Genetically modified potatoes (*Solanum tuberosum*)

Background

In New Zealand, potatoes are grown commercially throughout the country on approximately 12,000ha. There are about 380 commercial growers who are involved in producing a crop worth $84 million.

The New Zealand Institute for Crop and Food Research Ltd is conducting a series of small-scale contained field trials on potato plants. These plants have been genetically engineered to make them resistant to soft rot, a major problem for the New Zealand potato industry.

Traditional breeding techniques for resistance are limited by a lack of appropriate germ plasm, so current control measures often heavily rely on pesticide use. The transfer of genes from unrelated organisms offers a novel, broad-spectrum approach to improving disease and pest resistance in crop plants.

The Technology

The introduced DNA sequences are combinations of DNA segments from viruses, bacteria, animals and other plants that have been artificially modified to maximise their activity in plants.

Three genetic engineering approaches are being used to target improved resistance to soft rot bacteria. This involves the development and transfer of genes encoding three peptides:

- cecropin (artificial DNA sequence based on peptides from silkworms)
- magainin (artificial DNA sequence based on peptides from toads)
- lysozyme (from T4 bacteriophage)

The disease resistance genes are attached to a marker gene conferring resistance to the antibiotic kanamycin. This disease resistance is used to select engineered plant cells from non-engineered cells during the genetic engineering process.

DNA sequences involved in transferring the novel genes into potato were derived from the soil bacterium, *Agrobacterium tumefaciens*.

DNA sequences that control the activity of the novel genes/peptides in potatoes came from cauliflower mosaic virus, alfalfa mosaic virus, *Agrobacterium tumefaciens*, tobacco and potato.

Propagation

1. Micro-propagated potato plants will be multiplied and maintained *in vitro* until 4-5 weeks prior to field planting.
2. They will then be transferred to the containment greenhouse for establishment in soil and gradual hardening-off for field transplantation.
3. Tubers harvested from the containment greenhouse will be stored at 8oC within the containment facility for at least 6-8 weeks to fulfil any dormancy requirements.
4. The exact number of required tubers or transplants will be transported to the trial site in secure boxes.

Containment

- Carefully designed containment systems will minimise the risk of dispersal.
- The transgenic plants will be surrounded by a buffer zone of 3 rows of non-transgenic potato plants.
- There will also be an isolation distance of at least 50 metres from other non-modified potato crops.

This will virtually eliminate any opportunity of gene escape through pollen dispersal. Subsequent monitoring of the trial site for 1 - 2 years after harvest, coupled with the immediate removal of any potato plants, will ensure the complete elimination of genetically engineered potato plants from the trial site.

Following harvest, the site will be grubbed several times with surface picking of remaining tubers. Tuber dispersal would require human assistance.

Benefits of using genetically modified potatoes

- Potential to reduce pollution via reduced pesticide requirements
- The agricultural use of these transgenic potatoes will reduce pesticide residues in soils and ground water.
- The peptides being expressed have general activities so the effects may extend to other microbial diseases and possibly even mycorrhizal fungi.
- Potato seed producers and potato growers will benefit from the resistance to soft rot bacteria and other pests and diseases. There will be fewer losses to disease, an increase in efficiency and farming will be more profitable as less inputs will be required.
- Potato processors will benefit from the more reliable supply of high quality tubers without soft rot damage.
- The reliable supply of high quality tubers to processors should result in an economic benefit for consumers. Consumers will also benefit form the reliable production of high quality table tubers without insect damage and with minimal pesticide residues and the consequent health benefits.

