



# **Open Meeting**

## **GM crops: gene flow and fitness in natural and agricultural systems**

17 March 2003

The open meeting was organised by the BA for the GM Science Review which is part of the National Dialogue on GM.

This report was prepared by Rachel Tonkin on behalf of the BA and submitted to the GM Science Review Panel.

## **GM crops: gene flow and fitness in natural and agricultural systems**

### **Summary**

Gene flow and plant fitness in and beyond agricultural systems was the subject under discussion at the open meeting held in Aberystwyth, as part of the Science Review of genetic modification.

The meeting was chaired by Dr Toby Murcott and attended by members of the scientific community and also members of the general public who were interested in the issues surrounding genetic modification.

Issues such as gene flow as an ancient phenomenon, the potential for enhanced ecological fitness and the feasibility of co-existence between GM and non-GM crops were raised.

Professor Chris Pollock from the Institute of Grassland and Environmental Research explained that experiments on gene flow within grasses found evidence of small amounts of cross-pollination up to 1 km away from a donor block of plants. It was acknowledged that where populations of plants are sexually compatible, gene flow will almost certainly occur, and therefore Professor Pollock suggested that it is more important to look at the specific effects of gene flow in individual situations.

Dr Rosie Hails, who talked about ecological fitness, believes the focus of scientific research should be on constructs that are most likely to confer an ecological advantage, and cases where the rate of co-evolution may be different to that in natural populations and current conventional agricultural systems.

It was generally agreed that the consequences of gene flow in maize within the UK would be easier to manage as it has no wild relatives with which to breed, whereas oilseed rape and beet can cross with certain wild relatives.

## **Introduction**

The fourth open meeting of the Science Review of genetic modification (GM), held on 17<sup>th</sup> March, was kindly hosted by the Institute of Grassland and Environmental Research (IGER) in Aberystwyth.

The main issues under discussion at the meeting were those surrounding gene flow and plant fitness in natural and agricultural systems. Three speakers from the scientific community raised issues including the idea that gene flow is an ancient phenomenon, that GM disease resistance could raise some ecological issues and also the feasibility of co-existence between GM and non-GM crops.

This open meeting is part of the nationwide scientific debate, intended to establish the state of knowledge and understanding of the science of GM. Several open meetings have already taken place and covered topics such as GM food safety, GM animal feed safety and gene flow. The GM Science Review is not just for professional scientists to air their views, but also for science students and members of the general public to have their say.

Professor Sir David King, Chief Scientific Advisor to the Government, is chair of the GM Science Review Panel, whose job it is to summarise the state of scientific knowledge on issues of interest and concern to the scientific community and wider public. The GM Science Review Panel will produce a report to present to Government.

## **Gene flow in agricultural systems – an ancient phenomenon?**

Professor Chris Pollock, the Director of IGER in Aberystwyth, began the fourth open meeting of the GM Science Review by introducing gene flow as an ancient phenomenon.

Professor Pollock discussed the issues that determine how genes move, where they move and what happens to them once they have moved. He cited experiments that were carried out by IGER in the mid-1990s, in which scientists traced gene flow from one generation to the next by using genetic markers.

The experiment measured gene flow by having a central block of donor plants which contained the genetic markers, and then surrounding this with either linear or circular distributions of plants. The seeds of those plants were then looked at to obtain a quantitative assessment of gene flow, namely when certain genes move, and how fast they move.

The experiments showed that close to the donor block, up to 100% of the descendant plants would contain the marker, but that it was increasingly difficult to detect cross-pollination beyond 100 metres from the donor plants. However, when the recipient plants were arranged in circles around the donor block—resulting in an increase in numbers at a greater distance—multi-direction gene flow was detected at very low rates up to 1 km away.

From this Professor Pollock concluded that, if you have sexually compatible populations, then gene flow between them was the norm rather than the exception. As Professor Pollock explained, it is not the question of whether gene flow occurs, but of determining the significance of the consequences of this flow.

Professor Pollock then described the use of similar markers to measure historical gene flow between isolated populations of two grass species, one of which—perennial rye grass—was in use as animal feed, and the other—*Agrostis*—which was not. The *Agrostis* populations showed evidence of low rates of gene flow that were dependent on the distance between them. By contrast, the rye grass populations, despite being from old permanent pastures, showed marker patterns that suggested significant gene flow from improved (bred) ryegrass pastures. This was good evidence for agriculture having affected "natural" patterns of gene movement long before the onset of GM plants.

