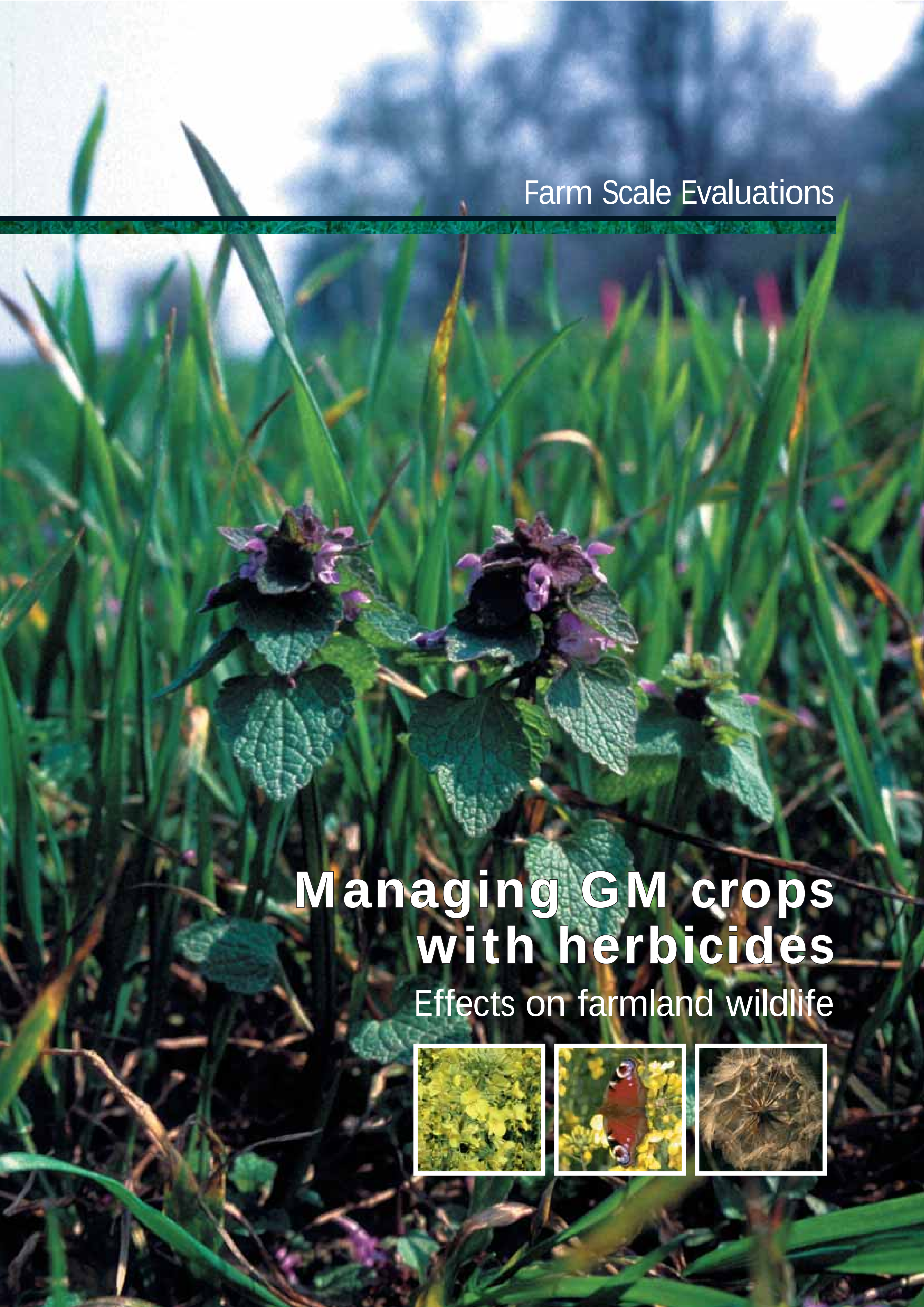
Farm Scale Evaluations



Managing GM crops with herbicides

Effects on farmland wildlife

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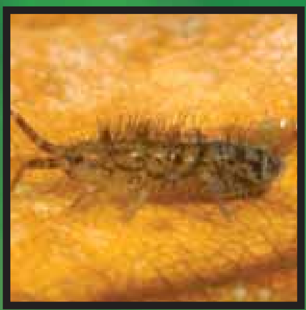


Summary

In 1999, the government asked an independent consortium of researchers to investigate how growing one kind of genetically modified (GM) crop might affect the abundance and diversity of farmland wildlife compared with growing conventional varieties of the same crops. It needed the results of this study to help decide whether to allow such GM crops to be grown commercially in the UK.

