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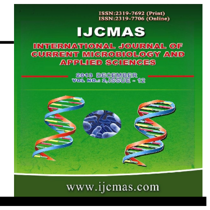

Review Article

Biotechnology is the cutting age in agriculture

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A B S T R A C T

Inaugurating to writing about the biotechnology I have remember the Malthus theory which dictate that the "population increase in geometrical manner whatever the agriculture produce is increase in arithmetic manner" this will naturally lead to an imbalance between the size of population and the quantity of food produced in such situation the role of biotechnology in agriculture is really a boon not only for India but also for the world. Dr. Norman Borlaug, Noble peace laureate once quoted that "the world need to double food production by 2050 if hunger were to be banished from the world and ongoing 'gene revolution' can definitely play a part in this. You cannot build peace on empty stomachs. Only 8 percent of countries with lower levels of hunger are mired in conflict". Biotechnology holds tremendous potential in increasing productivity and ensuring not only the food security but also nutritional security. In such situation by applying the biotechnology at farmer field enabling the farmers to increase their agricultural yields manifold. Plant biotechnology has emerged as exciting areas of plant sciences by creating unprecedented opportunities for the manipulation of biological systems. Agriculture Biotechnology is an area of production and research in which biological systems and biological principles are employed to solve technological problems. In this sense it becomes all inclusive

Introduction

Addressing food security has been in the headlines in recent times as it is an urgent challenge that should be tackled to avert serious crises in the next decades. Increased productivity from breeding high yielding varieties since the 1960s has contributed to conserving more than 1 billion hectares of land and has delayed or completely averted the use of pristine forest areas for new agricultural lands (Borlaug, 2007). Late 1800s Scientists have been only changing their genetic makeup of plants by using crossbreeding and hybridization, in which two related plants are cross-fertilized and the resulting offspring have characteristics of both parent plants. In this breeding approach, however, many undesirable traits often can appear in addition to the desirable ones. Some of those undesirable traits can be eliminated through additional breeding, which is time consuming. Breeders can then further select and reproduce the offspring that have the desired traits. Many of the foods that are already common in our diet are obtained from plant varieties that were developed using conventional genetic techniques of breeding and selection. The method and steps of developing improved variety by breeding methods and biotech methods were clear cut shown in Figure.1.

So to reduce the hurdle of time and money at proper management of biotech technique and its application leads to solve the entire problem related to conventional breeding technique. So Biotechnology is defined as the scientific field of studying and applying the most efficient methods and techniques to get useful end-products for the human society by using viable micro-organisms, cells, and tissues of plants or animals, or even certain functional components of their organisms, that are grown in fully controlled conditions to maximize their specific metabolism inside fully automatic bioreactors. Plant biotechnology is also defined as an area of production and research in which biological systems and biological principles are employed to solve technological problems. So Biotechnology allows the transfer of a gene for a specific trait from one plant variety or species to another, is one important piece of the puzzle of sustainable development. Experts assert that biotechnology innovations will triple crop yields without requiring any additional farmland, saving valuable rain forests and animal habitats. Other innovations can reduce or eliminate reliance on pesticides and herbicides that might contribute to environmental degradation. Still others can preserve precious ground soils and water resources. So in such situation, application of plant biotechnology is in broad area which are mentioned below-

1. Regeneration of rice (*Oryza sativa* L.), maize, eucalyptus, hot pepper, guava (*Psidium guajava* L.), stone fruit (*Pinis pinea*) and compares the features of in vitro grown plant to in vivo plants.
2. Transgenic plants production and application.
3. Biotechnological aspects of secondary metabolite production by using cell and tissue culture.
4. Secondary metabolite production with special reference to sennoside, genetic transformation of potato and biosafety.
5. Pharmaceutical sciences and production of recombinant proteins and plant molecular farming.
6. Bioinformatics and its application to crop improvement.
7. Development of abiotic resistance plant using plant biotechnology.
8. Development of biotic resistance plant using plant biotechnology including host pathogen interaction developing resistant crops.
9. Developmental studies: developmental mechanisms leading to a further understanding of an industrial use of

plants. Plant tissue culture and its role in plant biotechnology.

Today, by inserting one or more genes into a plant, scientists are able to produce a plant with new, advantageous characteristics. The new gene splicing techniques are being used to achieve many of the same goals and improvements that plant breeders historically have sought through conventional methods. They give scientists the ability to isolate genes and introduce new traits into foods without simultaneously introducing undesirable traits. This is an important improvement over traditional breeding and now the conventional breeding has change to molecular breeding by application of tools and technique of molecular biology and genetic engineering. So whatever the lacunae of traditional breeding approach that can be reduced by increased precision offered by the bioengineered methods, the risk of introducing detrimental traits is actually likely to be reduced. There are three bases by which we increase agriculture produce-

(I) Agro-chemical based agriculture;
(ii) Organic-based agriculture
(iii) Genetically engineered crop-based agriculture.

