

# Some facts about genetically modified (GM) plants

The advent of genetic modification has enabled plant breeders to develop new varieties of crops with a wide range of characteristics, at a faster rate than would be possible with traditional methods, and brings with it a huge potential for further beneficial developments. However, the development of such new techniques raises several concerns which need to be addressed.

## 1. What is genetic modification?

Humans have cultivated plants for thousands of years, during which time crop plants have been continually selected for improved yield and other desirable characteristics. The improvement of a plant species by conventional techniques involves the selection for breeding purposes of certain plants that express important characteristics. As a result of human intervention in selecting which plants to use for production of offspring, it is possible to produce new varieties at a much faster rate than would occur in the wild situation. Crop species have therefore been selected for a large number of different characteristics, resulting in a great number of varieties being produced to help feed the expanding World population. In their search for new characteristics, particularly for genes conferring pest and disease resistance, plant breeders continue to seek novel sources of breeding materials to bypass the normal barriers to sexual crosses. For example, in their search for fungal resistance genes, sunflower breeders use a technique called embryo rescue. Modern genetics offers an important additional source of such genes.

The characteristics of an organism are determined by its DNA (deoxyribonucleic acid) which is the information-containing component of the chromosome. DNA provides the genetic code which determines how the individual cells, and consequently the whole organism, will be constructed. This code is divided up into functional units, or genes. The total characteristics of a plant will depend on which genes it has received from the parent plants, whether or not those genes are '**switched on**' (**expressed**) and also the interactions between the genes and environmental factors.

The advent of modern techniques of genetic modification has enabled researchers to remove individual genes from one species and insert them into another, without the need for sexual compatibility. Once the new gene has been inserted into a plant, offspring that will contain copies of the new gene can be produced in the traditional manner. For example, this has enabled researchers to insert a bacterial gene from *Bacillus thuringiensis* (Bt) into a cotton plant, to give it resistance to certain insect pests (specifically the cotton budworm). Genetic modification has also made it possible to remove or '**switch off**' an undesirable gene already present in a particular variety, or modify the metabolism of the plant to improve the quality of the food product (for example, GM tomatoes, the Flavr Savr, which remain fresh for longer periods).

## 2. Is genetic modification regulated?

Since the commencement of research into genetic engineering in Australia in early 1970s, it was recognised that genetic engineering is a very powerful technology. Some of the researchers working with the technique were so concerned that it might be

possible to make hazardous microorganisms that they called for an investigation into the safety of the technique. Of course Australian were not alone in this concern.

In 1975 Molecular Biologists from around the world, including Australia, met in USA. Pressured by the delegates, the United States National Institutes of Health developed guidelines for the safe conduct of genetic engineering. These guidelines were finalised and distributed to all companies undertaking genetic engineering in 1976.

Australia did not just rely on overseas countries to decide what was acceptable. The Australian Academy of Science set up a committee on Recombinant DNA that drew up the first Australian guidelines for the technique in 1975. In 1981, the Department of Science (Australian Government) established the Recombinant DNA Monitoring Committee (RDMC). This committee reported to the minister of the time that monitoring of the technology up to date had been effective and would likely to remain so for at least the next five years and thus should be continued. In 1987, the minister of Industry, Technology and Commerce established the Genetic Manipulation Advisory Committee (GMAC) to replace RDMC. The Minister for Administrative Services took responsibility for GMAC in 1988. Gene Technology Technical Advisory Committee (GTTAC) was established in July 2001. This committee takes the place of the GMAC and provides scientific and technical advice to the Gene Technology Regulator (the Regulator) and the Gene Technology Ministerial Council (GTMC). GTMC advises the Regulator and Ministerial Council on matters of general concern to the community in relation to genetically modified organisms (GMOs). Both GTTAC and GTMC are situated within the Office of the Gene Technology Regulator. This office is part of the Therapeutic Goods Administration within the Commonwealth Department of Health and Ageing and is located in Canberra

The function of GTTAC was to review proposals for genetic manipulation work in Australia to identify and manage any risks associated with the organisms that resulted from the gene technology. GTTAC also advised the Minister on matters about regulating the technology.

Any organisation or institution involved in genetic engineering research, or involved with genetically modified organisms, was expected to follow the strict guidelines of GTTAC. This meant the institution has to set up an Institutional Biosafety Committee to assess and review proposals for genetic engineering and to submit them to GTTAC for assessment to ensure that they met the guidelines. Research institutions are also required to provide the resources and facilities for safe work and to ensure that their staff were adequately trained and supervised. For planned release proposals, GTTAC submitted its advice to the state and federal agencies that may have a legal jurisdiction over the proposed activity.