In the largest ever field trials of GM crops in the world, the researchers compared GM and conventional varieties of four crops. The crops were winter-sown oilseed rape, spring-sown oilseed rape, beet and maize. The GM crops had been genetically modified to make them resistant to specific herbicides; they are called herbicide-tolerant (GMHT).

In 2003, the team reported that there were differences in the abundance of wildlife between GMHT and conventional spring rape, beet and maize. New results show that there were also differences for winter rape, and these are broadly consistent with those for spring rape and beet.

Growing conventional beet and spring rape was better for many groups of wildlife than growing GMHT beet and spring rape. There were more insects, such as butterflies and bees, in and around the conventional crops because there were more weeds to provide food and shelter. There were also more weed seeds in conventional beet and spring rape crops than in their GM counterparts. Weed seeds are important in the diets of some animals, particularly farmland birds.

In contrast, growing GMHT maize was better for many groups of wildlife than conventional maize. There were more weeds in and around the GMHT crops, more butterflies and bees around at certain times of the year, and more weed seeds.

Growing GMHT winter rape resulted in the same number of weeds as in the conventional crops. However, in the GM crops, there were fewer broad-leaved, flowering weeds that are especially beneficial for wildlife, and there were more grass weeds. There were also fewer bees and butterflies. But there were no marked differences in overall numbers of other insects, slugs and spiders.

The researchers stress that the differences they found do not arise because the crops have been genetically modified. They arise because these GM crops give farmers new options for weed control. That is, they use different herbicides and apply them differently.

The results of this study suggest that growing such GM crops could have implications for wider farmland biodiversity. However, other issues will affect the medium- and long-term impacts, such as the areas and distribution of land involved, how the land is cultivated and how crop rotations are managed. These make it hard for researchers to predict the medium- and large-scale effects of GM cropping with certainty.

The researchers stress that the differences they found do not arise because the crops have been genetically modified.

Why do this study?

