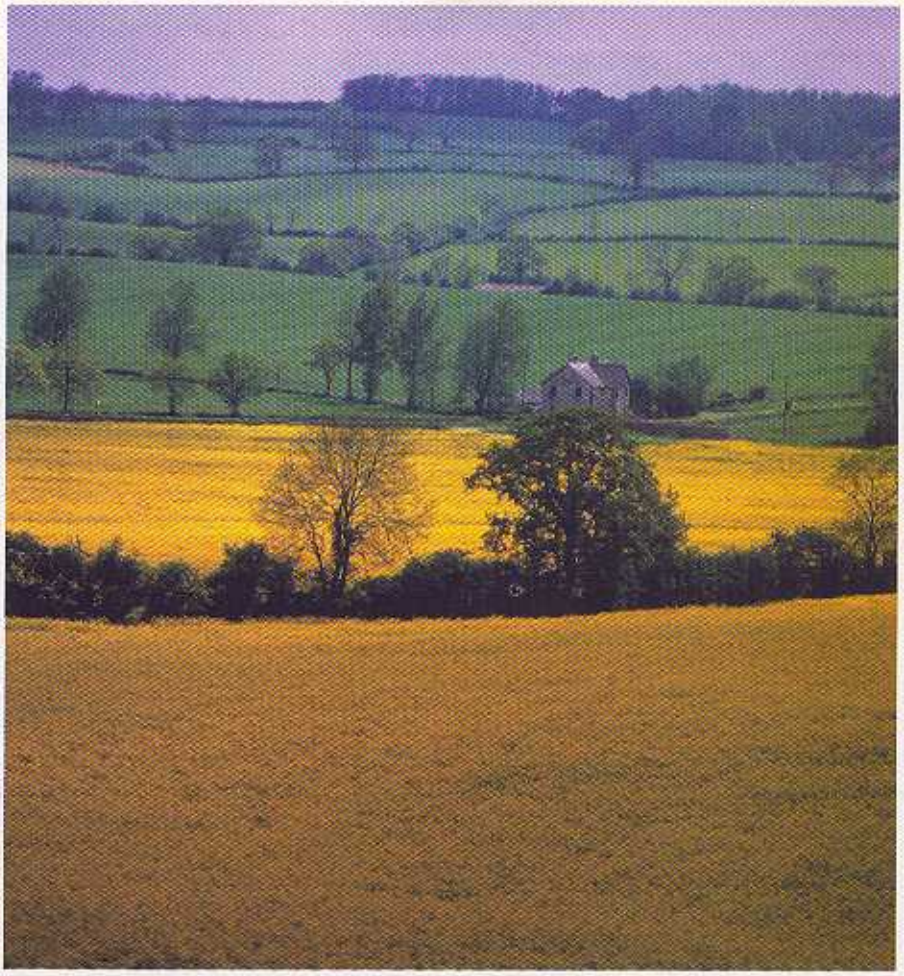
The battlefields of Britain

With its farm-scale trials of genetically modified crops, Britain has taken ecological studies of farming practices into new territory. But the trials are the focus of intense controversy. Trisha Gura spoke to the scientists involved.



NIGEL CATTLIN/HOLT STUDIOS

In the dock: oilseed rape is one of several crops that will be subjected to farm-scale trials in an attempt to evaluate the environmental impacts of its genetically modified counterparts.

Half a century ago, the British countryside echoed to the call of the skylark. Today, this much-loved bird is rarely heard. It was the fear that it and other farmland species might be silenced forever that in March 1997 led English Nature, a government conservation agency, to call for a moratorium on the introduction of crops genetically engineered to tolerate herbicides or to produce insecticidal proteins.

At a government conference in London to discuss developments in biotechnology, Brian Johnson, English Nature's biotechnology adviser, voiced concerns held by several groups. He blamed the long-term decline of bird populations, in part, on habitat destruction and intensive farming practices. He also warned that genetically modified (GM) crops could make a bad situation worse. Crops resistant to broad-spectrum herbicides such as glyphosate were a particular concern, Johnson argued. If these relatively new agrochemicals denuded fields of their non-GM plant life, he said, they could remove the seeds and insects on which farmland birds feed.

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Missing: skylark numbers have declined in Britain.

The response of the incoming Labour government, elected in April 1997, was to delay commercial introduction of the crops pending the results of a four-year experiment costing £4.4 million (US$6.4 million). Beginning with crop sowings in spring 2000, this unique study is comparing biodiversity in fields of herbicide-tolerant GM beet, maize and oilseed rape (canola) with that in comparable plots of equivalent non-GM varieties[1]. Unprecedented in their size, these 'farm-scale' trials are designed to ask one basic question about one type of GM crop, explains Les Firbank of the Centre for Ecology and Hydrology at Merlewood in Cumbria, who coordinated the experiments. "The concern is simply: will the large-scale growing of these crops be damaging to wildlife?"