The issue of gene flow was, therefore, not just a question of moving genetic material from one population to another, but rather a question of how long this introduced genetic material lasts within the new population and what the effect of it will be within that population. This can be defined as the proportionate contribution that an individual plant makes to future generations and is known as fitness.

Professor Pollock was keen to stress his view that the key to the whole gene flow debate is fitness; the persistency of the genetic material in the natural environment. He pointed out that the increasing scale of cultivation of GM crops worldwide had allowed scientists to measure both gene flow and persistence on a large scale, and that rates of long-term gene flow between the agricultural and "natural" environment had been at or below the limits of detection.

### **The consequence of gene flow in natural habitats; is there evidence of enhanced ecological fitness?**

The debate about the possible effects of GM on ecological fitness was continued by Dr Rosie Hails, an ecologist from the Centre for Ecology and Hydrology in Oxford. Dr Hails focussed on the potential consequences of gene flow, asking whether there is actually any evidence of enhanced ecological fitness as a result of genes from GM crops moving into wild relatives.

The rate at which genes flow is, to a certain extent, specific to the individual context. Oilseed rape can cross-breed with one of its wild relatives in the UK, for example wild turnip, but the rate at which this will happen depends upon factors such as whether the wild turnip is an isolated plant in an oilseed rape field, or one of a large population growing along a river bank.

Dr Hails explained, "It is hypothesised that one potential consequence of enhanced ecological fitness is that populations of wild plants may then become

weedy or invasive and this could disrupt ecological communities and even ultimately perhaps result in the extinction of other species.”

One way of measuring the fitness of a plant is to take a certain point in the life cycle of, for example, mature adult plants, and compare the numbers in one generation with the numbers in the subsequent generation. This is the rate of increase between one generation and the next. Only a small number of experiments have actually measured the rate of increase or fitness of plants that have been genetically modified compared with conventional plants in natural habitats.

Dr Hails cited one such experiment by Mick Crawley, carried out in the 1990s, which introduced GM seeds and wild seeds into very closely monitored natural habitats and followed them over subsequent generations.

This experiment showed that “in no case did the genetically modified plants perform better or were they fitter than the conventional plants.” However, when these experiments were carried out the genetically modified varieties were herbicide tolerant and insect resistant varieties.

To determine which factors are most likely to affect fitness, Dr Hails referred to an experiment carried out in the United States using wild sunflowers. *Bt*<sup>1</sup> transgenes, which produce an insecticidal protein protecting the plant from herbivores, were inserted into wild sunflowers. The result of the experiment found that the wild sunflowers produced more seeds than the conventional sunflowers.

Although this result would initially seem to suggest that modified wild plant populations could prosper and spread, as Dr Hails pointed out, this raises the question of whether this increase in seed production necessarily leads to enhanced fitness.

There are many examples in ecological literature where the absence of the selection pressure, for example, the absence of herbivores, means that there is a fitness cost to carrying extra genes. Dr Hails quoted one example which looked at wild radishes where it was found that, “even induced as well as constitutive herbivore defences in wild populations incurred fitness costs in the absence of the herbivore. The cost-benefit balance of such genes is going to depend upon how frequently herbivores are present in those wild populations and how frequently they are having an effect on fitness.

A second issue is whether enhanced fitness will lead to population increase. Dr Hails explained, “Enhanced fecundity may not lead to an increase in local population abundance because it depends upon your populations being seed-limited.”

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<sup>1</sup> *Bacillus thuringiensis (Bt)* is a bacterium that produces toxic crystals and is used as an organic pesticide. The *Bt* gene, inserting into GM plants, encodes for the toxic crystals.

A third issue is whether the herbivore populations can evolve to cope with the *Bt* toxins. “We do know that herbivore populations frequently contain *Bt* resistance genes, so whether any enhanced fitness is transient or rather more enduring is going to depend upon rates of co-evolution.” One of the main problems of growing *Bt* crops in the agricultural field is that the rate at which pests evolve resistance to the *Bt* crops has to be managed very carefully. If rapid co-evolution occurs in the agricultural habitat, it is likely to occur in natural habitats too.

However, GM virus resistance is more likely to raise some ecological issues. When using GM to produce resistance to viruses, essentially the genes of the agent causing disease (the pathogen) are used against it. This works by taking a gene from the protein coat of a viral pathogen, this surrounds its genetic material, and inserting this gene into the plant, which interferes with the infection mechanism.

