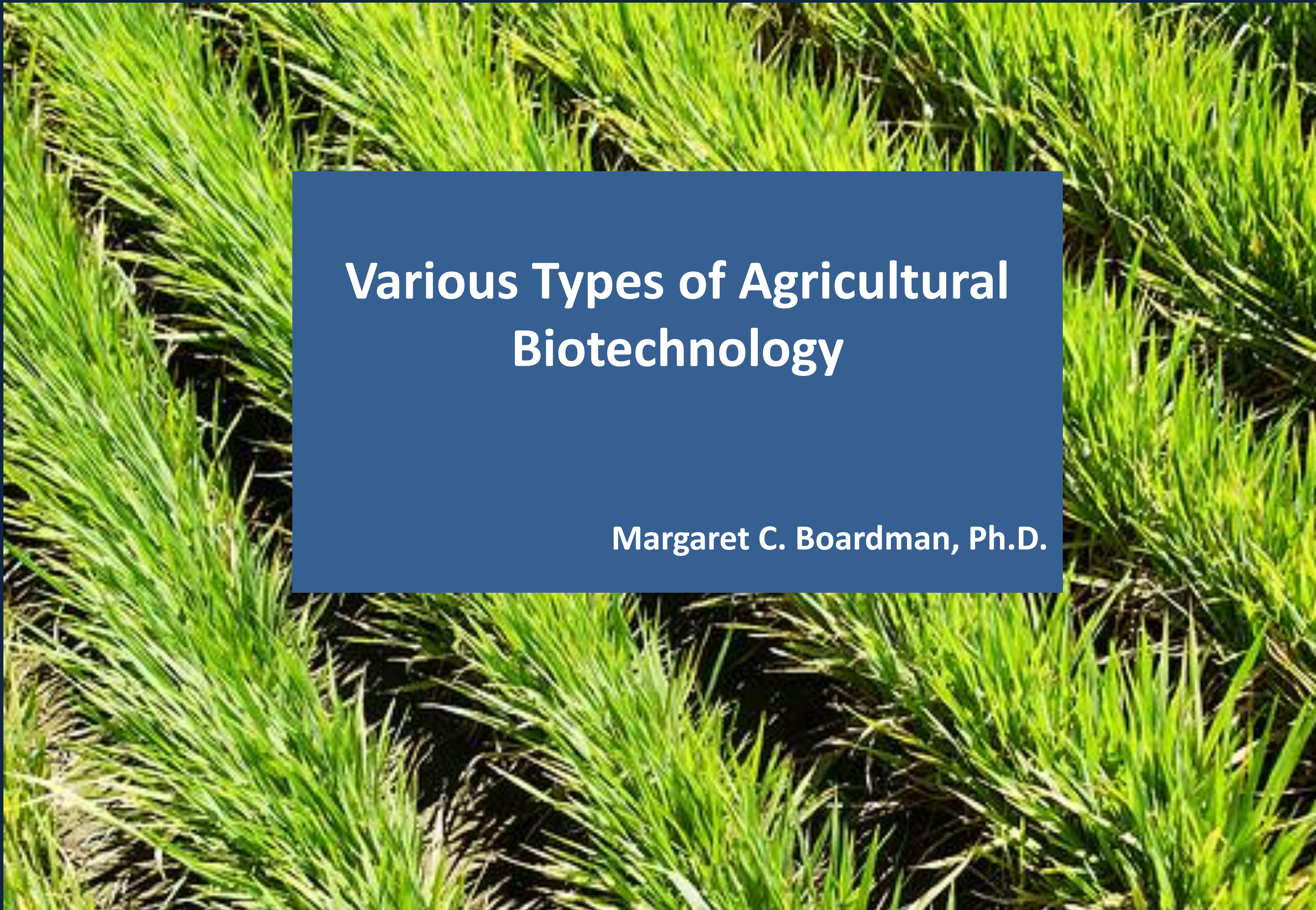


Various Types of Agricultural Biotechnology

Margaret C. Boardman, Ph.D.

Agricultural Biotechnology Terminology

Hybridization (Conventional Breeding)

Plants exchange large, unregulated chunks of their genomes. This can lead to both useful and unwanted traits in the offspring. Sometimes these unwanted traits can be unsafe.

Breeders sometimes have to cross many plants over multiple generations to produce the desired trait.

Genetic Engineering (GE)

Molecular biology is used to isolated and introduce new traits, one at a time without complications from extra genes and extensive crossbreeding.

