Key Biotech Crop Traits in Africa by 2014

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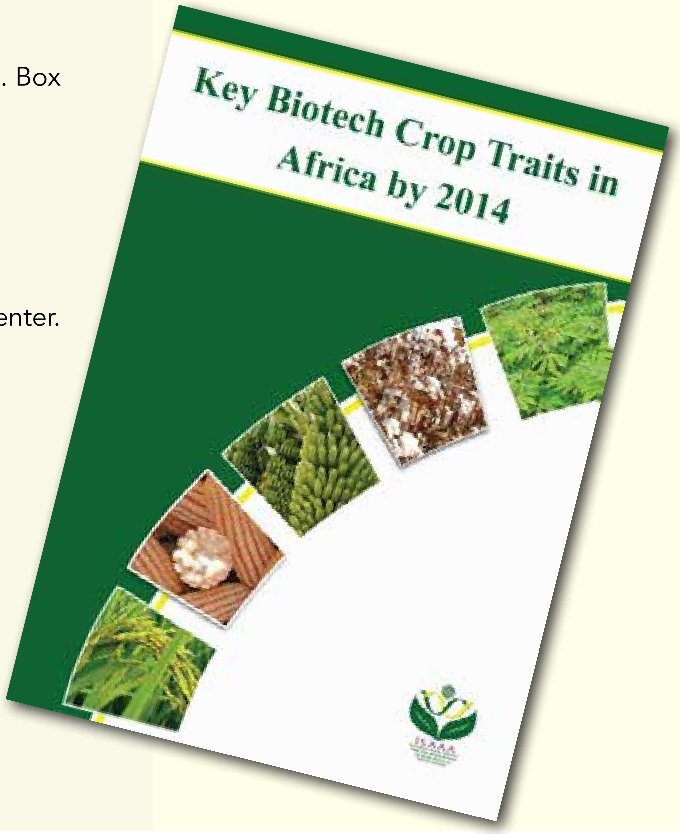

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Abbreviations

Bt	*Bacillus thuringiensis*
CMD	Cassava Mosaic Disease
CBSD	Cassava Brown Streak Disease
DNA	Deoxyribonucleic Acid
EFSA	European Food Safety Authority
EFSE	Early Food Safety Evaluation
GM-IR	Genetically Modified – Insect Resistant
HT	Herbicide Tolerance
NUE	Nitrogen Use Efficient
NERICA	New Rice for Africa
RNAi	Ribonucleic Acid interference
US-EPA	United States Environment Protection Authority
US-FDA	United States Federal Drug Administration
UV	Ultra Violet radiation
VIRCA	Virus Resistant Cassava for Africa

Introduction

This booklet discusses the basic details of biotech crops' traits, also known as genetically modified (GM) or transgenic crops in Africa. It provides facts about the development of the crops each trait at a time, their safety to consumers, benefits accruing from their adoption and the status in adoption in various countries. This comes as Africa continues to make progress in adoption of the crops with Burkina Faso, South Africa and Sudan already reaping from their commercialization. An additional seven countries (Cameroon, Egypt, Ghana, Kenya, Malawi, Nigeria and Uganda) are conducting field trials on biotech crops, which is the penultimate step prior to their approval.

Genetic engineering (GE) technology is without doubt one of the fastest adopted technologies in the recent past. From their first commercialization on 1.7 million hectares in 1996, they increased to 181.5 million hectares in 2014. This rapid adoption in only 19 years of commercialization, reflects the confidence accruing from multiple benefits already realized by both large and small farmers in industrial and developing countries growing these crops commercially. Benefits realized range from more convenient and flexible crop management, lower cost of production, higher productivity and/or net returns per hectare, health and social benefits as well as a cleaner environment through decreased use of select pesticides. These benefits, collectively contribute to a more sustainable agriculture.

Despite these benefits, adoption of biotech crops faces the challenge of misconception stemming from myths and fears that the crops may cause harm to people and the environment. It is therefore important to highlight the proven facts about GM crops' safety, as well as dispel unfounded fears that people may have regarding their development. It is hoped that this booklet will be useful in making the facts of biotech crops' traits currently in Africa known.

Insect Resistant (IR) Biotech Crops

In 2014, insect resistant crops occupied 27.4 million hectares globally

1 Insect Resistant (IR) Biotech Crops

Globally, crop yield losses due to insects vary between 5% and 30% depending on the crop species (Chitwood 2003). Factors which increase plant susceptibility to pests include: lack of genetic diversity within the genomes of cultivated crop species; changes in cultivation techniques, such as large-scale cropping of genetically uniform plants and reduced crop rotation. Expansion of crops into less suitable regions can also increase susceptibility to new pests.

To manage pests' damage, farmers' options are almost limited to spraying their crops with pesticides. Unfortunately, some of these pesticides are highly persistent and pose risks to human beings, animals and the environment, especially when they are not used according to prescribed recommendations. It is for this reason scientists are constantly researching newer ways of tackling plant pests' menace. One of the innovations is the use of a common soil bacterium to control pests scientifically called *Bacillus thuringiensis* (Bt). Bt produces a crystal structure protein (Cry) that paralyzes the larvae of common plant pests, including certain bollworms and borers that infest crops such as cotton, maize and vegetables.

Genetic Engineering of Insect Resistant (IR) Biotech Crops

Over the last 40 years, Bt has been used as a way of controlling pests by farmers globally. Organic farming in particular has benefited from Bt insecticide, as it is one of the very few pesticides permitted by organic standards. The insecticide is applied either as a spray, or as ground applications. It comes in both granules and liquefied form. The efficiency of both applications is quite limited, as target organisms often do not come in contact with the insecticide since they are found on the underside of leaves or have already penetrated into the plant.

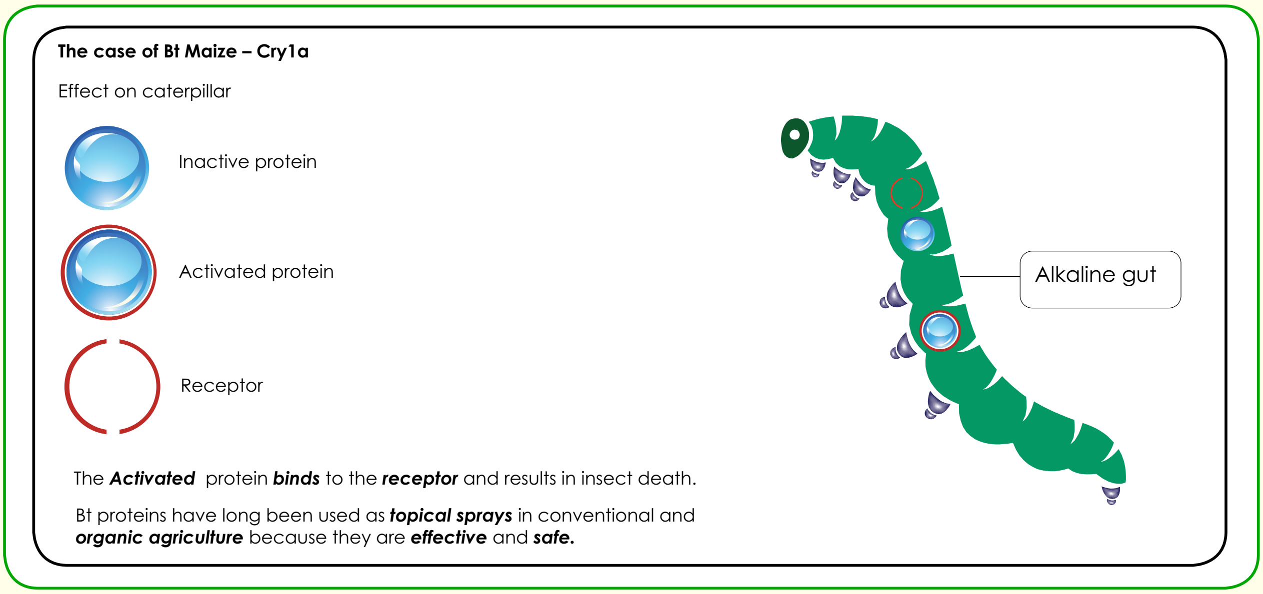
Due to this limitation, scientists have taken Bt gene responsible for production of insecticidal protein from the bacterium and incorporated it into plants' genome. These plants therefore acquire an inbuilt self protecting mechanism against targeted pests. The protein produced by the plants does not get washed away, nor is it destroyed by sunlight. This ensures that the plant is protected from the specific insects.

Mode of Action

When ingested by larvae of target insects, Bt protein is activated in the gut's alkaline condition and punctures it leaving the insect unable to eat. The insect dies within a few days. Due to its ability to produce the insecticidal protein, more research has been done to exploit the organism's agronomic value. To date, there are more than 200 types of Bt proteins identified with varying degrees of toxicity to some insects.

Status of IR Biotech Crops

The Bt genes have made a tremendous contribution to conferring resistance to a broad range of insect pests in some of the major crops, including maize, cotton, and important vegetables such as eggplant (Brinjal). Both industrial countries like the US and Canada, as well as developing countries for example Burkina Faso and Bangladesh have benefited from Bt genes. In 2014, insect resistant crops occupied 27.4 million hectares globally (James, 2014).