But now a day the agrochemical based and organic based agriculture in on saturation so in such situation biotech crop plays important role in tripling the agriculture produce and might bring second green revolution by application of genetic engineering in crop improvement. The agricultural biotechnology revolution is occurring in mainly in developed countries. But developing country like India now an opted the biotech crops but lags far behind in development, use and commercialization of biotechnology. So the development of human resources in both technical and policy areas is sorely needed.

Plants, bacteria, fungi and animals whose genes have been altered by manipulation are called Genetically Modified Organisms (GMO). The development of GM plants have involved following steps.-

Identification of gene that impart a useful character to the target crop plant and subsequent cloning of the gene. Strategies for this have been discuss above

Modification of target gene for expression in crop plants. The gene has to be isolated and cloned into a vector, which insure the stable integration of foreign gene into the chromosome of the recipient plant cells .the gene must be placed under the control of the appropriate regulatory sequence.

Transfer of modified gene into cells of plant species by various method of transformation.

Regeneration of complete GM crops capable of transmitting the incorporated gene to the next generation. This process involves the use of selectable markers, to select the transformed tissue. The transformed nature of the tissue is confirmed by PCR, southern and western blot expression assays.

Phenotypic analysis of transgenic progeny to measure expression and functionality of the transgene in the transformed plants and segregation analysis of transformed progeny.

Field trial of transgenic plant

Genetic modification has:-
Made crops more tolerant to abiotic stresses (cold, drought, salt and heat).

Made crops more tolerant to biotic stresses (fungi, bacteria, viruses).

Reduced reliance on chemical pesticides (pest-resistant crops).

Increased mineral uptake efficiency of the plant

Enhanced nutritional value of food

Creation of nutraceutical value of food by molecular farming

Creation of abiotic stress tolerant plants

The change in temperature, increased salinization of soil and water has made it vital to human survival that we find a way for our agriculture to cope with these stresses. The United Nations Environment Program estimates that approximately 20% of agricultural land and 50% of cropland in the world is salt stressed. This salinity, in particular, is an increasing problem and nearly half of the area under irrigation, is at risk to be lost due o building up of salinity. Therefore genetic improvement of salt tolerance has become an urgent need for the future of agriculture in arid and semiarid regions. One way in which we can do so is by genetically engineering crops to survive under these conditions. The crops are designed to induce over expression of certain transcription factors, such as CBF/DREB, HSP, SNAC11, OsCOIN1, and ABF3. Using genes that code for transcription factors is a promising method for genetic engineering because many of the ways in which plants can adapt to cold, drought, oxidative stress and extreme temperatures is through transcriptional control. Transcription factors that are a part of the regulon to help prevent the effects of abiotic stress have been constitutively over expressed to promote a greater amount of tolerance. Many of the studies in commercial crops were based upon Arabidopsis because not only are structural proteins conserved, but entire stress tolerance regulons too, making it a valuable model for biotechnological research. Selective Reports on Production of Cold Stress-Tolerant Transgenic Crops have been mention below in Table1.

The development of genetically engineered plants by the introduction and/or over expression of selected genes seems to be a viable option to hasten the breeding of ‘‘improved’’ plants. Intuitively, genetic engineering would be a faster way to insert beneficial genes than through conventional or molecular breeding. Also, it would be the only option when genes of interest originate from cross barrier species, distant relatives, or from non-plant sources. Applications of biotech approach and gene knockout strategies are progressing to accelerate efforts to assess systematically and understand complex quantitative traits such as acquired tolerance to temperature extremes. By using genetic and molecular approaches, a number of relevant genes have been identified and new information continually emerges to enrich the CBF cold-responsive pathway. Thus, the CBF/DREB1 genes are thought to be activators that integrate several components of the cold acclimation response by which plants increase their tolerance to low temperatures after exposure to non-freezing conditions. The DREB1/CBF genes have been successfully used to improve abiotic stress tolerance in a number of different crop plants. For example, increasing the accumulation of two compatible solutes, that is, glycinebetaine and trehalose, in transgenic rice by overexpressing either