Firbank and his colleagues argue that the trials are the first attempt to investigate on an appropriate scale the ecological effects of an important change in farming methods in advance of its widespread introduction. The researchers hope to pave the way for similar studies of other factors, such as pesticide use and tilling practices. "I see the farm-scale evaluations as being about developing techniques to assess the effect of proposed changes in land use and land management on biodiversity," says Firbank. "That makes it a very important study."

Trials on trial

But environmental groups and the organic farming movement view the trials in a very different light. They are implacably opposed to any GM plantings, commercial or experimental, and see the trials as an effort by the agribiotech industry to smooth the introduction of its new products. Mainstream environmental groups such as Friends of the Earth have attacked the trials' design as being scientifically inadequate, and more militant factions have attacked the experimental plots themselves.

The trials involve farmers growing one or more of the GM crops alongside its non-GM counterpart. Farmers who volunteered to take part sent their applications to a coordinating industry-backed body known as SCIMAC — the Supply Chain Initiative on Modified Agricultural Crops — which selected sites to be representative of a full range of British habitats.

For beet and maize, the trial will involve between 60 and 75 plantings of the GM crops,

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Harvesting data: Les Firbank hopes the farm trials will quantify the effects GM crops may have on plants such as the herb *Chenopodium album* (left).

each of about ten hectares in area, grown alongside matching plots of a non-GM variety. This breaks down to about 20 farms per crop, growing plots in successive years over the course of the study. "That should produce adequate statistical power to detect any differences," says Joe Perry of the Rothamsted Experimental Station in Harpenden, north of London, a statistician working on the trials.

For oilseed rape, there will be twice this number of plots — half sown as a winter crop in late August to mid-September, the remainder a spring crop, sown in March to May, depending on the weather conditions.

In each case, the non-GM crops are being treated according to the farmers' normal practices, including the application of conventional herbicides. The GM crops will be treated in the same way, except for herbicide sprayings. Here, participating farmers are being given a tighter protocol detailing the timings and quantities of sprayings with the broad-spectrum herbicides that the crops have been engineered to resist. This will be overseen by a scientific steering committee headed by Chris Pollock, research director of the Institute of Grassland and Environmental Research in Aberystwyth, Wales.

On the record

The GM and control plots are being monitored by a team of some 100 scientists, who are recording the species and number of key invertebrates such as slugs, butterflies and earthworms. They are also counting weeds and the presence of seeds in the soil. Although it was English Nature's concerns about birdlife that prompted the government to launch the experiment, only limited studies of avian biodiversity will be made. Birds range so widely, says Firbank, that individual fields are simply too small to study effects on bird populations.

But the researchers are confident that they can extrapolate the results on weed, seed and invertebrate biodiversity to bird populations. This will involve computer models such as those developed by Andrew Watkinson of the University of East Anglia in Norwich. Last September, Watkinson's team reported that herbicide-tolerant sugar beet and the associated application of glyphosate could almost eradicate the wild herb *Chenopodium album* — fat hen or lamb's quarters — and severely diminish skylark populations[2].

Firbank questions these specific projections, noting that they depend on assumptions about parameters that will be measured in the farm-scale trials. But he believes that the ideas behind Watkinson's model could be developed and applied to the trial results to infer the knock-on effects on a variety of bird populations[3]. Johnson of English Nature agrees: "We hope that the trials will proc data that will enable scientifically defens decisions to be made about whether t crops will pose a threat to biodiversity."

But environmental groups question decision not to monitor bird populat directly, and this is just one of a serie objections that they have raised.

First, they point out that the plots ch were not monitored for biodiversity for eral years before the trial began, giving baseline data against which to track cha caused by GM farming. They also comp about the trials' specific focus, arguing t chance to investigate practices in which

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Called to account: the trials will assess invertebrates such as earthworms (above) in a number of crops including sugar beet (top right) and maize.

or no herbicides are used has been missed.

"What we need is a proper agricultural research programme that looks at all of the options, including reduced dependency on chemicals," says Peter Riley, who heads Friends of the Earth's Real Food Campaign.

But the most loudly voiced complaints surround the possibility of herbicide genes being transferred to organic crops, or to weed species. The transfer of herbicide-tolerance genes to weeds is a long-running concern. Legal standards for organic produce — implemented by organizations such as the Soil Association, the biggest provider of accreditation to Britain's organic farmers — demand that it must be GM-free.