Potential Risks of using genetically modified potatoes

- **The new genes may have unforeseen effects.** All the transgenic potato lines to be field-tested contain two new genes: a kanamycin resistance marker gene and a gene for improved disease resistance.
  Comment
  There is no information to suggest any consequences of the proposed small-scale field trial on tangata whenua, human or animal health, on target and non-target organisms, or on the general ecology, environmental quality and pollution in the area.
- **Genes may transfer to other organisms.**
  Comment
  Previous research suggests the risk of gene transfer from transgenic potatoes to associated pathogens such as viroid, viral, bacterial and fungal diseases, insects and nematodes, is negligible.
  It is highly unlikely that larger animals such as birds or rodents will consume the transgenic potatoes. Potato berries contain alkaloids that give them bitter taste and neither birds nor rodents are known to consume them. Although it is conceivable that rodents may dig up tubers, it is highly unlikely in such a small-scale trial and in an area with considerable human activity.
- One possible negative effect of the introduced genetic trait is a pleiotropic effect on the plant phenotype and the yield of tubers. This means that the new genetic material may cause multiple effects in the phenotype, including some unexpected ones.
- **Reduction in genetic diversity in New Zealand.**
  Comment
  The consequences of these transgenic lines will be no different from that posed by the release of new potato cultivars developed by traditional breeding. The gene transfer associated with the development of the transgenic potato lines represents an increase in genetic diversity within potato germ plasm.
- **The transgenic potatoes may cause disease, be parasitic, or become a vector or reservoir for human, plant or animal disease.**
  Comment
  This is unlikely as the transgenic potato lines are expected to behave in an identical manner to other potato crops, except for the improved resistance to soft rot.

Other unlikely impacts

Additional unlikely impacts that have been proposed for transgenic plants include:

- the transgenic plants will become weeds;
- disease resistant transgenic plants will cause ecological imbalance;
- growing disease-resistant transgenic plants will lead to the development of superpests;
- the transgenes will be transferred to weeds and enhance their weedy status; and
- the use of antibiotic-resistant marker genes may contribute to the development of antibiotic resistance in microbes.

The risks of disease-resistant transgenic potatoes to natural ecosystems, agricultural ecosystems, food industries, and consumers will be no different than the effects of growing, processing and eating new cultivars with disease resistance developed via traditional potato breeding.

The Social and Cultural Issues

It is not expected that the proposed release would have any effect on Maori traditional resources, culture and taonga. The potato is an introduced crop plant and the plants which have been genetically modified and whose release is being sought represent cultivars already grown and/or bred in New Zealand.

Local iwi have been consulted over possible effects of the release of these genetically modified organisms.

Definitions

Term	Meaning
alkaloid	Alkaloids are a group of chemical compounds obtained from plants. They are often used in medicine. Common alkaloids include morphine, cocaine and caffeine. Some, such as strychnine, are poisonous.
antibiotic	These are chemical compounds that fight bacterial infections. They do not work against viruses. Antibiotics are produced naturally by micro-organisms such as moulds and other bacteria. The most famous antibiotic is penicillin formed by the mould *Penicillium*. Other common antibiotics are Streptomycin and Anthromycin.
bacteria	Bacteria are micro-organisms (very, very small) that consist of a single cell. Inside the cell there is no separate nucleus.
virus	A very small infectious particle. When outside a cell viruses are lifeless, inert particles made of DNA, fats and proteins. When they invade a cell, they take over the cell, making more viruses, usually destroying the cell in the process.
bacteriophage	A bacteriophage is a virus that infects a bacterium. The bacteriophage usually multiplies within the host bacteria and then destroys its host. In genetic engineering, bacteriophages are used to introduce foreign genetic material into the bacterial cell.
broad-spectrum	A broad-spectrum approach is designed to cope with a wide range of situations. A broad-spectrum pesticide will kill many different pest species. A narrow spectrum pesticide will, perhaps, kill just one pest species.
cell	The cell is the building block of all living organisms. It has many structures inside it but not all features are found in all cells. For example, some plant cells have chloroplasts to allow the plant to carry out photosynthesis.
DNA	The symbol DNA stands for **d**eoxyribo**n**ucleic **a**cid. DNA are long, chain-like strands that contain the genetic information for an organism. The chain is often many times longer than the cell that contains it. It is wrapped tightly to fit inside the cell.

