Information and Guide to Plant Genetic Engineering.

The introduction of genetically engineered (or GM) crop plants and foods has given rise to several concerns in Europe and elsewhere. Proponents claim the technology improves agricultural productivity, has the potential to reduce the use of herbicides and pesticides, to increase yields, and is needed to breed the next generation of crops to meet a wide range of new threats to our food security. On the other hand opponents of the technology suggest that genetically engineered crop plants and products may harm the environment and human health, may cause unintended genetic changes in other plants, and permit vendors of GM seeds to gain an unacceptable degree of control of the food chain. Many people also want to know more about how food is produced and what it contains so they can make their own choices about the provenance of the food they consume.

As the application of genetics underlies the production of crop plants, the Genetics Society aims to provide the public with information on how genetic principles are used to create crop plants and provide information on future trends in crop plant genetics. The purpose of this report is to describe GM technology, to explain how it differs from plant breeding, and to outline future developments in this area.

Where do crop plants come from?

Most of our nutrition comes from plants- either directly or as fodder for domesticated animals. The plants we use in agriculture are nearly always specially adapted to provide an abundant and reliable supply of nutrition. The major cereal crops we use today, which provide the bulk of our calories, are descended from plants selected in prehistory for their useful traits.

Maize was domesticated in central America from a wild relation called teosinte approximately 8,000 years ago. In the Middle East wild grasses with large seeds were cultivated as annual crops, and bread wheat was domesticated from hybrids of these wild grasses perhaps as recently as 10,000 years ago. The chance hybridization of wheat species led to a larger grain that was not encased in a hard cover, making it easier to harvest and mill. Generations of selection have led to modern wheat varieties. Since then a wide range of crop plants have been domesticated for food, fibre, and oil production and a multitude of other uses. This was achieved through continuous adaptations and refinements of local varieties and the movement of species around the globe to develop new industries for the production of sugar, cotton and rubber.

Figure 1a

Figure 1b

Figure 1a shows the ears of wild ancestors of wheat, and Figure 1b shows the ears of modern cultivated wheat.

When the principles of genetics were established by studying pea seed and flower characteristics, they were incorporated into the new science of plant breeding during the early 20th century. Today nearly all our crop plants are descended from many generations lines that have been carefully selected for desirable genetic changes, and breeders continue to make new genetic combinations to improve performance and to meet new requirements. The discovery of DNA as the genetic material has helped breeders to select desired progeny from crosses of parents that are increasingly diverse. In this way a wider range of characteristics from wild relations of crop plants, such as disease resistance and fruit size (see Figure 2), can be incorporated into crops.

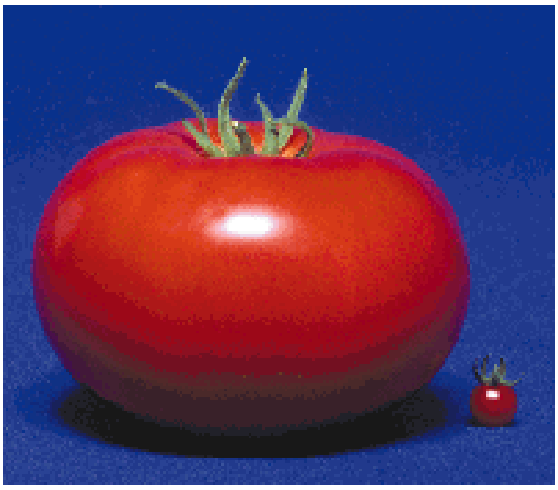

Figure 2. Wild tomato fruit (*L. peruvianum*) is shown on the right, compared to a cultivated variety descended from wild tomato.

What is crop plant breeding?

Plant breeding involves selecting optimal combinations of genes that provide desired characteristics. To understand plant breeding and its relationship to genetic engineering, the function of DNA and genes needs to be considered.

All organisms contain many genes in their genetic material that provide the instructions for making the organism and for passing these instructions to the next generation. The genetic material of plants and most other organisms is a very long molecule called DNA that carries instructions (the DNA code) in packages called genes. A gene is a unit of information that usually makes one specific protein that performs a specific function in cells.

