of the release of the transgenic but

become apparent as a direct or indirect effect either at a later stage or after termination of the release

- Extensive and detailed studies of the long-term effects of the transgenics to the environment in addition to regular glasshouse and field trials are essential for regulatory approval and public acceptance. Transgene confinement and mitigation strategies can provide an effective tool for minimizing any environmental consequences created by transgenics.

**Competent Authorities:** The competent authorities and their composition for dealing with all aspects of GMOs

1. Recombinant DNA Advisory Committee (RDAC)
2. Review Committee on Genetic Manipulation (RCGM)
3. Institutional Biosafety Committee (IBSC)
4. Genetic Engineering Approval Committee (GEAC)
5. State Biotechnology Co-ordination Committee (SBCC)
6. District Level Committee (DLC)

**1. Recombinant DNA Advisory Committee (RDAC)**

**Main functions:**

- ✓ Review developments in Biotechnology at National and International level.
- ✓ Recommend suitable and appropriate safety regulations for India in r-DNA research, use and applications.

**2. Review Committee on Genetic Manipulation**

**Main functions:**

- ✓ To bring out manuals of guidelines specifying procedures for regulatory process on GMOs in research, use and applications including industry with a view to ensure environmental safety.
- ✓ To review all on going r-DNA projects involving high risk category and controlled field experiments.
- ✓ To lay down procedures for restriction or prohibition, production, sale, import & use of GMOs both for research and applications.
- ✓ To authorize imports of GMOs/ transgenes for research purposes.
- ✓ To authorize field experiments in 20 acres in multi-locations in one crop season with up to one acre at one site.

**3. Institutional Bio-Safety Committee (IBSC)**

**Main functions:**

- ✓ To note and to approve r-DNA work.
- ✓ To ensure adherence of r-DNA safety guidelines of government.
- ✓ To prepare emergency plan according to guidelines.

- ✓ To ensure experimentation at designated location, taking into account approved protocols

**4. Genetic Engineering Approval Committee (GEAC)**

**Main functions:**

- ✓ To permit the use of GMOs and products for commercial applications.
- ✓ To adopt procedures for restriction or prohibition, production, sale, import & use of GMOs both for research and applications.
- ✓ To authorize large scale production and release of GMOs and products thereof into the environment.
- ✓ To authorize agencies or persons to have powers to take punitive actions under.

**5. State Biotechnology Co-Ordination Committee (SBCC)**

**Main functions:**

- ✓ Powers to inspect, investigate and to take punitive action in case of violations of statutory provisions through the State Pollution Control Board or the Directorate of Health etc.
- ✓ To review periodically the safety and control measures in various institutions handling GMOs.
- ✓ To act as nodal agency at State level to assess the damage, if any, due to release of GMOs and to take on site control measures.

**6. District Level Committee (DLC)**

**Main functions:**

- ✓ To monitor the safety regulations in installations.
- ✓ Have powers to inspect, investigate and report to the SBCC or the GEAC about compliance or non compliance of r-DNA guidelines or violations under EPA.
- ✓ To act as nodal agency at District level to assess the damage, if any, due to release of GMOs and to take on site control measures.

**Bio-safety and Cartagena Protocol:**

- ➢ The Cartagena Protocol on Bio-safety is the first international regulatory framework for bio-safety, negotiated under the aegis of the Convention on Biological Diversity (CBD).
- ➢ It is a regulatory system for ensuring the safe transfer, handling and use of Living Modified Organisms (LMOs) with a focus on transboundary movement. The Protocol deals primarily with LMOs that are to be intentionally introduced into the environment (such as seeds, trees or fish) and with genetically modified farm commodities (such as corn and grain used for food, animal feed or processing)
- ➢ The Protocol was adopted on 29th January 2000 and entered into force from September 11, 2003.

- India ratified the Protocol on January 23, 2003 and the Ministry of Environment & Forests (MoEF) is the nodal ministry for implementation of Cartagena Protocol.