Table.1 Reports on Production of Cold Stress-Tolerant Transgenic Crops

Gene (s) / Gene product	Cellular role	Transgenic Host-Plant	Performance of transgenic plants	Reference
SCOF1 cold-inducible zinc finger protein	Regulator of SGBF-1 as a transcription factor	Glycine max	activate COR gene expression and increase freezing tolerance in non-acclimated transgenic plants	[102]
abi3 Abscisic acid induced protein	Transcription factor	A. thaliana	Marked increase in expression of low tem-perature-induced freezing tolerance accom-panied by up-regulation of RAB18, LTI129, LTI130 and LTI178	[13]
CuCOR19 citrus dehydrin	Inhibition of lipid peroxidation	N. tabacum	Increased the cold tolerance	[89]
CBF1/ DREB1b DRE-binding protein	Transcription factor	O. sativa	The cold-responsive genes lip5, lip9, and OsDhn1 were up-regulated in the transgenic plants	[124]
DREB1A (rd29A) DRE-binding protein	Stress-inducible pro-moter	N. tabacum	Improved drought and low-temperature stress tolerance	[83]
OSISAP1 Zinc-finger protein	Transcription factor	N. tabacum	The transcript level of OSISAP1 was in-creased to a very high level during a 12-h cold treatment	[125]
Osmyb4	Transcription factor	Arabidopsis	Increases chilling and freezing tolerance	[126]
HOS10 Encodes an R2R3-type protein	Transcription factor	O. sativa	Enhanced cold tolerance	[127]
ZAT12 C2H2 zinc finger	Transcription factor	Arabidopsis	Improved cold acclimation	[55]
Cor15am Chloroplast stromal protein	Stress-inducible pro-moter	Arabidopsis	Enhanced cryoprotective activity	[128]
OsMYB3R-2 DNA-binding domain	Transcription factor	Arabidopsis	Overexpression of OsMYB3R-2 leads to increased tolerance to freezing, drought, and salt stress	[93]

ACBP6 Acyl-CoA-binding protein	Decline in phosphati-dylcholine and eleva-tion of phosphatidic acid	Arabidopsis	Overexpression of ACBP6 enhanches freezing tolerance	[129]
OsMYB3R-2 DNA-binding domain	Transcription factor	O. sativa	Overexpression of OsMYB3R-2 exhibited enhanced cold tolerance	[130]
AtCSP3 Cold shock protein	RNA chaperon	Arabidopsis	Transgenic plants conferred enhanced freez-ing tolerance as compared to wild type plants hence demonstrating essential role of RNA chaperones for cold adaptation in higher plants	[131]
MYBS3 DNA-binding repeat MYB	Transcription factor	O. sativa	Plays a critical role in cold adaptation in rice	[99]
mybc1 Regulate osmotic stress tolerance	Transcription factor	Arabidopsis	Exhibited an increased tolerance to freezing stress	[132]
ThpI Thermal hysteresis proteins (Anti freeze protein)	Transcription factor	Arabidopsis	Enhanced low temperature tolerance in transgenic plants was observed by changes of electrolyte leakage activity, malonyldialdehyde and proline contents	[133]
CBF1/CRT/DRE binding factor 1	Transcription factor	Solanum Lycopersicu m	Detection of higher activity of superoxide dismutase (SOD), higher non-photochemical quenching (NPQ), and lower malondialdehyde (MDA) content in transgenic tomato leaves suggest that CBF1 protein plays an important role in protection of PSII and PSI during low temperature stress at low irradiance	[108]

Figure.1 Method and steps of developing improved variety by breeding methods and biotech methods