GE techniques also allow traits from different organisms to be applied, such as pest resistance.

Precautionary Principle –The theory that if the effects of a certain technology are unknown, then the technology should not be used or the action should not be taken. (used by the European Union to decide GE agricultural issues)

Anti-Precautionary Principle – Permitting release of a new technology after a sampling of regulatory testing has not shown it to be dangerous. (used by the United States to decide GE agricultural issues)

Co-existence The development of guidelines and regulations that allow for the planting of organic, conventionally hybridized, and gene-engineered (GE) plants. This can be within a small locality, region, or country depending the jurisdiction. The purpose of the guidelines is to ensure that the crops do not cross-pollinate and contaminate one another.

Agricultural Biotechnology
First Generation of GE Crops

- Introduced in the United States in 1996
- GE crops grew faster in acreage than any other technology in U.S. agricultural history.
- Commodity farmers interested purchase GE seeds because:
  - lower input costs
  - higher yields promise higher revenues
  - less use of toxic chemicals
  - less intensive weed and pest management
  - Provide the farmers with more time and labor for other things
- The first commercial GE crops addressed:
  - Insect Resistant - Bacterial Bt genes (*Cry deltaendotoxins)*
  - Herbicide Resistant – tolerance of the glyphosate (Roundup®) and glufosinate (Liberty®) herbicides

Agricultural Biotechnology

Some Possible Applications/Products

In Production

- Insect Resistant (BT)
- Herbicide Tolerant Crops (HT, RoundUp)
- Virus-Resistant
- Drought Tolerant (DT)
- Nutritionally Enhanced Crops (QPM, Golden Rice)
- Nitrogen Efficiency
- Phytoremediation

Risk Assessment –

Different countries have different ways to test GE crops. Some basic risk level assessments include:

- Low Risk – New trait that is comparable to traditional breeding.
- Moderate Risk – Low environmental toxicity, non-food crops.
- Higher Moderate Risk – New pest or herbicide resistance
- High Risk – Vertical Transfer, intra-species genes, possibility of accumulation of high levels of toxins.

Agricultural Biotechnology
BT – Insect Resistant Products

Bacillus thuringiensis (BT) is a soil-dwelling bacterium that has been used as a natural insecticide by organic farmers since the 1950s.

BT bacterium form various different strains of crystal proteins known as cry toxins that are poisonous to certain insects. In GE BT crops, these cry genes are engineered into the DNA of the plant. When insects ingest the BT crystals the alkaline PH of their digestive tract causes the toxin to activate. The toxins are not poisonous to humans although critics of BT crops claim that it increases toxicity of the liver.

The most popular BT products are BT cotton and BT Maize.

Agricultural Biotechnology
BT – Cotton

- 25% of all insecticides used in agriculture are applied to cotton, more than any other crop.
- This % can reach staggering proportions in some countries such as:
  - Central and West Africa 80%
  - Pakistan 79%
  - India (48%)
- In the cotton fields, pesticides are applied by farm workers carrying backpacks of the pesticides on their bodies. They do not use protective clothing and regularly fall ill to poisoning.

Bt cotton and cotton from an untreated control plot. Source: California Agriculture

Sources: Clive James, Global Status of Commercialized Biotech/GM Crops, 2004. Ithaca, NY: ISAAA, 2004; and K M Wu and Y Y Guo, "The Evolution of Cotton Pest Management Practices in China," *Annual Review of Entomology* 50, 31-32.

BT Crop Refuge Area

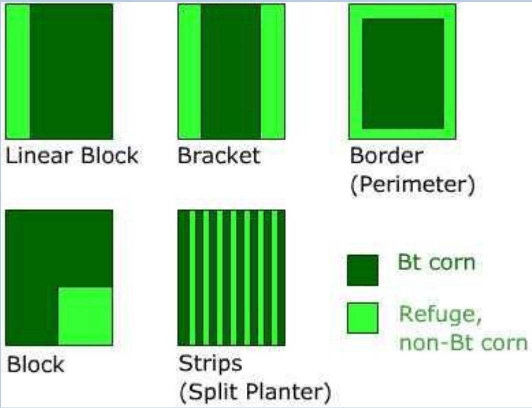
BT seed manufacturers and government regulators require that farmers set aside a certain % of acreage to non-BT varieties. These areas are known as refuges. The recommended separation strips are 200 meters (218 yards).