**Major elements of the protocol:** The various elements of the protocol are:

1. Advance informed Agreement procedure
2. Simplified system for agricultural commodities
3. Risk assessments
4. Risk management and emergency procedures
5. Export documentation
6. Bio-safety clearing House
7. Capacity-building and finance
8. Public awareness and participation
9. Issue of non-parties.

**Nanotechnology and biosafety management:**

- Nanotechnology refers to a new set of technologies that are used to develop nanometer-sized structures and devices with unique, or enhanced properties for commercial application .At the nanometer scale, certain materials exhibit new properties not exhibited at the macro scale.
- Nanotechnology-enabled applications in medical imaging, diagnosis, drug delivery and anticancer therapy offer exciting new possibilities for significantly advancing medical science in the 21st century.
- In 2004, the National Institute for Occupational Safety and Health (NIOSH) established a Nanotechnology Research Center to identify the risk implications of nanotechnology for worker health, and to devise ways to protect workers from any identified adverse health effects from working with nanomaterials
- Effective risk assessment, risk characterization and risk management of nanotechnology requires:
  1) knowing how engineered nanoscale particles (NPs) gain entry into the human body (routes of exposure);
  2) knowing whether engineered NPs can migrate from their point of entry to other locations in the body (translocation);
  3) determining what adverse biologic effects may occur in response to engineered NP exposure (toxicity);
  4) knowing which measurement of exposure and dose correlates best to toxicity (exposure and dose metrics); and
  5) Knowing how to best monitor exposed populations to detect the occurrence of any adverse health effects (health surveillance).
- NIOSH's Approaches to Safe Nanotechnology describes current NIOSH recommendations for control measures to

reduce exposures to nanoscale engineered materials in general occupational setting (NIOSH, 2006).

- In general, control techniques such as source enclosure (isolating the generation source from the worker), and local exhaust ventilation systems are expected to be effective for capturing airborne engineered nanoscale particles based on what is known of nanoscale particle motion and behavior in air.
- Current knowledge also indicates that a well-designed exhaust ventilation system with a high-efficiency particulate air (HEPA) filter should effectively remove NPs.
- Filters are tested using particles that have the lowest probability of being captured, typically around 300 nm in diameter. It is expected that the collection efficiencies for smaller particles should exceed the measured collection efficiency at this particle diameter (Lee & Liu, 1982; Pui & Kim, 2006). Similarly, it is expected that NIOSH certified respirators can provide the expected levels of protection (NIOSH, 2004).

**Xenobiology: A new form of life as the ultimate biosafety tool**

- Synthetic biologists try to engineer useful biological systems that do not exist in nature.
- One of their goals is to design an orthogonal chromosome different from DNA and RNA, termed XNA for xeno nucleic acids. XNA exhibits a variety of structural chemical changes relative to its natural counterparts.
- These changes make this novel information-storing biopolymer ‘‘invisible’’ to natural biological systems.

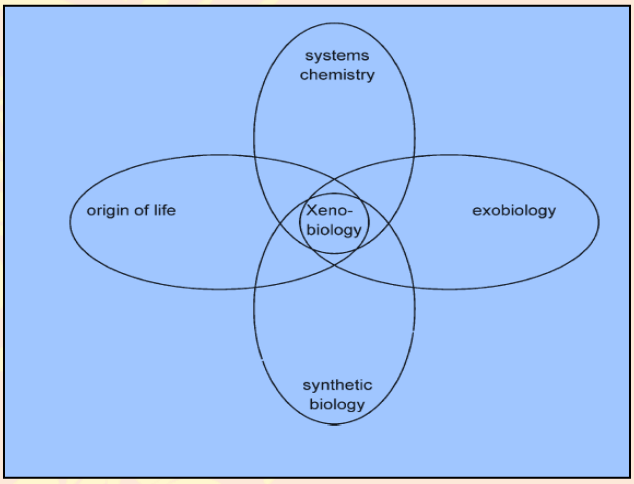


**Fig.1: Diagrammatic display of Xenobiology**.

- The lack of cognition to the natural world, however, is seen as an opportunity to implement a genetic firewall that impedes exchange of genetic information with the natural world, which means it could be the ultimate biosafety tool.

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