The function of cells and complex organisms composed of many cells requires many proteins, and hence genes, to function. For example bacteria have between 2,000-8,000 genes, while plants, mice, humans and flies have between 15,000-50,000 genes. Genes are kept in a specific order on long stretches of DNA called chromosomes that are visible in cells. DNA is extraordinarily stable, but over very many generations changes in the DNA code occur and accumulate. These changes are called mutations and they can affect the functions of proteins, such that they might not perform their function properly, they may change the way the protein works, or they may interfere with another protein’s functions.

Most organisms accumulate many changes in their DNA with no outward effects, but some small changes in the DNA code can lead to large changes in the appearance of organisms. Figure 3 shows broccoli, cauliflower, brussels sprouts, turnip and cabbage plants. The differences in these plants are due to mutations in a few genes that control the growing regions of floral stems. In this case random mutations in the cabbage family have given rise to useful changes that breeders have continued to refine and adapt.

Figure 3. The large variety of Brassica crops is based on a few genetic differences.

But mutation is not the only process shaping our DNA- there is also sex. The fusion of an egg and sperm cell mixes two sets of DNA that combine to create a novel mixture of genes from each parent. This new combination of genes, just as a newly shuffled pack of cards provides new possibilities for the next game, generates new genetic variation that makes progeny different from their parents and every other individual. Genetic variation is the building material of plant breeding, and understanding how this variation is inherited, and what effects it has on plant performance, are complex and interesting problems for plant scientists.

In plant breeding, progeny with new combinations of genes from each parent are screened for desired characteristics over several generations by sifting out combinations of genes giving unwanted characters while preserving sets that give the desired character. This process typically takes up to 8-10 years for a new variety to make it to the field. It may take even longer to breed new lines in the future because the useful genetic variation available in elite breeding lines is tending to become exhausted. Wild species related to modern crop plants are a very important source of new genetic material for breeding as wild relatives have often evolved useful adaptive traits such as disease resistance or tolerance of extreme environmental conditions. For example wild grasses collected in the Middle East are useful sources of drought and salt tolerance. The loss of habitat for wild species is therefore of great concern to plant breeders, and much effort is spent on collecting and cataloging wild relatives of crop plants.

Plant breeders can also make hybrid plants that have the entire set of genetic information from each parent. For example oilseed rape (*Brassica napus*) is a combination of Chinese cabbage (*Brassica rapa*) and broccoli (*Brassica oleracea*). These plants are called polyploids (meaning several sets of genomes) and this process happens naturally at a low rate to generate new species and increase diversity. These polyploids can then be bred as described above to select desired progeny. Breeders have also used a variety of other methods to create mixtures of genes from un-related plants from which useful new crop varieties can be selected in breeding programmes.

New ways of breeding plants

As our knowledge of the DNA code increases, breeders are using this knowledge to try and speed up the breeding process and to include new sources of genetic variation into breeding programmes. For example, crosses between a cultivated tomato and a wild tomato have been used to make new lines with larger fruit, improved processing quality and pest resistance. The difficulty with crosses between more distantly related plants is the larger degree of variation among the offspring of the cross.

To sort out the few desired characteristics from the many unwanted ones, landmarks on DNA are used to track the inheritance of different regions of DNA in the progeny. By knowing which landmarks (or markers to use the correct term) are associated with desired and undesirable characteristics, breeders are now able to sort through the complex genetic make-up of progeny of distantly related plants directly to select improved lines. This new technology is called marker assisted breeding, and large projects are now going on to map precisely the DNA code of crop plants and related species, in order to facilitate breeding.

Identifying potentially useful characteristics in wild relatives of crop plants is a key feature of this strategy; therefore much effort is spent on understanding the genetic make up of wild relatives of wheat and barley from the Middle East, wild relatives of tomato, potato and pepper from the Andes, and legumes from the Mediterranean basin. Consequently the loss of plant biodiversity is a major threat to plant breeding and food security.