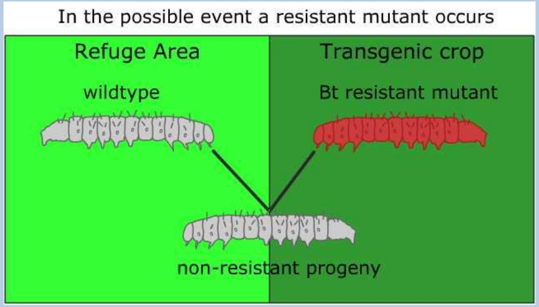
The refuge areas are meant to allow insects to escape into them. The purpose is to allow insects in the refuges to overtake any in the non-refuge area that might become resistant to the BT toxins. If insect resistant does happen, it is thought that combining 2 different strains of BT (there are 100s of different varieties) could arrest this process.

If insects develop BT resistance, the refuges increase odds that they will mate with an insect that has not developed resistance. By the laws of genetics, the progenies produced will be insects would not be resistant to BT.

Source: Aroian Laboratory, University of San Diego

A field of Bt cotton with a border of non Bt cotton. Source: California Agriculture





Agricultural Biotechnology
Herbicide Tolerant Crops

Herbicide Tolerant (HT) crops have been genetically engineered to contain genes that allow them to degrade the active ingredient in certain herbicides (weed killers). Farmers plant the seeds, allowing weeds to grow with the crops. This means they can reduce tilling the soil, which means less erosion. Once the weeds grow up, farmers apply certain herbicides to the crop. This kills the weeds and the crops are resistant so they remain healthy.

The two most common herbicides used are patented *RoundupReady* (active agent: glyphosate) and *Liberty Link* (active agent glufosinate). Both active agents are suppose to dissolve or dissipate naturally into the environment, not leaving a toxic residue that will be harmful to wildlife or next year's crop.

To date, the most common HT crops are soybeans, maize, rapeseed (canola), and cotton.

Critics believe that this technology: 1) promotes increased use of these patented herbicides, and 2) might produce herbicide resistant weeds and damage biodiversity. To date scientific fields have not found this to be the case. Several studies have shown that no tillage and planting HT maize has encourages increased wildlife on the farm (e.g. beneficial insects, birds) while others found that HT sugar beets and rapeseed slightly decreased it.

Agricultural Biotechnology
Virus Resistant

GE virus resistant plants are immune to a particular virus because a mild strain of the viral RNA has been inserted into the GE plant's DNA. The concept is similar to giving it an immunization so it acquires a natural defense against the disease.

Virus-Resistant Papaya

- 1950s-1970s - The papaya industry on the island of Oahu is decimated by the papaya ring spot virus (PRSV) and moves to the island of Hawaii.
- 1978 Dr. Dennis Gonsalves begins studying PRSV viral RNA
- 1992-1995 PRSV becomes widespread throughout Hawaii's papaya crop. Dr. Dennis Gonsalves sucessfully inserted viral RNA into the papaya DNA. The new GE papaya seedlings are found to be resistant.
- 1997-98 Papaya production is down to 26 million lbs.
- 1998-99 Gonsalves distributes GE papaya seeds through a non-profit organization to 90% of Hawaii's papaya farmers. Approximately 76% plant the GE seeds.
- 2001 – Combined GE and conventional papaya production up to 40 millon lbs. GE papaya growers plant refuges with conventional papaya. (If the conventional papaya survives it can be sold. Non-GE papaya is a major export to Japan).
- There are currently no other solutions to PRSV.

Nutritionally Enhanced Crops

Nutritionally enhanced crops are ones that augment the micronutrient content and enhance the nutritional value of staple foods. This may be achieved by either using traditional hybridization methods or gene-engineering.

Quality Protein Maize (QPM)

QPM was hybridized to contain the two missing essential amino acids (lysine and tryptophan) that conventional maize lacks to make it a more complete protein. It has been bred to grow in the tropics.

QPM research was started by Norman Borlaug, the 1970 Nobel Peace Prize Laureate who oversaw the transfer of the first Green Revolution to Asia. It was completed by Dr. Surinder Vasal and Dr. Evangelina Villegas who were both awarded the 2000 World Food Prize.

Between 1996-2001 seeds from field tests Ghana were transferred to Mozambique, Uganda, Benin, Togo, Mali, Burkina Faso, Nigeria, and Ethiopia.

