The field-scale evaluation of herbicide-tolerant genetically modified crops conducted in the UK (1998–2003)

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Abstract

In 1998 the UK Government, in conjunction with Supply Chain Initiative on Modified Agricultural Crops (SCIMAC, a cross-industry group representing the supply chain), established a large-scale programme to examine the impact of genetically modified herbicide-tolerant crops on farmland biodiversity. The trials programme lasted three years and was conducted by a consortium of scientists who were responsible to an independent scientific subcommittee. The background to the establishment of these trials is described and the political pressures facing the Government at that time and the reactions of key stakeholders are discussed.

The field-scale evaluations were a pioneering project to examine the impact of genetically modified crops on farmland biodiversity. The exercise was one of the largest experiments ever carried out to measure the environmental impact of specific farming practices, and shows that robust results can be obtained, while the resultant database represents a wealth of ecological information on three important arable crops – beet, maize and oilseed rape. It is clear that other such trials could be carried out to test other variables as part of a longer-term effort to steer farm management systems in ways more acceptable to society. However, in view of their costs (both to the UK Government and the technology providers) together with the adverse response by the environmental campaign groups, and the length of time needed to carry out the work, it seems unlikely that an exercise of similar scale will be undertaken in the near future.

Keywords: *field trials, GM crops, biodiversity, arable weeds, seedbank, invertebrates*

INTRODUCTION

During 1997 and 1998 there developed an increasing public concern about the way in which genetic modification (GM) technology was being applied to agricultural use in the UK. One important driver was the realisation by the scientific regulatory bodies, particularly the Advisory Committee on Releases to the Environment (ACRE), which had set up a subgroup on biodiversity issues, that many of the potential environmental impacts of GM crops were not easy to predict, while the Royal Society for the Protection of Birds (RSPB) and English Nature also played an important role in raising the issue. Another major driver was the campaign led by environmental pressure groups who had made a number of allegations about the deleterious effects that might arise from the use of the technology.[1] The campaign was taken up, and amplified by some popular newspapers, notably the *Daily Mail* and *Daily Express*. Banner headlines about 'Frankenfoods' captured the public imagination and the issue of GM crops rose up the political agenda.

This increasing political attention coincided with the passage of certain herbicide-tolerant GM (HTGM) crops through the normal approval process to commercialisation in the EU. However, the regulatory process in the EU had been stalled for several years because an informal moratorium was in place. This

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moratorium was the result of a variety of factors – reluctance by the EU Commission to move ahead with approval before labelling and traceability legislation was in place; growing unease in some EU member states over increasing concerns among their own citizens; the realisation by the technology providers that consumers might be unwilling to buy GM-based foods, because of these concerns, and the increasing commercial pressures on the agri-food companies, which led, on the one hand, to worldwide consolidation and, on the other, to concentration on those markets most likely to accept GM crops. All these issues were taken advantage of by the environmental non-governmental organisations (NGOs) to raise public anxiety about these crops.[2] At the same time, there was a recognition by governments of the political difficulties that the planting of some crops (in particular forage maize) – which had been approved by the EU regulatory processes, so farmers were permitted to plant – would precipitate. Governments foresaw these political difficulties and were keen to persuade the technology providers not to proceed at that time. Governments also realised that they had no legal basis to stop either the planting or the development of GM crops, nor did they wish to inhibit the development of a new technology in Europe. However, on the other hand, governments faced increasing political pressure from a worried public. A political solution had to be found to this dilemma.

NGOs raised public anxiety about GM crops

GM technology used by its opponents to raise funds

THE SCENARIO

A Labour Government was elected in May 1997, and had, as a key objective, a reversal of the decline in the UK's fabric of public services. Education, health and transport were key areas for the new Government, and in all three areas it was very important to meet the concerns of the consumer. Social pressures for change were developing and the Labour Government saw that consumers' needs and concerns should be met. The high public profile of plant GM technology was a new experience for the plant-breeding industry, which was uncomfortable at being brought more into the public eye because it changed the public's perception of the industry from one that satisfied a public need and acted as an agent for beneficial change for UK and European agriculture to one that was introducing a new and threatening technology.[3]

