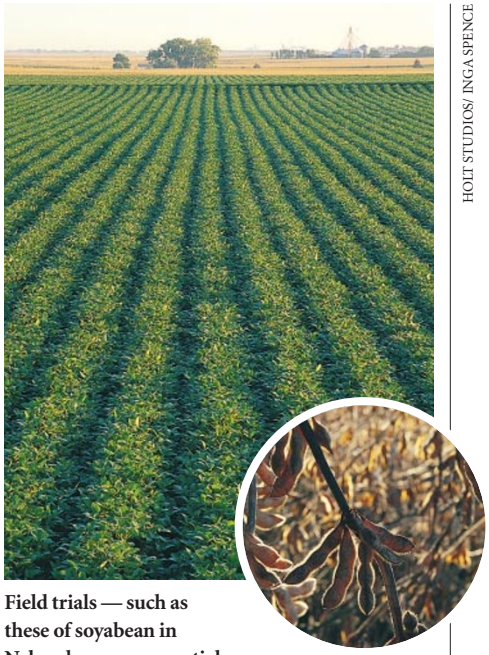
# Assessing the threat to biodiversity on the farm



HOLT STUDIOS/ INGA SPENCE

Field trials — such as these of soyabean in Nebraska — are essential.

The unintended consequences of genetically modified agriculture for the preservation of biodiversity have long been the focus of international attention, perhaps raising even more controversy than the potential impact on human health.

Talks on a new global treaty to minimize the possible adverse environmental impacts of GMOs broke down earlier this year, for example, partly because governments, environmentalists and industry disagree strongly over the ecological risks of GM crops (see *Nature* **398,** 6; 1999).

This disagreement is fuelled by the patchy state of research on the issue. Although there is plenty of evidence that modern farming methods have reduced biodiversity in many countries, a report by the British government's advisers on GM releases expresses a widely held view when it says that researchers do not yet know whether the planting of genetically modified crops will make things better or worse (see http://www.environment.detr.gov.uk/acre/wildlife/index.htm).

These issues have perhaps been of more concern to small countries such as Britain, where most of the countryside is used for agriculture, than to larger ones with wide expanses of land that is not farmed. Growing protests from environmentalist and conservation lobbies have persuaded the UK government and the scientific community to embark on a comprehensive programme of research on the impacts of GMOs on wildlife and the countryside.

In contrast, there has been less consciousness of these research needs in the United States. This is partly because of a perception that such research is not required, as the distances between farmland and the wider countryside are much greater. But it may also be because the US biotechnology industry, the world's largest, has had greater success in conveying to the public the message that GMOs are environmentally friendlier than conventional agrisystems.

Most GM crops already in use have been modified to confer tolerance to herbicides or to insects (although many other varieties of GM plants have also been commercialized). Herbicide-tolerant plants, in general, are modified to resist the commonly used herbicides glyphosate and glufosinate, which can therefore be sprayed on crops without damaging them. Insect-resistant plants are modified to produce toxins made by the soil bacterium *Bacillus thuringiensis* (*Bt*) that kill specific target pests because of the interaction between proteins produced by the bacterium and the pest.

Whether insect-tolerant plants can in practice harm non-target insects — and birds and mammals — is high on the list of questions for multi-year farm-scale experiments with GM crops that are being planned

## A pragmatist comes to the defence of the British countryside

**No-one would lightly accuse Sir Robert May, the British government's chief scientific adviser, of being a romantic. The Australian-born theoretical-physicist-turned-population-biologist has established a powerful reputation for applying mathematical modelling to problems ranging from the preservation of biodiversity to the spread of AIDS.**

**His pragmatism has been well to the fore during the recent British controversy over the potential health effects of GM foods. A willingness vehemently to criticize the unscientific nature of many of the claims being made turned him into a key spokesman for the government. Equally passionate was his dismissal of the popular newspapers whose reports were fanning the controversy over so-called 'Frankenstein foods' as "straight entertainment".**

**Where May does have concerns is about the long-term implications of GM-based agriculture on biodiversity. He points out that the history of agricultural change is in the direction of growing crops "that no one eats but us". This has obvious consequences for the animals that also depend on the fields we use. May quotes, for example, recent surveys of the decline of many bird populations, and says he is convinced by evidence for corresponding effects on invertebrate and plant diversity. "The thrust of GM crops is to accelerate this trend."**

**May admits that there remain scientific uncertainties about the health and environmental effects of GM food and crops. But he has little time for the claims by Scottish researcher Arpad Pusztai to have detected a depressed immune response from eating potatoes genetically engineered to produce the toxin lectin.**