### **3. Will genes transfer from GM plants?**

#### **3.1 Transfer of genes from GM crop plants to wild plant species**

Crop systems can be divided into three groups with respect to the possibility of natural transfer of genes from genetically modified (GM) crop plants to wild relatives:

No sexually compatible wild relatives in the region where the crop is grown, therefore no gene transfer to other species can occur (e.g. GM maize grown in Australia)

Gene transfer unlikely due to the nature of the crop species (e.g. Rice and Soybean which are inbreeding species)

Gene transfer likely (e.g. Canola which is an outbreeding species and has many wild or naturalised weedy relatives)

The likelihood of gene transfer to wild relatives therefore depends on the species of crop and the location in which the crop will be grown.

However, there are several steps involved in gene transfer: the pollen must contain a copy of the inserted gene(s); it must then move away from the area in which the crop plant is grown and come into contact with the part of a compatible plant that receives pollen; if fertilisation occurs successfully, it may not always result in a plant able to grow successfully, or if a plant is produced then it may not compete well with other species in the environment. In addition, if the resulting plant produces pollen that goes on to fertilise other plants, then the inserted gene(s) will become increasingly diluted in the overall population if there is no selective advantage for the plants that contain it. It is inevitable that some gene transfer will occur from certain crops, but the level of gene transfer to wild relatives from GM crops is likely to be exactly the same as from non-GM crops.

If gene transfer is judged to be likely, then it is important to assess what the consequences will be. This will depend on whether the inserted genes are likely to have a deleterious or advantageous effect as a result of expression in the plant to which they are transferred, if expressed in the wild species. The fate of crosses between crop species and wild relatives will be largely crop dependent. In general cultivated crop species or '**escapées**' will not be competitive in the wild. Indeed, most crosses between different species will produce sterile hybrids. Hybrids produced from crosses between most crops and wild relatives are unlikely to survive many generations. It is also notable that disease and pest resistant crops have been available for many years as a result of conventional breeding techniques, and there are no reported problems as a result of transfer of such traits.

### **3.2 Transfer of genes from GM crops to non-GM crops**

As with the transfer of genes to wild plant species, the likelihood of transfer to non-GM crops will depend on the biology of the crop species and the location in which it is grown. The chance of transfer from a GM crop species to a non-GM member of the same species is increased if the crops are adjacent. Transfer may also be possible between crops: for example, wheat can occasionally be pollinated by rye. However, cross-pollination of a hybrid crop is unlikely to be a problem for seed production since such crops are not used to produce seed for the next crop, so any acquired genes will not be deliberately propagated, although some movement of seed from the release site via birds or animals is inevitable. However, if two herbicide tolerant varieties crossed, the resulting seeds may be tolerant to both herbicides. This could have an impact on the control of '**volunteer plants**' (these are plants that grow in a field in the year after the original crop was grown as a result of seed being shed from the crop and remaining

dormant in the soil for some time (seed bank). Some volunteer plants may germinate several years after the original seed was shed) in the next crop or in set aside land. There will therefore be a need to assess the consequences of any potential transfer.

Inserted genes may have potentially harmful effects if transferred to other crop plants. For example, genes for production of vaccines or pharmaceutical products in food plants should be prevented from entering the general food chain, by molecular methods (such as prevention of pollen formation) or by growing the crop at an isolation distance that minimises pollen transfer. This is normal practice for plant breeders and farmers who must enforce strict isolation distances when producing certified seed for sale. Also, for example, canola is grown for human consumption with low levels of erucic acid. Industrial canola produces high levels of erucic acid, which is toxic to humans. High erucic acid canola is therefore grown at suitable isolation distances from edible rape varieties.

Transfer of genes from GM crops to non-GM crops may also have an unwanted effect if the latter are grown organically. If the award of organic certification depends on the grower being able to guarantee that no inserted genes are present, then problems will arise if the crop has been grown in fields adjacent to a GM crop. Crops able to outbreed, such as maize or canola, will be affected to the greatest extent. A lawsuit was lodged in USA in 1999 when an organic corn farmer lost his certification because of the proximity of his farm to a GM corn farm. The only way of resolving these types of problems in future is to introduce guidelines for minimum isolation distances between crops and an agreement on the level of acceptable gene transfer below which products can be labelled as not containing GM material. For example guidelines can be developed to state if greater than 0.1% of the total weight of the product consists of protein encoded by "foreign" genes it may not be labelled as "GM free". However, such guidelines rely on the availability of suitably **accurate** and **officially recognised** methods of analysis.