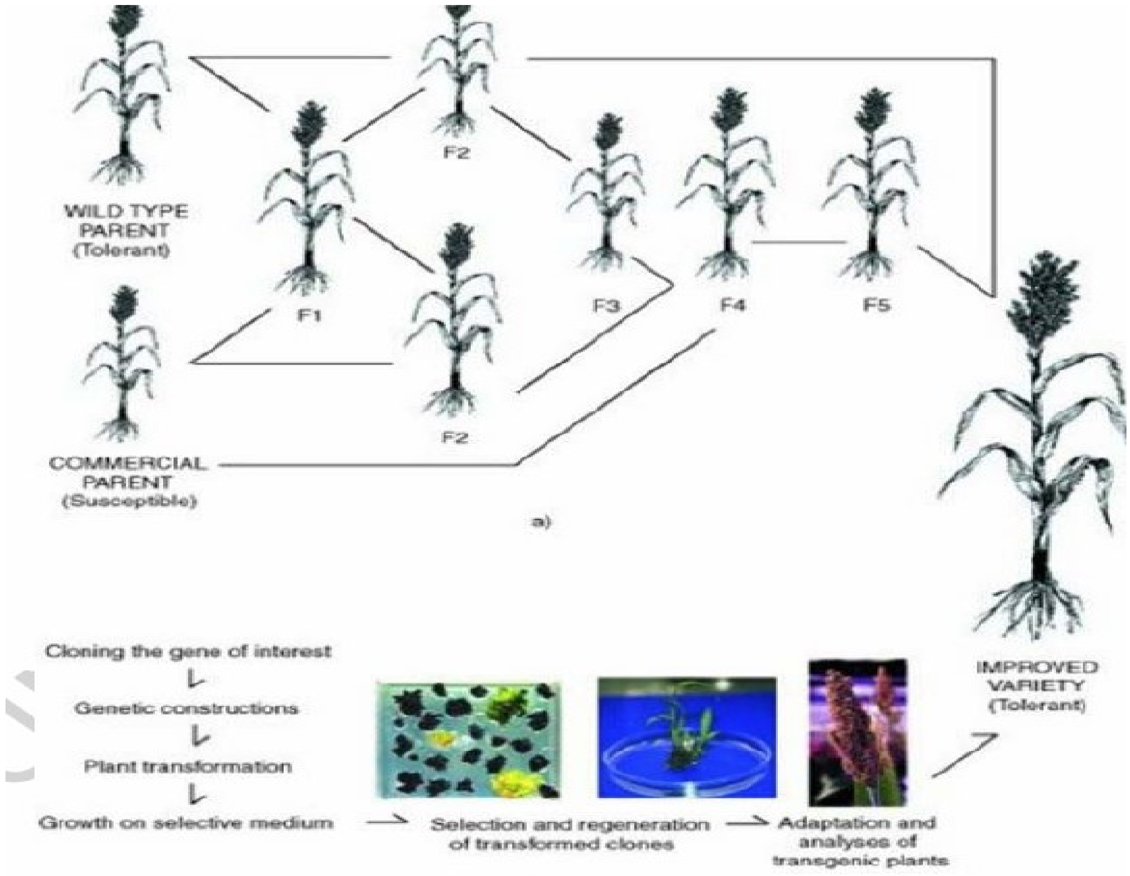
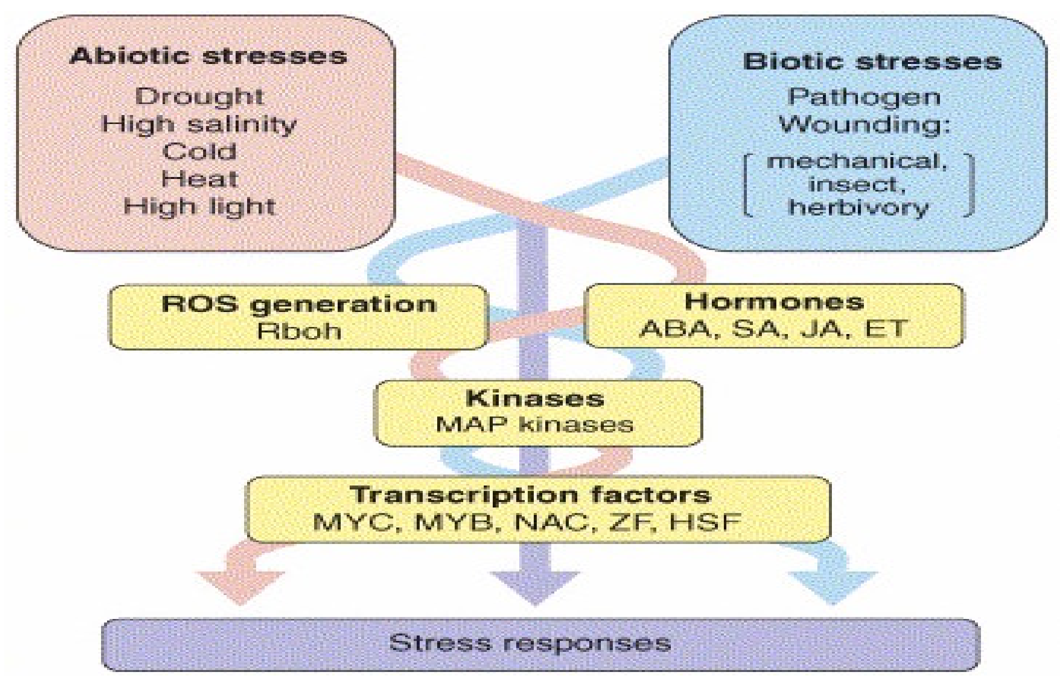


Figure.2 The crosstalk mechanism of biotic and abiotic stress



E. coli choline oxidase, or trehalose-6-phosphate synthase fused to trehalose-6-phosphate phosphatase, enhanced tolerance to both salt and cold.

A well focused approach combining the molecular, physiological and metabolic aspects of cold stress tolerance is required for bridging the knowledge gaps between short- and long-term effects of the genes and their products, and between the molecular or cellular expression of the genes and the whole plant phenotype under stress.

Creation of biotic stress tolerant plants

Plants, bacteria, fungi and animals whose genes have been altered by manipulation are called Genetically Modified Organisms (GMO). GM plants have been useful in many ways. Genetic modification has plants undergo continuous exposure to various biotic stresses in their natural environment. To survive under such conditions, plants have evolved intricate mechanisms to perceive external signals, allowing optimal response to environmental conditions. Phytohormones such as salicylic acid (SA), jasmonic acid (JA), ethylene (ET), and abscisic acid (ABA) are endogenous, low-molecular-weight molecules that primarily regulate the protective responses of plants against biotic stresses via synergistic and antagonistic actions, which are referred to as signaling crosstalk. The crosstalk mechanism of biotic and abiotic stress is clear cut is shown in Figure 2.