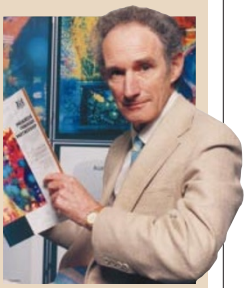
**"That is not scientific uncertainty; as long as it remains unpublished, it is outside the canon of science," says May.**

**May is confident that, if there had turned out to be such a danger with existing GM foods, Britain's regulatory authorities would have picked it up. But he also points out that the experience with bovine spongiform encephalopathy has brought home the need to expect the unexpected. "We must test," he wrote in a paper for the Prime Minister Tony Blair. "No-one was looking for untoward effects in cattle. In the case of GM food, we are testing for unexpected and unwanted effects on health and the environment."**

**Some widely quoted risks are, he says, relatively low, even if undesirable. One is the spread of 'superweeds' resulting from the interbreeding of herbicide-resistant crops with wild relatives. Although admitting that this could happen, he argues that the weeds would remain vulnerable to other herbicides.**

**Of slightly greater concern, he says, is possible cross-pollination with other crops. "We need to know rather more about this than we do at present."**

**His real worry, however, is about the impact of GM crops on biodiversity. "We need wider mechanisms to reconcile farming with preservation of the countryside," he says. "There is a much larger role for trying to understand how subsidies and other instruments interact with environmental protection."**



**May: concerns for the countryside.**

**But May is adamant that the remaining uncertainties provide a basis for field trials "on a scale sufficient to answer the questions we face" — not for a moratorium on trials.**

by the British government. Another question to receive close scrutiny will be the extent to which modified genes can be transferred to other plants, and what effect this might have on, for example, organic produce. A third question is whether herbicide tolerance can spread to nearby plants, whether weeds or other crops.

The limited evidence available so far has left researchers apparently divided on the risks to non-target insects from *Bt* crops. William Hutchison and colleagues from the department of entomology at the University of Minnesota, for example, told a meeting of the Entomological Society of America last month that they found no difference in the numbers of 'beneficial' insects when they sampled fields of *Bt* sweetcorn and non-*Bt* corn in Minnesota (see http://www.ent.iastate.edu/entsoc/ncb99/prog/abs/d51.html).

In contrast, Nicholas Birch, a research entomologist at the Scottish Crop Research Institute in Dundee, has demonstrated in lab studies that an anti-aphid toxin expressed by an experimental GM potato reduces the fertility and shortens the lives of ladybirds that eat the target aphids. Critics, though, point out that the toxin in question, snowdrop lectin, is unlikely to be approved for a GM crop given previous evidence of its toxicity.

Perhaps a more realistic pointer to potential dangers has come from Angelika Hilbeck, of the Swiss Federal Research Station for Agroecology and Agriculture in Zurich, who has found that lacewings, another beneficial insect, have higher death rates when fed the larvae of target insects that have eaten *Bt* corn compared with larvae fed on ordinary corn.

But Hilbeck's studies were conducted in the laboratory (see *Environmental Entomology* **27,** 480–487; 1998). Under farm conditions, the results may be different, as the target insect — the European cornborer — lives inside corn stalks, where under normal conditions it is largely protected from lacewings.

Research has also been under way for some time to assess the impact on nearby flora of herbicide-tolerant GM crops. Researchers from Denmark, France and the United States have already suggested that the results of trial experiments indicate that herbicide-tolerant genes can in principle 'escape' from GM plants to nearby weedy relatives through pollen transfer.

Similarly Anne-Marie Chevre, a plant researcher at the Institut National de la Recherche Agronomique in Le Rheu, France, has found that oilseed rape genetically modified to withstand herbicide easily produced fertile offspring when crossed with a common weed, the wild radish — although she also found that the herbicide-tolerance genes became more diluted with each generation of hybrids.

Scientists working for environmentalist groups are among those who claim that such gene transfer could encourage the proliferation of 'superweeds', which might turn out to be highly invasive.

The consensus from a recent gathering of scientists, regulators and research managers in Bethesda, Maryland, convened to consider the ecological impacts of GM crops, was that there is little risk of enhanced weediness from the handful of transgenic plants on the market. Their genetically enhanced traits would not confer any competitive advantage over other plants, and would eventually die out, it was concluded.