But scientists involved in the farm-scale trials argue that most of these objections have already been addressed. The lack of baseline data is not a serious issue, they argue, as the careful matching of experimental and control plots will ensure that meaningful comparisons can be made. Pollock and his colleagues add that they have looked at contamination issues, sponsoring a public forum to discuss the study design. Later, SCIMAC disqualified a farm near Coventry in the English midlands, some three kilometres from the headquarters of the Henry Doubleday Research Association, which conducts research into organic farming methods, following representations from the Soil Association and environment minister Michael Meacher. Two additional sites in Wales were abandoned after the farmers came under pressure from their local communities.

Turf wars: Greenpeace activists are arrested for removing GM maize from a farm trial in Lyng, Norfolk.

Over the years, investigations into gene transfer from GM crops to weed species have yielded mixed results[4], depending on the crops involved and the presence or absence of closely related weeds. But a previous multi-year experiment, conducted at sites across Britain by a team led by Mick Crawley of Imperial College at Silwood Park, west of London, has shown that the transfer of genes to weeds from the crops involved in the farm-scale trials should not pose serious problems. Crawley's team did not monitor gene transfer directly, but found no evidence that weeds were becoming more invasive, or surviving longer, at the experimental plots[5–7]. "There was no measurable difference in the ecology," says Crawley.

Design issues

Given the controversy surrounding the farm-scale trials, the scientists involved have taken the unusual step of submitting their study design to the *Journal of Applied Ecology* for peer review and publication. But this seems unlikely to placate groups such as Friends of the Earth, nor the more militant activists who have attempted to destroy several of the experimental plots.

The damage caused by these actions is difficult to quantify, says Firbank, because some attacks were limited to field edges, and for others the samples had been collected before the assault took place.

If the crop-destruction threatens to undermine the trials' statistical power, the study may be extended into subsequent growing seasons. But despite their determination not to be thrown off course by anti-GM activists, scientists working on the trials admit that the intensity of opposition has caused problems. "There is difficulty conducting the experiment within this hothouse atmosphere," says Perry.

But on one point, Perry and his colleagues can find some common ground with the more moderate of their environmentalist critics. Many of the scientists behind the trials would like to respond to Riley's call for a wider research programme investigating the ecological effects of other farming practices. Experiments into the effects on biodiversity of methods that rely heavily on pesticides, compared with methods featuring reduced chemical inputs, have been carried out at Rothamsted and other centres. But there has been nothing on the scale of the GM farm-scale trials. "Large-scale definitive studies cost a lot of money and there have been few, if any, of these," says Perry.

Pollock echoes Firbank's hope that the farm-scale trials will be the blueprint for

A green and pleasant land

Viewed from the United States, the surge of concern about farmland biodiversity that prompted Britain's farm-scale trials of herbicide-tolerant genetically modified (GM) crops is difficult to understand. Since the mid-1990s, US farmers have adopted GM varieties on an enormous scale, with barely a public murmur about the knock-on effects for wildlife — at least until concerns were raised about possible threats to the endangered Monarch butterfly (*Danaus plexippus*)[8].

But the prairie-scale farms of the American Midwest have relatively little biodiversity to protect, except at their borders. And in a country that spans a continent, there is plenty of room to separate industrial-scale agriculture from areas of pristine wilderness.

"In the United States, we simply don't think in the same way because we have so much land," says Frank Forcella of the US Department of Agriculture's research station in Morris, Minnesota, and the University of Minnesota in St Paul.

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Although scientists such as Forcella are now planning studies of weed biodiversity in areas planted with herbicide-tolerant GM crops, the huge commercial plantings of these varieties in the United States have been accompanied by little in the way of studies into their effects on biodiversity. In the most part, the follow-up has concentrated on questions of yield and agrochemical use[10].

Britain, by contrast, is a crowded and heavily developed island in which the countryside consists of a patchwork of smaller fields, hedgerows, patches of woodland and human settlements. Agriculture, biodiversity, and the use of the countryside for leisure pursuits must all coexist. "We take much more concern with our farmland landscape much because we have so few truly wild places," says Les Firbank of the Centre for Ecology and Hydrology at Merlewood in Cumbria.

These factors explain why British ecologists have a long-standing reputation for studies of biodiversity in fields and hedgerows — which seem to be particularly important as havens for wildlife. Given this previous experience, the plots selected for the farm-scale GM trials include a range of different plots, from small fields surrounded by biologically rich hedgerows to the large arable fields of East Anglia that are Britain's nearest equivalent to the US 'cornbelt'.

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future experiments investigating the influence on biodiversity of current and proposed farming practices. "This whole debate about the integration of agronomy into landscape is bubbling up in Europe right now," he says.