So cloning and over expression of gene involved in resistance mechanism of the plant against various pathogen leads to resistance and tolerance to plant with particular strains.

3. Insect pest resistance plant

Some of the applications of biotechnology in agriculture that you will study in detail are the production of pest resistant plants, which could decrease the amount of pesticide used. Bt toxin is produced by a bacterium called Bacillus thuringiensis (Bt for short). Bt toxin gene has been cloned from the bacteria and been expressed in plants to provide resistance to insects without the need for insecticides; in effect created a bio-pesticide. Examples are Bt cotton, Bt corn, rice, tomato, potato and soybean etc. Why does this toxin not kill the Bacillus? Actually, the Bt toxin protein exist as inactive protoxins but once an insect ingest the inactive toxin, it is converted into an active form of toxin due to the alkaline pH of the gut which solubilise the crystals. The activated toxin binds to the surface of midgut epithelial cells and creates pores that cause cell swelling and lysis and eventually cause death of the insect.

The soil bacterium Bacillus thuringiensis produces crystal proteins called Cry proteins, that are toxic to larvae of insects like Tobacco budworm, armyworm, beetles and mosquitoes. The Cry proteins exist as inactive protoxins and get converted into active toxin when ingested by the insect, as the alkaline pH of gut solubilises the crystals. The activated toxin binds to the surface of epithelial cells of midgut and creates pores. This causes swelling and lysis of cells leading to the death of the insect (Larva). The genes (cry genes) encoding this protein are isolated from the bacterium and incorporated into several crop plants like cotton, tomato, corn, rice, soybean, etc. The proteins encoded by the following cry genes control the pest given against them.

cry I Ac and cry II Ab control cotton bollworms.

cry I Ab controls corn borer.

cry III Ab controls colarado potato beetle.

cry III Bb controls corn rootworm.

Pest Resistant Plants: Several nematodes parasitise a wide variety of plants and animals including human beings. A nematode Meloidegyne incognitia infects the roots of tobacco plants and causes a great reduction in yield. A novel strategy was adopted to prevent this infestation which was based on the process of RNA interference (RNAi). RNAi takes place in all eukaryotic organisms as a method of cellular defense. This method involves silencing of a specific mRNA due to a complementary dsRNA molecule that binds to and prevents translation of the mRNA (silencing). The source of this complementary RNA could be from an infection by viruses having RNA genomes or mobile genetic elements (transposons) that replicate via an RNA intermediate.

The specific genes (in the form of c DNA) from the parasite are introduced into the plant using Agrobacterium as the vector. The genes are introduced in such a way that both sense/coding RNA and antisense RNA (Complimentary to the sense/ coding RNA) are produced. Since these two RNAs are complementary, they from a double stranded RNA (ds RNA). This neutralizes the specific RNA of the nematode, by a process called RNA – interference. As result the parasite cannot line in the transgenic host and the transgenic plant protected from the pest.

Enhanced nutritional value of food by biofortification

Bio fortification of food crops makes sense as part of an integrated food-systems approach to reducing malnutrition. It addresses the root causes of micronutrient deficiencies, targets the poorest people, and is scientifically feasible and cost-effective. It is a first step in enabling rural households to improve family nutrition and health in a sustainable way. Biotech and genetic engineering is a multiple sector through which we breed and disseminate crops with improved nutritive value, e.g. with a higher content of iron, zinc and vitamin A. The biofortification approach is backed by sound science. Research on this funded by the Danish International Development Assistance (DANIDA) and coordinated by the International Food Policy Research Institute (IFPRI) led to the following conclusions:

Substantial, useful genetic variation exists in key staple crops; Breeding programmes can readily manage nutritional quality traits, which for some crops have proven to be highly suitable and simple to screen for; Desired traits are sufficiently stable across a wide range of growing environments; and Traits for high nutrition content can be combined with superior agronomic traits and high yields.

Initial biofortification efforts (as of 2005) will focus on six staple crops for which pre breeding studies have been completed: beans, cassava, sweet potatoes, rice, maize and wheat. The potential for nutrient enhancement will also be studied in ten additional crops that are important components in the diets of those with micronutrient deficiencies: bananas /plantains, barley, cowpeas, groundnuts, lentils, millet, pigeon-peas, potatoes, sorghum and yams. Continuing improvements in molecular and genomic technologies are contributing to the acceleration of product development. This was listed as examples of crops with nutritionally improved traits intended to