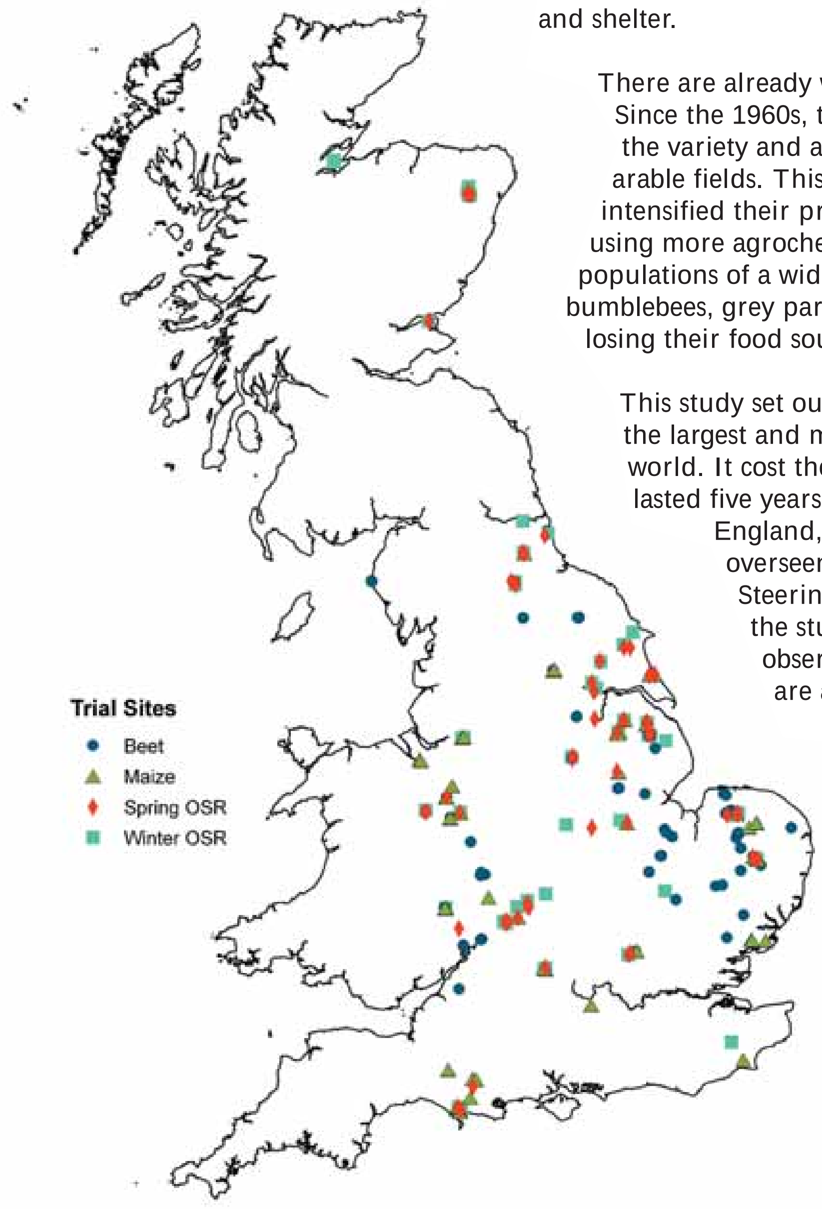
Since the 1960s, there has been a steady decline in the variety and abundance of weeds in and around arable fields.

By late 1998, several types of GM crops had reached the final stages of government approval before they could be grown commercially in the UK. These were all herbicide-tolerant crops. That is, they had been genetically modified to tolerate one of two ‘broad-spectrum’ herbicides, which kill a wide range of weeds. The farmer can use one appropriate broad-spectrum herbicide to control most of the weeds without harming the crop. In contrast, farmers usually have to use more than one herbicide to protect a conventional crop. (Using broad-spectrum herbicides on conventional crops would kill the crop as well as the weeds.)

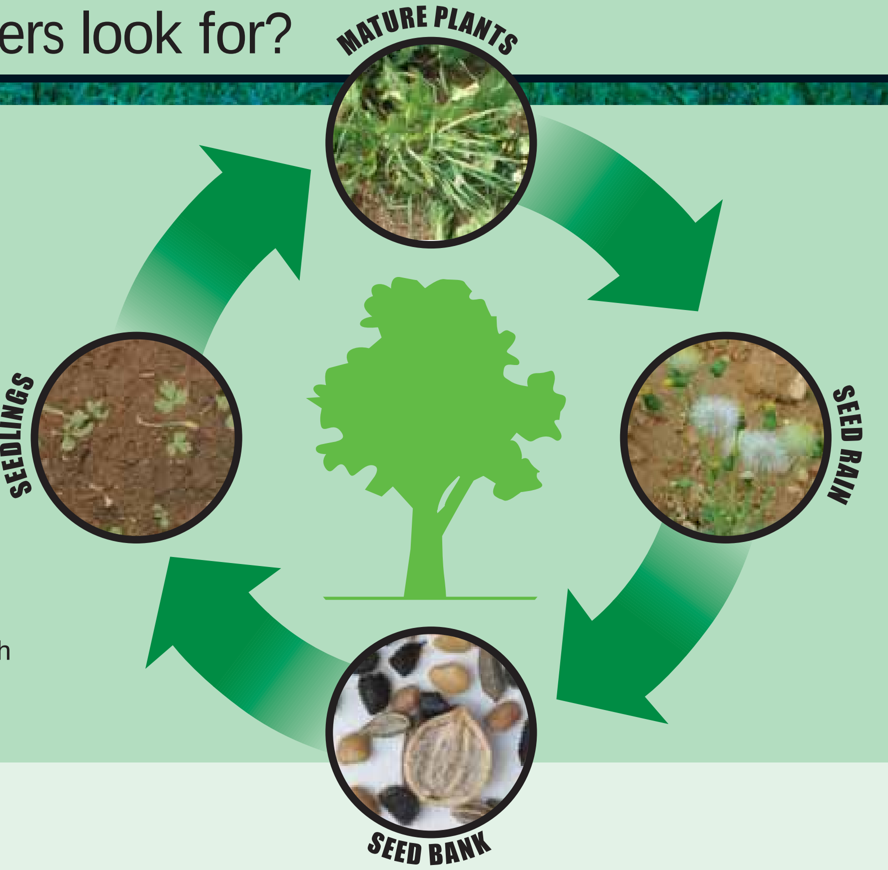
However, environmentalists and conservationists had expressed some concerns about herbicide-tolerant crops. They feared that the herbicides used with these crops would wipe out the weeds and wildflowers that farmland wildlife depend on for food and shelter.