Source: ISAAA

Table 1: Countries with Insect Resistant Biotech Crops in Africa

Status	Country	Crop
Commercialized Bt biotech crops	Burkina Faso, South Africa, Sudan	Cotton and Maize
Confined Field Trials (CFTs) of Bt biotech crops	Burkina Faso, Ghana, Egypt, Nigeria, Cameroon, Kenya, Uganda, Malawi, South Africa	Cotton, Maize, Cowpea, Sweetpotato

Source: (James, 2014)

Safety Aspects of IR Biotech Crops

Effects on Human Health

European Food Safety Authority (EFSA) GMO Panel Working Group on Animal Feeding Trials (2008) published a review article that included their assessment of a number of published toxicology studies conducted on GM crops (Bt and non-Bt) over time. According to the review, the majority of these studies showed no adverse effects. Similarly, independent researchers reviewed 24 long-term or multigenerational studies with GM crops and came to the conclusion that GM plants are nutritionally equivalent to their non-GM counterparts and can be safely used in food and feed (Snell et al., 2012). Another recent review article evaluated the reliability of a number of the published toxicology studies carried out with GM crops and proteins in general, and Bt crops in specific. Of the studies determined to be reliable, none found evidence of adverse effects from consumption of GM crops containing Cry proteins or of purified Cry proteins (Koch et al., 2014).

Further, Environment Protection Agency (EPA), the institution in the US responsible for protecting human health and the environment has not found any human health hazards related to using Bt. This is despite US being among countries with the longest history of use of Bt crops ("Bacillus thurinigiensis", 2000).

Effects on non-Target Organisms

The potential impact of Bt crops on soil organisms is well studied. A comprehensive review of the available literature on the effects of Bt crops on soil ecosystems from the results of 70 scientific articles has been done (Icoz et al., 2008).The review found that, in general, few or no toxic effects of Cry proteins on woodlice, collembolans, mites, earthworms, nematodes, protozoa and the activity of various enzymes in soil have been reported. Although some effects, ranging from no effect to minor and significant effects, of Bt plants on microbial communities in soil have been reported, they were mostly the result of differences in geography, temperature, plant variety and soil type and, in general, were transient and not related to the presence of the Cry proteins.

Benefits of IR Biotech Crops

In global terms, the farm level impact of using GM insect resitant maize was $6.08 billion in 2013. Cumulatively since 1996, the benefit has been (in nominal terms) $27.3 billion. This farm income gain has mostly been derived from improved yields (less pest damage) although in some countries, farmers have derived a net cost saving associated with reduced expenditure on insecticides. In terms of the total value of maize production from the countries growing GM insect resistant maize in 2013, the additional farm income generated by the technology is equal to a value added equivalent of 5.9%. As an example relative to the value of global maize production in 2013, the farm income benefit added the equivalent of 3.3%.

For GM IR cotton, the farm level impact was $4.7 billion in 2013. Cumulatively since 1996, the farm income benefit has been (in nominal terms) $40.81 billion. Within this, 78% of the farm income gain has been derived from harvest gains (less pest damage) and the balance (22%) from reduced expenditure on crop protection (spraying of insecticides). In terms of the total value of cotton production from the countries growing GM-IR in 2013, the additional farm income generated by the technology was equal to a value-added equivalent of 12.2%. Relative to the value of global cotton production in 2012, the farm income benefit added the equivalent of 10.3% (Brookes and Barfoot, 2015).

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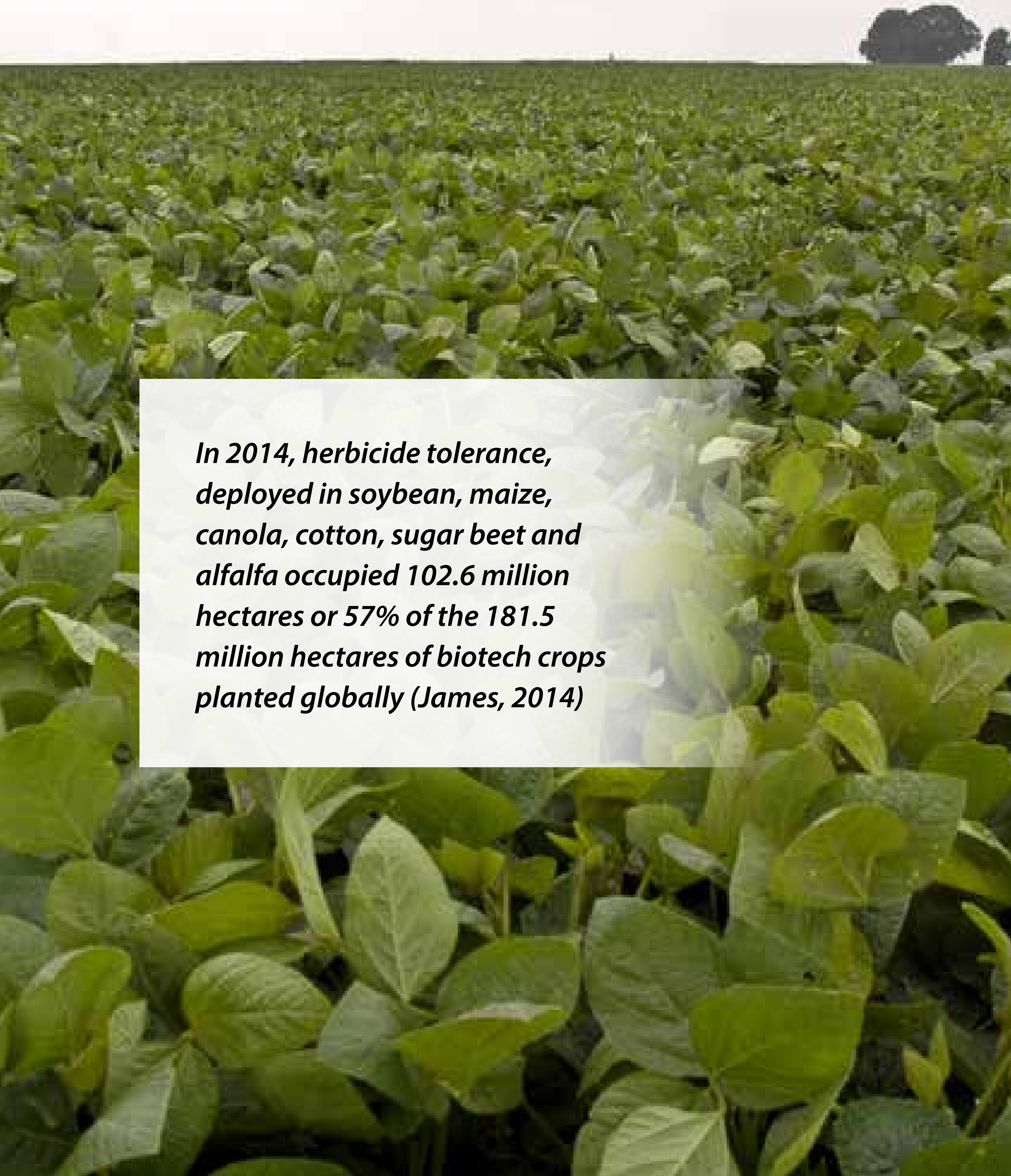
Herbicide Tolerant (HT) Biotech Crops



In 2014, herbicide tolerance, deployed in soybean, maize, canola, cotton, sugar beet and alfalfa occupied 102.6 million hectares or 57% of the 181.5 million hectares of biotech crops planted globally (James, 2014)

2 Herbicide Tolerant (HT) Biotech Crops

Weeds compete with crops for water, nutrients, sunlight, and space. They also, harbor insect and disease pests; clog irrigation and drainage systems; undermine crop quality; and deposit weed seeds into crop harvests. If left uncontrolled, weeds can reduce crop yields significantly. Farmers fight weeds with tillage, hand weeding, herbicides, or typically a combination of all techniques. Unfortunately, tillage leaves valuable topsoil exposed to wind and water erosion, leading to long-term negative consequences to the environment. For this reason, farmers are increasingly opting for reduced or no-till methods of farming made possible when herbicide tolerant (HT) crops are used.

Genetic Engineering of (HT) Biotech Crops

Herbicide tolerant crops have been modified in several ways to survive exposure to herbicides. The mode of action constitutes of any of the following methods:

1. Producing a new protein that detoxifies the herbicide.
2. Modifying the herbicide's target protein so that it will not be affected by the herbicide.
3. Producing physical or physiological barriers preventing the entry of the herbicide into the plant.

Table 2: Countries with Herbicide Tolerant Biotech Crops in Africa

Status	Country	Crop
Commercialized HT biotech crops	South Africa	Soybean, Maize
Confined Field Trials (CFTs) of HT biotech crops	Ghana	Cotton

Source: (James, 2014)

The first two approaches are the most common ways scientists develop herbicide tolerant crops.