Table.2 Crop traits and their details

Trait Crop	(Trait Detail)	Reference
Protein quality and level	Bahiagrass (protein) Canola (amino acid composition) Maize (amino acid composition;protein Potato (amino acid composition; protein Rice (protein; amino acid composition) Soybean (amino acid balance Sweet potato (protein)	Luciani et al. (2005) ,Yang et al. (2002), Young et al. (2004), Chakraborty et al. (2000), Li et al. (2001), Atanassov et al. (2004) Katsube et al. (1999)) Dinkins et al. (2001), Rapp (2002)[Egnin and Prakash (1997)
Essential amino acids	Canola (Lys) Lupin (Met) Maize (Lys, Met) Potato (Met) Sorghum (Lys) Soybean (Lys, Trp)	Falco et al. (1995) White et al. (2001) Lai and Messing (2002), Zhao et al. (2003)
Oils and fatty acids	Canola (lauric acid, GLA; 1v-3 fatty acids; 8:0 and 10:0 fatty acids; lauricand myristic acids; oleic acid) Cotton (oleic acid, oleic 1 stearic acids) Grass, legumes (Ytrans-fatty acids) Linseed (1v-3 and v-6 fatty acids) Maize (oil) Oil palm (oleic acid or stearic acid ,oleic acid, 1palmitic acidY) Rice (a-linolenic acid) Soybean (oleic acid, GLA) Safflower (GLA)	Froman and Ursin (2002, 2003), James et al. (2003), Agbios (2008) Chapman et al. (2001), Liu et al. (2002) O’Neill (2007) Abbadi et al. (2004) Young et al. (2004), Parveez (2003) Anai et al. (2003) Reddy and Thomas (1996), Kinney and Knowlton (1998) Jalani et al. Arcadia Biosciences (2008)
Carbohydrates Fructans	Chicory (fructan[, fructan modification) Maize (fructan), Potato (fructan) Sugar beet (fructan)	Smeekens (1997), Sprenger et al. (1997), Se´venier et al. (1998) Caimi et al. (1996) Hellwege et al. (1997) S
Fru, raffinose, stachyose Inulin Starch	Soybean Potato (inulin[) Rice (amylase)	Hartwig et al. (1997) Chiang Hellwege et al. (2000) Schwall et al. (2000),
Micronutrients and functional metabolites Vitamins and carotenoids	Canola (vitamin E) Maize (vitamin E, vitamin C) Mustard (1b-carotene) Potato (b-carotene and lutein,Rice (1b-carotene) Strawberry (vitamin CTomato (folate, phytoene andb-carotene, lycopene, provitamin A)	Rocheford et al. (2002), Cahoon et al. (2003), Chen et al. (2003) Shewmaker et al. (1999) [) Ducreux et al. (2005) Ye et al. (2000) Agius et al. (2003) Rosati et al. (2000), Fraser et al. (2001), Mehta et al. (2002), Dı´az de la

		Garza et al. (2004), Enfissi et al. (2005), DellaPenna (2007)
Functional secondary Metabolites	Apple (1stilbenes) Alfalfa (1resveratrol Kiwi (1resveratrol) Maize (flavonoids) Potato (anthocyanin and alkaloid glycosideY, solaninY) Rice (flavonoids, 1resveratrol Soybean (flavonoids)	Szankowski et al. (2003)) Hipskind and Paiva (2000) Kobayashi et al. (2000) Yu et al. (2000) Lukaszewicz et al. (2004)) Stark-Lorenzen et al. (1997), Shin et al. (2006) Yu et al. (2003)
Mineral availabilities	Alfalfa (phytase) Lettuce (iron) Maize (phytase, ferritin) Rice (iron) Soybean (phytase) Wheat (phytase)	Austin-Phillips et al. (1999) Goto et al. (2000) Lucca et al. (2002) Drakakaki et al. (2005) Denbow et al. (1998) Brinch- Pedersen et al. (2000)

Table.3 Important pharmaceutical proteins that have been produced in plants

Protein	**Host plant system**	**Comments/ Medical application**
Growth hormone	Tobacco, sunflower	First human protein expressed in plants; initially expressed as fusion
		protein with nos gene in transgenic tobacco; later the first human protein expressed in chloroplasts, with expression levels ~7% of total leaf protein
Human serum albumin	Tobacco, Potato	First full size native human protein expressed in plants; low expression levels in transgenics (0.1% of total soluble protein) but high levels (11% of total leaf protein) in transformed chloroplasts/ Liver cirrhosis, burns, surgery
α-interferon	Rice, turnip	First human pharmaceutical protein produced in rice
Erythropoietin	Tobacco	First human protein produced in tobacco suspension cells/ Anemia
Human-secreted alkaline phosphatase	Tobacco	Produced by secretion from roots and leaves
Aprotinin	Maize	Human pharmaceutical protein produced in maize
Collagen	Tobacco	First human structural-protein polymer produced in