There are already worrying trends in this direction. Since the 1960s, there has been a steady decline in the variety and abundance of weeds in and around arable fields. This is mainly because farmers have intensified their production techniques, including using more agrochemicals. As weed numbers fall, populations of a wide range of species, including bumblebees, grey partridge and corn buntings, are losing their food sources and habitats.

This study set out to address these concerns. It was the largest and most thorough of its kind in the world. It cost the government around £6 million, lasted five years, involved 266 trial fields around England, Wales and Scotland, and was overseen by an independent Scientific Steering Committee. As never before, the study has allowed researchers to observe how changing farm practices are affecting wildlife across the country.



What did the researchers look for?



The researchers looked at how weeds - both grasses and broad-leaved, flowering weeds - grew in and around the crops. They monitored the seeds the weeds produced (seed rain) and the seeds that were left in the soil (seedbank). This was done before, during and after the crops were grown and harvested.

The team also monitored insects and other small creatures, including bees and butterflies (pollinators); insects such as springtails that feed off decaying weed material (detritivores); creatures such as shield bugs and certain beetles (herbivores) that eat weeds and crops; and creatures such as spiders that eat herbivores (predators).

What did they find?

The main finding was that the differences between crops arose because of the way farmers used herbicides differently on different crops.

Compared to the conventional crop, they found

GMHT winter rape:
- same numbers of weeds overall
- more grass weeds but fewer broad-leaved weeds
- more grass weed seeds but fewer broad-leaved weed seeds
- fewer butterflies and bees
- more springtails

GMHT spring rape and beet:
- fewer weeds
- fewer seeds
- fewer bees and butterflies
- more springtails

GMHT maize:
- more weeds
- more seeds
- more bees and butterflies
- more springtails

What would growing GMHT crops mean for wildlife?

1 Weeds

Growing GMHT beet and spring rape would mean fewer weeds and weed seeds because the broad-spectrum herbicides are more effective weedkillers than the combination of herbicides used on conventional crops. Spring-sown crops like beet and spring rape are important for weeds because farmers grow these crops as breaks in cereal crop rotations. During the break year, broad-leaved weed control is often less effective giving weeds a chance to grow and their seeds a chance to collect in the soil. The researchers aren't sure yet whether the differences in weed and seed numbers would persist after several years of cropping with cereals, but seed stores could get severely depleted and may not recover. Without careful management, some weeds could eventually become so scarce that they will no longer be a source of food and shelter for wildlife.

Growing GMHT winter rape would have no effect on total weed numbers, but could speed up the long-term decline of flowering weeds if the store of seeds in the soil (seedbank) is not replenished. This is important because it is these weeds that birds, small mammals and insects particularly rely on. However, growing GMHT winter rape would encourage grass weeds, possibly providing food for some animals. But this may concern some farmers, as these weeds tend to be harder to control. The differences observed arise because the particular broad-spectrum herbicide used with this GM crop was relatively better at controlling broad-leaved weeds and worse at controlling grass weeds than the conventional herbicides.

