

A better understanding of gene flow

Gene Flow in Plants and Microorganisms Initiative

Highlights

- Separation distances in the order of 100m between GM and conventional crops can meet most impurity thresholds and restrict gene flow
- Lower frequency cross pollination occurs up to several kilometres from the crop edge
- Crosses between conventionally-bred oil seed rape and its waterside wild relative are not rare; about 32,000 oilseed rape/*B.rapa* hybrids are produced annually in the UK
- Gene transfer from genetically modified organisms to soil bacteria is vanishingly small and highly unlikely
- Introducing traits by GM methods can have less impact on overall gene expression than conventional breeding methods

The Gene Flow in Plants and Microorganisms Initiative, launched by the Biotechnology and Biological Sciences Research Council (BBSRC) and the Natural Environment Research Council (NERC) in 2000, looked at the likelihood of gene transfer from plants and other organisms, and the potential outcomes of such transfers (gene flow).

The aim of the initiative was to increase knowledge of what happens when new or 'foreign' genes are inserted into an organism's genome, what mechanisms control the insertion, whether inserted genetic material can transfer between organisms and, if so, what the consequences of any gene flow might be.

The initiative was preceded by an online consultation that sought the views of stakeholders and the wider public on the focus and desired outcomes of research funded through the initiative. The comments received during the consultation process were considered by the

initiative. Following consultation with the wider public and scientists working in this area of research, the scientific priorities for the initiative were defined.

The anticipated outputs of the initiative were:

- Increased knowledge of the mechanisms of introducing new genes into the genome, the effect of insertion on gene expression and the consequences of gene flow
- Increased knowledge of how genes have moved between related species in the past and an improved ability to predict the consequences of gene flow
- A better understanding of the traits that make plants more competitive in specific environments
- A fundamental pool of knowledge that will inform policy development and the regulatory process
- Increased coordination and collaboration within the research community

Crop to crop gene flow

- Cross pollination falls steeply from the edge of the crop
- Separation distances in the order of 100m between GM and conventional crops can meet most impurity thresholds and restrict gene flow
- Lower frequency cross pollination occurs up to several kilometres from the crop edge
- Weedy descendents of crops (the same species) exchange genes with crops and can persist to affect purity thresholds or cause a weed burden
- Mechanisms must be found to introduce traits that restrict gene flow and persistence of weedy relatives

Genetically modified (GM) genes can move from GM crops to conventional crops by pollen. In order to regulate GM crops and develop policy we need to know how far genes move and how they get transferred.

Insects and wind move pollen between plants. Genes can also move in seed dropped by crops to give weedy plants (called volunteers or ferals). Early measurements underestimated the distance that pollen could move, but recent studies show a steep fall in cross pollination from the edge of a crop, and a lower frequency of cross pollination extending for up to several kilometres.



Crossing between crops and their weedy descendents occurs frequently in agriculture. However, we know little of the frequency of rare crossing events (e.g. crossing between species that do not readily cross) and the consequent stabilising of the hybrid in a population. We also need to understand the expression and stability of a transgene (introduced gene) after crossing.

What factors determine the persistence of genes in populations? Climate and soil factors affect how long seed can remain alive. Field management also has a strong influence. There are varied effects of orientation and density or sources and sinks for pollen and seed in the landscape.

Genes moving from crops to wild plants

- Crosses between conventionally-bred oil seed rape and its waterside wild relatives are not rare; about 32,000 oilseed rape/*B.rapa* hybrids are produced annually in the UK
- Hybrid abundance is regionally variable, mainly occurring in eastern and central England. Riverside hybrids are absent from Scotland and Northern Ireland
- Hybrid populations near to oilseed rape have increased amounts of crop DNA
- Reduced hybrid fitness depresses 2nd generation hybrid frequency
- Transgene position in the genome affects the dynamics of gene flow

There is concern that genetically modified crops will cross with wild or weedy relatives to produce hybrids that will ultimately change natural habitats or be hard to control as weeds. To predict these risks and to develop efficient measures to prevent hybrid formation, we first need to know how many hybrids are formed across the country.

We developed a model system that provides national estimates of the number of crop-wild relative hybrids, using conventionally bred oilseed rape and the waterside wild plant, Bargeman's cabbage, *Brassica rapa* as a case study. We calculated the frequency of crossing in locations where the species coexisted, and pollen dispersal models to predict long-range crossings.