By 2006, there were approximately 1 million hectares of QPM planted in sub-Saharan Africa. Commercial QPM hybrids were also being successfully grown in China, India, Brazil, Mexico, and Central America.
(Source: MCB interview with Dr. Borlaug, 2006)

Golden Rice

Golden rice was gene-engineered to increase vitamin A. Where deficiencies in this vitamin are widespread in the developing world, there is an increase in blindness, disease susceptibility and premature death of young children.

Rice plants produce β-carotene (provitamin A) in green tissues but not in the endosperm (the edible part of the seed). The outer coat of the dehusked grains—the so-called aleurone layer—contains a number of valuable nutrients, e.g. vitamin B and nutritious fats, but no provitamin A. Even though all required genes to produce provitamin A are present in the grain, some of them are turned off during development. This is reversed in Golden Rice, increasing the levels of vitamin A and making the rice a “golden” in color.

Golden rice has been opposed by anti-GE food activists and awaits regulatory approval.

Agricultural Biotechnology
Drought Tolerant

Water shortage is a key problem that many farmers face. Scientists are working to use both traditional hybridization and gene-engineering to find new drought tolerant (DT) plants.

- 1998 Dr. Peter McCourt at the University of Toronto isolates single gene (ERA1) that suppresses stomatal aperture in leaves, helping to reduce water. McCourt teams with Performance Plants and later in 2004 with Sygenta Biotechnology to develop "Yield Protection Technology" in corn, soybeans, and cotton.
- 1999 South Africa's Research Council (ARC) improves drought tolerance in soybeans.
- 2003-2004 Monsanto and Pioneer-Hi announce they are developing DT plants.
- 2004 Egyptian researchers at Cairo's AGERI publish findings on making DT wheat ("Wheat for the desert")
- 2005 Researchers at the University of Connecticut engineer tomato plants for greater drought stress by allowing the plants to produce a specific enzyme that allows their roots to be more efficient at drawing water during drought. This team is also working on similar results for rice, poplar trees, and legumes.
- 2007 Chinese researchers collaborating with Purdue publish findings on making cow peas more DT and also more salt tolerant.
- 2007 Monsanto announces it is in the early product development stages for DT maize and could possible have it commercially available to US farmers by 2010. Monsanto, Pioneer Hi-Bred and Sygenta Biotechnology are all gearing their DT seeds for use in temperate zones, with a target market in the USA, Brazil, and Argentina. They are not currently researching options for tropical conditions applicable to Africa.

% of Agro-system Crops at Risk for Drought

Africa	20%
India	24%
China	27%
Latin American	31%
USA	44%
Eastern Europe	56%

Source: Paarlberg, Robert L. *Starved for Science: How Biotechnology Is Being Kept Out of Africa*. Cambridge, Mass: Harvard University Press, 2008, 151-160.

Table 1. Global Area of Biotech Crops in 2009: by Country (Million Hectares)

Table 1. Global Area of Biotech Crops in 2009: by Country (Million Hectares)

Rank	Country	Area (million hectares)	Biotech Crops
1*	USA*	64.0	Soybean, maize, cotton, canola, squash, papaya, alfalfa, sugarbeet
2*	Brazil*	21.4	Soybean, maize, cotton
3*	Argentina*	21.3	Soybean, maize, cotton
4*	India*	8.4	Cotton
5*	Canada*	8.2	Canola, maize, soybean, sugarbeet
6*	China*	3.7	Cotton, tomato, poplar, papaya, sweet pepper
7*	Paraguay*	2.2	Soybean
8*	South Africa*	2.1	Maize, soybean, cotton
9*	Uruguay*	0.8	Soybean, maize
10*	Bolivia*	0.8	Soybean
11*	Philippines*	0.5	Maize
12*	Australia*	0.2	Cotton, canola
13*	Burkina Faso*	0.1	Cotton
14*	Spain*	0.1	Maize
15*	Mexico*	0.1	Cotton, soybean
16	Chile	<0.1	Maize, soybean, canola
17	Colombia	<0.1	Cotton
18	Honduras	<0.1	Maize
19	Czech Republic	<0.1	Maize
20	Portugal	<0.1	Maize
21	Romania	<0.1	Maize
22	Poland	<0.1	Maize
23	Costa Rica	<0.1	Cotton, soybean
24	Egypt	<0.1	Maize
25	Slovakia	<0.1	Maize

* 15 biotech mega-countries growing 50,000 hectares, or more, of biotech crops

Source: Clive James, 2009.