

Royal Society Discussion Meeting 11 Feb 03
GM crops, modern agriculture and the environment

While there is optimism in some quarters that GM technology can play a role in reducing the damage done to the environment by modern agricultural practices others have expressed concerns that GM crops will have unintended consequences on the surrounding environment. This discussion meeting will examine the scientific basis for these positions and will contribute to the scientific strand of the public debate on the commercialisation of GM crops in the UK.

Programme:

09.00 Introduction and welcome by President Lord May of Oxford OM AC Kt PRS

Session 1 Establishing the baseline: conventional agriculture and the environment

Chair: **Professor Howard Dalton FRS** Chief Scientific Advisor, DEFRA

09.10 **Professor Andrew Watkinson** University of East Anglia, Norwich

Conventional agriculture and the environment

Agriculture represents the dominant land use throughout much of Western Europe and a significant amount of biodiversity is associated with this habitat. As a result of changes in methods of agricultural production over the last century there have been both winners and losers. Declines have been particularly marked amongst habitat specialists; many of the taxa that are still common on farmland are habitat generalists.

Increases in agricultural production over the twentieth century have been associated with a wide range of inter-correlated factors including changes in varieties, cropping patterns, mechanisation and chemical inputs. Of particular significance in the context of biodiversity during the latter half of the twentieth century has been an increase in farm specialisation and the switches from spring to autumn cereals in arable systems and from hay to silage production in grassland systems. The impact of changing agricultural practices on weed populations will be illustrated.

It is emphasised that the potential impacts of GM technology on biodiversity within the agricultural environment has to be seen within the context of the serious declines in biodiversity that conventional agriculture has produced.

09.30 **Dr Juliet Vickery** British Trust for Ornithology, Norfolk

A case study – farmland birds

The last 25-30 years have seen marked population declines and range contractions in a broad suite of farmland bird species in Britain. A wealth of evidence now exists to link these declines to changes agricultural practices and this provides an important backdrop against to consider the potential consequences of the wide scale introduction of GM crops for farmland biodiversity in general.

Underlying mechanisms by which agricultural changes have affected birds are often species specific but they include loss of semi natural habitat, changes and specialisation in cropping patterns and increases in chemical inputs. First, I will provide an overview of the scale and nature of these declines, showing that, although they have been most marked for farmland specialists (species for which farmland supports the majority of the population) these include a wide range of taxonomic and functional groups. Focussing on changes in the cropped habitat, I will then outline the ways in which agricultural changes, particularly in cropping patterns and levels of chemical inputs, have reduced the quality of farmland for birds as breeding and wintering habitat. Finally, I will show how the impact of the introduction of GM crops in Britain on birds will be heavily influenced by the patterns of adoption of this new technology within different sectors of the agricultural community.

09.45 **Dr Liz Stockdale¹ and Dr Bruce Pearce²** ¹Rothamsted Research, Harpenden and ²Elm Farm Research Centre, Newbury

Organic farming and the environment

Organic farming aims to redesign farming systems to work with natural systems and to deliver increased productivity alongside a consideration for soil, environmental, plant, animal and human health.

Production standards are drawn from globally-shared principles but these are related to local conditions and expressed in great practical detail (e.g. EC Regulations 2092/91 and 1804/99). Crop and livestock production use networks of partial solutions e.g. for pest control, which seek to reduce the emergence of problems through system design and tactical intervention. The environment is critical to the functioning of the system as whole, providing a source of natural diversity, a home for natural predators, the powerhouse of nutrient cycling and much more. This presentation will draw on published data to present evidence of the environmental impact of organic farming systems, particularly in relation to soil quality, pollution, nutrient losses, and biodiversity.

10.00 Discussion

10.20 Tea

Session 2 The escape of genes from cultivation

Chair: **Dr Rosie Hails** NERC Centre for Ecology and Hydrology, Oxford

10.50 **Professor Alan Gray** NERC Centre for Ecology and Hydrology, Dorset

Gene flow: the great escape?

From a global perspective almost all domesticated crop plants are known to hybridise with plants of the same, or related, species growing in the wild. However the extent of contemporary gene flow (the incorporation of genes into the gene pool of one population from another) is imperfectly known, and difficult to quantify, for all but a small number of crop plants. Recent studies, prompted by the GM debate and using molecular markers, have confirmed that gene flow varies greatly between species and from place to place. I will describe the factors which appear to affect this variation in two of the arable crops currently under review – oilseed rape and sugar beet.