Government recognised consumer concerns

It was against this political landscape that the development of HTGM crops was moving towards commercialisation. However, the adverse climate that had been stirred-up by the media campaigns in the press, with the aid of the NGOs, put pressure on the Government. There were several reasons why the NGOs' campaign was so successful – GM food and crops make good political targets: the science is novel and not easily understood and easily represented as threatening; there might be adverse implications for both health and the environment, for everyone remembered how incorrect the reassurances about BSE had been. In addition, the technology providers were multinational businesses, and it is easy to represent the American dimension as imperialism and, crucially, HTGM crops offered no immediate consumer benefits. The benefits were commonly perceived to be going to the biotechnology companies and the farmers, while the consumers were taking all the risks. The NGO groups need, of course, to maintain a flow of new funds so that they are constantly seeking new targets for their campaigns. Indeed GM technology was a good choice for them and appears to have raised a lot of money.

During the early part of 1999 the GM controversy took on a wider political dimension when the Conservative Party used the opportunity to challenge the Government on its GM policy, putting its finger on the Government's dilemma. For example, the Leader of the Opposition (William Hague MP) asked the Prime Minister (Tony Blair MP) the following Parliamentary Question in the House of Commons:

> The effect of the muddle in Government policy is to increase public concern, not to decrease it. Why do the Government not do the commonsense thing, listen to the advice of their experts and at least put on hold the release of new and unfamiliar seeds until the research is done?

HT genes easily transferred

The Prime Minister replied as follows:

> With the greatest respect, I do not think that this should be a great political issue between the parties, the Rt. Hon Gentleman's course of action is wrong. I think that it is far better and more important to proceed on the basis of the scientific evidence. As for food safety issues – far be it for me to accuse the Rt. Hon Gentleman of opportunism – I point out that most of the main problems with food safety in this country have resulted from the Conservative Government's legacy.[4]

Public controversy escalated in its intensity

From this point onwards the public controversy rapidly escalated in intensity. Even during the Kosovo war in the Balkans, the GM issue made headlines. In some newspapers awful wartime atrocities and abuses against humankind were relegated to the inside pages while GM made front-page headlines. The Government wrestled with the dilemma of trying to balance the legitimate interests of the biotechnology industry and plant breeders with the calls from the consumer activists.

It is worth commenting on the nature of HTGM crops, which were such a target for the campaigners. First, herbicide-tolerant plant varieties can readily be obtained, and this has resulted in their successful development and exploitation.

Value of HT crops in global scenario

On an international scale, the market for herbicides is estimated at 47.5 per cent of the total global sales of agrochemical products of US$27,104bn in 2001.[5] In 2002 in the UK, farmers and growers spent US$330m on chemical weed control[5] in agriculture and horticulture. The value of this market represents a significant opportunity to any company for the development of new herbicides and the recognition that the genes for herbicide tolerance were easily transferable, gave HTGM crops an important impetus – what was desirable was also possible. Such genes were quickly identified and simple selectable marker systems were developed to make transfer possible.[6] It is not often realised by the public that in agronomic terms weed control is an essential part of agriculture. If allowed to go unchecked, weeds can ruin crop productivity: 'Weeds are the major crop protection constraint to food production'.[6] It is therefore easy to understand the reasoning behind HTGM crops as a potentially valuable market.

At this point English Nature and the RSPB entered the debate. Both felt strongly that introducing GM crops would lead to further intensification of UK farmland with a resulting loss in farmland biodiversity. The RSPB was concerned about deleterious impact on farmland birds. The intervention from English Nature was particularly critical because as independent advisers to Government its views could not be ignored and increased the pressure for Government action.

A cross-industry body, SCIMAC (Supply Chain Initiative on Modified Agricultural Crops), had been established in 1998. It was set up to support the responsible and effective introduction of GM crops in the UK. It is an association of associations (British Society of Plant Breeders, BSPB; British Sugar Beet Seed Producers Association, BSBSPA; Crop Protection Association, CPA; National Farmers' Union, NFU; and United Kingdom Agricultural Supply Trade Association, UKASTA) and represents the entire farm supply chain, from initial seed stock to harvested crop. The UK Government was more comfortable in dealing with a single umbrella body such as SCIMAC than working with either one or a few individual technology providers (such as Monsanto, Syngenta, Aventis (now Bayer), DuPont).