Status of HT Biotech Crops

During the 19 years (1996 to 2014) of commercialization of biotech crops, herbicide tolerance has consistently been the dominant trait. In 2014, the trait deployed in soybean, maize, canola, cotton, sugar beet and alfalfa occupied 102.6 million hectares or 57% of the 181.5 million hectares of biotech crops planted globally (James, 2014).

Safety Aspects of HT Biotech Crops

Toxicity and Allergenicity

Regulatory agencies in several countries have ruled that crops possessing herbicide-tolerant conferring proteins do not pose any added health risks than their non-herbicide tolerant counterparts.

Introduced proteins are assessed for potential toxic and allergenic activity in accordance with guidelines developed by relevant international organizations. The proteins including the ones conferring herbicide tolerance traits must be from sources with no history of allergenicity or toxicity; they do not resemble known toxins or allergens; and they have functions, which are well understood.

Effects on Plants

The expression of proteins that detoxify herbicides does not damage the plant's growth nor result in poorer agronomic performance compared to parental crops. Except for expression of an additional enzyme for herbicide tolerance or the alteration of an already existing enzyme, no other metabolic changes occur in the plant.

Persistence or Invasiveness of HT Biotech Crops

The current scientific evidence indicates that, in the absence of herbicide applications, GM herbicide-tolerant crops are no more likely to be invasive in agricultural fields or in natural habitats than their non-GM counterparts (Dale et al., 2002). With the appropriate agronomic management practices, the herbicide-tolerant crops show little evidence of enhanced persistence or invasiveness.

Benefits of HT Biotech Crops

Herbicide tolerant crops provide excellent weed control and hence higher yields. They also offer flexibility in that it is possible to control weeds later in the plant's growth. The plants have enabled the reduction of the number of sprays in a season and in effect reduced the need to use a lot of fuel. The HT crops have also led to improved soil conditions. This is due to reduced soil compaction as well the use of low toxicity compounds which do not remain in the soil for a long time. In so doing, soil organisms are conserved.

Women have also benefited by being alleviated from hard labour in manual weeding. Presently weeding, which is the major activity in food production is manual and 60-80 % of the labour is by women in sub-Saharan Africa ("Women farmers productivity in sub-Saharan Africa", n.d.).

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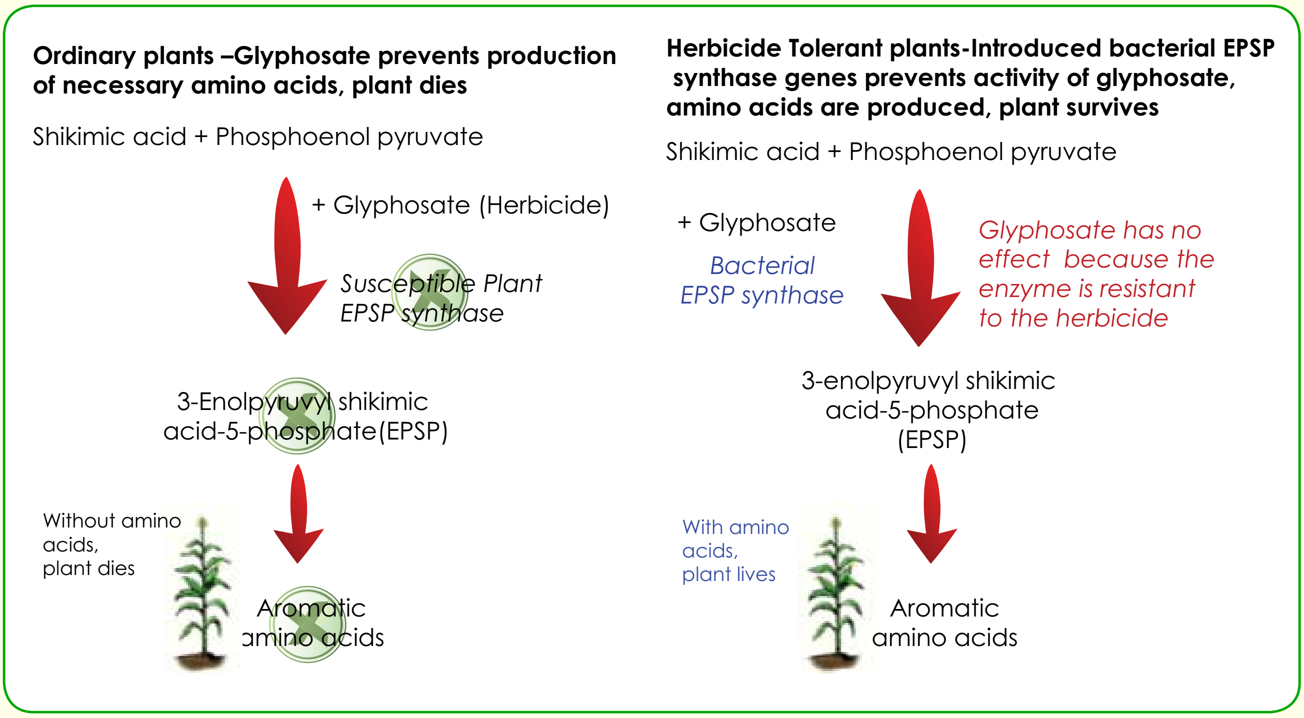
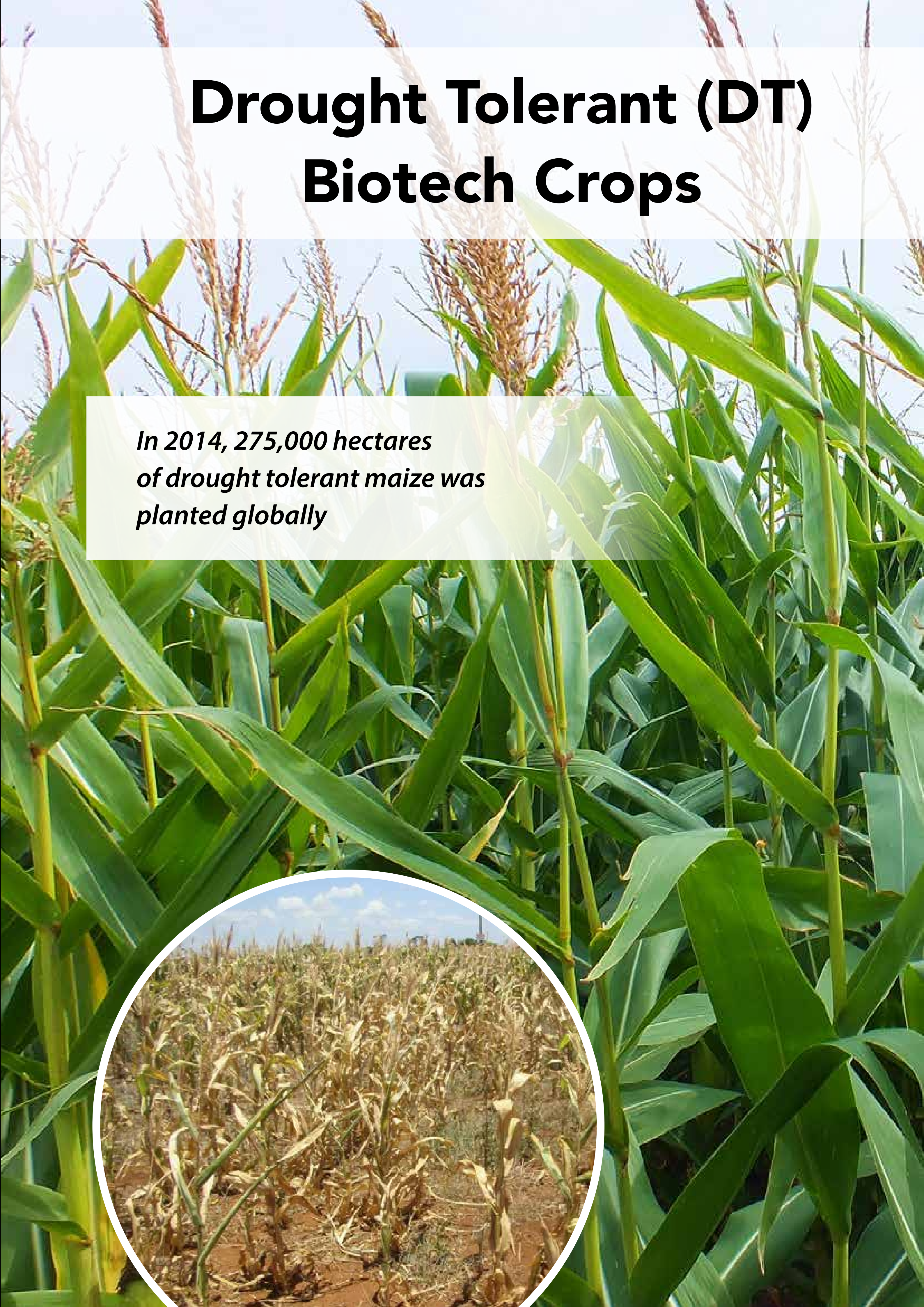


Source: NDSU. Extension. (2003). The Science of Transgenics. Phil McClean. De partment of Plant Science. North Dakota State University.