dormancy	Dormancy occurs when an organism is in a resting state. The organism is still alive but stops growing. Dormancy is often used a survival technique to protect the organism during unfavourable conditions. It is common in plant seeds.
ERMA	This acronym stands for the New Zealand **E**nvironmental **R**isk **M**anagement **A**uthority. This is a government organisation charged with administering the HSNO Act. It mainly deals with applications to bring new organisms into New Zealand and research involving genetic engineering in New Zealand.
gene	A small section of a DNA strand that contains the information to create a specific protein. This protein will have a specific role within the organism.
gene expression	Gene expression occurs when a protein is produced by the cells of an organism. The instructions for producing the protein are found in a gene in the DNA of the organism.
genotype	The genotype is the genetic code of a cell or individual organism.
gamete	A gamete is a sex cell or germ cell. It is a cell specialised for fertilisation or reproduction. A gamete from the male parent is usually called a sperm; a gamete from the female parent is usually called an egg or ovum. Each gamete contributes genetic material from one parent. When the gametes join together a fertilised egg (zygote) is formed.
germ plasm	Germ plasm is the hereditary material that is transmitted to an organism's offspring. This material is transferred in the gametes of the parents.
hardening off	The process of hardening off helps plants or seeds survive the transition from a protected indoor environment to the outside world. Hardening off consists of gradually exposing the plant/seeds to harsher and harsher conditions - for example, longer time exposed to natural sunlight and normal outside temperatures.
HSNO Act	The **H**azardous **S**ubstances and **N**ew **O**rganisms Act was passed by New Zealand's Parliament in 1996 and implemented in 1998. The Act controls how new organisms and hazardous substances can be brought into New Zealand. It also controls the use of genetic modification to create new organisms within New Zealand.
in vitro	In Latin, this means "in glass". It describes any biological process that occurs outside the cell or organism. This includes experiments in Petri dishes or test tubes.
iwi	A Maori word meaning community, a group of people living in the same area.
kanamycin	Kanamycin is an antibiotic used to fight bacterial infections. Resistance to kanamycin is often added to organisms when genetic material is introduced during genetic modification. This resistance can be used to identify and select the organisms that have successfully accepted the new genetic material.
Maori	The indigenous people of New Zealand (Aotearoa).
micro-propagation	A biotechnology technique in which a whole plant can be raised from a single cell. The technique is commonly used with potatoes, strawberries and tomatoes.
mosaic virus	The **mosaic virus** is a plant disease. It is physically seen as a mosaic or blotchy pattern on the leaves of a plant. This virus is often used in genetic engineering to insert genetic material into another species.
nematode	Nematodes are roundworms. They are very common and are important in the breakdown and recycling of organic material. Nematodes have a smooth, cylinder-shaped body tapered at both ends.

peptide	Peptides are chemical compounds formed when two or more amino acids are joined together. The bond formed between the amino acids is called a peptide bond.
phenotype	The phenotype is the physical appearance of an organism. This appearance is a result of the interaction between its genetic material (genotype) and the environment.
pleiotropic	A pleiotropic gene controls more than one characteristic or feature of an organism.
protein	Proteins are an organism's workers. They carry out many functions including: chemical reactions within cells, forming structural elements such as cell walls, and moving chemicals throughout out the organism. Each protein is composed of a sequence of amino acids. There are 20 different amino acids. By varying the length of the protein and the sequence of the amino acids different proteins are formed.
soft rot	Soft rot is a bacterial infection of the tuber of a plant. It is common in potato crops. The affected plant appears stunted and its leaves turn yellowish before the plant collapses and dies. The infected tuber is finally reduced to a whitish, slimy, foul-smelling, pulp.
taonga	A Maori word meaning belongings, assets or treasure.
transgene	A transgene is a gene in which genetic material from another species has been added.
transgenic	Any organism in which the genetic material is composed of DNA from two or more species.
tuber	Tubers occur in plants. They are used by the plant to store food and are produced underground. A common example of a tuber plant is the potato.
viroid	Viroids are like viruses but they are smaller. Unlike viruses, they do not have a protein coat surrounding their RNA strand.

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