THE AGREEMENT BETWEEN INDUSTRY AND GOVERNMENT

Informal discussions led to a voluntary agreement between SCIMAC and the UK Government in 1998. This agreement was extended and formally agreed with a public announcement on 5th November, 1999. The agreement covered the key issues where political sensitives had emerged:

Formal agreement between UK Government and SCIMAC

- There would be no general unrestricted cultivation of GM crops until the field-scale evaluations (FSEs) were completed. No direct commercial benefits would be sought from these plantings by the consent holders (viz. Aventis (now Bayer), Monsanto, Syngenta).
- The scale of the FSE was limited to 20–25 fields per crop per year. This would be subject to the advice from the independent Scientific Steering Committee (see below).
- None of the produce from these crops would be used in a way that was of direct commercial benefit to the consent holders.
- Proposals for any other field-scale planting of these crops to be decided by the Scientific Steering Committee.

Agreement not a ban or moratorium on GM crops

In return the Government acknowledged, 'This agreement is not a ban or moratorium on GM crops; there are no legal, scientific or safety reasons for such action.' The Government itself recognised that this agreement delayed the decision on GM crops until after the lifetime of that Parliament (May 1997 to June 2001), and this of course gave a political advantage. The FSE would end in 2002 with a further elapsed period of time before the scientific outcome was announced.

Majority of public supportive of field trials programme

The agreement covered three main crop types: beet (both sugar and fodder), oilseed rape (both winter and spring) and forage maize. To grow GM crops in Europe requires approval under the European legislation EC 90/220 (revised as EC 2001/18) which controls 'deliberate release of GM organisms'. Clearance is given at either the research level (a Part B release which has many restrictions placed upon it in terms of planting area, pollen barriers, separation distances, crop disposal) or via a Part C marketing approval. In this latter case the approval requires clearance by a lead country (in the UK by ACRE) with support from the other member states (who are given a short period (90 days) in which to raise any objections).

For the FSEs the beet and oilseed rape (OSR) crops both had a Part B consent. The forage maize had a Part C marketing approval, allowing unrestricted planting throughout the EU (Spain grew in excess of 25,000 ha of this GM crop in 2003). However, in the UK, although the crop has a Part C consent, it did not have varietal clearance (under the UK Plant Varieties Act 1997) nor did the glufosinate herbicide have clearance for use on maize (under the Control of Pesticide Regulations 1986). One can only marvel that a herbicide that had already been used on several thousand hectares throughout the world needed further regulatory approval. Indeed the chemical could be sprayed on an uncropped field to control weeds but not if that same field had a maize crop!

THE REACTION TO THE ESTABLISHMENT OF THE FSEs

The reaction from the majority of the public to the announcement of the programme of FSEs was very positive. The need to get evidence was seen as an important aspect of the technology's development. Various opinion surveys were undertaken and in general the majority of respondents were supportive of the FSEs.

However, the opponents of the technology were angry that a trials programme of such size, distribution and

Trials easily located

longevity had been agreed. An open meeting was organised by the Department of the Environment, Transport and the Regions (DETR; now reorganised as the Department of the Environment, Food and Rural Agency, DEFRA) and a wide range of interested parties attended.[7] Several NGO groups attended but were muted in their attitude and questioning. However, a few days later Greenpeace, led by Lord Peter Melchett, destroyed a maize trial in Ling, Norfolk. (The various protesters were found not guilty by a jury trial some months later.)

Impact of vandalism of trials

Various attempts to damage the trials were made over the next three years. There were in total 110 incidents of reported vandalism (this does not mean attacks on 110 trials, as on several occasions a site suffered repeated attacks). There were 52 sites vandalised (from the total 282 trial sites in the FSE programme) but only six trial sites had to be discontinued as a result of the vandalism.[8]

Fortunately, the level of damage was minimal and indeed this possibility had been anticipated in the trial design by reasoning that a 10 ha field was less easy to damage than a 10 m^2 plot.