Drought Tolerant (DT) Biotech Crops

In 2014, 275,000 hectares of drought tolerant maize was planted globally



3 Drought Tolerant (DT) Biotech Crops

Agriculture is one of the largest consumers of water globally (Hamdy et. al, 2003). It is thus essential to improve water use efficiency in agriculture. This will require an integrated approach to water resources management to encourage an efficient and equitable use of the resource, and to ensure sustainability.

Efficient water use is ever more relevant especially because water scarcity represents the most severe constraint to agriculture. The Food and Agricultural Organization (FAO) estimates that by 2025 approximately 480 million people in Africa could be living in areas with very scarce water. As climatic conditions deteriorate, 600,000 square km currently classified as moderately constrained will become severely limited.

The develpment of crop varieties with increased tolerance to drought, both by conventional breeding methods and through genetic engineering is an important strategy to meet global food demands.

Genetic Engineering DT Biotech Crops

The development of drought tolerant crops by genetic engineering, requires identification of key genetic determinants underlying stress tolerance in plants, and introducing these genes into crops.

Drought triggers a wide array of physiological responses in plants, and affects the activity of a large number of genes. Experiments have identified several hundred genes which are either induced or repressed during drought. Many of these are isolated in Arabidopsis (a model laboratory plant).

Although not a crop plant, Arabidopsis has played a vital role in the elucidation of the basic processes underlying stress tolerance. The knowledge obtained has been transferred to a certain degree to important food plants.

The introduction of these stress- inducible genes into plants by genetic engineering has resulted to increased tolerance of biotech crops to drought, cold and salinity.

Status of DT Biotech Crops

Maize is one of the best examples of drought tolerant crops. The US was the first country globaly to comercialize drought tolerant maize. In 2014, 275,000 hectares of DroughtGard™ maize was planted in the country. Water Efficient Maize for Africa (WEMA), a public-private partnership (PPP) is designed to deliver the first biotech drought tolerant maize to select African countries. The WEMA countries are Kenya, Mozambique, Republic of South Africa, Tanzania and Uganda.

Safety Aspects of DT Biotech Crops

The EPA and FDA of the US approved the first DT maize following a thorough safety assesment. The new WEMA varieties as is the case for other drought tolerant crops, will need to pass all regulatory requirements and evaluations in the countries where they will be grown before farmers can grow them. The varieties developed through transgenic approaches must also undergo extensive health and safety risk assessments - these detailed food, feed and environmental safety assessments confirm product safety.

Table 3: Status of Drought Tolerant Biotech Crops in Africa

Status	Country	Crop
Commercialized DT biotech crops	None	None
Confined Field Trials (CFTs) of DT biotech crops	Egypt, Kenya, Uganda, South Africa	Maize and Wheat

Source: (James, 2014)

Benefits of DT Biotech Crops

The drought-tolerant crops will provide valuable economic, agronomic and environmental benefits to millions of farmers by helping them produce more reliable harvests under moderate rainfall conditions.This will help farmers harvest enough to feed their families and produce a surplus harvest which they can sell to increase their incomes.

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Nitrogen-Use-Efficient (NUE) Biotech Crops

Improving the nitrogen use efficiency of plants has been achieved by inserting genes encoding for enzymes that enable photosynthesis to take place even under conditions of low oxygen which leads to nitrogen deficiency

4 Nitrogen-Use-Efficient (NUE) Biotech Crops

Nitrogen is one of the primary macronutrients that plants need for survival, aside from phosphorus and potassium. It is important for plant growth and development, particularly in metabolic processes such as production of nucleic acids and proteins.

The macronutrient is a basic component of plant's green pigment known as chlorophyll, which is vital for photosynthesis. It is abundant in the atmosphere but is not readily available for plants. It can be used up by plants when converted into ammonia from fixation by bacteria to make nitrogen-containing molecules.

Biological nitrogen fixation occurs in some plants through metabolic activities of free-living or symbiotic bacteria. A common symbiotic bacterium involved in nitrogen fixation is Rhizobium. It attacks and reproduces in the legume plants' roots to get their nutrition. After about a week of infection, white or grey nodules form in roots. The bacteria through action of enzyme nitrogenase, convert nitrogen gas (N2) into ammonia (NH3). The plants use ammonia to produce amino acids and other nitrogen-containing molecules. Plants that do not form associations with bacteria must get nitrogen from the soil. This nitrogen gets depleted with frequent use of soils in farmlands. Thus, nitrogen fertilizers are applied (Lindermann et al., 2003).

Since the discovery of nitrogen fertilizer, use of synthetic nitrogen has increased dramatically leading to significant boost in crop yields. Out of this, only 30-50% nitrogen is absorbed by plants. The rest is wasted and cause considerable impacts on the environment. It can contribute to algal bloom and hypoxia (reduced oxygen in water) leading to significant loss of aquatic life and diversity. It also contributes to depletion of ozone and global warming. Thus, scientists seek for more environment-friendly and cost-effective strategies to improve nitrogen use efficiency of crops. One of these strategies is the use of genetic engineering.

Genetic Engineering of NUE Biotech Crops

Improving nitrogen use efficiency (NUE) of plants has been achieved by inserting genes encoding for enzymes that enable photosynthesis to take place even under conditions of low oxygen. Several genes from different sources have been found to control these processes leading to improved nitrogen use of plants. (McAllister et al., 2012)

Status of NUE Biotech Crops

One of the crops under study for improvement of NUE is maize, an important global food crop that requires intensive amount of nitrogen fertilizer. Like most crops, maize only absorbs a small amount of the nitrogen applied to it, leading to economic loss to growers. Another crop under study is NUE wheat, projected to significantly impact 35 percent of the world population where wheat is a staple crop, once commercialized. Wheat represents 20 percent of the total protein intake.

Researchers have integrated the nitrogen use efficiency technology with New Rice for Africa (NERICA) varieties developed by Africa Rice Center. Results of confined field trials showed that with an application of 50 percent of usual amount of nitrogen, transgenic rice lines out-yielded

Table 4: Countries with Nitrogen Use Efficient Biotech Crops in Africa

Status	Country	Crop
Commercialized NUE biotech crops	None	None
Confined Field Trials (CFTs) of NUE biotech crops	Ghana, Nigeria, Cameroon, Uganda	Rice

Source: (James, 2014)

conventional NERICA variety by 22 % on the first year of trial and 30 percent by the following year.

Safety Aspects of Nitrogen Efficient Biotech Crops

The US Food and Drug Administration (FDA) has completed the Early Food Safety Evaluation (EFSE) for the plant protein responsible for NUE trait. This review concluded that the functional protein for NUE trait, alanine aminotransferase, is safe for consumption by humans and animals and would not raise safety concerns if present in the food supply. The EFSE is applicable to all plant species utilizing NUE trait ("Arcadia Biosciences' Nitrogen Use Efficiency", 2015).

Benefits of NUE Biotech Crops

The crops help farmers increase yields with half the amount of fertilizer they would use in conventional crops. They also reduce the cost of fertilizer usage. Further these crops improve the environmental footprint of agriculture by reduction of chemical fertilizer usage.

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Nitrogen use efficient crop


Non-transformed crop in a nitrogen deficient field

Salt Tolerant Biotech Crops

The development of salt-tolerant crops by genetic engineering have focused on the following strategies: increasing the plant's ability to limit the uptake of salt ions from the soil; increasing the active extrusion rate of salt ions; and improving the compartmentalization of salt ions in the cell vacuole where they do not affect cellular functions

5 Salt Tolerant Biotech Crops

Most crops are very sensitive to excessive salt, as it severely affects yield; increases the severity of other stresses such as diseases and pollutants; and, can be lethal to the plant. The excessive presence of salt also has a very negative effect on the soil structure, affecting porosity and water retention properties. It can eventually render fields unsuitable for agriculture.

Salt stress effectively decreases the availability of water in the soil to plants. Hence there is a substantial overlap between plant responses to drought and to salinity. Generally, varieties developed to be more tolerant to drought and efficiently use water will also be more resilient to salt stress.

Genetic Engineering of Salt Tolerant Biotech Crops

The development of salt-tolerant crops by genetic engineering have focused on the following strategies:

1. Increasing the plant's ability to limit the uptake of salt ions from soil.
2. Increasing the active extrusion rate of salt ions.
3. Improving the compartmentalization of salt ions in the cell vacuole where they do not affect cellular functions.

Genes encoding small molecules that help the plants survive extreme osmotic stress have also been the targets of genetic modification experiments. Their over-expression in some cases improves salt tolerance.

Mutant analysis-the screening for mutations that affect the plant's response to stress-has been a crucial tool in the discovery of genes acting in the salt stress tolerance network. Screens designed include those aimed at mutations with increased or decreased sensitivity to drought, salinity and cold stresses. Also important has been the use of DNA microarray technology, which allows monitoring changes in gene expression in response to stress. This identifies genes that are either induced or repressed by the treatment. Many of the genes known to be involved in stress tolerance have been isolated from Arabidopsis.