Dr Hails ended her talk by giving an example of where the technique of producing pathogen-resistant crops has enabled farmers to continue growing their crops. Papaya crops in Hawaii were suffering from viral diseases and as a result, farmers now only grow the GM variety. In summary, “this form of transgenic pathogen resistance can be very enduring which is good news in the agricultural context, but could lead to enhanced ecological fitness in wild relatives that are rather more enduring in nature.”

The concern that enhanced ecological fitness could cause environmental harm was raised by a member of the GM Science Review Panel. Dr Hails believes that even if enhanced ecological fitness is demonstrated, this does not necessarily lead to environmental harm.

She agreed with the panel member and expressed her view that the challenge of this debate is, “to piece together all the different impacts of a GM crop on the environment to get an overall assessment of the environmental footprint of a particular crop and its associated management practices.”

The second question raised by the Panel concerned herbicide tolerance and its effect on hedgerows and field margins, namely how scientists would measure the ecological impact on the surroundings of GM crops.

Dr Hails pointed out that one particular advantage of using GM with regards to hedgerows and field margins, particularly in the case of insect resistant crops, could be the reduced use of synthetic chemicals. As a result the use of GM for this would “positively enhance biodiversity in field margins.”

Although, Dr Hails also acknowledged that with herbicide tolerant crops there could be a potential negative impact on field margins. But she agreed that this is an important aspect of the GM debate and added that farm-scale evaluations are actually investigating biodiversity in field margins as a consequence of the management of herbicide tolerant GM crops. There should therefore be more information on this issue later this year.

Dr Hails highlighted once more the importance of taking into consideration the cost-benefit factor, namely the effect of the GM crop and the associated herbicides in comparison to the crop it is intended to replace.

The question of deciding the point at which enough research has been done to assess the ecological impact of new GM crops was also raised by the panel.

Dr Hails defended the need to do as much research as possible by saying, “we’re in a dynamic situation in which we already have declining biodiversity, so therefore I think we have a responsibility to consider all options available for moving towards a more sustainable agriculture and in some cases that may include use of GM crops in specific ways.”

In terms of herbicide tolerant crops becoming commercialised, Dr Hails believes there is already a substantial amount of information about herbicide tolerant crops and their potential ecological consequences.

But in terms of the commercial possibilities of *Bt* crops, Dr Hails admitted that “I think one of the key points there is the rate at which pest populations can evolve resistance to *Bt* because *Bt* is essentially a selection pressure that is already out there in the environment.”

The key to successfully producing *Bt* crops would be managing the agricultural systems so that the advantage of using *Bt* crops is not lost, that is, closely monitoring the rate at which insect populations evolve to circumvent these resistance mechanisms.

The ability of insects to evolve like this is the reason why Dr Hails suspects that any plant fitness changes in natural habitats would more likely be short-term rather than enduring. It is important to note, however, that this ability to breakdown resistance is a feature that is common with conventional agriculture. It is the rate at which this process happens that scientists use to inform part of the risk assessment of GM.

### **Gene flow and co-existence**

Dr Jeremy Sweet from NIAB, Cambridge, gave the last of the three talks by discussing the scientific issues surrounding the co-existence of GM crop production alongside non-GM crop production.

It is important that co-existence is fully researched to establish the feasibility of separate supply and production chains for GM and non-GM crops.

Dr Sweet discussed maize and oilseed rape to demonstrate that the basis of establishing whether co-existence is possible is to establish an understanding of the crops themselves and how the genes move. For example, an open-pollinating crop, such as maize or oilseed rape, can disperse genes quite widely to like crops. There are other ways in which genetically modified material could

spread to non-GM crops, such as inadvertent mixing of seed before planting or the persistence of seeds from previous years' crops. In addition oilseed rape can hybridise with related plants like wild turnip, for example, and these in turn can hybridise with other rape plants.

SEED: One problem of co-existence is the way in which seeds are dispersed and the difficulties of controlling this.

Oilseed rape sheds many seeds (6000-10,000 per sq metre) which escape being harvested and fall to the ground. These seeds can survive and as a result, can persist in the ground and come up again in subsequent years in other rape crops.

Experiments to test the persistency of oilseed rape seeds showed that "there appears to be no inherent ability for GM rape to persist in the soil more than non-GM." Persistency depends on several factors including the dormancy characteristics of a variety, soil type, soil temperature and the type of soil cultivations done to encourage germination and depletion of the seed bank.