		plant; correct modification achieved by co-transformation with modification enzyme
α1-antitrypsin	Rice	First use of rice suspension cells for molecular farming
Lactoferrin	Rice, tomato	Antimicrobal activity
Protein C	Tobacco	Anticoagulant
Hirudin	Canola	Thrombin inhibitor
Colony-stimulating factor	Tobacco	Neutropenia
Enkephalins	Arabidopsis	Antihyperanalgesic by opiate activity
Epidermal growth	Tobacco	Wound repair and control of cell proliferation
Immunoglobulin G1	Tobacco	First antibody expressed in plants; full length serum IgG produced by crossing plants that expressed heavy and light chains
Immunoglobulin M	Tobacco	First IgM expressed in plants and protein targeted to chloroplasts for accumulation
Secretory immunoglobulin A	Tobacco	First secretory antibody expressed in plants by sequential crossing of four lines carrying individual components; at present the most advanced plant-derived pharmaceutical protein
Immunoglobulin G (herpes simplex virus)	Soybean	First pharmaceutical protein produced in soybean
Hepetititis B Virus envelope protein	Tobacco	First vaccine candidate expressed in plants; third plant-derived vaccine to reach clinical trials stage
Rabies virus glycoprotein	Tomato	First example of an 'edible vaccine' expressed in edible plant tissue
Escherichia coli heat-labile enterotoxin	Tobacco, potato	First plant vaccine to reach clinical trials stage
Diabetes autoantigen	Tobacco, potato	First plant-derived vaccine for an autoimmune disease
Cholera toxin B subunit	Tobacco, potato	First vaccine candidate expressed in chloroplasts
Cholera toxin B and A2 subunits, rotavirus enterotoxin	Potato	First example of oral feeding inducing protection in an animal

provide health benefits for consumers and animals (Table 2). This list excludes protein/starch functionality, shelf life, taste/aesthetics, fiber quality, and allergen, anti nutrient, and toxin reduction traits.

Creation of Nutraceuticals value of food by molecular farming

Plants provide an inexpensive and convenient system for the large-scale production of valuable recombinant proteins. This principle has been demonstrated by the commercial success of several first-generation products, and many others are currently under development. A major advantage of transgenic plants for molecular farming is the comparatively low cost of large-scale production. But initially typically synthesized by modified bacteria, mammal and insect cells, yeasts but now in plants known as genetically modified (GM) plants. The technique consists in transferring a specific gene into plant cells. The production of pharmaceuticals by plants-called "plant molecular farming" (PMF) or "biopharming" represents the third generation of agricultural biotechnologies. Many types of substances can be obtained from GM plants used in PMF: Both capital and running costs are significantly lower than those of cell-based production systems because there is no need for fermenters or the skilled personnel to run them. So at low cost of time and money we produce large amount of target recombinant protein. It is estimated that recombinant proteins can be produced in plants at 2–10% of the cost of microbial fermentation systems and at 0.1% of the cost of mammalian cell cultures, although this depends on the product yield. Recently maize was chosen by Prodigene (http://www.prodigene.com/) as the first plant species for commercial molecular farming.

Research over the past 10 years has significantly increased our knowledge of gene regulation and protein synthesis in different plants. This has enabled a move from proof-of principle studies in model species to exploration of a variety of different plants for the production of recombinant proteins. A diverse repertoire of technical, pharmaceutical and industrial proteins has been produced in plants, some on a commercial basis Table 3.

Much effort is being devoted to overcoming the technical limitations of molecular farming, particularly by increasing the low yields in certain expression systems and producing human proteins with authentic glycan chains. However, there are several further challenges concerning issues of environmental impact, biosafety and risk assessment, which reflect the release and agricultural-scale cultivation of transgenic plants, as well as the safety of the plant derived products themselves. The progress of plant derived pharmaceutical proteins through preclinical development and clinical trials are a significant bottleneck. The products of plant molecular farming are-

Primary products: Antibodies, antibody fragments, enzymes (industrial, therapeutic, diagnostic, cosmetic), structural proteins, antigens (vaccines), therapeutic agents, drugs, enzyme inhibitors.

Table.4 The Global area of biotech crops during 2012

Rank	Country	Area (million ha)	Biotech Crops
1.	USA	69.5	Maize, Soybean, Cotton, Canola, Sugarbeet, alfalfa, Papaya, Squash
2.	Brazil	36.9	Maize, Soybean, Cotton
3	Argentina	23.9	Maize, Soybean, Cotton
4	Canada	11.6	Maize, Soybean, Canola, Sugarbeet
5	India	10.8	Cotton
6	China	4.0	Cotton, Papaya, Tomato, Sweet peppar, Poplar
7	Paraguay	3.4	Maize, Soybean, Cotton
8	South Africa	2.9	Maize, Soybean, Cotton
9	Pakistan	2.8	Cotton
10	Uruguay	1.4	Soybean, Maize
11	Bolivia	1.0	Soybean
12	Philippines	0.8	Maize
13	Australia	0.7	Cotton, Canola
14	Burkina Faso	0.3	Cotton
15	Myanmar	0.3	Cotton
16	Mexico	0.2	Cotton, Soybean
17	Spain	0.1	Maize
18	Chile	<0.1	Maize, Soybean, Canola
19	Colombia	<0.1	Cotton
20	Honduras	<0.1	Maize
21	Sudan	<0.1	Cotton
22	Portugal	<0.1	Maize
23	Czech Republic	<0.1	Maize
24	Cuba	<0.1	Maize
25	Egypt	<0.1	Maize
26	Costa Rica	<0.1	Cotton
27	Romania	<0.1	Maize
28	Slovakia	<0.1	Maize
	Total	170.3	