Growing GMHT maize would allow more weeds to grow than conventional maize and these weeds would produce twice as many seeds. There were relatively more weeds and seeds in the GM maize because the broad-spectrum herbicide was not as powerful as the persistent herbicides often used before, or just after, weeds started to grow in most of the conventional maize fields.

2 Insects and other small creatures

Growing GMHT spring and winter rape, and beet might provide benefits to some insects and other small creatures. For example, populations of springtails and their predators, such as beetles and spiders, might flourish in the short- to medium-term.

Because the broad-spectrum herbicide works so well, the farmers leave weeds within the GM crops until later in the season. This benefits springtails, which can feed from a more abundant supply of larger rotting weeds, and the springtails' predators, which have bigger, more numerous prey. This is not the case in conventional crops where farmers control weeds before they start growing with 'pre-emergence' herbicides. However, this boost for these animals may be short-lived as, over the years, there could be fewer weeds left for the herbicide to kill, reducing the supply of rotting weeds.

However, the small creatures that survive on seeds dropped by weeds would not fare as well in GM spring rape and beet crops. For these animals, fewer weeds would mean a shrinking food supply. If the seed stores remain depleted in the long-term, this would have serious repercussions on their survival.

Apart from springtails and their predators, other small creatures in the GMHT winter rape survived equally well as in the conventional crop. One reason could be that the large winter rape plants provide enough shelter and food by themselves.

3 Bees and butterflies

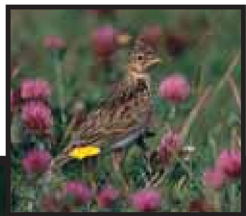
Bumble bees and butterflies rely on flowering crops, weeds and wildflowers to provide them with nectar and pollen so they will be affected if flowering weed numbers decline. However, bumble bees and butterflies can fly long distances until they find the plants they need so a decline in weeds may have little immediate impact on them. But if weeds die away over large areas over several years, the effects on nectar resources would become more important.

This could happen if GMHT beet, and winter and spring rape were grown over many years and over large areas of arable land. In areas where nectar resources are very meagre, such as in beet-growing regions, any reduction in weed populations in the long-term could exacerbate the decline in bumble bee and butterfly populations. As butterfly numbers were lower in all GM fields (except in GMHT maize where they were marginally higher), the findings suggest that growing conventional crops may be important for butterflies in regions where there are not many suitable flowers in the field margins and hedgerows.

4 Birds

This study did not involve farmland birds, but its results do have implications for them. Numbers of these birds, such as the skylark, the corn bunting and the grey partridge, have declined over the past three decades. As agriculture has intensified, there are fewer places for them to nest and dwindling supplies of seeds and insects to eat.

As growing GM spring rape and beet dramatically cut the number of weed seeds, bird populations could struggle to find enough to eat, especially later in the year. Some farmland birds rely heavily on weed seeds for their survival, especially over the winter. Those farmland birds that particularly forage seeds from broad-leaved weeds would have less food within the crop of GM winter rape. Although a few birds might benefit from the grass seeds that predominated in GM winter rape, grass seeds are substantially less important in bird diets than those of broad-leaved weeds. Some farmland birds also use weed plants for food so they may be affected by the smaller, less leafy weeds found in the GM fields. However, insect-eating birds would probably experience fewer differences in GM fields of spring and winter rape, and beet.



Growing GMHT maize crops on a large-scale may benefit farmland birds. There were more weeds growing in these fields, including those that are important food resources for seed-eating birds, than there were in the conventional maize fields. More weeds produce more seeds for the birds in the autumn and winter.

What are the wider implications for the future?

The database gives researchers a baseline so they can monitor future changes to farmland wildlife.

If any of these GM crops were grown commercially, the researchers expect that the effects on wildlife would be similar to those reported here, as long as the crops were managed in the same way as in this study. The size of these effects on wildlife would change if farmers managed the crop differently, for example if they if they applied more or less herbicide or sprayed at different times. These effects would also be influenced by how many farmers used these GM crops and the area the crops covered, and by whether there were alternative sources of food and shelter for birds and other animals nearby.