### **3.3 Ways to minimise or prevent gene transfer**

In addition to isolation of the crop from other crops, there are currently three alternative approaches to minimisation of gene transfer.

As mentioned earlier, gene transfer from crops that are hybrids may not be a problem because such seed is not propagated in the next generation and the farmer buys new hybrid seed each year. More and more crops are now grown from hybrid seed so this provides an **in-built** protection against crop to crop gene transfer, which is relevant to purity of seed stocks. Currently maize, sorghum, sugar beet, and sunflower are hybrid crops. Canola hybrids are under development and breeders are still evaluating the potential of wheat, rice and cotton hybrids.

Inserted genes, or **transgenes**, can be introduced into the chromosomes of the plant cells or, with greater difficulty, into the additional genetic material that is contained in other parts of the plant cell such as the chloroplasts. The advantage of insertion into the chloroplasts is that the genes may not be transferred by the pollen, as the chloroplasts may be excluded during fertilisation. This approach may consequently be preferable if there is a desire to prevent gene transfer by pollen, for example when inserting genes for tolerance to certain herbicides or production of pharmaceutical compounds. However,

this technology is still in its infancy and is unlikely to be effective for all genes. It is not effective in certain species in which chloroplasts are transferred between generations by pollen (biparental chloroplast transformation). In addition, herbicide tolerant crops may produce hybrids by pollination by weed species. Hybrid seeds may then be disseminated by birds or animals.

A second approach that may minimise gene transfer would be to link the inserted genes to genes conferring sterility by switching off pollen production. Alternatively another molecular method called, '**terminator technology**' may be used. Terminator technology refers to a genetic manipulation technology described in a recent US patent by which the seeds of GM crop varieties can be prevented from germinating. In agriculture, this would mean that farmers would have to buy new seed each year. It is possible that, in time, all the major seed breeding companies could adopt this type of technology. Concerns have been raised that this would severely disadvantage farmers wishing to store seed for future use. These saved seeds may soon be liable to royalties.

Farmers in developing countries have expressed concern regarding terminator technology for the same reason, although Breeding Centres, such as the International Rice Research Centre in the Philippines, could continue to produce conventionally bred varieties which could compete directly with GM varieties incorporating terminator technology. Although there may be obvious advantages to developing countries in GM crops in general, (such as drought tolerance, increased yields, or ability to exploit poor soils), there are also general concerns regarding intellectual property rights, financing and the necessity for adequate regulatory mechanisms.

### **3.4 Uptake of genes via the food chain**

One of the concerns associated with the introduction into the diet of foods and ingredients derived from, or produced with the aid of, genetically modified plants is the possibility that the genes from such plants may be taken up by consumers when eaten, and become part of their own genetic makeup. It is worth remembering that the medical profession has been trying to develop ways to insert genes into the body cells of humans for some time, with so far rather limited success. No evidence exists for transfer of intact genes to humans, either from bacteria in the gut, or from foodstuffs such as potatoes, wheat or chickens, despite daily consumption of DNA in the diet.

Experiments have shown that DNA remaining after digestion consists of very small fragments and have failed to show survival of intact DNA in stools or blood of animals fed with large quantities of DNA. There is no reason to suppose that DNA in GM plants would behave differently. For DNA to have any effect, any fragments would need to be of sufficient size to contain a whole gene and these experiments showed that such fragments are too small to contain intact animal or plant genes. In addition to the necessity for fragments of a sufficient size, a body cell would have to take up the DNA in question and integrate it into its own genetic material. Also, the acquired gene must have the ability to be switched on in the animal cell (genes from bacteria are not switched on if transferred to an animal cell).

It is also important to distinguish between foodstuffs that actually contain the genetically modified material (e.g. fresh GM tomatoes), foodstuffs in which the DNA has been degraded by processing (e.g. tomato paste from GM tomatoes), and foodstuffs

that contain the products of genetically modified organisms but not the original gene (e.g. cheese made with enzymes manufactured by GM micro-organisms). Foods that contain ingredients derived from GM plants, such as oils and sugars, will not contain genetic material from those organisms as the product is highly purified and processed before addition to the food. It should be noted, however, that foods produced from GM microorganisms such as vitamins or supplements should be subject to the same quality control measures as those produced by traditional methods. This was highlighted in the production of the amino acid tryptophan (used as a dietary supplement) by GM bacteria. Owing to relaxation of quality assurance measures the resulting product contained impurities which were toxic to humans.