Status of Salt Tolerant Biotech crops

The only crop engineered for salt tolerance is rice, which is at experimental stage in Nigeria. Salt tolerance is a very complex trait, both at the physiological and genetic levels. It is also highly influenced by other environmental factors acting on the plant at the same time.

In addition, the genetic control to salt stress differs in different stages of the plant's life cycle: tolerance at the adult stage does not necessarily correlate with tolerance at the seedling and juvenile stages, or to the ability to germinate in the presence of salts (Flowers, 2004). Rice, for example, is much more affected in grain filling than in vegetative growth by the presence of salt in the soil. To complicate matters further, it is very difficult to design field trials to test the agronomic performance of improved salt-tolerant varieties, as the salt concentration in soils is very variable. This is worsened by the presence of additional

Status	Country	Crop
Commercialized salt tolerant biotech crops	None	None
Confined Field Trials (CFTs) of salt tolerant biotech crops	Ghana, Nigeria, Uganda	Rice

Table 5: Status of Salt Tolerant Biotech Crops in Africa

Source: (James, 2014)

pollutants and inland water intrusion.

Plant genomes need to be very plastic, a feature required to cope with a variable environment that requires a constant adjustment of the plant's metabolism. It is therefore essential to test newly developed stress-tolerant varieties to multiple stresses in laboratory conditions. The importance of carrying out extensive field studies in a large range of conditions that assess tolerance as absolute yield increases cannot be over-emphasized (Mittler, 2006).

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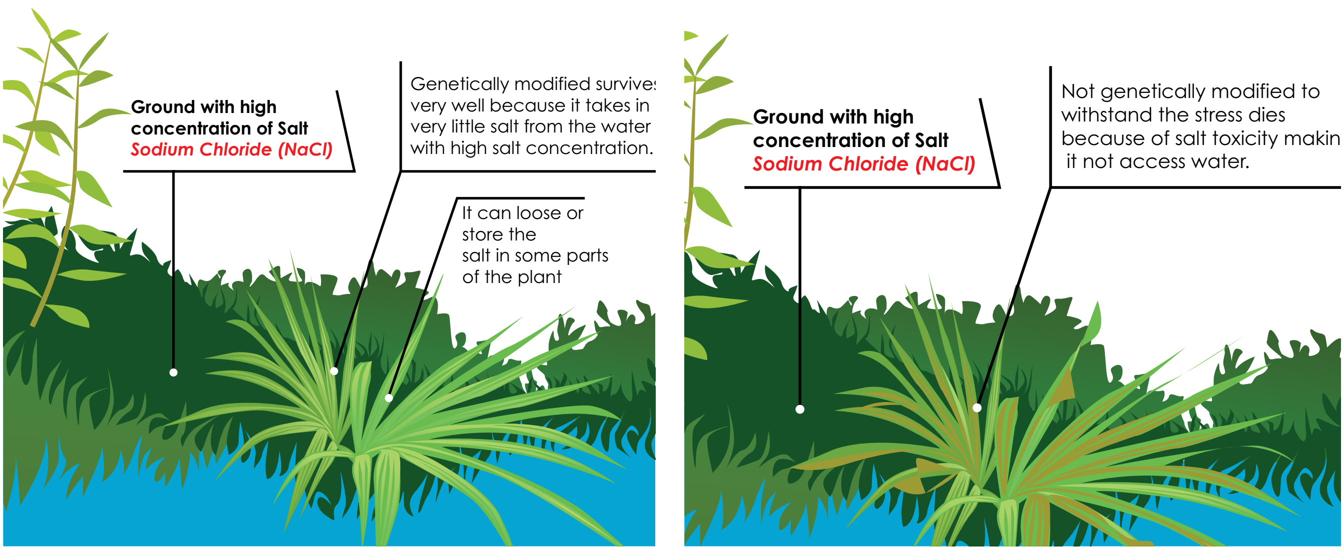
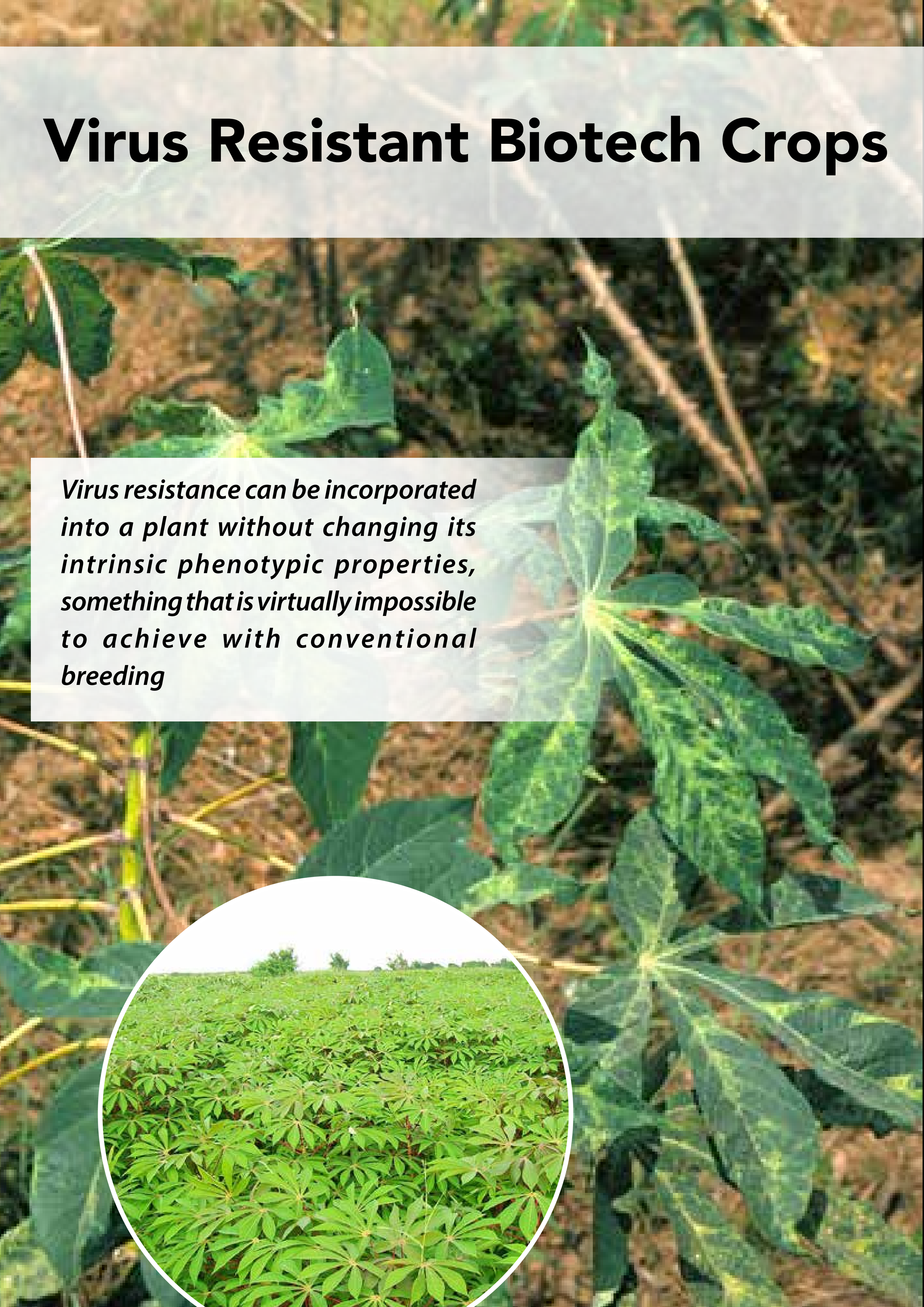


Source: ISAAA

Virus Resistant Biotech Crops

Virus resistance can be incorporated into a plant without changing its intrinsic phenotypic properties, something that is virtually impossible to achieve with conventional breeding



6 Virus Resistant Biotech Crops

Viruses are very small (submicroscopic) infectious particles (virions) composed of a protein coat and a nucleic acid core. They carry genetic information encoded in their nucleic acid, which typically specifies two or more proteins. Translation of the genome (to produce proteins) or transcription and replication (to produce more nucleic acid) takes place within the host cell and uses some of the host's biochemical "machinery". Viruses do not capture or store free energy and are not functionally active outside their host. They are therefore parasites (and pathogens) but are not regarded as genuine microorganisms.

Viruses cause many important plant diseases and are responsible for huge losses in crop production and quality in all parts of the world. Infected plants may show a range of symptoms depending on the disease but often there is leaf yellowing (either of the whole leaf or in a pattern of stripes or blotches), leaf distortion (e.g. curling) and/or other growth distortions (e.g. stunting of the whole plant, abnormalities in flower or fruit formation).

Conventionally, plant viruses cannot be directly controlled by chemical application. Their control is achieved through the elimination of the organism transmiting them either biologically or chemically. It can aslo be achieved by growing resistant crop varieties, use of virus free planting material and exclusion (prevention of disease occurence in areas where it has not yet.