By-products: Bioplastics, vitamins, cofactors, nutraceutics, secondary metabolites (phenolic copounds, glucosinolates, tannin, starches, sugars, perfumes, scents and aromas, alkaloids), fibres.

Global Status of Commercialized Biotech/GM Crops: 2012:

As per the record of ISAAA Biotech Crop hectares increased by an unprecedented 100-fold, from 1.7 million hectares in 1996, to 170 million hectares in 2012 (Table 4). The dedication of biotech crops to Global Status of Commercialized Biotech/GM Crops: to displaced the 1 billion poor and hungry people and their survival. In the period 1996 to 2012, millions of farmers in ~30 countries worldwide, adopted biotech crops at unprecedented rates. The most compelling and credible testimony to biotech crops is that during the 17 year period 1996 to 2012, millions of farmers in ~30 countries worldwide, elected to make more than 100 million independent decisions to plant and replant an accumulated hectarage of more than 1.5 billion hectares – an area 50% larger than the total land mass of the US or China – there is one principal and overwhelming reason that underpins the trust and confidence of risk-averse farmers in biotechnology – biotech crops deliver substantial, and sustainable, socio-economic and environmental benefits. The 2011 study conducted in Europe confirmed that biotech crops are safe. 28 countries grow biotech crops in which 20 were developing and 8 were industrial countries with the top ten each growing more than 1 million hectares.

The 5 lead biotech developing countries are China, India, Brazil, Argentina and South Africa. They grew 46% of global biotech crops, and have ~40% of world population. Brazil ranks second only to the USA in biotech crop hectare in the world, with 36.6 million hectares, and emerging as a global leader in biotech crops. For the fourth consecutive year, Brazil was the engine of growth globally in 2012, increasing its hectare of biotech crops more than any other country in the world – a record 6.3 million hectare increase, equivalent to an impressive year-over-year increase of 21%.India cultivated a record 10.8 million hectares of Bt cotton with an adoption rate of 93%, whilst 7.2 million small resource poor farmers in China grew 4.0 million hectares of Bt cotton with an adoption rate of 80%, cultivating on average, 0.5 hectare per farmer. India enhanced farm income from Bt cotton by US$12.6 billion in the period 2002 to 2011 and US$3.2 billion in 2011 alone. Five EU countries planted a record 129,071 hectares of biotech Bt maize, up 13% from 2011. Spain was by far the largest adopter planting 90% of the total Bt maize hectarage in the EU. From 1996 to 2011, biotech crops contributed to Food Security, Sustainability and Climate Change by: increasing crop production valued at US$98.2 billion; providing a better environment, by saving 473 million kg a.i. of pesticides; in 2011 alone reducing CO2 emissions by 23.1 billion kg, equivalent to taking 10.2 million cars off the road; conserving biodiversity by saving 108.7 million hectares of land; and helped alleviate poverty by helping >15.0 million small farmers, and their families totalling >50 million people, who are some of the poorest people in the world. Biotech crops are essential but are not a panacea and adherence to good farming practices such as rotations and resistance management, are a must for biotech crops as they are for conventional crops. Contribution of biotech crops in

Sustainability in food, feed and fibre security and self sufficiency, Conserving biodiversity, Contributing to the alleviation of poverty and hunger, Reducing agriculture's environmental footprint, helping mitigate climate change and reducing greenhouse gases.

Conclusion and Future Prospects

Biotechnology has tremendous potential for increasing food production and improving food processing. Productivity must first increase in developed countries before real benefits can be reaped in developing countries. Where biotechnologies are applied to production destined for domestic markets, "demonstration effects" can stimulate developments in other countries. In this case, there is considerable scope for cooperation among developing countries. However, the future scope of biotech crops increase tremendously in both developed and developing country the first biotech based drought tolerant maize planned for release in North America in 2013 and in Africa by ~2017.

The first stacked soybean tolerant to herbicide and insect resistant will be planted in Brazil in 2013; subject to regulatory approval, Golden Rice could be released in the Philippines in 2013/2014. Drought tolerant sugarcane is a possible candidate in Indonesia, and biotech maize in China. So the adoption and application of this new technology aims to increase productivity in the export sectors, successes in some countries could be at the expense of the market position of others. In such an event, international competition may endanger cooperation among developing countries, which seems necessary for the application of biotechnologies that are specifically suited to their interests.

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