A high-profile campaign against the trials was run by the organic farming lobbying group, the Soil Association. At one point the Soil Association claimed 277 farms would have to lose their organic status because they were at risk from a nearly site. As it turned out, no organic land was de-certified, a tribute to the cooperation and good neighbourliness among farmers.

No organic land was de-certified during trials

The FSEs were particularly vulnerable to attack on two counts. First, the EU Regulations require the site to be identified. This has been interpreted in the UK by publication in local newspapers and on the web with a six-figure grid reference. It was then a simple matter to find their location. Secondly, it is almost impossible to protect crops grown in open fields since the fields can be entered at any time of the day or night and the crops are present for large periods of time – March to November for spring crops such as sugar beet and August to July for winter oilseed rape. This vulnerability was exploited by the environmental campaigners and the photogenic value of flowering oilseed rape was used in their publicity.

Independent audit of growers undertaken

OTHER POLITICAL RESPONSES

When announcing the FSEs the Government also announced the formation of the AEBC (Agriculture and Environment Biotechnology Commission). This is a stakeholder's forum with representatives from all sides of the debate, NGOs, consumer groups, plant breeders, farmers, scientists, representatives from the devolved administrations, public figures and individuals. The AEBC remit was to review a range of issues around biotechnology and agriculture. Its first report, 'Crops on Trial',[9] looked at the FSEs and made several recommendations, among which the more significant were that 'the programme of FSEs should be completed' and that a public debate on GM crops should be organised. The Government accepted this advice and commissioned a national debate which was held in the summer of 2003. Unfortunately the debate has been severely criticised by independent assessors,[10] and also a Select Committee of the House of Commons who concluded *inter alia*, 'Although the public debate was imaginative and was modestly successful in some areas, overall it was an opportunity missed.'[11] Nevertheless, the formation of the AEBC was a politically adroit move by Government in trying to delegate difficult decisions to a third party. The AEBC became the focus of GM concern and helped to reduce the temperature of the controversy over GM crops. It was seen to be a neutral forum that would listen to public concerns. Time will tell how fruitful this approach is.

THE TRIAL DESIGNS

A unique feature of the trials was the need to establish independence from

Independence of scientists and trial management essential for credibility of results

Government, industry and the NGOs in planning and conducting the trials. This independence was achieved by several methods. First, in order to safeguard this independence the ecological monitoring was conducted by a consortium of scientists from independent research organisations led by the Centre for Ecology and Hydrology and including scientific inputs from the Institute of Arable Crop Research (now Rothamsted Research) and the Scottish Crop Research Institute. In order to ensure the ecological work was conducted to the highest possible standards, a further level of independent scrutiny was organised by a Scientific Steering Committee with representatives from English Nature, RSPB, the Game Conservancy Council and universities and chaired by Prof. Chris Pollock from the Institute of Grassland and Environmental Research, Aberystwyth. The trial sites were provided in cooperation with SCIMAC. These sites were offered to the consortium that made their own final selection from the many sites offered for each crop in each year. Once chosen for the experiment the site was managed by the farmer and the scientific consortium. SCIMAC had no direct involvement in determining the design of the trials, the scientific questions being addressed or the structure, scope or methodology. These issues were entirely the responsibility of the independent research consortium conducting the scientific monitoring and the scientific subcommittee.

Legal obligations enforced

There were three levels of further audit to ensure independence and legal compliance:

- Statutory inspections by the GM Inspectorate (Central Science Laboratory in England and Wales; Scottish Agricultural Science Agency in Scotland) to ensure legal compliance with Part B and Part C consent conditions.

- Independent audit of growers' compliance with SCIMAC crop management guidelines conducted by ADAS Consulting Ltd.

- Evaluation of the growers' management decisions by BASIS qualified agronomist.