In fact, the design of the farm-scale trials could allow the investigation of one farming practice other than the use of herbicide-tolerant GM crops. Over the past three decades, farmers in northwest Europe have increasingly adopted a practice known as 'autumn sowing', in which crops are grown over the winter and harvested in spring. But ecologists are concerned that this practice, and its associated use of herbicides, has largely eliminated the 'weedy stubble' in which birds and insects find food and shelter in the early spring. As both winter and spring oilseed rape have been included in the farm-scale trials, it would be easy to adapt the trials to address this issue.

For agribiotech companies, such questions are of secondary interest to their hope that the trials will absolve herbicide-tolerant GM crops of the charge that they threaten biodiversity. GM proponents have long argued the reverse, pointing out that many farmers growing conventional crops use a range of different herbicides in startling quantities throughout the growing season — maize crops in Florida, for instance, can be sprayed up to 40 times.

Weeding out objections

In theory, the use of broad-spectrum herbicides in conjunction with GM crops engineered to tolerate their effects should mean that many fewer sprayings are needed. By using these crops, companies such as industry-leader Monsanto of St Louis, Missouri, argue that farmers can afford to wait until weeds are some 15 centimetres tall before spraying, providing enhanced habitat and food for invertebrates and birds. The herbicide-application protocols devised by Pollock's steering committee for the GM plots in the farm-scale trials reflect this recommended practice. Fewer sprays should also slow the emergence of herbicide resistance in weed species, say GM proponents.

The companies also argue that the GM technology will allow farmers to avoid tilling the soil at the beginning of every season — a practice that is meant to destroy weeds, but which is also thought to diminish biodiversity by reducing soil moisture and nutrients, and increasing the risk of erosion.

The British farm-scale trials are not designed to investigate tilling practices. But at Kansas State University, weed scientist Kassim al-Khatib is examining this issue in a much smaller study of soya beans and maize. This spring, he embarked on a four-year experiment, planting the crops at two sites of about 8 hectares each in Kansas, one dry and the other more humid. One-third of each site was planted with non-GM varieties, and sprayed with a conventional herbicide

Exteaded cover: Chris Pollock (left) hopes the trials can be developed to address other farming issues; a concern echoed by Peter Riley.

regime; the other two-thirds were sown with glyphosate-tolerant GM crops and sprayed with this herbicide when the weeds had grown to between 5 and 8 centimetres, or when they had reached 20 centimetres. Within each treatment, the plots were further split in half to investigate the effects of prior tilling versus no tillage.

But neither the farm-scale trials nor al-Khatib's experiment can predict what will happen once herbicide-tolerant GM crops get into the hands of farmers away from the controlled conditions of a field experiment. Experience with maize engineered to produce an insecticidal protein does not bode well.

In May, John Obrycki at Iowa State University in Ames and John Losey of Cornell University in Ithaca, New York, reviewed a cluster of studies into the use of maize genetically engineered to carry a gene from the bacterium *Bacillus thuringiensis* that encodes a natural insecticide[5]. Obrycki and Losey concluded that most farmers growing the crops in the American Midwest were using the same amount of chemical insecticide as they had before the GM maize became available.

Julio Scursoni, a weed scientist at the University of Buenos Aires, and his colleague Eduardo Leguizamon at Argentina's National University of Rosario in Santa Fe, are now investigating whether farmers in Argentina are adopting a similarly aggressive approach with herbicide-tolerant crops. Argentinian farmers have enthusiastically embraced GM technology since its introduction four yea ago — 95% of the country's soya bean cr consists of herbicide-tolerant GM varieti Scursoni fears that many farmers are spra ing with herbicide more frequently than re ommended. "Farmers tend to overcompe sate," he says. "They see a clean field and th think it is a very nice result."

The scientists behind Britain's farm-sca trials accept that their study cannot answ all the questions surrounding the ecologic effects of herbicide-tolerant GM crops much less GM technology in general. B they hope that the principles of experimen design underpinning the trials will be used a model for investigating these questions plus a host of other issues surrounding farr ing practices — on a sufficiently expansi scale to yield conclusive results.

But the danger is that the controversy su rounding GM crops in Britain is now intense that this message will be lost — ar with it the chance to subject modern farmi practices to rigorous ecological scruti Even if the farm-scale trials fail to find G

In opposition: the GM farm trials have met with significant resistance from environment groups.

crops guilty of harming biodiversity, su gests Crawley, it will make little difference public perception. "Activists have so effe tively demonized GM plants," he says, "th lay people now wouldn't believe a study th says there is no problem, no matter how w it has been done."

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