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An insight into transgenic crops: assessing risks and benefits

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Abstract

An organism's character is mainly decided by the sequence of nucleotides in deoxyribonucleic acid (DNA). Hence, modifying it, in a way to introduce "target gene of interest" having desirable traits using genetic engineering for betterment of a crop, known as Genetically Modified crops, has been a blessing to the mankind. GM crops came under cultivation during mid-1990s. While many GM crops are widespread around the world for its boon, "Bt cotton" is the only GM crop approved in India for its commercial cultivation since 2002. The bright side of transgenic crops comes with multiple advantages benefiting producers and consumers in many ways, however its dark side possessing potential threat to biodiversity, human, and environmental health, which is a big concern to surmount and must be considered carefully. So, keeping in view "The boon and bane of GM crops", some significant points are henceforth discussed in this article.

Introduction

In the unfolding chain of eras, Nature has always witnessed the evolution of organisms since time immemorial. The blueprint of life functioning within micro miniature to a giant has been well exploited and manipulated skillfully to habilitate in the constant course of evolving changes. Human race, being the cerebral society on earth has not only accomplished in developing many technologies-cum-tools to study the ongoing alterations but also has drawn better and nec-essary benefits from it. Plant Breeding, a revelatory branch under science has played a great role in delving the changes in crop species for creating or developing new varieties from the existing ones with many desirable traits following scientific and practical methods which enabled us to fulfil the need and to feed the expanding population. Coming to methods underway, the conventional approach relies on mixing traits to produce new plant species only on interspecific or inter-varietal level, known as Cis-genic plants. The cons of former method have been successfully solved by a newer, more sophisticated way, known as "Transgenic technology" which inclines on inserting genetic elements and thus making it possible to cross even a bacterium with a plant. It plays arithmetically on the genomic level, it might be addition of a gene for resistance to a specific pest or eliminating the undesirable ones and providing strength to crop from attack by a pathogen, even programming the cell to synthesize particular biochemicals or modifying a gene responsible for prolonging shelf life. As we know the quaternary gene pool (GP-4) does not allow any transfer of DNA between the crop of interest or any other organism by mating or sexual reproduction. Through transgenic technology we can exploit the quaternary gene pool which contains immense source of genetic variations derived from unrelated plants and organisms.

What is Transgenic technology and GM crop?

Plant Genetic Engineering or transgenic technology can be defined as isolation, introduction and expression of foreign DNA in plants to develop 'genetically modified (GM) plants' or 'transgenic

plants' in order to introduce some unique traits, not possible through natural breeding methods. The area under GM crops is on the rise globally and has increased to manifolds from 1.7 million ha in 1996 to 191.7 million ha in 2018. Due to its fastest adoption, it has become mainstay in the history of modern agriculture. Till now, 18 out of 26 countries are considered as biotech mega countries which grew >50,000 ha. Meanwhile in India, the area under Bt cotton has increased from 0.29 lakh ha in 2002-03 to 117.47 lakh ha in 2019-2020.

Table 1: Global area of top 10 biotech mega countries (2017-18)

Rank	Country	Area (million hectares)	Transgenic crops grown
1	USA	75.0	Maize, soybean, cotton, canola, sugar beet, alfalfa, papaya, squash,
2	Brazil	51.3	Soybean, maize, cotton
3	Argentina	23.9	Soybean, maize, cotton
4	Canada	12.7	Canola, maize, soybean, sugar beet
5	India	11.6	Cotton
6	Paraguay	3.8	Soybean
7	China	2.9	Cotton, papaya, poplar, tomato, sweet pepper
8	Pakistan	2.8	Cotton
9	South Africa	2.7	Maize, soybean, cotton
10	Uruguay	1.1	Soybean, maize

Sources: ISAAA

How GM crops have benefitted agriculture?

Transgenic plant as "Bioreactors":

Plant provides an inexpensive and simple system for the production of valuable recombinant proteins on large scale and can be modified to act as a bioreactor for producing wide range of biologically important compounds through "Molecular Pharming" which bear numerous advantages in terms of economy, safety and applicability as compared to other systems.

As a bioreactor it can

- Offer efficient solutions for current growing need for bio-medicines.
- Production of recombinant proteins and secondary metabolites in plants that code for useful pharmaceuticals on large scale.
- Production of therapeutic products, vaccines, antibodies, nutritional components, biodegradable plastics and many industrial products.

E.g. Transgenic Tobacco is being used to grow antibodies for treatment of HIV and Ebola virus and production of million doses of potential coronavirus vaccine for fighting the ongoing pandemic is somehow underway.