Another type of breeding involves the production of hybrid varieties. F1 hybrids have generally increased vigour and increased yield, and several important crops such as maize and tomato are usually grown from F1 hybrid seed. F1 hybrids can show improved performance over that of each of the parents, but this advantage is lost in subsequent generations. Very little is understood about the mechanisms giving rise to hybrid vigour, and it is quite a difficult method to establish. For example establishing F1 hybrid wheat has been a major challenge for breeders.

What is Genetic Engineering in plants?

Genetic engineering uses three features of DNA, two of which have not been described so far. Genes contain two distinct sets of information in their DNA. The first, described above, provides the code to make a specific protein; one gene usually makes one type of protein. The second type of information comprises genetic switches that dictate the amount, location and timing of protein production by the gene. For example the eye lens needs lots of protein called crystallin to be made a specific time in the right place, and a genetic switch achieves this complex task.

The information in DNA is extremely stable, as described above, but DNA molecules are far from inert. DNA can be moved about by a variety of natural processes; for example bacteria can exchange certain types of DNA very readily by a mating process called conjugation. About 20 years ago it was realized that some bacteria naturally use this mechanism to transfer DNA into plant cells. This “transferred DNA” becomes stably incorporated into the plant DNA and is henceforth stably inherited as part of the plant DNA.

The technology of DNA cloning could then be used to harness this natural DNA transfer method by incorporating a plant genetic switch into the transferred DNA and hooking the switch up to the coding part of a gene. The combination of a plant genetic switch with the coding information of a gene in a piece of DNA that can be transformed into a plant provided the basis for the so- called “genetic engineering” of plants. The revolutionary feature of this new technology was that the coding region of any gene could be used successfully- from bacteria to human, because the genetic switch functions in plants to make the new protein. Essentially what was originally a bacterial or human gene had now become a functioning plant gene, and many new opportunities for changing the genetic makeup of crop plants became available.

Since the development of this technology over 20 years ago it has been substantially refined so that many types of plants can be genetically engineered. Novel methods of introducing DNA into plants have been invented, such as the biolistic gun that shoots tiny DNA- coated gold spheres directly into plants. Genetic engineering is widely used in the laboratory to identify genes and understand their function, and is also used to make crop plant varieties with novel characteristics.

How is genetic engineering different from plant breeding?

Plant breeding uses genetic differences between related plants to identify and select combinations of genes that give desired traits, such as increased disease resistance or drought tolerance. The range of genetic variation available limits breeding to characteristics already present or latent in crops and their near relations, but it permits very complex characteristics to be selected for without any prior knowledge of the genes involved apart from their approximate location on chromosomes.

Genetic engineering attempts to achieve the same objectives as plant breeding more directly by identifying a gene of interest that confers a desired trait and transferring it to the crop plant to be improved. Genetic engineering can use any gene in any organism, and as long as this can be transferred and switched on when required, it will be a suitable target for genetic engineering methods. At the moment the main limitations to the genetic engineering approach to plant breeding involve identifying appropriate genes to transfer. This problem is being solved by understanding the functions of plant genes.

What is plant genetic engineering used for?

When genetic engineering was first developed for plants there were two main challenges. The first was to find ways of making gene transfer work effectively in the major crop plants. This has been achieved for a wide range of plants, from pine to wheat. The second was to identify genes that might confer a useful characteristic in a crop. So far only a very limited number of potentially useful genes have made it into commercially successful crop varieties. Among these are genes isolated from bacteria that confer tolerance to herbicides and resistance to harmful pests. Table 1 shows most of the main genetically engineered crop plants and their traits grown in the USA. Several highly developed technologies are in the pipeline. For example herbicide- tolerant and disease resistant wheat lines are ready for introduction when market conditions are favorable, as is cold- tolerant canola. There are many new products in development that aim to improve the nutrient quality of crops, disease and stress tolerance and to make new products in plants. These are described below.