It's now clear that none of these GM crop varieties will be grown in the UK in the near future. In March 2004, the UK government announced approval of GMHT fodder maize for commercial cultivation under certain conditions. One of these conditions was that farmers managed the crop in the same way as in these trials. But the producer withdrew the crop. The government stated that it would oppose commercial cultivation of GMHT beet and spring rape anywhere in the European Union, if farmers managed the crop in the same way as in these trials.

These trials compared GM crops with conventional crops, but their significance extends beyond the debate on GM technology. As a result of these trials, researchers now have a database on wildlife living in and around conventional arable fields. For the first time, they have information on animal and plant numbers, and how different species interact with one another. The database gives researchers a baseline so they can monitor future changes to farmland wildlife.

In the past, changes in agricultural practices, such as moving from spring-sown to winter-sown crops or cutting down hedgerows between fields, have had huge effects on farmland wildlife. But these changes have never been regulated, and their effects were difficult to measure. This database will help researchers track and forecast the effects of any major future change in conventional agricultural practice, in the UK and overseas. It will help governments to decide agricultural policies, and ecologists to work out the best systems to protect and encourage wildlife.

How were the trials carried out?

The researchers needed a large number of farmers to take part in the trials. Farmers applied initially to an agrochemical industry group called SCIMAC, made up of herbicide manufacturers, biotechnology companies and representatives from the National Farmers Union. The research consortium selected farmers independently from this pool of applicants to ensure they had a good spread of farms around the country, including those that were farmed intensively and those that were farmed less intensively. On the trial farms, the researchers used fields spanning the typical sizes for the particular crop to represent a range of commercial growing conditions.

The GMHT maize, winter rape and spring rape used in the trials were resistant to the broad-spectrum herbicide *Liberty* (glufosinate-ammonium) made by BayerCropScience. The GMHT beet was resistant to the broad-spectrum herbicide *Roundup* (glyphosate) made by Monsanto. These crops were chosen because they were closest to receiving consent for commercial growing in the UK. The government's advisory committee on GM crops - the Advisory Committee on Releases to the Environment (ACRE) - considered that using these crops in the trials would not pose a direct threat to human health or the environment.

Each trial field was divided into two. Half was sown with the GM crop and half with its conventional equivalent. The farmers decided how and when to cultivate the fields; and how and when to apply herbicides, pesticides and fertilisers. Farmers mostly managed each half-field in the same way, apart from the choice and timing of herbicide applications. The herbicides used on the GM crops were applied according to specific draft label instructions from the manufacturers.

The scientific teams checked that the farmers managed their crops as normal by reviewing all the farmers' paper records, comparing them with other management routines on non-trial farms and assessing the fields for signs of unusual farm practices.

The farmers mainly grew the GM crops in rotation with conventional crops. This means that the GM crop was normally grown for one year as part of a set sequence of crops grown in the field. This is how farmers would normally grow and manage these crops. By using a large number of sites, the researchers reduced the chances of local variations, or differences among the farmers, affecting the overall results and ensured that they would spot any important differences in plant or animal numbers.

GMHT winter-sown oilseed rape

Winter-sown oilseed rape is the most widely cultivated of all four crops studied. About 330,000 hectares are grown all over the UK, but mostly in the south. Typically, it is sown in September and harvested the following August.

The researchers found that there were similar total weed densities in both GM and conventional winter rape fields. However, they observed significant differences in the abundance of different types of weed. They found there were more grass weeds, but fewer broad-leaved, flowering weeds in the GM crops than in the conventional crops. This marked imbalance between grass and broad-leaved weeds was only found in winter rape. It probably occurred because the GM herbicide is not as good at controlling grasses as the herbicides used with conventional crops and is applied at a much later stage of weed growth.

By October, farmers had treated half of the conventional winter rape crop with pre-emergence herbicides. At this time, broad-leaved weed densities were two times higher and numbers of grass weeds were three times higher in the GM crop than in the conventional crop. But after the farmers had applied herbicide to the GM crop, broad-leaved weed densities fell to one third those found in the conventional crop. However, herbicide application didn't make any difference to the grass weeds; their densities remained three times higher until harvest.