The patterns of gene flow typically produced by cross-pollination and hybridisation, in crops and natural populations, have been used to calculate the distances by which crops might be separated to reduce gene flow to very low levels. But in specific cases the movement of genes in seed is likely to be more important.

11.10 **Professor Mick Crawley FRS** Imperial College, Silwood Park

Will GM crops and their hybrids become invasive?

There is a conjectural risk that GM crop plants might be more invasive of natural habitats than their conventional counterparts. I introduce the models that have been used to assess this risk, including the Alien Species Model. I conclude that the Alien Species Model provides a poor estimate of the probability of GM crops becoming invasive, and a poor estimate of the costs of such an invasion should it occur. Study of conventional crops like oilseed rape in natural and semi-natural habitats indicates that their populations are typically ephemeral (although they can form long-persistent seed banks), and that the environmental costs of such escaped crop populations are low. I argue that the only way to approach the question of invasibility is through long term field experiments that compare the population dynamics of GM and conventional plants directly, using a range of ecological communities and a range of climatic and soil conditions. Experiments on oilseed rape, sugar beet, potato and maize were carried out in 1990, 1991 and 1992 and monitored closely until 2000. In no case did they show that the GM plants were more

invasive, and in several cases they were significantly less persistent in natural habitats than were their conventional counterparts. For current GM constructs and current crop plants, therefore, there is no evidence to suggest that GM makes crop plants more invasive of natural habitats.

11.30 **Dr Linda Hall** University of Alberta, Canada

A case study: gene flow in herbicide resistant Brassica napus (oil seed rape) in Canada

Herbicide-resistant (HR) Brassica napus has been widely adopted by Canadian producers since its introduction in 1996. In 2001, glyphosate, imidazolinone and glufosinate resistant B. napus occupied 55, 15 and 15%, respectively, of the 4.5 million ha of canola grown in Canada. Producers grow HR B. napus to provide improved weed control, increased yield and profitability, and the ability to reduce tillage. Gene flow by seed and pollen transfer was predicted prior to release of HR varieties and thus HR B. napus provides a unique case study of the incidence and consequences of gene flow under field scale conditions. B. napus is a partial outcrossing species. Between adjacent crops frequency of outcrossing diminishes with distance from pollen source. Gene flow and stacking of herbicide resistance genes may be amplified by the presence of crop volunteers. In a single field, seeds with resistance to three types of herbicides have been documented after only two growing seasons. Volunteer B. napus occurs in 11% of crop fields in western Canada and seed may persist in the seed bank for up to 5 years. The persistence of B. napus seed in soil extends potential temporal gene flow. Seed movement, either through transfer with farm equipment or admixture, may facilitate gene flow. Some conventional B. napus seed grown by Certified Seed growers, has been documented to contain >0.25% seed with unexpected transgenes. Introgression of herbicide resistant genes is a concern. B. rapa, one of the co-genitors of B. napus, co-occurs with B. napus crops in eastern Canada and has a high probability of outcrossing. While, Raphanus raphanistrum, B. kaber and Erucastrum gallicum also co-occur with B. napus, the probability of introgression of herbicide resistant genes is probably lower than the risk of selection for herbicide resistance in these weeds. HR B. napus volunteers have necessitated changes in management practices in subsequent crops, however the ability to use non-selective herbicides in B. napus has increased weed control for most weeds, including multiple-herbicide resistant Avena fatua, the most serious weed problem in western Canadian cropping systems. Documented benefits to the environment of HR B. napus include an annual reduction of 6,000 tons of herbicide, and 32 million litres of fossil fuel.

11.45 Discussion

Session 3 Other risks and benefits of GM crops

Chair: **Lord May** of Oxford OM AC Kt PRS

12.05 **Dr Guy Poppy** University of Southampton, Southampton

Risks and benefits to non-target species – How to navigate a long and winding road

The use of recombinant DNA technology to engineer plants was proclaimed as a new era in pest control. However, bearing in mind that all new technologies carry risks, assessing the risks and comparing them to the benefits, will establish whether the technology will be successfully adopted or rejected. In any method of controlling insect pests, the impact on non-target species is a critical part of risk assessment and during the last 10 years, we have progressed from hazard identification towards establishing tiered risk assessment. However, risk communication is still in its infancy and has resulted in many misconceptions about GM plants. I will outline how a tiered risk assessment scheme can address both direct and indirect effects of GM plants and, significantly, allows one to link cause with effect. Nevertheless, tiered risk assessments have their limitations and I will explore how we can move forward beyond the initial tiered testing and how we can consider potential benefits so that cost/benefit scenarios can be developed. To undertake this effectively we must address the central issues about what GM should be compared with and what risks are acceptable in relation to benefits.