### **3.5 Antibiotic Resistance Genes in GM food**

When researchers wish to insert a new gene into a plant, for example to express a protein that will make the plant resistant to a specific insect pest, it is often linked to another gene known as a '**marker gene**'. During the late 1980s, genes for resistance to a range of antibiotics were introduced as markers for selection. The marker genes are used to make it easier to select in the laboratory the cells, and subsequently the plants, in which the genes have been successfully inserted. Plants that contain a gene for resistance to an antibiotic will grow on material that contains that antibiotic; whereas if the genes have not been successfully inserted the plants will not grow. Because the 'marker gene' is linked to the other gene, those plants that have grown on the antibiotic will also contain the gene for resistance to the insect pest. The most commonly used antibiotic resistance marker genes in GM plants confer resistance for such purposes to kanamycin or hygromycin. In GM bacteria, ampicillin resistance marker genes are more often used.

The use of antibiotic resistance as a marker for selection in GM plants for human or animal consumption has resulted in the fear that these genes may be transferred into the bacteria present in the stomach of the consumer. If this were to happen then the genes might be transferred from these bacteria into bacteria that cause disease in humans, making them resistant to the antibiotics that are usually prescribed. It is likely that if transfer occurs, it would only occur following consumption of the unprocessed GM plant, since processing of food causes DNA present in the food to be degraded. Further research is necessary to determine whether such gene transfer could occur, and to what extent. However, it should be noted that the widespread use of antibiotics as feed additives for animals, and as over-the-counter and prescribed medicines for humans, carries a greater risk of creating antibiotic resistant bacteria than transfer of marker genes from GM plants. Indeed, a large number of bacteria present in the gut already carry resistance to several antibiotics, including kanamycin and ampicillin. In any case alternative strategies should be sought.

Although the insertion of "marker genes" is a necessary part of the selection process, it should be emphasised that it is possible (although time consuming) to remove such genes later. In addition, recent developments have made it possible to use alternative marker systems that do not utilise antibiotic resistance.

## **4. Will GM crops harm the environment?**

### **4.1 Insect tolerant crops**

To date, all commercially-released insect-tolerant GM crops express toxins derived from the bacterium *Bacillus thuringiensis* (Bt), which are toxic to insects but not humans and provide a very high level of protection against specific insect pests. In addition, an increasing number of other genes are being transferred experimentally into crop varieties, in particular ones encoding plant proteins (e.g. lectins and inhibitors of insect digestive enzymes). At present, most insect tolerance genes incorporated into GM plants are continuously switched on and expressed in most parts of the plant.

Aside from its commercial prospects, the development of insect-tolerant plants offers numerous potential benefits to agriculture. Such crops could dramatically reduce the use of conventional, wide-acting, insecticides in some cropping systems (for example Bt cotton is now entering its fifth commercial year in Australia. Over the past four seasons, it has reduced chemical sprays against *Heliothis* by 50-70%), as well as overcome the dependence of pest control on factors such as weather and the efficiency of traditional application methods. However, this area of biotechnology does also introduce risks, especially those of unwanted side effects to non-target species, and of pests adapting rapidly to become resistant to engineered insecticidal toxins.

#### **4.1.1 Effects on non-target species**

Many crops are home to a range of insect parasitoids and predatory insects and mites that often play an important role in the regulation of pest insects. The most obvious way that GM crops can affect these natural enemies is by severely depleting the supply of prey or hosts. Such effects will be most profound for natural enemies that live exclusively on insects which the GM crop is designed to kill. However, this also applies to all pest control measures and is by no means unique to insect-tolerant GM plants.

More subtle effects on the survival, reproduction and/or behaviour of beneficial species are possible, and may require sophisticated experimentation to detect and interpret. The majority of field and laboratory studies conducted to date have not disclosed any significant, adverse impact of GM crops on the abundance or performance of a range of parasitoids and predators including lacewings, ladybirds and damsel bugs. However, one report of reduced survival of lacewings (*Chrysopa carnea*) fed on prey reared on GM maize (containing a toxin gene from *Bacillus thuringiensis*), and one of reduced fertility of ladybirds fed on aphids reared on potatoes expressing a lectin gene, highlight the importance of continued work on this topic. Indeed, the evaluation of side effects on non-target organisms such as these is now a mandatory part of most approval schemes for insect-tolerant GM crops. To retain a balanced perspective, it is essential that any negative effects identified be judged in relation to those of the conventional insecticides that these crops are intended partly to replace.

