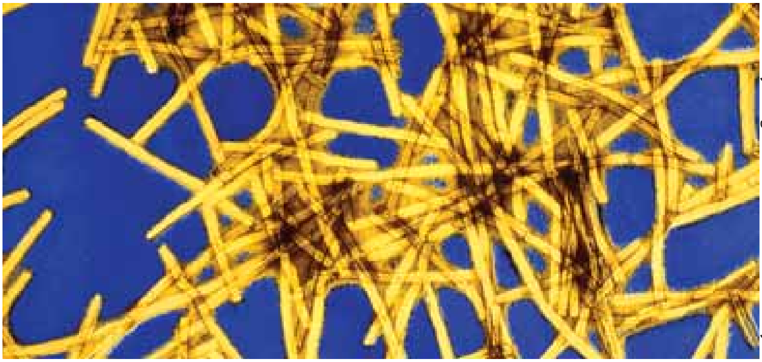
Hazards and benefits of GM crops: a case study



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Viruses are tiny pathogenic particles inside cells that infect other living organisms: in humans they cause chickenpox, influenza, polio, smallpox and other diseases. The first virus ever to be described infects plants – it was tobacco mosaic virus (illustrated above) – and plant viruses, like those of humans, cause disease. When they infect crops, they can be a serious problem for farmers.

Some crops are protected from viruses by disease-resistance genes. Plants carrying these genes are identified by plant breeders and refined as new varieties for use in agriculture through a lengthy crossing programme. However, the appropriate resistance genes are not always available and many crops are susceptible to virus disease. To protect these susceptible crops there is a promising new strategy that

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illustrates the benefits of genetic modification (GM) technologies. It also provides a new opportunity to test the level of risk of such technologies in the field.

This new GM approach has been successful in the laboratory with many viruses[1] and, in one example, with papaya, it has been used in regions of Hawaii to protect against papaya ringspot virus. This disease was previously destroying virus-susceptible plants[2] but, with the new GM varieties, the plantations have been re-established and farmers' livelihoods have been restored.

The chromosomes of these GM plants contain pieces of introduced DNA (transgenes) that include a fragment of the viral genome. Recent research indicates that these transgenes are effective in virus resistance because they reinforce a natural defence system against viruses that is known as 'ribonucleic acid silencing' (RNA silencing). Perhaps there is a message in this finding: innovation in biotechnology is best achieved by modifications to natural processes rather than by attempts to synthesise a new mechanism?

If RNA silencing is compared, metaphorically, to the immune system in humans and other mammals, the transgene that includes a piece of viral DNA is like a 'nucleic acid antigen' and the plant responds by the production of an 'RNA antibody'. In effect the foreign nucleic acid in the transgene boosts the natural defence of the crop in the same way that a vaccine protects us from polio, influenza or other viral diseases. The hope is that African crops could be protected by GM RNA silencing against maize lethal necrosis, African cassava mosaic, cassava brown streak, rice yellow mottle, groundnut rosette, banana bunchy top and many other viral diseases.[3]

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Of course it is not a simple matter to tackle crop disease. One of the most significant complicating factors is the ability of viruses to evolve rapidly. When we grow virus-resistant crops we introduce strong selection pressure for strains of the virus that can evade the resistance mechanism. With conventionally bred plants this problem is difficult to address and, eventually, the resistance gene is useless because the resistance-breaking viruses become so abundant. However, with RNA silencing, we can 'immunise' the crop with multiple elements of the viral DNA. This strategy would minimise the risk that the resistance is overcome because the virus would require two or more simultaneous mutations to evade the 'RNA antibody'. Mutations are rare and two simultaneous mutations at defined sites are almost impossible.

A second complicating factor is the potential for resistance genes, including transgenes, to affect the safety of the crop. A recent report, for example, suggests that plant RNA in the diet of a mammal can be taken up into the liver where it can switch off, or silence, gene expression.[4] In such a scenario the 'RNA antibody' produced in the GM plants could be hazardous if, by chance, it targets human liver genes. However, the transgene RNA would be diluted by the large amount of RNA produced naturally in the plants. There is, therefore, a much greater risk, by many orders of magnitude, from the natural plant RNAs in our diet than from the transgene. As humans eat many plants without harm it is unlikely that absorbed transgene RNA presents a hazard.

Another potential complication of GM arises if a transgene encodes a protein that affects the safety, nutritional value or quality of the crop. There is the same potential hazard with conventional breeding in which thousands of protein-coding genes with potential to cause harm are transferred into the crop from, for example, a wild relative. However, with RNA silencing, the resistance does not depend on transgene-encoded proteins. It is therefore highly unlikely that

RNA silencing would introduce a protein-based hazard to human health or the environment.

Modern agriculture uses fewer varieties of crops than traditional or local farming and there is concern that we are losing diversity in crop germplasm. The focus on few varieties is, in part, because it is difficult to transfer desirable traits by conventional breeding from a wild plant into multiple new varieties of a crop. However, this limitation does not apply with GM traits. A transgene can be introduced simultaneously into many different varieties and they would all be improved without loss of their original agronomic characteristics. To improve several varieties in this way is not a trivial undertaking but it would be much easier than with conventional breeding. A GM strategy could, therefore, preserve biodiversity in cropping systems, not reduce it.

Other hazards of RNA silencing in GM plants are similar to those associated with conventional genetic traits. It could be, just as new conventional varieties sometimes fail in large-scale trials, that RNA silencing is not as effective in the field as in the laboratory. Conversely, the GM trait could be very effective in the field and the crop could acquire the damaging invasive characteristics of weeds. However, the problem of crops as weeds is not new. In the UK, for example, the yellow flowers of rapeseed are a common sight as a weed in other crops. There is no reason to think that transgenes would be more hazardous or pose greater risk in this sense than conventional genes conferring virus resistance.

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A prudent approach for GM in Africa, taking these various hazards into account, would involve a testing programme similar to that used for GM crops in the UK.[5] First the trait and the potential hazards would be tested in growth chambers, glasshouses and then field plots. Progressively more extensive field trials in several locations are then used to assess the effectiveness and stability of the trait and the impact to the environment including any effects on gene flow.

However, even when virus resistance from GM is demonstrably effective and safe in the field, it should not be considered as a panacea: other protection strategies should also be used. Planting of the crop, for example, should be in rotations and at times of the year that are not compatible with the life cycle of the insects and nematodes that carry the disease from plant to plant (vectors). Similarly the weed control and tillage methods should discourage these vectors and prevent infection reservoirs that could spread to the crop. With good crop management there is no reason why virus resistance achieved by RNA silencing should not become a durable and widely used technology to help achieve food security in Africa.

References

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