Genetic Engineering of Virus Resistant Biotech Crops

RNA interference (RNAi) also known as gene silencing is a method of blocking gene function, thus no proteins are produced. RNAi has provided a way to control pests and diseases, introduce novel plant traits and increase crop yield. It was first used to develop plant varieties resistant to viruses. Engineered antiviral strategies in plants mimic natural RNA silencing mechanisms. (Qu et al.,2007).

Status of Virus Resistant Biotech Crops

One of the best known examples of engineered virus resistant crops is the Hawaiian papaya resistant against Papaya Ring Spot Virus (PRSV). The crop was commercialized in the US in 1998. It led to recovery of papaya production that was at the blink of collapse on account of the virus. Besides the crop being consumed in the country, it is being exported to Japan and Canada. Although Hawaiian GMO papayas are resistant only to Hawaiian PRSV, the successful development in Hawaii inspired other papaya cultivating countries to develop virus resistant papayas for their local markets. Resistant papaya varieties are now being developed in Brazil, Taiwan, Jamaica, Indonesia, Malaysia, Thailand, Venezuela, Australia and the Philippines. In the US, there are a nominal 1,000 hectares planted to virus-resistant papaya and 1,000 hectares with virus resistant squash.

In Africa, a virus resistant cassava is being developed by VIRCA (Virus Resistant Cassava for Africa) project. The project's goal is to improve cassava for resistance to the viral diseases cassava brown streak disease (CBSD) and cassava mosaic disease (CMD) using pathogen-derived RNAi technology ("The VIRCA Project", 2012).

Table 6: Status of Virus Resistant Biotech Crops in Africa

Status	Country	Crop
Commercialized virus resistant biotech crops	None	None
Confined Field Trials (CFTs) of virus resistant biotech crops	Nigeria, Kenya, Uganda	Cassava, Sweetpotato

Source: (James, 2014)

Safety Aspects of Virus Resistant Biotech Crops

Numerous observations suggest that a viral protein in transgenic plants does not pose a threat to safety. Most notable is that virus-infected crops have been consumed over the centuries with no apparent ill effects known to be due to virus components ("Safety of Virus-Resistant Transgenic Plants", 2007).

Benefits of Virus Resistant Biotech Crops

Virus resistance is incorporated into a plant without changing its intrinsic phenotypic properties, something that is virtually impossible to achieve with conventional breeding. The gene is incorporated into different plant genera and species that are affected by a given virus and are amenable to transformation and regeneration.This is done for plants whose planting material is not seed (vegetatively propagated plants), some of which may be impossible to confer the traits through conventional breeding due to genetic incompatibility or linkage to undesired traits.

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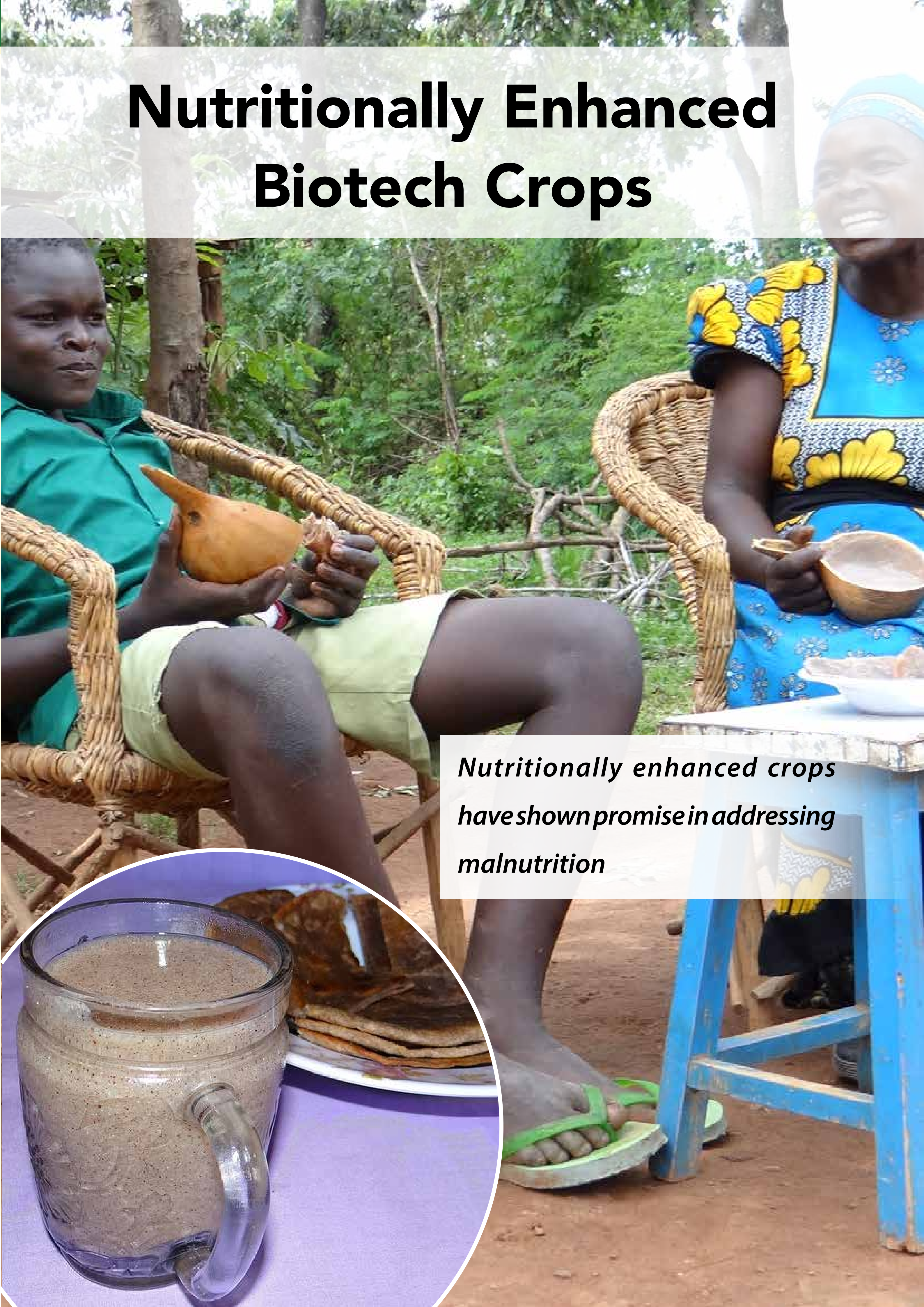
Nutritionally Enhanced Biotech Crops



Nutritionally enhanced crops have shown promise in addressing malnutrition

7 Nutritionally Enhanced Biotech Crops

Micronutrient malnutrition has been acknowledged as the root cause of many health problems in developing countries. Around the world, two billion people do not receive enough essential vitamins and minerals. They are considered malnourished or suffering from hidden hunger.

FAO estimates that 13 per cent of the world's population do not have access to an adequate amount of food, with 826 million being undernourished. The World Health Organization (WHO) believes that half of all childhood deaths in developing countries are due to malnutrition. One in three children is underweight and two-fifths have stunted growth. There is strong evidence that the main deficiencies are iron, vitamins, zinc and iodine.

Half of all countries are facing health issues revolving around vitamin A deficiency, with approximately 670,000 children under the age of five dying each year. Three billion people are iron deficient; globally, more than 115,000 maternal deaths each year are linked to anaemia ("The GM Food Potential", 2011).

One intervention that has shown promise involves nutritionally enhancing crops. It also has the potential to enhance the nutritional value of staple foods that make up the primary diet in many developing countries. These countries lack some macronutrients for example, amino acids; and micronutrients such as iron and vitamins e.g vitamin A. This technology could allow people in developing countries to have a more balanced and diverse diets.

Genetic Engineering of Nutritionally Enhanced Biotech Crops

The conventional staple food crops have the pathways for particular important nutrients turned off because of lack of specific enzymes. For these pathways to release the nutrients e.g. vitamin A, the genes for these enzymes have been inserted, thus making food crops that are not naturally known to provide certain nutritional benefits able to be relied upon for such nutrients.

Status of Nutritionally Enhanced Biotech Crops

Vitamin A enriched rice has been developed to provide the vitamin to large populations in developing countries whose rice is their everyday meal. The rice crop, also known as 'Golden Rice', contains beta carotene, which is converted into Vitamin A by the body. Much like rice, banana, cassava and sorghum are rich in calories but are lacking in nutrients, such as vitamin A, iron, and protein. In Kenya, Nigeria and Uganda for example these crops constitute the biggest part of their daily food and as a result, malnutrition is widespread. The three crops that have been modified to enhance these nutrients are already under trial.