Finally, after the fieldwork had been completed, an independent panel was used to peer-review the data and its interpretation. Overall this process worked well in practice and has been described in more detail in scientific papers by the research consortium.[12,13]

THE RESULTS

The results have recently been published by the Royal Society in a special issue of the *Philosophical Transactions* as a series of eight scientific papers covering the results for beet, maize and spring oilseed rape. These papers are complemented by a layperson's summary ('GM Crops – Effects on Farmland Wildlife') and a so-called 'Commentary' ('Implications of spring-sown genetically modified herbicide-tolerant crops for farmland biodiversity').[14] The volume of work, the effort and attention to detail are all to be commended but the data and their interpretation need thoughtful deliberation, and both the GM Science Review Panel and ACRE are currently debating the implications of the trials as I write.

Results interpreted in many different ways

In contrast, the media rushed to judgment,[15] and to quote the generally conservative *Daily Telegraph* (17th October, 2003) 'Field trials show GM crop farming could be ''disastrous'' for wildlife', and 'Bumblebees, butterflies, skylarks, yellowhammers, house sparrows, beetles and slugs all face disaster if ministers approved a nationwide cultivation of transgenic plants'. But the editorial on the leader page of the same issue, however, revealed a different picture: 'All that motivates anti-GM feeling is fear of the new, a perfectly justifiable emotion until tests such as these show how unfounded and irrational it is'. The findings did not prove that GM crops

were dangerous: 'All they show is that GM beet and spring rape crops encourage fewer weeds than conventional crops. And when it comes to maize, more weeds grow and that's it – no venomous seeds, no wiping out of organic food, no spectre of agricultural holocaust'. In contrast, the *Daily Mirror* (17th October, 2003) under the headline 'Silent Spring' said 'Green campaigners say the results foretell a future without birdsong in the spring as their food and habitats are hit' and 'The technology damages wildlife'. The *Independent on Sunday* (19th October, 2003) ran no less than three articles plus a leader, starting with an article by the former Cabinet Minister, Michael Meacher: 'Science backs consumers' rejection of GM food – are you listening Tony?'

Only the *New Scientist* (24th October, 2003) offered a more balanced summary: 'If the aim of the exercise really was to save farm land wildlife, then banning any of the transgenic plants tested was unlikely to make much difference'. Indeed, the trials showed that the cultivation of herbicide-tolerant GM beet and GM OSR had environmental downsides because of the effects of the herbicide management regime but, in contrast, cultivation of GM maize has environmental benefits when compared with conventional soil-acting weedkillers. Thus the study was one of comparative herbicide management regimes, not one comparing GM crops *per se* with non-GM crops.

Different crops give different results

The essential message is that more weeds result in more wildlife. If a farmer reduces the levels of weed control, more wildlife can be supported, and this will be true irrespective of exactly how the weeds are controlled – whether it is by chemical or non-chemical methods, for example by mechanical methods. The herbicide management regime had a significant effect on the abundance of the infield weeds and a range of invertebrate species in all three crops, irrespective of inter-annual or regional variation. Broadly speaking, over the lifetime of the crop, GM OSR and beet fields had fewer weeds, produced fewer seeds and had fewer insects of those species dependent on weeds than did fields of their conventional counterparts. On the other hand, some insects were more abundant in the GM beet and OSR fields. In contrast, fields of GM forage maize produced three times the density and biomass of conventional forage maize fields. They also supported more butterflies and bees, although the numbers in maize fields generally were low.

In addition, the later in the season the weed control is applied then the less time the weeds have to recover and produce seeds. For example, although GM beet and OSR fields had higher levels of weeds early in the season, the later use of broad-spectrum herbicides led to fewer weeds later in the season, fewer weed flowers and fewer weed seeds (by a factor of five in some cases). This resulted in lower counts of many insects monitored, including bees and butterflies. Spiders, ground beetles and slugs and snails were generally not affected, although there were some differences for individual species. Springtails, which live on decaying vegetation, were significantly increased in numbers. The situation was reversed in the case of maize: the GM fields had more weeds and more wildlife. However, the conventional fields were treated with atrazine, which is likely to be banned, and so critics are claiming that the maize results are effectively invalid and that new trials are needed, to using whatever replaces atrazine as the benchmark.