12.25 Dr Penny Hirsch Rothamsted Research, Harpenden

A case study: the soil ecosystem

Soil is both familiar and mysterious, displaying few obvious indicators of its condition and function other than its texture and ability to support plant growth. Interactions between local geology and climate, history of land use and current vegetation all contribute to the mineral and organic composition of soil and the microbial populations it supports. Plant inputs influence availability of carbon and energy that are the major factors controlling microbial growth. Soil microbes in turn affect both soil properties and plant growth. Soil microbial populations are large and diverse, with around 1 km of fungal hyphae and 10^8 bacterial cells per g arable soil, belonging to at least 10^4 different species. Impacts of GM plants on soil organisms must be considered in relation to the other gross effects of conventional agriculture; knowledge of the spatial and temporal variability of dynamic microbial soil ecosystems is a prerequisite!

12.40 Discussion

13.00 Lunch

14.15 Dr Jeremy Sweet NIAB, Cambridge

A case study: Herbicides and Herbicide Tolerant Crops

One of the main constraints on the development of herbicides has been the problem of finding chemicals which are selectively active on weeds without affecting crops. This can be a particular problem in broad leaved crops or crops with very closely related weeds where current selective herbicides can be expensive, of low efficacy and damaging to crops. This problem can be overcome by making crops tolerant to more economical chemicals which have a broad spectrum of activity against a wide range plant species.

Herbicide tolerance technology was first introduced in N. America and the rapid uptake indicates that there are benefits to farmers. The main benefit seems to be the simplification of weed management rather than direct reductions in the cost of weed control. The technology provides the opportunity to target and treat visible weeds rather than using prophylactic treatments often applied to soil. Thus while on the one hand herbicides such as glyphosate and glufosinate have a broad spectrum of activity against a wider diversity of weeds, in practice the technology can be used to target weeds at particular times and densities. Glufosinate and glyphosate have none of the soil residual effects of present conventional herbicides, which tend to inhibit subsequent germination of weeds in fields, and both have relatively benign environmental profiles. In addition reductions of tillage will tend to conserve soil biodiversity (including weed seed banks) and soil moisture.

Conversely, the introduction of GMHT crops may pose new management problems for the control of herbicide tolerant volunteers. In addition the broader spectrum weed control attainable with glyphosate and glufosinate may have a greater negative impact on arable ecosystems due to greater reductions in botanical diversity than current farm practices. This paper will review recent and current research programmes in Europe which are investigating the impacts of HT crops on the botanical diversity in farm ecosystems and discuss possible outcomes from this research.

14.30 Professor Chris Lamb John Innes Centre, Norwich

Future potential of GM crops to promote environmentally sustainable agriculture

The availability of the Arabidopsis and rice genome sequences and continuing functional genomics efforts in model species and key crops promise major insights into the genetic basis of plant growth, development and environmental interactions. GM is a potentially important new breeding tool for the application of this burgeoning knowledge to enhance environmental and economic sustainability. I shall evaluate this potential by reference to illustrative case studies in different areas including (1) yield- the

gai “green revolution” gene, (2) crop protection- viral resistance in papaya and (3) non-food crops-engineering of starch as an industrial polymer.

14.55 Discussion

Session 4

15.45 **Final discussion: environmentally sustainable agriculture – a role for GM crops?**

Chair: **Earl of Selborne** KBE DL FRS

Panel: **Professor Mick Crawley** FRS, **Dr Linda Hall**, **Prof Chris Lamb**, **Dr Juliet Vickery**

17.15 Close

For more information please contact:

Dr Rachel Quinn. Senior Manager Science Policy, The Royal Society, 6-9 Carlton House Terrace, London SW1Y 5AG, UK. tel. +44 (0) 20 7451 2546; fax +44 (0) 20 7451 2692; e-mail rachel.quinn@royalsoc.ac.uk.