Another concern is the effect of GM crops on insect pollinators such as bumblebees and honeybees. Since proteins are very unlikely to occur in nectar, the main risk of exposure is through expression of toxins in pollen, which depends on the promoter used and varies between GM varieties. Toxins from *Bacillus thuringiensis* have not so far shown any adverse effects against bees, but in 1998 the Bt-modified corn pollen which contains crystalline endotoxin from the bacterium gene caused headlines in the world news because it killed monarch butterflies feeding on these pollen. Although the issue

of monarch butterflies has now been resolved such studies indicate that further studies are necessary to evaluate the effect of Bt-modified plants on "**nontargeted**" organisms.

#### **4.1.2 Pest resistance to insect-tolerant GM crops**

The ability of pests to evolve resistance to crop protection agents has been a long-standing problem with conventional insecticides, and without proper management there is no reason to assume that this problem will not be repeated for GM crops. At present, most attention is focused on pests that have historically developed resistance most readily, including *Heliothis* bollworms on cotton and Colorado beetle on potatoes. However, even species that have so far appeared less prone to resistance (e.g. cornborers on maize) could constitute a threat under extended exposure to GM plants.

The simplest and probably most effective way to reduce the selection pressure for resistance of target insects to GM plants is to provide refuges in which susceptible individuals survive and reproduce. This would also be one way of maintaining biodiversity by allowing survival of a greater variety of species. Such refuges can be created deliberately (e.g. by providing areas of non-GM crops) or may arise through the availability of alternative hosts. Management of refuges is also an important consideration; those treated with conventional insecticides need to be considerably larger than ones left entirely unmanaged, in order to have the required dilution effect.

The level at which toxins are produced in plant tissues could, in principle, be adjusted to combat resistance development. Lowering expression to allow even a relatively small proportion (10-20%) of target insects to survive exposure could assist with delaying resistance, although the resulting loss of efficacy may necessitate other control measures, and could reinstate a need for insecticide sprays. There is also a threat of environmental influences on gene expression being more pronounced when aiming for moderate rather than complete kill of pests. Indeed, there is stronger theoretical support for raising expression levels as far as toxicological and environmental considerations permit, in the hope of killing heterozygous resistant insects as well as fully susceptible ones. The effectiveness of this tactic depends on genes for resistance still being rare in the pest population, and on the provision of refuges generating susceptible insects to mate with any resistant ones that do survive on the GM plant.

Other possible approaches to contending with resistance to GM crops entail moderating exposure through time- or tissue-specific expression of toxin genes, alternating between varieties expressing different toxins, or the stacking (or pyramiding) of more than one toxin gene in the same plant (ensuring that pest insects are exposed to several mechanisms of toxicity simultaneously). All are limited at present by technical difficulties and/or lack of alternative toxins as effective as those derived from *Bacillus thuringiensis*.

In summary, large-scale use of insect-tolerant GM plants can pose a significant risk of resistance development by target pests and unforeseen effects on non-target organisms. Anticipating this risk and developing effective countermeasures (e.g. the use of refuges) requires a sound knowledge of the biology of target pests. Therefore the regulatory authorities need to consider making this a compulsory consideration prior to commercial release. In addition, regular monitoring of the responses of pests to GM crops is vital to detect incipient resistance problems as quickly as possible. To

minimise such effects, it may also be necessary to introduce statutory restrictions on the marketing of such crops as has already been done in other countries.

## **4.2 Herbicide Tolerant Crops**

Advances in genetics have enabled plant breeders to develop crop varieties that are tolerant to a specific herbicide or group of herbicides which cannot normally be used on those crops. This can be achieved by the utilisation of traditional breeding and selection techniques, or by the use of genetic modification. Although many of these new GM crops are not yet commercially grown, the majority of applications for field releases and marketing of GM crops have been for herbicide tolerant crops, specifically those with tolerance to herbicides containing the chemicals glyphosate or glufosinate ammonium (for example Roundup® and Basta®). Insertion of such genes allows the crops in question to be sprayed with a broad-acting herbicide so that weeds can be destroyed without harming the crop species (such herbicides would normally kill the crop as well as the weeds). The companies marketing such GM crops claim that they result in use of less herbicide and altered agronomic practices, producing increased yields for the growers and environmental benefits.