Table 1. Examples of the major Biotech crops grown in the USA

CROP	GENETIC MODIFICATION	PURPOSE
Herbicide tolerant Maize & Soybean	EPSPS gene from a soil bacterium that is resistant to glyphosate herbicide.	Weed control and low tillage
BT Maize & Cotton	Cry1Ab gene from the soil bacterium Bacillus thuringiensis (Bt) that encodes δ-endotoxin, specific for lepidopteran insects.	Maize resistance to European corn borer, corn earworm, southwestern corn borer. Cotton resistance to Boll Weevil

What are the benefits of genetically engineered crop plants?

Genetically engineered crops have different attributes depending on the functions of the introduced genes. So far three main crops have been engineered for two characteristics- herbicide tolerance and insect pest resistance (Table 1). Insect resistant cotton and maize plants, when grown with appropriate refuges to permit pests to propagate normally and avoid excessive selection pressure, do not require so many applications of insecticide and have on average higher yields. Herbicide tolerant crops require fewer treatments with herbicide and tilling is reduced, which helps to maintain soil quality. Biotech papaya has been grown in Hawaii since 1998 in order to combat a virus that devastated the crop. Currently about half of the fresh fruit crop is biotech, while the other half is maintained as non-biotech to supply export markets. Interestingly the biotech papaya plans appear to act as a buffer that stops virus spread to the susceptible crop.

The 2002 farm gate value of GM produce in the USA was $20bn (ISAAA Briefs No. 29 Global Review of Commercialized Transgenic Crops: 2002). The evidence of continued yearly increases in the acreages of genetically engineered crops in the USA suggests farmers benefit from these crops; otherwise they would not spend a premium on seeds or submit to product testing. These benefits include increased yields and reduced inputs (see http://www.ncfap.org. National Centre for Food and Agricultural Policy report on the impact of GM crops on US agriculture- 11 case studies). These reports suggest that small- scale producers also benefit as well as larger scale producers. Seed merchants selling these successful crops have seen yearly increases in the proportion of their lines sold with world-wide seed sales worth $4bn. In contrast sales of insecticides used in cotton production have been predicted to decrease from $300m in 2002 to less that $70m in 2012 (http://www.isaaa.org/kc. Crop Biotech Update Dec 12 2003). Possible future gains for other groups of farmers can be anticipated; for example pests and disease accounts for the annual loss of approximately 27 m tons of rice, therefore rice producers will benefit from the introduction of disease resistant rice varieties. About 30% of the 81 million hectares (200 million acres) of global transgenic crops were grown in developing countries in 2004 (James, C. Preview: Global status of Commercialized Biotech/GM Crops: 2004. *ISAAA Briefs No*. 32. ISAAA, Ithaca, NY). Table 2 shows the 2004 GM Crop Areas for the major growers.

Table2. Areas of Biotech Crop Growth 2004

COUNTRY	AREA (m HA)	CROP
USA	47.6	Cotton, Maize, Soybean
Argentina	16.2	Soybean, Maize, Cotton
Canada	5.4	Canola, Maize, Soybean
Brazil	5.0	Soybean
China	3.7	Cotton
South Africa	0.5	Maize, Soybean, Cotton
India	0.5	Cotton
Paraguay	1.2	Cotton
Uruguay	0.3	Soybean, Maize
Australia	0.2	Soybean
Romania	0.1	Soybean
Spain	0.1	Maize
Mexico	0.1	Cotton, Soybean

Data from ISAAA Briefs No. 32. ISAAA.

Ethical concerns

In comparison to the obvious importance attached to ethical issues surrounding human genetic research, the ethical issues surrounding plant genetics have not yet been systematically explored. Current concerns focus on the growth of genetically engineered plants as an intrusion on nature that may have unknown and irreversible consequences, and on the amassing of unprecedented power by corporations through ownership and control of the supply of food from seed to plate. These and related issues have generated substantial debate in some countries, including those where the crops are not grown.

Crop plant genetic engineering has the potential to introduce genes from animals and even humans into food, therefore important ethical concerns arise. For example, would it be appropriate to eat food containing a human gene? Would vegetarians consider crops containing animal genes to be non- vegetable? How do these concerns relate to the fact that plants and animals have many genes in common? Genetically engineered crops so far only contain genes from bacteria, plant viruses and other plants so these particular issues remain hypothetical for the moment.