The seedbank (ie the numbers of weed seeds left in fields after harvest, acting as a future food store for wildlife) generally increases for all three crops. This is important, because beet, maize and rape are grown as break crops between several years of cereal production and such crops offer some of the few opportunities to increase the size of the seedbank. For the GM crops, the size of the seedbanks increased only slightly or remained static. It is suggested that this could lead to a long-term decline in weed populations

No adverse impact of GM crops

(and insect numbers) if such crops were grown on significant areas of land. No findings were attributed to the genetic modification of the crops: the results would have been the same if the herbicide tolerance had been introduced by conventional breeding.

Thus the use of different GM crop and weedkiller combinations offer considerable flexibility in the future to develop weed control strategies that favour wildlife. Indeed the possibility of exploiting this flexibility has already been reported for sugar beet.[16] The results with this crop show that it is possible to achieve weed control, allow weed seeds into the crop environment to benefit wildlife and still optimise crop yields.[17] Field trials conducted over two years in Denmark show how the increased flexibility of management of HTGM crops gives biodiversity benefits.[18] Similar benefits have been demonstrated in the BRIGHT (Botanical and Rotational Implications of Genetically modified Herbicide Tolerance) project carried out in the UK over four years.[19]

Statistical significance versus biological significance

The impact on wildlife of the GM crops compared with the non-GM crops was statistically significant but it appears to be of limited biological significance compared with the many other variables in agriculture, such as crop, seasons, position in the field, set-aside and other parameters.

Influence of herbicide dose and timing

Finally, the FSE looked at only one set of crop management guidelines for the GM technology and it is clear that varying the dose, timing and method of application of the herbicides will have a significant influence on their impact on biodiversity.

CONCLUSIONS

Crop management is key issue

First, the FSEs have been a pioneering study, one of the largest programmes of ecological research anywhere in the world. The results provide the most detailed and extensive database of ecological information for arable fields yet produced. Irrespective of the particular HTGM crops chosen, the data give a basis for a wider understanding of the relationship between agriculture and farmland ecology.

Secondly, the results of the FSEs clearly demonstrate that it is not the technology of genetic modification but the weed management system associated with it, such as the volumes of herbicide used and its persistence, that determines the environmental effects of a particular agricultural system.

Thirdly, to quote Lord May, the President of the Royal Society:

> The most pressing question arising from the FSEs is not whether genetically modified crops are better or worse for the environment than conventional agriculture, but what do we want from modern agriculture? How do we balance the use of crops that are pest-resistant or out-compete weeds with alleviating the damaging effects on field biodiversity associated with conventional agriculture, such as fewer wild plants, fewer insects and fewer birds? The UK has already experienced a pronounced loss of biodiversity, and we need to decide that if this trend is to be halted, how is this best achieved? It could be through working with a grain of nature, such as targeting land for non-agricultural practises, or by growing our food more efficiently, such as using techniques like genetic modification to develop crops that require fewer chemicals.[20]

Finally, to quote from another recent review:

> The FSEs have not produced evidence for any new environmental damage as a result of GM technology. The reductions in biodiversity result solely from increased control of weeds, and the FSEs appear to show that introducing HTGM crops is equivalent to the development of a new, very efficient herbicide. Such changes in technology occur routinely and without public debate. Although

the impacts of HTGM crops on biodiversity may be negative, future technological developments could also yield effects of this sort, and there is no reason to make a special case for GM crops. On the other hand, environmentalists might argue that if biodiversity is to be conserved in farmland habitats, the negative aspects of farming technology need to be halted, and GM crops may be the place to start. Thus, the FSE will, inevitably, provide ammunition for both sides of the debate.[21]

How can inherent flexibility of HTGM crops be used for environmental benefit?

It is clear that the debate will continue and that the initial media treatment of the results was both superficial and inaccurate. The challenge now is to consider whether and how the flexibility offered by these new crops can be used for the benefit of farmland environment. Any such a decision in the UK will be a political one, although based on interpretation of the data by its advisory committees. The decision point is close and it will be interesting to see how the UK Government handles this difficult question.

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