### **4.2.1 Transfer of genes to wild relatives**

One concern which has been raised with regard to such crops is that the genes will transfer to wild relatives of the crop species and produce weed species resistant to herbicides and therefore more difficult to control. The more extreme possibility is that transgenes from several herbicide tolerant varieties could be concentrated in one weed species and create a '**superweed**' that is resistant to several herbicides. This concern is not specifically related to GM crops, as agriculture has been developing herbicide tolerant crops for several years using traditional breeding.

As already mentioned, extensive field trials in Australia and elsewhere have indicated that the likelihood of genes from GM crops spreading into the non-farm environment is no different from that of the conventional crops from which they are derived. While cross-pollination and outcrossing is to some extent inevitable, the significance of it depends on the crop species being used, and the types of wild plants which surround the growing area.

The development of herbicide tolerant crops by traditional methods does not appear to have been accompanied by an increase in problems due to herbicide tolerant weed species. In addition, if weed species were to become more resistant to glyphosate or glufosinate ammonium herbicides it should be remembered that there are alternative, more selective herbicides available. Control of weeds resistant to herbicides is therefore an issue for effective agricultural management and crop rotation, and it is important that sufficient guidelines are available to provide advice to growers on best practise for growth of GM crops. Nevertheless, such guidelines may not always be observed and this should be taken into consideration by policy makers.

### **4.2.2 Transfer of genes to non-GM crops**

There is also concern that herbicide tolerance genes will be transferred to non-GM crops, or to other GM crops. This could result in the formation of herbicide tolerant

'volunteer plants' in follow-on crops. Alternatively GM crops that are resistant to several herbicides may be created that may also cause a 'volunteer' problem. However, studies have shown that volunteers of GM canola are no greater problem than non-modified crops, since alternative herbicides are available for use.

Again, this is an issue that should be dealt with by appropriate agricultural management and it is important that guidelines for use of herbicide tolerant crops are provided to growers. Such guidelines should specify crop separation distances for each GM crop to reduce the likelihood of cross-pollination occurring. The likelihood of multiple herbicide tolerance arising from transfer of several genes is considered to be small. However, crop rotation proposals in growers' guidelines should define appropriate crop rotation strategies.

#### **4.2.3 Will the use of the herbicide affect other plants and animals?**

The field environment is not a 'natural' system as the habitat is already highly controlled irrespective of the use of herbicide tolerant crops. The use of land for crop production whether non-GM or GM crops, will lead to what is essentially a monoculture, with many plant and animal species existing at much lower levels than would be the case without cultivation. Wildlife biodiversity is partly influenced by improved control of pests, diseases and weeds in the agricultural environment. If there has been a decrease in biodiversity in recent years, as indicated by recent studies, this is likely to be a feature of current agricultural practices. It is therefore important to ask how GM crops will influence such practices.

GM crops may result in reduced use of agrochemicals which may be beneficial to the environment. However, the major suggested adverse environmental effects of the use of herbicide tolerant crops derive from more effective destruction of weeds. This is likely to reduce the availability of habitats for various insects and other invertebrates. It would also have effects on the organisms that are associated with the root systems of weed species. In turn, this may have an effect on the availability of food for predators that feed on them. It may be possible to incorporate features to minimise such environmental effects in guidelines issued to growers of herbicide tolerant crops. Advisory bodies should consider whether such guidelines should be obligatory. However, it should be noted that licensing of herbicides in Australia includes a review of their potential environmental impact through National Registration Authority. In addition, there is a monitoring program in place to assess overall use of herbicides. Perhaps these should be extended to the use of GM herbicide tolerant crops.

As GM herbicide tolerant crops have only been grown commercially since 1995 (in USA and Canada) there are insufficient research data relating to possible effects on the field environment. A detailed program of post-release monitoring of environmental impact should be a requirement of all releases of GM herbicide tolerant crops. It may be necessary for such monitoring to be carried out by an independent body or organisation on behalf of the company or companies marketing the crop for example by National Registration Authority. It will also be highly desirable to have separate scientific studies of specific topics, such as the effect of herbicide tolerant crops on numbers and variety of species of nematodes or bacteria; population structures of insects; and numbers of birds and animals. It should also be noted, however, that there have been herbicide tolerant non-GM crops on the market for several years which were

produced by traditional breeding methods. Systematic monitoring of the ecological effects both GM and non-GM herbicide tolerant crops are of paramount importance. Protocols for post-release monitoring may need to be developed so that adequate monitoring is ensured. It is also important that any monitoring compares results with those obtained from current agricultural practice to give a realistic baseline.