Resistance to biotic stress:

Plants are prone to attack by a number of insect pests and pathogens during its growth cycle and results in drastic reduction of biological yield and subsequently lower the farmer's income.

The problems associated with biotic causes (i.e. insect pest and pathogens) are:

- About 15% of the world's crop yield is lost due to insects or pests.

ϒ Spending lots of money on pesticides.
ϒ Adverse effect on environment and human health
ϒ About 95% sprayed pesticide washed away from plant surface and pollute soil and ground water

So, transgenic technology has tackled the problems by developing many crop varieties which provides resistance against these pests and pathogens thus help in minimizing it.

E.g., Bt cotton against bollworm
GM Maize against European corn borer
GM Potato against Colorado beetle
GM tobacco against *Alternaria longipens*
GM tomato against *Fusarium oxysporum* etc.

Resistance to abiotic stress:

Plants are constantly subjected to stress by abiotic elements of environment such as temperature (heat, freezing, chilling), nutrients, water availability and salinity.

ϒ Temperature and light: Important for transpiration and photosynthesis but fluctuation beyond higher and lower limit affects the growth badly.
ϒ Nutrients: It is required for proper growth and development of plants. It causes toxicity above and deficiency below the critical range of nutrient requirement.
ϒ Salinity: A high amount of salt in soil affects nutrients transport and decreases soil water potential.

Many transgenic crop varieties have been released as a solution to this issue

E.g. Transgenic rice producing high glycine betaine offers tolerance against water deficit stress.

Use of ice-minus bacteria of *Pseudomonas syringae* (1st transgenic bacteria) on potato crop to reduce frost damage

Resistance to herbicides:

Due to wider use of broad-spectrum herbicides, a need for producing herbicide resistant plants has been solved to some extent by introducing glyphosate resistant, phosphoenithrin resistant, atrazine resistant genes into the plants.

GM version of many crops have been developed to overcome these issues,-

E.g. Glyphosate resistant transgenic crops- tomato, soybean and maize.

Phosphoenithrin resistant transgenic crops– maize, cotton, tomato, potato, rice and sugar beet.

Improvement in crop yield and food quality:

Photosynthetic efficiency and harvest index are the primary factors of crop yield. The food quality depends on a wide range of desirable characters such as nutritional composition of edible parts, flavors, processing quality, shelf-life etc. As the world modernizing and agriculture is advancing, it has led to increase in use of pesticides and fertilizers in crops. We are not getting enough of nutrient rich foods and malnutrition has become a deep concern worldwide which implies the need for nutrient rich diet for making a body healthy and to buildup immunity.

Genetic engineering has made possible in developing different transgenic varieties of crop to counteract the anti-nutritional properties and foods with higher proteins, minerals and vitamins.

E.g. Golden rice (rich in Vit -A), Methionine rich maize (28%), rice (20%) and sunflower (16%), production of lysine rich rice

Improved Shelf life:

Fruits and vegetables have short shelf life and has sprouted many concerns. Transgenic technology has tailored crops in such a way that it has solved the problems by introducing gene responsible for prolonging shelf life in plants which subsequently facilitated

ϒ Improve in flavor
ϒ Easy transportation to distant market as a solution to distress sell
ϒ Extended storage life for a longer duration and successfully reduced the wastage of foods and vegetables worldwide.

E.g. Flavr-Savr tomato

Table 2. The chart below summarizes some of the commercialized GM crops along with its developer w.r.t the various applications enlisted above

Sl. No.	Crop	Trade name	Developer	Modified trait
1	**Apple**	1. Arctic "golden delicious" apple 2. Arctic fuji apple	Okanagan specialty fruits incorporated	Antibiotic resistance Non browning
2	**Rapeseed**	Laurical Canola	Monsanto company	Modified fatty acids, antibiotic resistance
3	**Carnation**	1.Moondust 2.Moonshadow 3.Moonshade 4.Moonaqua 5.Moonlite 6.Moonpearl	Florigen pvt. Ltd.	Sulfonylurea herbicide tolerance, modified flower color
4	**Maize**	Enogen	Syngenta	Modified α-amylase , Mannose metabolism
		Mavera 'YieldGuard' maize	Renessen LLC (Netherlands)	Lepidopteran insect resistance , modified amino acid
5	**Pineapple**	Rose	Del monte fresh produce company	Delayed ripening /senescence, modified fruit color
6	**Soybean**	Vistive Gold	Monsanto company	Glyphosate herbicide tolerance, Modified oil/fatty acids
		Treus , Plenish	DuPont (pioneer Hi-Bred International Inc.)	Sulfonylurea herbicide tolerance, modified oil quality
7	**Potato**	1.Innate cultivate 2.Innate Generate	J.R. Simplot Co.	Lowered free asparagine and reducing sugars, reduced black spot
		Amflora	BASF	Modified starch/carbohydrate, Antibiotic resistance
8	**Cotton**	Bollgard II, Bollgard III	Monsanto	Resistant to lepidopteran insects

Sources: ISAAA

Limitations of GM crops and foods

As "there is no pack of cards without a knave", GM crops also have some unguaranteed downsides, which definitely needs to be discussed and assessed properly as the increasing cultivation of transgenic crops has raised substantial concerns in different areas worldwide.