Seed numbers from grass weeds were five times greater in the GM crop and this difference persisted in the seedbank in the following year. However, broad-leaved weeds produced three times more seeds in the conventional crop, resulting in differences in weed numbers that lasted to the next year.

There were more butterflies and bees in conventional winter rape because there were more flowering broad-leaved weeds. The numbers of springtails were higher in the GM crop. They feed on rotting broad-leaved weeds so they benefited from weeds killed later in the year when they were bigger and more abundant.

By comparison with all other crops, though, few differences were found in the numbers of insects and other small animals between the GM and conventional winter rape. This could be because they use the large winter rape plants as substitutes for shelter and food when there are not enough weeds.

GMHT spring-sown oilseed rape

Spring-sown oilseed rape is grown in many regions of the UK, but is more popular in the north of the country because its growth is slow in dry, warm springs. In any one year, spring rape can cover 60,000 hectares. Typically, it is sown in April and harvested in September.

The trial farmers treated almost half of the conventional spring rape crops with herbicides applied before the weeds emerged in March. This meant that weed density was, on average, higher in the GM fields until farmers applied the GM herbicide. Then, weed density, particularly of broad-leaved plants, fell drastically. This is probably because the herbicide used in these trials acts more effectively against these types of weeds and is less effective against grass weeds.

Although the numbers of surviving broad-leaved weeds were similar in conventional and GM crops, the plants had a 70 per cent lower biomass in the GM crops. Seed rain was also lower, with 80 per cent fewer broad-leaved weed seeds. Overall, the weed seedbank was smaller following GM crops. After one year in the conventional spring rape fields, the seedbank of broad-leaved weeds doubled but it only increased slightly in the GM equivalent.

Butterfly numbers were higher in the fields and field margins of conventional spring rape crops, attracted mainly by the greater numbers of flowering weeds in and around the crop. Most other insect groups, including bees, were found in similar numbers in the GM and conventional fields, although there were some seasonal differences.

Springtails and spiders were significantly more abundant in GM crops in July and August, respectively, just before harvest. This was probably because springtails feed on rotting weeds, which were more abundant in the GM crops late in the year. The GM herbicides are used later in the year so the weeds are bigger when they are killed, providing more food for springtails. The spiders were probably feeding off the springtails. One particular type of seed-eating ground beetle also appeared more frequently in the conventional beet fields because there were more seeds for them to eat.

GMHT beet

About 170,000 hectares of sugar beet are typically grown in the UK (including cultivated field margins), a high proportion in the open, arable landscapes of East Anglia. It is grown particularly in East Anglia, as well as in western England and some parts of the north.

In spring, the density of weed seedlings growing in the GMHT beet fields was four times that in the conventional beet fields because many farmers used pre-emergence herbicide on the conventional halves of the field. However, applying the broad-spectrum herbicide to the GM crops in May soon halved the weed density compared with the conventional crops. After this, the biomass of the remaining weeds was six times lower and the seed rain was three times lower compared with the conventional crops.

The seedbank of weed grasses remained the same at the end of the trials as it was at the beginning two years earlier. The seedbank of broad-leaved weeds remained constant in the GM fields but increased in the conventional fields.

Although there are never many bees and butterflies in beet crops, there were even fewer in the GMHT beet crops than in the conventional crops, probably because there were fewer suitable flowering weeds to attract them. There were also fewer butterflies in the tilled field margins. Bee numbers, while generally low everywhere, were even lower in the GM crops, falling to their lowest in August in the crops and in July in the field margins.

The populations of two insects, springtails and true bugs, also showed some differences between crops. There were more springtails and some of their predators, such as one species of ground beetle, around in the GM crop in August than in the conventional crop. This was probably because springtails feed on rotting weeds, which were more abundant in the GM crops late in the year. The GM herbicides are used later in the year so the weeds are bigger when they are killed, providing more food for springtails.