Maize seed is less of a problem as it does not generally survive in the ground through the winter.

POLLEN: Studies on maize, carried out in Canada, showed that generally, 99% of pollen will only travel 50 meters away from the plant and 100% of pollen would have been deposited by 100 metres. But there are certain factors, as Dr Sweet pointed out, that can move small amounts of pollen much further than that, for example high velocity winds.

In order to assess the feasibility of co-existence, experiments have been carried out which look at the rate of out-crossing that can occur. There are factors which can affect the rate of out-crossing and these have to be taken into account when considering co-existence. Time of flowering, crop height, intervening crop space, size of the GM crop, landscape features and the type of crop being grown could all affect the rate of cross-hybridisation between plants.

For example, trials in Germany found that if a ripening field of corn is placed between two maize fields, there is an increase in atmospheric convection and therefore higher levels of cross-hybridisation occur than if there was a grass field in between.

Dr Sweet highlighted one particular area of concern, namely what happens when GM crops are grown on a larger scale. Experiments were carried out looking at farm-scale sites, 10 hectare fields, and in one site, quite high levels across the fields were found.

COEXISTENCE: Dr Sweet concluded by saying that the issue of co-existence is not simply a yes or no answer. It very much depends on what you are trying to achieve and the individual situation.

“I think realistically, it’s going to be very difficult for GM oilseed rape to co-exist with non-GM on the same farm.” Dr Sweet further explained this statement by saying that he believes a gradual build up of GM seeds will occur in the seed banks and certain levels of out-crossing will occur—both of which could become very difficult to manage.

However, Dr Sweet believes that co-existence between GM maize and non-GM maize is quite feasible and manageable.

A member of the Science Review Panel raised the problem of regulating the use of GM crops by farmers; specifically how would the measures required to ensure that GM crops don’t contaminate non-GM crops be regulated and enforced.

Dr Sweet referred to SCIMAC (Supply Chain Initiative in Modified Agricultural Crops), which is a stewardship programme. Farmers would be expected to comply with the regulations, but Dr Sweet raised doubts as to whether this would work in all cases.

The production of high erucic acid rape was also discussed, as this is a type of conventional oilseed rape for industrial oils and is inedible. As a result, there are isolation requirements in place for this crop to avoid contamination of edible rape.

Dr Sweet remarked that the production of erucic acid rape is not actually a problem in terms of contamination because the production level is quite low. But he is concerned that if GM oilseed rape becomes more than 20%-30% of the total oilseed rape crop, then it would become increasingly difficult to manage.

Where Dr Sweet sees a problem arising is in the area of farms saving rape seed. He is concerned that it will be difficult to save the seed from non-GM oilseed rape if you are also growing the GM variety on the same farm. Tests will be needed to ensure that a 0.9% threshold for GM can be met in the crops grown from farm saved seed.

### **Questions from the audience**

An audience member raised her concerns that GM oilseed rape could be entering the UK through importation, in things such as bird-seed. Dr Sweet, however, blames the spread of oilseed rape on our own activities and believes that once GM oilseed rape is introduced into the UK, it will be as wide-spread as conventional rape.

The subject of horizontal gene flow was also mentioned, and the fears that this occurs as plants rot in the soil. Professor Pollock answered this by explaining that although this is theoretically possible, “there is as yet no evidence of it occurring to a significant extent under natural circumstances.”

A scientist from IGER brought up the issue of the relationship between the effect of GM crops and their non-GM equivalents. By stating that herbicide tolerance can be generated by a non-GM means, he asked whether scientists

should be considering the traits rather than the mechanism by which they are produced.

It was generally agreed that it would be more logical if it were the novelty of the plant and not the production method that were analysed, as is the case in Canada, but it was recognised that the production method was the driving force for regulation in Europe.

Another member of the audience posed this question to the panel, “I would like to know why you think the British Medical Association is so concerned about antibiotic resistance in particular in this context, and why they have called for a halt to the farm-scale trials?”

Professor Pollock said that he was not aware of evidence that the use of antibiotic-resistance markers in GM technology had resulted in any increase in antibiotic resistance in humans or animals. The marker genes used in GM were for antibiotics not generally used in human medicine, and antibiotics themselves, via medical or veterinary use, were likely to be a major cause of the development of resistance. The research community accepted, however, that this was an issue of public concern, and other markers were becoming increasingly common.