#### **4.3 Virus Resistant Crops**

Virus resistance was one of the first targets for genetic modification of crops as plant viruses have a relatively simple genetic makeup, the function of which is reasonably well understood. There have now been several releases of GM virus resistant crops. Three basic types of genes are used in such plants. The most common method is to use viral DNA sequences themselves which, when inserted into plants and expressed, interfere with the infecting virus to give what is called '**pathogen-derived protection**'. The second type of anti-viral GM plant utilises genes from various sources that express anti-viral proteins which usually operate against a stage in the viral replication cycle. A third method is to use virus-resistance genes isolated and transferred by genetic modification to species which are sexually incompatible with the donor source.

Most of the risk assessment considerations regarding GM virus resistant plants have focused on genes derived from viral sequences. Three possible risks have been identified, all environmental, as there is no increased risk to human health since we all eat virus infected plant material every day. Firstly, in plants containing coat protein (most plant viruses consist of RNA surrounded by a protein capsule or coat) genes there is a possibility that such genes will be taken up by unrelated viruses infecting the plant. In this situation, the foreign gene changes the coat structure of the virus and may confer properties such as changed method of transmission between plants. The second potential risk is that there is recombination between the inserted gene and unrelated viruses infecting the GM plants creating a new virus. Third, there is the possibility that switching on the inserted gene at the same time in the plant which is infected with an unrelated virus will aggravate the symptoms. All these potential risks have to be viewed in relation to the natural situation of joint infections by two or more viruses, a common occurrence in plants. There is relatively little information on how viruses interact in natural simultaneous infections, but it is well known that transgenes are expressed to much lower levels than those reached in normal virus infections.

### **5. Specific issues related to GM plants for food use**

There are concerns amongst some consumers about the addition of GM crop plants to food, because ingredients derived from GM crops are beginning to be used in food manufacture. However, the difficulty in guaranteeing segregation of GM and non-GM commodity crops, such as soybean and maize, due to long distribution lines between growers and consumers and differing regulations between producer countries, is causing severe problems with attempts to offer consumer choice through clear labelling. It is important for companies to recognise the widespread desire on the part of the consumers to have appropriate labelling of foods. The following paragraph considers specific concerns relating to GM plants and their products in food.

#### **5.1 Labelling and segregation**

Guidelines are required for labelling, not only, in specific cases such as to meet ethical, religious, or health concerns for example, if a gene from a pig had been inserted into a soybean, the resulting product would have to be labelled on ethical and religious grounds, but also for any new crop which is substantially changed (according to specified criteria) from that of its conventional counterpart, to allow consumers choice. It is important to note that when it comes to setting in place guidelines for labelling GMOs Australia is indeed leading the world.

## **5.2 Toxic or allergenic effects as a result of the inserted gene**

It is important to stress that highly purified materials derived from a GM crop, for example sucrose derived from a sugar cane genetically modified to be resistant to insects, will be identical to material derived from the non-GM variety. Such material is therefore no more likely to be toxic or allergenic than material from non-GM sources.

A number of plants produce toxins (Phytoalexins) as a protection against insect and fungal pests. These are part of their innate defence systems and as such are important to maintain. They are generally present at low levels that humans and animals are able to tolerate. Genetic modification may be used beneficially to remove allergens or toxins in existing food crops. It is possible however, that such toxin levels could be increased by genetic modification (by switching on genes to a greater level); this should be taken into consideration during assessment of applications for release or marketing.

There are many databases of known allergens that could help to identify proteins that may be problematic if inserted into food products. When submitting an application to market a GM plant for growth, information on likely toxic or allergenic effects must be included in the application. However, the current system of relying on identification of non allergens in the GM plant, coupled with the reliance on 'substantial equivalence' may result in potential allergenicity problems being impossible to predict if there are no data available on the substances in question, particularly since mechanisms of allergenicity are often poorly understood.