We also considered the fitness of hybrids and subsequent generations, and whether the location of the transgene in the plant's genome affects the dynamics of gene flow.

Our data enabled the construction of geographically explicit and accurate models of the timescale and spread of genes from crops to wild relatives.

The potential of transgenes to alter ecological fitness

- Insects can carry resistance to both insecticides and transgenic toxins without substantial costs to themselves.
- Models can be used to pinpoint key properties of a plant which, if changed, would later affect its population growth rate or abundance.
- These models must include the kind of variation that occurs in real life, from weather, pathogens, disturbance or other factors otherwise they could be misleading.

Genetic modification can be used to give plants resistance to herbicides, resistance to the insects that eat them, to modify the oils produced in their seeds, and a range of other properties. However, there may also be other unintended impacts, for example, on the pest insects feeding on the plants, on their natural enemies, on their wild relatives, or on the crop plants themselves.

One possibility is that the ecological fitness of a plant or insect may be altered by the transgene.

Ecological fitness can be calculated as the number of individuals produced in the next generation by one individual in this generation.

Horizontal gene flow is at the most extremely rare

- We developed systems to optimise gene transfer, especially to soil bacteria, and to follow the fate of genes in the environment
- We developed highly sensitive reporter bacteria to evaluate the frequency of the gene transfer
- We found actual gene transfer was only recorded under optimum laboratory conditions
- We found no evidence for direct gene transfer from plants to soil bacteria
- Thus gene transfer from genetically modified organisms to soil bacteria is vanishingly small and highly unlikely

People are concerned that genes transferred into genetically modified plants (transgenes) will then transfer to organisms in the soil. We need to understand how the transfer might happen, how likely it is to do so and what the consequences might be.

Our experimental models measure the frequency of horizontal gene flow to assess if ecological hot spots exist where ideal conditions promote gene transfer. The models consider the genetic location of the transgene, life history traits, routes of transmission and the likelihood of gene uptake and fixation in recipient populations. We investigated how different types of genetic modification of plants might affect the likelihood of horizontal gene flow.

The studies involved detailed analyses to investigate the potential for gene transfer between plants and associated soil bacteria.

Clues to optimising transgene stability

- Introducing traits by GM methods can have less impact on overall gene expression than conventional breeding methods
- New genes involved in transgene silencing (shutting it down) were identified
- Techniques to target transgene insertion into sites that do not influence transgene



genetic modification are often unstable. For example, genes introduced into a plant genome can be affected by normal processes such as the cell's response to infection by viruses. These cellular processes affect the level of expression of the introduced gene (transgene) and even shut down or 'silence' it. The expression of inserted genes can also be affected by their location and surroundings in the genome - their insertion site.

We have studied the cellular mechanisms that silence transgenes to understand more of the processes involved. We have developed techniques that could enable plant breeders to target transgenes to insert into specific sites in the genome. This could make it possible to produce GM plants with more stable and predictable transgene expression.

We also compared plant varieties that had been produced either by introducing a trait by transgene insertion or by conventional breeding methods. We found that introducing traits by GM methods has fewer effects on the overall gene expression in plants. This demonstrates that GM can be a more precise approach than conventional breeding.

expression were developed

- We found that transgene integration does not affect the normal arrangement of chromosomes during interphase
- Transgenic traits that depend on gene silencing are unaffected by infection by viruses

Genetic modification of plants has many technical challenges. Traits introduced by

About BBSRC

The Biotechnology and Biological Sciences Research Council (BBSRC) is the UK funding agency for research in the life sciences. Sponsored by Government, BBSRC annually invests around £336 million in a wide range of research that makes a significant contribution to the quality of life for UK citizens and supports a number of important industrial stakeholders including the agriculture, food, chemical, healthcare and pharmaceutical sectors. <http://www.bbsrc.ac.uk>

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The Natural Environment Research Council (NERC) is one of the UK's eight Research Councils. It uses a budget of about £330 million a year to fund and carry out impartial scientific research in the sciences of the environment. NERC trains the next generation of independent environmental scientists. It specialises in earth system science, addressing some of the key questions facing mankind such as global warming, renewable energy and sustainable economic development.

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