Increased experience of genetic modification including new products and more comprehensive regulatory procedures (see below) may contribute to focusing arguments and resolving ethical and social concerns over our food supply.

Environmental concerns

Much concern has been raised over the potential of genetically engineered crop plants to harm the environment. Particular anxiety surrounds the possibility of exchanging genetically engineered characteristics between crop plants and wild plants. Pollen movement can transfer the genetic material of flowering plants over substantial distances to sexually compatible species. This problem is well known to plant breeders, who need to ensure the proper genetic composition of seeds for crop plants. To do this they produce seeds from plants that are an appropriate distance apart that results in minimally acceptable cross- pollination, usually about 1%. In the field pollen exchange between sexually compatible crop and weed species also has the potential to intermingle traits from crops and weeds. Pollen exchange is generally not an important issue in crops harvested from single plantings of genetically pure seedlings. In farm- kept seeds any traits derived from infrequent crosses with wild relatives generally only have a minor effect in the population of crop seeds, but over time favourable characteristics of the crop may start to be lost. Similarly weedy relatives of crop plants may inherit characteristics from crop plants, and in principle this has the potential to enhance weediness, although this has not been observed. Because genetically engineered genes are stably inherited they can also be spread by pollen from crops to weedy species, and this has the potential to confer traits such as herbicide and virus tolerance on weeds. It is conceivable that these traits may confer a selective advantage on populations of weeds, but this requires the close cultivation of genetically engineered crops with sexually compatible weedy species over time, and also requires a relatively undisturbed cultivation of weeds. Current agricultural practices generally mitigate these conditions.

Large- scale experiments have been conducted to measure the movement of genetically engineered traits between crop plants. These have helped to determine minimum separation distances to reduce cross pollination to levels that are below the limits needed to maintain genetic purity. Cross- pollination between organically cultivated and non-organically cultivated crops can be controlled by implementing separation distances that are dependent on the crop, the likely means of pollen transfer (insect- borne or wind for example) and the degree of cross pollination in each crop type that has been defined as maintaining the genetic purity of the crop. Of the major UK crops that may eventually be introduced as genetically engineered varieties, sugar beet and oilseed rape can interbreed with weedy relations. Relatively simple agronomic measures to limit any potential effects of crosses between weedy species and crops can be implemented, such as thorough weed control. For example if herbicide tolerant weeds arise in unwanted numbers in fields, they can be combated by application of another type of herbicide. Outside the field herbicide tolerance in weeds is not likely to confer a selective advantage as herbicides are not widely used in these environments.

The so-called “Terminator Technology” was developed, but not applied, for stopping the flow of pollen from GM plants. The technology makes crop plants sterile and was originally invented as a “technology protection system” to prevent farmers from keeping seeds and growing these in the next season. This technology has the potential to ensure GM plants producing non-food products are genetically isolated in the field.

Cross- pollination between crop species and their wild relatives raises the possibility that this process may erase essential differences between wild relations and their cultivated relatives. The loss of these differences has the potential to reduce genetic variation that may be useful for future breeding programmes. As described above the erosion of genetic diversity is among the most serious threats to agriculture and the environment because of the increasing scale of irreversible loss of genetic variation. For example maize has been cultivated in regions of Mexico where wild varieties also grow for many thousands of years, and there is evidence of widespread cross-pollination in overlapping populations of cultivated maize and wild relatives. Nevertheless the wild populations have maintained their distinctive identities over many generations, suggesting cross- pollination is not a major contributor to the loss of genetic diversity. Instead, habitat destruction is the principal and obvious cause of the irretrievable loss of wild species.

Are genetically engineered crops safe for human health?

To date no effects on human or animal health of consuming soybean or maize genetically engineered for herbicide tolerance or insect resistance have been attributable to the novel genes present in these crops after many years of consumption worldwide. Public concerns about the risks of ingesting DNA from genetically engineered plants have been addressed by phasing out the use of marker genes conferring antibiotic resistance. DNA is broken down during digestion in humans and is not able to pass through the gut wall and function effectively in human cells or be passed on to the next generation. We have all been eating DNA for generations and there is no evidence of transfer of DNA from food to our DNA.