Safety Aspects of Nutritionally Enhanced Crops

At the moment, none of the genetically modified crops has been released into the market. According to (WHO), for the GM foods to be available on the international market, they will have passed safety assessments and not likely to present risks for human health. Continuous application

Table 7: Status of Nutritionally Enhanced Crops in Africa

Status	Country	Crop
Commercialized nutritionally enhanced biotech crops	None	None
Confined Field Trials (CFTs) of nutritionally enhanced biotech crops	Nigeria, Kenya, Uganda	Banana, cassava and sorghum

Source: (James, 2014)

of safety assessments based on the Codex Alimentarius principles and, where appropriate, adequate post market monitoring, should form the basis for ensuring the safety of GM foods ("Frequently Asked Questions on Genetically Modified Foods", n.d.).

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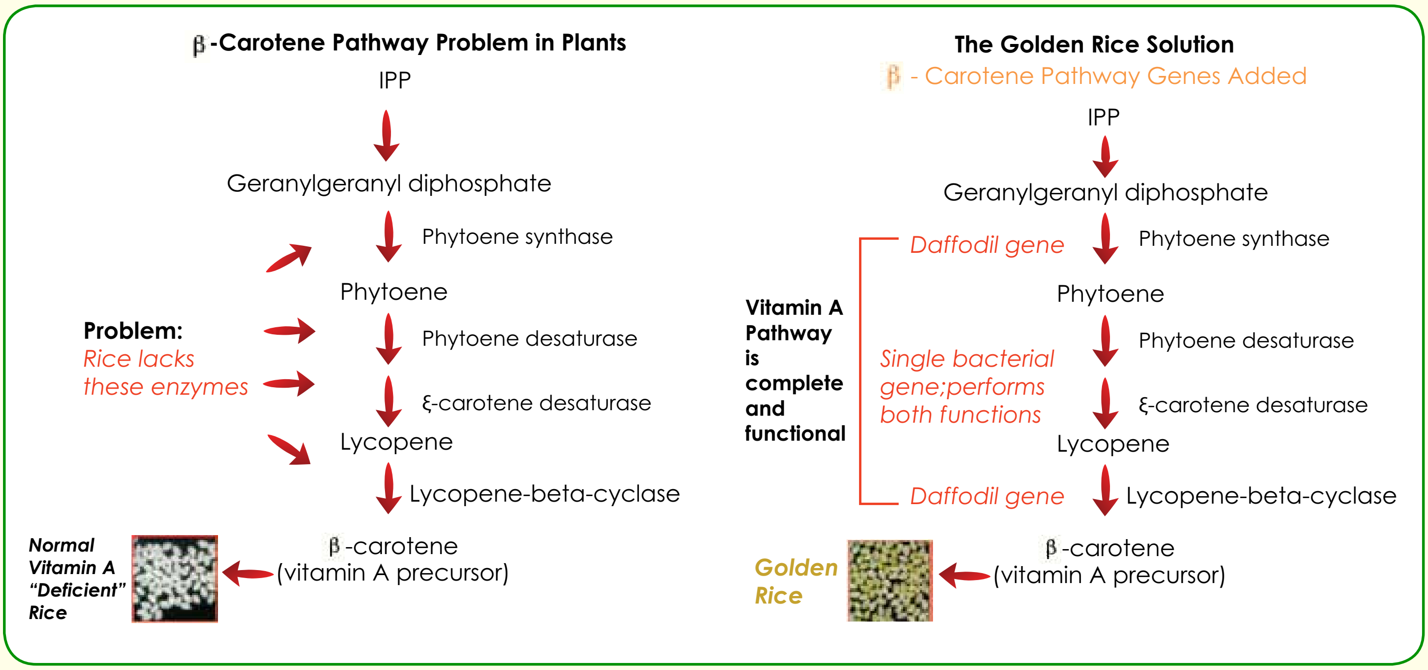

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Stacked Traits in Biotech Crops

Gene stacking refers to the process of combining two or more genes of interest into a single plant

8 Stacked Traits in Biotech Crops

Gene stacking refers to the process of combining two or more genes of interest into a single plant. Gene pyramiding and multigene transfer refer to the same process. The combined traits resulting from this process are called stacked traits. A crop variety that bears stacked traits is called a biotech stack or simply a stack. An example of a stack is a plant transformed with two or more genes that confer insect resistance proteins having different modes of action, or a hybrid plant expressing both insect resistance and herbicide tolerance genes derived from two parent plants.

Genetic Engineering of Stacked Traits Biotech Crops

The easiest and quickest way to stack up genes into a plant is to make crosses between parental plants that have different biotech traits, an approach known as hybrid stacking. Most of the commercially available biotech stacks, like triple stack, and quadruple stack, are products of serial hybrid stacking which is widely adapted and accepted ("GM Approval Database", 2015).

Another method of gene stacking is known as molecular stacking. This involves the introduction of gene constructs simultaneously or sequentially into the target plant by standard delivery systems such as Agrobacterium-mediated and biolistic methods (Haplin, 2005).

Status of Stacked Traits Biotech Crops

In 2014, an estimated 51.4 million ha were planted to biotech stacks. This accounted for more than 28 percent of the 181.5 million ha of biotech crops planted worldwide in that year (James, 2014). Unlike previously where biotech crops were engineered for only one trait, it is now not uncommon to have two or more traits in one biotech crop.

Benefits of Stacked Traits Biotech Crops

Compared to single-trait crop varieties, stacks offer broader agronomic benefits that allow farmers to meet their needs under complex farming conditions. Biotech stacks are engineered for better chances of overcoming the myriad of problems in the field such as insect pests, diseases, weeds, and environmental stresses. Experience has shown that the resistance conferred by a single Bt gene for instance, has the potential to break down as the target insect pest mutates and adapts to defeat the Bt trait, therefore the need for stacking.

Biosafety regulations world over require that a certain percentage of land planted on Bt crops be planted with the same crop that is non Bt, for conservation of the insect pest species. This area is referred to as a refuge area. Gene stacking eliminates the need for a big area for refuge. While the refuge strategy lessens the chance for the insect pest to overcome the Bt trait, farmers cannot realize the full production benefit of the Bt crop.

The next generation of Bt crops with multiple modes of action for insect control have been developed by stacking several classes of Bt genes. This gene stacking approach has reduced the potential of resistance breakdown as it is more difficult for the pest to overcome multiple

Table 8: Status of Stacked Traits Biotech Crops in Africa

Status	Country	Crop
Commercialized stacked traits biotech crops	South Africa	Cotton, Maize, Soybean
Confined Field Trials (CFTs) of stacked traits biotech crops	South Africa, Cameroon, Egypt, Ghana	Cotton, Wheat, Maize, Soybean

Source: (James, 2014)

insecticidal proteins. This greater durability of Bt stacks allows a lower refuge area requirement that somehow limits yield (Storer et al., 2012).

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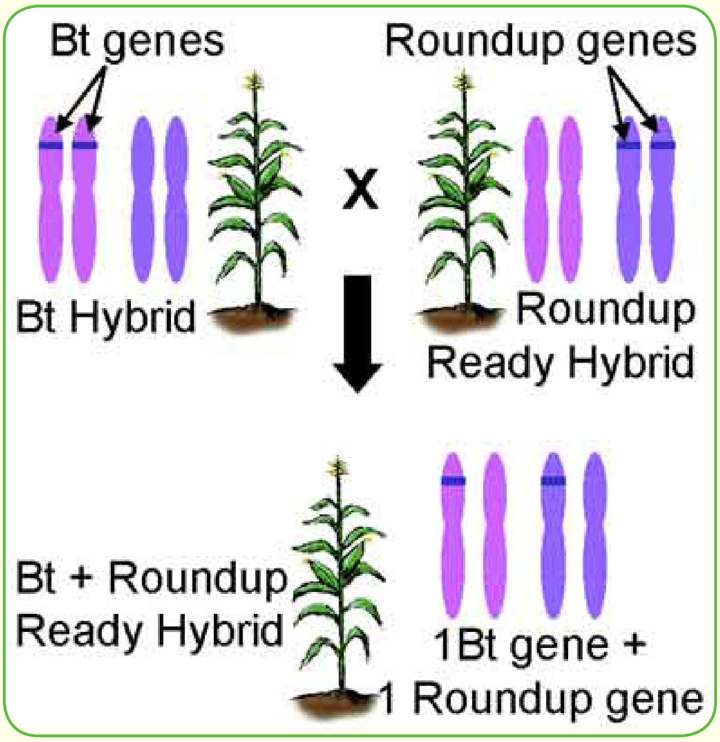