Therefore the regulations require that products be clearly labelled if they contain genes that may result in toxicity or allergenicity, particularly if such genes would not normally be expected to occur in the food. For example, if an allergen gene from a nut were to be inserted into a potato to be used for food purposes, such products would not be approved for marketing under the current regulatory system without such labelling being a condition of approval. GM plants which contained expressed toxins which are harmful to humans would not receive regulatory approval. Attention must be paid to consideration of whether long-term animal feeding studies are necessary to provide greater information on allergenicity or toxicity.

## **5.3 GM crops containing non-food genes**

Several commodity crops that would normally be used for food, for example canola, are currently being developed as 'bioreactors' to express genes for production of pharmaceutical compounds or ingredients for biodegradable plastics. Such plants are intended to act as factories for the safe and economic production of such compounds. In addition, food plants, such as bananas, are being specifically targeted for insertion of genes for the production of vaccines. It is important that such plants are well segregated

from food crops to prevent genes inadvertently entering the food chain by cross-pollination, or mixing of crops during harvesting. Alternative methods of minimising gene transfer may also be necessary. In practice it is envisaged that production plots will be grown mostly in glasshouses.

Another new technology is the development of vaccines for humans known as **Bio-pharming**. Under this technology vaccines will be produced in virus particles that can be grown in plants without causing disease. Here, production is contemplated by harvesting the heavily inoculated crops. This work will be carried out only in containment owing to the value of the product and necessity for frequent monitoring.

#### **5.4 Phenotypic / genotypic stability of GM crops**

Concerns have been raised that expression of genes that have been inserted by genetic modification may be easily lost, returning the crop to its non-GM state. Any set of genetic modification experiments yields a variety of plants, some genetically unstable, others stable. Selection is made on the basis of stability and efficacy, first in the glasshouse and then in the field. Ultimately, the chosen GM plants are crossed by the plant breeder into elite lines of the crop in question so that the gene(s) of choice can be put into the best possible commercial background. This is tested extensively, usually in multi-locational trials over at least three years to check for overall performance based on the following criteria:

- 1- Distinctiveness - is it genetically different from anything already on sale?
- 2- Uniformity - are all the seeds in the bag what they should be?
- 3- Stability - is the product stable over several generations?

Aside from the above, it is not in a company's interest to produce an unstable product. To do so could involve them in lawsuits, compensation costs and would severely prejudice their market share in future years.

#### **5.5 Pleiotropic effects of genes**

Pleiotropic (a process in which one gene affects more than one trait) effects are indirect effects arising from the insertion of the genes into the GM plant. For example, the insertion of a gene attached to a strong promoter into the plant's chromosome might cause a problem if it was inserted next to a toxin gene that had previously been present but not expressed in the plant. The insertion might trigger the expression of the toxin in addition to the novel gene product.

Pleiotropic effects are not confined to plants created as a result of modern methods of genetic modification. Indeed, plant breeders often rely on such unexpected effects to produce useful varieties. However, if deleterious effects were produced from traditional breeding then the line would no longer be grown as it would not be useful from an agronomic point of view. In GM plants, information is available about the gene which has been inserted, such as where it is in the plant's DNA and what effects it has. In this respect, it may be easier to predict pleiotropic effects arising from genetic modification. It is, however, important for the governmental advisory committees to maintain vigilance for them and that further research into the likelihood of their occurrence be conducted.

### **6. Conclusions**

The use of Genetically Modified Organisms (GMOs) has the potential to offer benefits in agricultural practice, food quality, nutrition and health. There are, however, uncertainties about several aspects of GMOs. Continued research is essential if these uncertainties are to be properly addressed, the risks understood and the full potential of the new technology made clear. Whilst there may be some perceived risks attached to genetically modified plants we need to keep the big picture in mind. Genetically Modified crops have the potential for reducing pesticide and herbicide use and increasing yield.

If Australia does not participate in the development of this technology, we will be left behind. Some say that we can get an idea of what the effect will be if we imagine Australia chose not to be involved in computer technology in the 1960s. In the case of genetic engineering, we will miss the opportunity to provide better health care, improved agricultural productivity, and a sustainable environment for our country. By participating now in the latest techniques, we will capture the benefits for Australia, rather than having to buy them from other countries. However, the public's legitimate concerns must be acknowledged because consumer confidence, based on an appreciation of the scientific evidence and the regulatory checks and balances, is central to whether GMOs will contribute to feeding the world's rapidly expanding population in the twenty-first century.

## **7. Further reading**

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