In anticipation of the wider adoption of current and anticipated new genetically engineered crops and products, the standards used to test the potential impact of genetically engineered crops on human health and on the health of farm animals are under review in many countries to ensure greater standardization and conformity to best scientific practice. New biosafety laws may involve appropriate tests comparing the composition, nutritional value, toxicity and allergenicity of the genetically engineered crop to its non-engineered counterpart. In the UK the ecological impact of the crop and any agronomic practices associated with its use can now be judged using standards and methods developed in the recent farm-scale trials in the UK.

These procedures, when applied consistently to genetically engineered crops, should provide the evidence necessary to either support or reject each case for introduction. These tests could also be applied to conventionally bred plants grown in different agricultural systems to provide consumers with information to help establish and guide their preferences. This information could be provided by labeling to track and audit each step of the supply chain and recording the provenance and processing of food. This validation and labeling is proposed to help consumers make informed choices.

What does the future hold?

Currently a variety of genetically engineered crop plants are used in commercial production (Table 1). There appears to be a trend towards increased acceptance of growing genetically engineered crops subject to appropriate local rules and practices after thorough review and consultation processes. Thailand, Brazil, Paraguay, New Zealand, Australia and England have all recently decided on limited case-by-case introduction of genetically engineered crops after the formulation of appropriate biosafety regulations. Planned introductions in Australia include herbicide- tolerate canola and in England herbicide- tolerant maize can be grown for a limited period.

Some of the major influences on these decisions are increasingly based on a pragmatic assessment of the added value to the farmer and processors. These include reduced inputs of chemicals and improved yields and quality due to effective resistance to pests and herbicides. In the UK a high emphasis is placed on the environmental impact of growing genetically engineered crops because conventional agricultural practices are thought to have had an unacceptably deleterious effect on farmed ecosystems. The farm scale evaluation of the influence of genetically engineered crops provides a baseline for assessing these effects.

There are two broad trends in crop plant genetic engineering. The first is the rapid extension of the technology to a wider range of crops. In India for example important local crops such as millet, chickpea and pigeon-pea are all being genetically engineered. In Uganda biosafety laws are being established so genetic engineering for resistance of banana to wilt disease can be performed. Research programmes in China, Mexico, Australia and New Zealand and elsewhere are all working on developing local crops by genetic engineering.

The second major trend is to find a far wider range of characteristics for genetic engineering. A wide variety of interesting leads is available, although many may not be taken up commercially due to the need to make a profit from seed sales to support development costs. Engineering crop plants with improved nutrition such as vitamin- and iron- enhanced rice is relatively well advanced, and a major research programme to combat human micronutrient deficiencies has begun. The fatty acid composition of oilseed crops such as sunflower and canola is being altered to improve human nutrition and provide special fats for fish meal. Farmed fish require specific polyunsaturated fatty acids currently obtained by harvesting other fish, and finding a plant- based source may alleviate loss of marine wildlife. Disease causes huge crop losses, and many projects in industry and universities aim to provide resistance to pests in grape, cereals, potato and trees. Environmental stresses such as salinity and cold also reduce yield, and extensive research has identified genes conferring salt tolerance in tomato and cold tolerance in canola. Research aimed at producing antibodies and vaccines in plants is at an advanced stage, as plants can yield high quantities of specifically modified therapeutic proteins.

Extensive research aimed at using genetically engineered plants to make commodities such as specialist starches and oils for industrial applications is also underway. Before these crops can be considered for release extensive precautions need to be established to prevent cross- pollination and to establish health risks due to ingestion of material from these crops. Current legislation provides a framework for these considerations but there are many issues related to the coexistence of industrial and food products that remain to be studied and debated before possible introduction.

What are the challenges facing plant genetics?