Source: Plant & Soil Sciences eLibrary^{PRO}

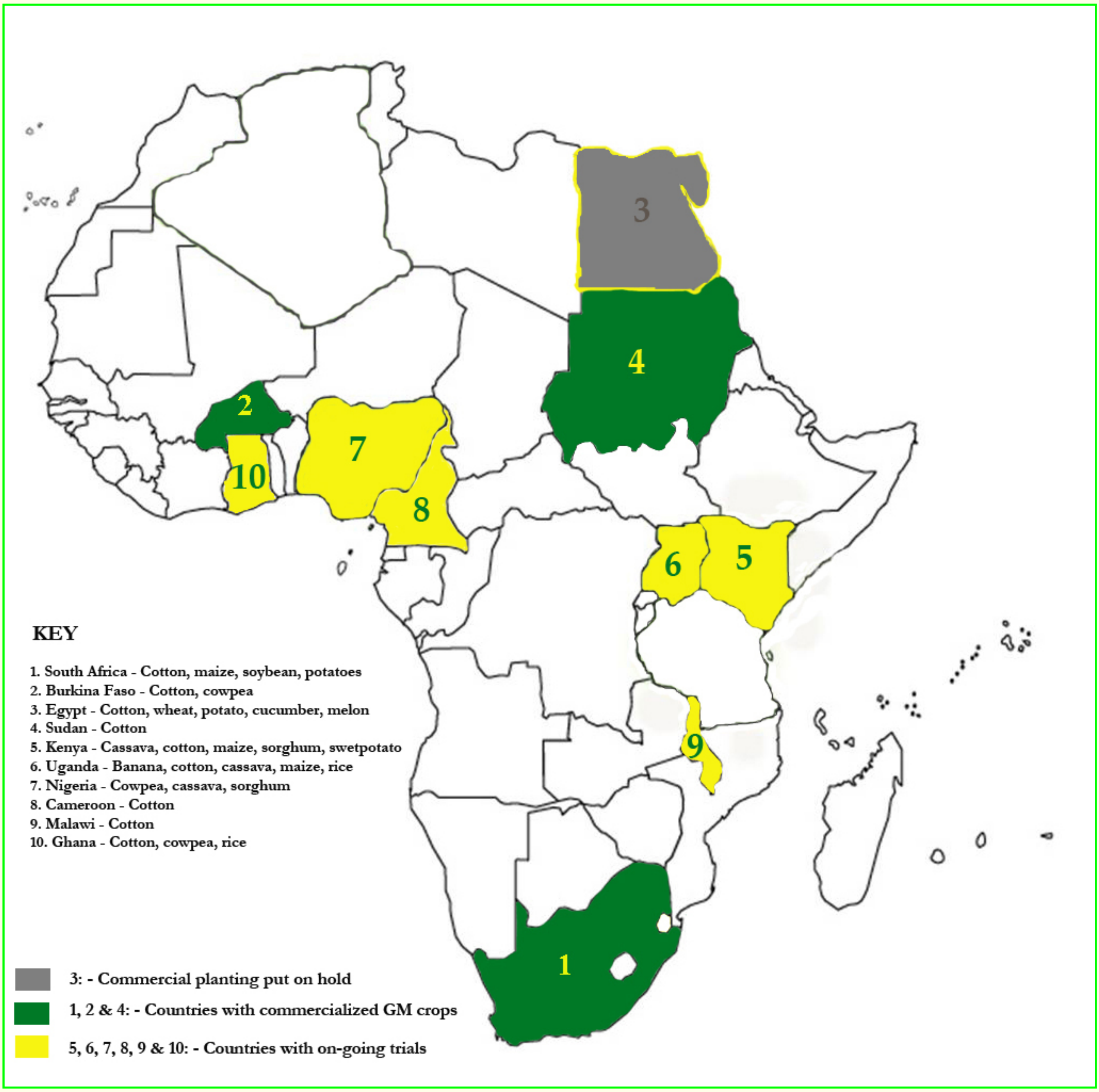
Conclusion

On account of the traits genetically engineered into them, biotech crops have undoubtedly delivered substantial agronomic, environmental, economic, health and social benefits to farmers and, increasingly, to society at large. The adoption rates for the crops during their 19 years of commercialization have been unprecedented and, by recent agricultural industry standards, they represent the highest adoption rates for improved crops. This reflects farmer satisfaction with the products that offer substantial benefits. These range from more convenient and flexible crop management, lower cost of production, higher productivity and / or net returns per hectare, health and social benefits, and a cleaner environment through decreased use of select pesticides, which collectively contribute to a more sustainable agriculture. There is a growing body of consistent evidence across years, countries, crops and traits generated by public sector institutions that clearly confirm these findings.

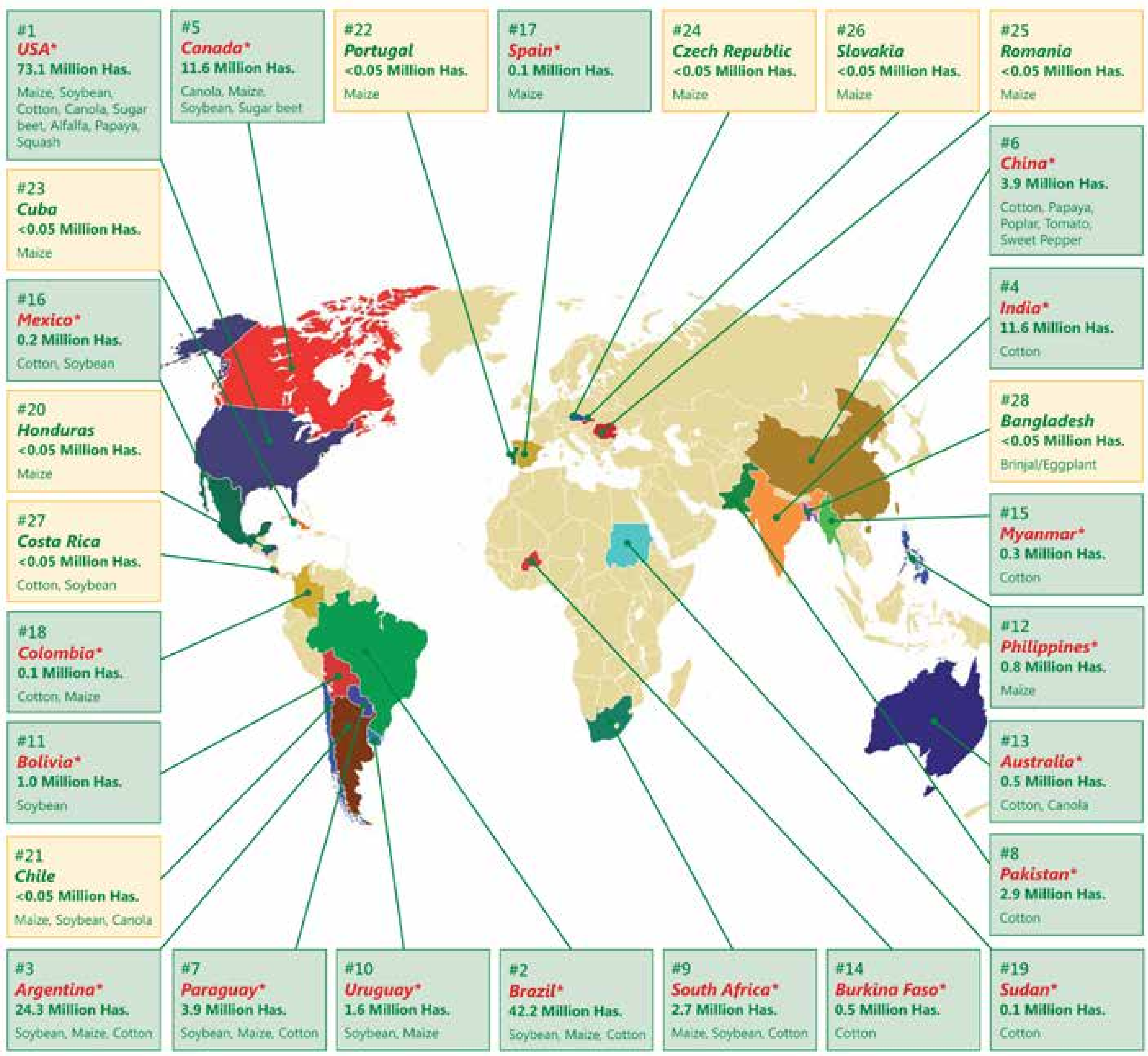
In Africa, as is the case elsewhere in the world, the IR crops, have enabled effective insect pest control with minimal insecticide sprays while HT crops have reduced farm labour in weeding, attracting more youths into agricultural production. Technology advancement has led to the two traits being stacked into the same crop, making them more effective with optimal utilization of farmland. The continent is progressing fast towards adoption of biotech crops with Burkina Faso, South Africa and Sudan already leading the way. Other countries including Kenya, Uganda, Malawi, Nigeria, Egypt, Ghana and Cameroon have advanced trials with traits for drought tolerance (DT), virus resistance, nitrogen use efficiency (NUE), nutritional enhancement, salt tolerance among others. These traits have been incorporated in important staple crops.

Over the years, a host of institutions have tested and found the biotech crops genetically engineered with these traits to be safe for use by humans including use as food and feed. The World Health Organization (WHO), Food and Agriculture Organization (FAO), European Food Safety Authority (EFSA), Environment Protection Authority (EPA), United States-Federal Department of Agriculture (US-FDA) are some of the notable organizations that have endorsed safety of biotech crops. They have largely concluded that genetically modified crops not pose any additional risk to human health and the environment compared to their conventional counterparts.

MAP OF AFRICA SHOWING STATUS OF BIOTECH CROPS BY 2014



BIOTECH CROP COUNTRIES AND MEGA-COUNTRIES*,2014



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

Source: Clive James, 2014.

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