Some important issues are enlisted below -

Food and Human health

- Resistance to antibiotics: Genetic modifications can turn medicines ineffective and may result in the formation of new toxins and allergens.
- Allergic reactions: This occurs-
- When alien protein/allergen present in the GM crops enters into our body, stimulates immune reactions or
- Due to consumption of GM foods for longer time (according to some recent reports)
- Toxins: Averting from its plus side, toxins produced by GM crops hold potential ability to affect non target organisms but also poses the danger of unintentionally introducing allergens and other anti-nutritional factors into foods.

Environmental Health

- Cross pollination: It paves a way for getting better characters in a species. But, Pollination and fertilization of GM crop with non-GM crop in open field cause problems viz.
- By creating super weeds and
- In maintaining certification standards and genetic purity of GM crops.
- 'Super weeds' - These are the weeds which remains unaffected by herbicide treatment, and because of its uncontrolled growth, they are able to threaten the sustenance of other crops and pests in GM crop production cycle.
- 'Super pests': Due to high use of pesticides, pest develops resistance against its treatment, which leads to evolution of super pests.
- Effect on non-target organisms: Toxins contained in GM plants may harm other organisms, such as monarch caterpillars (in Bt corn), bees and birds.
- Loss of biodiversity: Not only plants but the pesticide found in Bt cotton and Bt corn has implicated the deaths of many livestock and poultry worldwide.
- Accumulation of toxins in food chain: According to some environmentalists, the characteristics of GM crop may encourage farmers to increase the use of herbicides and pesticides in field, which explains a main reason for the above cause.
- Soil pollution: GM crops also manufacture their own pesticides, which can poison the nurturing soil and may cause unforeseen changes in the environment.

Social and Ethical issues

- Adoption of GM technologies has raised a range of concerns about restricting access to genetic resources and new technologies.
- Loss of indigenous traditions (such as saving seeds): To get higher profit multinational seed companies use 'terminator technology' or 'suicide seeds' due to which seeds produced are sterile and thus prevent farmers from saving it for the next year sowing.
- Private sector monopoly: Due to introduction of 'traitor technology', a crop is responsive to only a particular brand of herbicides or pesticides which creates problems of monopoly.
- Public perceptions about genetically modified organisms in food and agriculture are divided with a tendency toward avoiding GM foods and products in many developing and developed countries.

Bio-safety Concerns

Biodiversity is critical for well functioning and sustainability of the ecosystem, nevertheless, GM crops also poses potential threat to the biodiversity and has raised biosafety concerns such as,

- Threat to wild varieties: Introduction of GM versions of Cotton, Rice, Brinjal and Mustard could be a major threat to its vast number of domestic and wild varieties.
- Elimination of important beneficial species: As GM crops have pest resistance characteristics which could eliminate important species of insect pests that are responsible for sustaining domestic and wild varieties.

Regulatory Control and Labelling

GM crop is a biotech crop. The top regulatory and statutory body responsible for approval and release of GM crops in India is Genetic Engineering Appraisal Committee (GEAC). The main concerns are

- Lack of transparency and stringency in regulatory body: It leads to black marketing and increment of unlabeled GM seeds.
- Adulteration in GM food marketing: Most GM food companies do not disclose "GM" on their labels but claim it as "GM-free" and vice versa.
- Unorganized sector: Retailing being largely an unorganized sector, enforcing truthful labeling is not pragmatic.

Conclusion:

GM crops definitely have certain advantages which contributes in decreasing the cost of cultivation of farmers mainly by reducing the use of pesticides and herbicides but it comes with unbearable costs. The drawbacks associated with GM crops couldn't be overlooked easily as it can negatively impact human and environmental health and it is also a threat to loss of biodiversity. The lab to land process for GM crops monitored by top regulatory bodies must be reinforced to have transparency in sensitive issues and accountability towards the public. It must be strengthened to deal each and every element carefully and any kind of insignificant interventions from the person in power or any other organizations must not be entertained.

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