But overall the jury is still out. For example, the scientists attending the Bethesda meeting agreed that, when many different GM plants exchange genes, a kind of 'gene stacking' of multiple desirable traits could theoretically produce a highly competitive weed. And some, such as Allison Snow, an ecologist at Ohio State University, point out that this is not likely to be known until many GM crops are in wide use.

Nor do researchers yet know whether a fitness-improving gene — such as one that confers resistance to pests, herbicides or drought — will necessarily make a weed or a GM crop more invasive. In the case of herbicide resistance, unless the weed is sprayed with herbicide, there should be no selection pressure favouring the survival of resistant plants, and the trait should die out in time.

Representatives of the biotechnology industry are among those who believe strongly that the benefits to agriculture and the environment from GM crops tend to be

## Japan defends its drive for self-sufficiency

**Despite widespread public concern over genetically modified food, Japan's scientists — in concert with those in other countries — have only recently begun to address questions on the potential long-term risks to human health and the environment from GM crops.**

**On 1 April, the Ministry of Agriculture, Forestry and Fisheries (MAFF) embarked on the government's first project to examine the risks from GM crops. As elsewhere, the project will focus on the long-term impacts of herbicide- and insect-tolerant crops on ecology and on agricultural practices.**

**A substantial proportion of the Japanese public, like their counterparts in Europe, are uneasy about GM foods. Some invoke ethical concerns about the manipulation of genes. Another reason is a relative lack of public understanding of genetic modification techniques. A third reason is government reluctance to label GM foods.**

**But other factors may be at work. According to Naoto Shibuya, a researcher in bioengineering at the National Institute of Agro-Environmental Sciences in Tsukuba, public unease can partly be attributed to an absence of effective public communication of the risks. Shibuya says scientists need to communicate in a way that "indicates what is understood and what is not".**

**A low level of public confidence in GM foods is not good news for the government, which is relying on GM agriculture to make Japan self-sufficient in food. Unsurprisingly, finding ways of allaying public concerns is a key aim of the MAFF research project.**

**Japan's GM regulations are modelled on a framework set out by the Organization for Economic Cooperation and Development (OECD), with a strong emphasis on the concept of 'substantial equivalence' (see page 652). But critics question 'substantial equivalence' as a basis for deciding whether a product is safe, and argue that there is no substitute for long-term risk assessments. "The regulators have overlooked the potential residual toxicity after several growing seasons, and the consequences on genetic diversity," says Setsuko Yasuda, director-general of Japan's Consumers' Association.**

HOLT STUDIOS/ NIGEL CATTLIN

**Farm tests: Japan has tough rules on field trials.**

**But representatives of the Ministry of Health and Welfare, as well as MAFF, which are both involved in the approval of GM products, claim that the chances of GM crops posing health and environmental risks are negligible, and that such risks would be detected during safety tests.**

**In some ways, Japan's regulatory system for GM crops is tougher than in other industrialized countries. Once a potentially useful crop plant has been developed, small scale, isolated field trials are carried out, followed by cultivation over at least one generation in a farm-scale environment. Farm-scale trials are not a regulatory requirement in many OECD countries.**

**Although the government is keen to press ahead with the development of GM crops, the private sector is more cautious than in other industrialized countries. Companies such as Japan Tobacco, Kirin Beer and Suntory are carrying out farm-scale trials — including virus-resistant rice and petunia — but there are no immediate plans to commercialize any of these products.**

**According to government sources, this is because few locally-based companies are keen to be the first to commercialize GM crops because of a fear that this could create a negative image of the company, and perhaps trigger a boycott of its products.**

understated in debates on the impacts of such crops.

One such benefit is that insect-tolerant crops need smaller quantities of conventional pesticides, whose ability to harm the environment is well documented. Indeed, a report by the privately financed National Center for Food and Agricultural Policy in Washington D.C. points out that pesticide applications in southern US states have dropped significantly in recent years, coinciding with the spread of *Bt* crops (see http://www.ncfap.org/biotech/sld014.htm).

Despite such a benefit, however, the use of *Bt* as a spray, as well as what has been described as an exponential increase in '*Bt* plants', has raised concern that target insects could eventually become immune to the toxin, a scenario that would harm both agriculture and the environment.

One exponent of this view is Bruce Tabashnik, an entomologist at the University of Arizona. Tabashnik admits that there are no well documented cases of pests becoming resistant to *Bt* crops. But, in common with many farmers, he believes that resistance is inevitable. So far, Tabashnik and others have shown that one species, the diamondback moth, has shown widespread resistance to *Bt* spray. And Fred Gould, an entomologist at North Carolina State University, has found higher than expected frequencies of alleles conferring resistance to *Bt* in field populations of the tobacco budworm (*Proc. Natl Acad. Sci. USA* **94,** 3519–3523; 1997).