The availability of fresh water and fertile soils has always dictated agricultural production and these factors still determine global food security today. For example, unsustainable use of key aquifers is reducing the water table in key agricultural areas and lakes are drying up. Previously fertile soils, especially in irrigated areas of high production, are becoming more polluted with salt by irrigation. Moreover, the postulated increased unpredictability in weather systems due to global warming and an ever- increasing world population seriously exacerbate these threats to food security. The most serious current concern of plant scientists is the irretrievable loss of biodiversity, which reduces the scope for breeding crops to tolerate more extreme climates, to resist pests and diseases and produce more nutritious food.

Until recently the prevailing strategy in crop plant breeding and research was to increase yield. The environmental costs of this strategy, such as elevated nitrate and phosphate levels in ground water, have led to the embracing of a new strategy of sustainable agricultural production in the UK. This strategy is being framed within larger concerns about the balance between farming practices, production subsidies and the environment. Current systems supporting production are thought by many to be inconsistent with both international trade agreements and with the long- term stewardship of the farmed environment for food production and promoting wildlife.

How can plant genetics contribute to the related objectives of achieving sustainable food production with a reduced environmental impact and at the same time provide a livelihood for rural communities in the face of reduced production subsidies? There are several examples. Reduced insecticide use on insect-resistant cotton crops has already substantially reduced the market for agricultural insecticides in the US. The use of herbicide tolerant crops has improved soil condition by increasing low-till agriculture and reducing tractor usage. Further reductions in the environmental impact of agriculture can be expected from novel management systems and increased knowledge of plant nutrition and plant interactions with the soil ecosystem. Clearly many disciplines will need to be mobilized and integrated with different production systems to help address objectives set for achieving greater sustainability. Genetic engineering is only one of many methods that may contribute to maintaining productivity and food quality while reducing inputs and improving agricultural ecosystems.

Links

The following links provide further information about plant biotechnology.

Fact sheet on GM plants.
http://www.bbsrc.ac.uk/life/ingeneious/index.html

Transgenic Crops- an Introduction and Resource Guide
www.colostate.edu/programs/lifesciences/TransgenicCrops/

Database of publications in plant biotechnology
http://ucbiotech.org

World Health Organisation site on Foods derived from Biotechnology
http://www.who.int/fsf/GMfood/index.htm

Genetically Engineered Organisms: Public Issues Education Project.
http://www.geo-pie.cornell.edu/

Biotechnology in Food and Agriculture
http://www.fao.org/biotech/

International Service for the Acquisition of Agri-Biotech Applications. This group reports regularly on world-wide developments in agricultural biotechnology.
http://www/isaaa.org

The International Plant Genetic Resources Institute promotes the protection, identification and use of plant genetic diversity in agriculture.
http://www.ipgri.cgiar.org/index.htm

Glossary of Terms.

Chromosome
A length of DNA that contains many thousands of genes that is packaged into long string- like bundles visible under a light microscope.
DNA
Deoxyribonucleic Acid is a molecule that contains the “blueprint of life” for most organisms (some viruses use the related molecule Ribonucleic Acid). It is a long double chain of 4 different repeating units called basepairs, and the order of repeating units provides the genetic code or instruction set for making all the components of cells.
DNA Cloning
DNA molecules can be cut into specific pieces by enzymes and these pieces can be spliced together with other fragments of DNA to make novel combinations of DNA. These pieces can then be propagated in bacteria to multiply the number of copies for further analysis.
Domestication.
Many of our crop plants were originally wild species that our distant ancestors found to have useful properties. These were cultivated and lines with improved properties have been selected, leading to the domestication of crop plants.
Gene
A gene is a region of DNA that has the instruction set for making a protein (proteins are the building blocks of cells).
Mutation
A mutation is a change in the order of the 4 bases that make up the DNA molecule. Mutations can therefore change the instruction set and make a faulty protein. These errors can be repaired, but the repair process can be weakened, for example by exposure to excessive sunlight or cigarette smoke.
Transformation
Transformation is the experimental process of transferring DNA between organisms in a form in which it can be inherited. It is a common laboratory procedure used to study DNA.

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