On the other hand, populations of true bugs were much smaller than those found in conventional crops, probably because they could not find enough weeds and seeds to eat in the GM fields. One particular type of seed-eating ground beetle was also more frequent in the conventional beet fields because there were more seeds for them to eat.

GMHT maize

British farmers grow forage maize to make into silage to feed to cattle. More than 100,000 hectares are grown throughout southern England and the mixed farming areas of western England. Maize, unlike beet or rape, can be grown continuously in the same field.

Both the density and biomass of broad-leaved weeds was three times higher in the GMHT maize fields than in the conventional maize fields. Taken together, the weeds in the GM crops produced twice as many seeds as the weeds in the conventional crops. There was no effect on the seedbank.

Over the growing season from May to September, butterflies were attracted to the GMHT maize fields and field margins in the same numbers as the conventional fields. However, significantly more butterflies visited the GM crops in July while August saw nearly three times as many honey-bees in the GM field boundaries as in the conventional fields, probably because there were more plants in flower in the field margins at this time. But the researchers stress that, even in the GM fields, numbers of bees and butterflies were still low.

Most groups of insects were found in similar numbers in both crops. The main differences were a consistently greater number of springtails in the GM crops, especially in August, probably because springtails feed on rotting weeds, which were more abundant in the GM crops late in the year. There were also more butterflies in the GM crops in July, and more honey bees in August. There were fewer spiders in the GM crop margins, reflecting the lower abundance of plants to aid web-spinning.

Just before publication of the results for spring crops in October 2003, the European Union announced a ban on three herbicides used extensively in conventional maize, including the persistent chemical atrazine. This meant that comparisons the researchers had made between conventional and GM maize crops might not hold for the future, because most farmers in the study had used one of these chemicals on their conventional maize fields.

The researchers looked again at the study's results for maize. In March 2004, they predicted that growing GMHT maize would still benefit wildlife, but the effects would be reduced by about one-third. This is because agricultural experts agree that farmers are likely to use equally persistent chemicals on conventional maize fields.

Glossary

ACRE
This panel, the Advisory Committee on Releases to the Environment, advises the UK government on regulating and releasing genetically modified plants and animals. www.defra.gov.uk/environment/acre

Broad-spectrum herbicide
A chemical that kills a wide range of weeds.

Crop rotations
Farmers grow crops in a set sequence in a field. For example, they will grow a cereal crop for two years then use a 'break' crop, such as beet or oilseed rape, to remove any pests that may have colonised the field. Farmers can use some break crops to 'clean' the field of grass weeds as they can apply specific grass herbicides that don't affect the break crop.

Field margins
The area in between the crop and the outer boundary of the field (such as, the hedgerow) including paths, verges or any strip of bare earth that has been tilled but not sown.

Genetic modification (GM)
Where researchers have manipulated DNA to produce a certain effect, such as making a crop resistant to a particular insect or herbicide.

Herbicide
A chemical that kills weeds. Many herbicides only kill a few types of weeds.

Herbicide-tolerant crop
A crop that has been genetically modified to be resistant to a particular herbicide (GMHT).

Plant or weed density
The number of plants in a certain area.

Plant or weed biomass
The weight of the dried plants, indicating the quantity of foliage, flowers, seeds and stems that were above ground.

Scientific Steering Committee
The group that oversaw the trials consisting of members of the scientific and conservation communities.

SCIMAC
The Supply Chain Initiative for Modified Agricultural Crops is the agrochemical manufacturers and users advisory panel.

Seedbank
The number of seeds left in the soil available to grow into future weeds.

Seed rain
The number of seeds that were shed from the weeds on to the soil surface.

This brochure was produced by the Farmscale Evaluations Research Consortium and the Scientific Steering Committee, and written by Maria Burke.
For further details, see http://www.defra.gov.uk/environment/gm/fse/index.htm.
The 2003 published FSE papers may be downloaded from the Royal Society website: http://www.pubs.royalsoc.ac.uk/. Further documents are available from: http://www.rothamsted.bbsrc.ac.uk/pie/joe_general_work_GM_FSE_page_3_1.htm

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