**Scare tactics: talk of 'Frankenstein foods' may be exaggerated and misleading. But the biotech industry has still been forced to respond to many of the concerns of consumer groups and environmentalists.**

DYLAN GARCIA/STILL PICTURES

Gould, in common with other researchers and farmers, says that methods need to be found to deal with the risk of pests becoming immune to *Bt*. One method being proposed is for farmers to deliberately set aside more field space for growing non-*Bt*-cotton. The idea behind such 'refuges' would be to allow budworms to breed with *Bt*-exposed pests, so diluting *Bt*-resistance genes in future generations of budworms.

There appears to be a consensus among corn growers, researchers and biotechnology companies that at least 20 per cent of the growing area should be set aside for non-*Bt* corn in this way — farmers currently set aside just four per cent. The loss of *Bt* as an effective pesticide would not necessarily pose a new ecological hazard; resistance to pesticides predates GM crops. But it could make biotechnology's victory in increasing food production a short-lived one.

## Industry critic warns that damages claims 'could run into millions'

**"It's an 'emperor has no clothes' situation," says Jeremy Rifkin, one of the biotechnology industry's most vocal critics. "You cannot have governments telling us that the technology is safe when there is no science to judge it by."**

**The absence of what he calls a 'predictive ecology' will, he suggests, have a direct impact on the industry: insurance companies will be reluctant to issue protection against claims for environmental damage if there is no way of quantifying what this damage might be.**

**"You're going to see lots of litigation when genes start flowing to organic crops, or to wild relatives on neighbouring lands," he predicts. "The gene flow is going to be on a scale that people have not understood. Liability is going to be the Achilles' heel of the biotechnology industry."**

**Rifkin has headed a small but influential Washington-based pressure group, the Foundation for Economic Trends, since the late 1970s. His apocalyptic scenarios have won him few friends — and many enemies — in the biotech community.**

**But the themes he emphasizes — in particular, that genetic engineering is somehow 'unnatural', and almost by definition potentially dangerous — have hit a responsive chord among the public. And it is the implications of that for indicating the direction of consumer demands, such as growing insurance claims, that have given him a ready audience in US boardrooms.**

**Rifkin has a clear sense of where he sees future problem areas. With herbicide resistance in plants, for example, he identifies the issue of such resistance spreading out of control. "The industry argues that inserting a herbicide-resistant gene will mean more sustainable agriculture, but it could be the opposite. If you put in a herbicide-tolerant plant, and then increase the use of that herbicide, how long will it take for resistant strains of weeds to appear?**

**"You see it more urgently in the case of pest resistance. Here you could end up with every cell of every plant producing a toxin. Because it is only a single gene, the 'magic bullet' runs out very quickly. It is faster and easier for an insect to build up resistance and, the more widely these plants are used, the greater the problem is likely to be."**

**Even if no overt damage occurs, Rifkin argues that gene flow into neighbouring crops is likely to become a source of conflict. "Foreign genes are a 'smoking gun'. They are going to flow all over the place, and they will always be identifiable.**

**"Claims for damages could come from gardeners or organic farmers who find they are unable to sell their crops. All that has to happen is for a gene to turn up that you did not want. The overall claims for damages could make the recent litigation associated with smoking pale in comparison."**

**One option for the industry, he suggests, is to turn to the government for financial protection. "But I don't know anyone in the world who will allow it to happen for biotechnology. There is a potential vulnerability here that is so dramatic and so unaddressed that it cries out for attention."**

**Rifkin: liability will be biotech's Achilles' heel.**

GINO SPRIO

**Hence the need for a predictive ecology — to provide financial security, if nothing else. "At present, the insurance industry is not likely to want to touch this type of thing; you have to have predictability."**

**The same issue applies to potential health impacts. "We just do not know, if you take a gene from an unrelated species that codes for a protein that has never been part of our diet, what the allergenic impact is likely to be.**

**"It does not take much imagination to suggest that not all the genes that code for proteins are going to be safe. And, given the scale on which these foreign genes are being introduced into foods, I predict that there could be quite a bit of illness — another issue that is going to force the liability question."**

**Scare tactics, perhaps. But, given the extent to which the regulatory agenda is set by the reaction of politicians to public sentiment, Rifkin insists that these issues need to be taken seriously. He stresses the need for "serious research" into long-term, low-level consequences: "This is essential if the industry is going to survive".** □