

GM CROPS
Effects on Farmland Wildlife

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Rationale and results in brief

In 1999, the government asked an independent consortium of researchers to investigate how growing genetically modified (GM) crops might affect the abundance and diversity of farmland wildlife compared with growing conventional varieties of the same crops. It will use the results of this study to help it 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 studied three GM and conventional crops. The crops were sugar and fodder beet (considered as a single crop), spring-sown oilseed rape and maize. The GM crops had been genetically modified to make them resistant to specific herbicides; they are called herbicide-tolerant (GMHT). Other types of GM crops, such as those engineered to be resistant to certain insect pests, were not included in the study.

The team found that there *were* differences in the abundance of wildlife between GMHT crop fields and conventional crop fields.

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 cover.

There were also more weed seeds in conventional beet and spring rape crops than in their GM counterparts. Such seeds are important in the diets of some animals, particularly some 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.

The researchers stress that the differences they found do not arise just 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 any certainty. In addition, other management decisions taken by farmers growing conventional crops will continue to impact on wildlife.



Why did the government commission this study?

Four years ago, several types of GM crops had reached the final stages of government approval before they could be grown commercially in Europe, including 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 the appropriate broad-spectrum herbicide to control most of the weeds without harming the crop. Using broad-spectrum herbicides on conventional crops would kill the crop itself as well as the weeds.

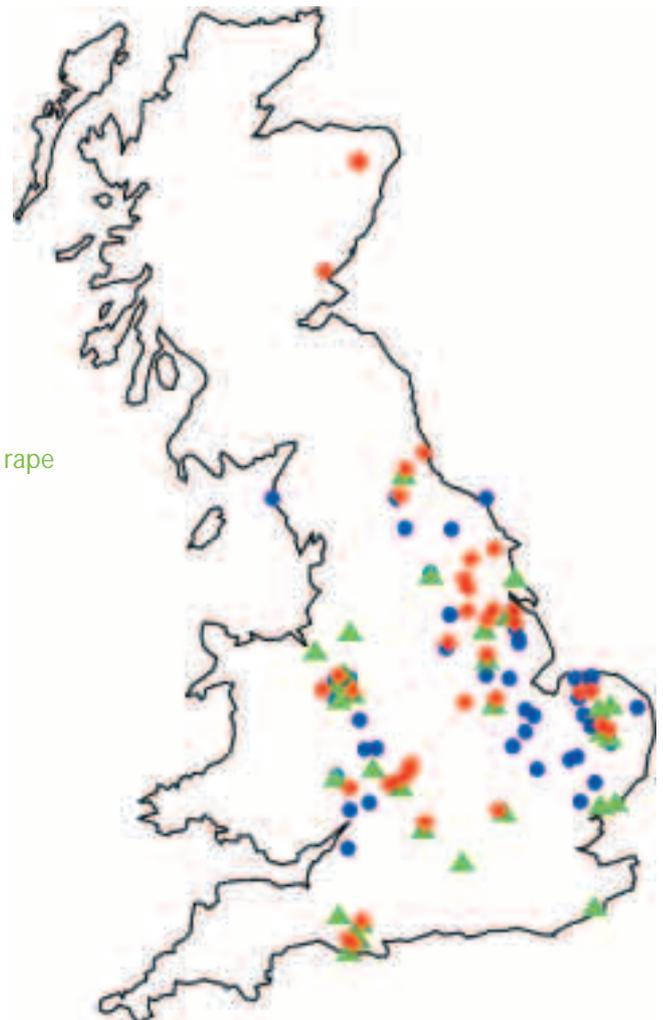
In contrast, a conventional herbicide may kill only a few types of weeds. This makes life harder for farmers because they usually have to use more than one herbicide to protect a crop. What's more, they may be restricted to certain herbicides depending on the crops they want to grow. For example, farmers can't use some grass-killing herbicides on cereal crops because cereals are types of grass.

Herbicide-tolerant crops may be good news for the farmer, but environmentalists and conservationists felt that it might not be such good news for wildlife. Weeds, wildflowers and other plants in and around cropped fields are essential for insects and birds because they provide food and cover. If the herbicides used with these GM crops were too good at eliminating these weeds, the fear was that wildlife would suffer.

There are already worrying trends in this direction. Since the 1960s in the UK, 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 numbers of weeds fall in and around cropped fields, populations of a wide range of animal species, including bumble bees, grey partridges and corn buntings, are losing their food sources and habitats.

Trial sites

- Beet
- ◆ Spring oilseed rape
- ▲ Maize



The UK is miles ahead of other countries in studying the impact of GM crops on biodiversity. We are setting standards for the world to follow.

Les Firbank
Research Consortium Coordinator

What was the scientific scope of this study?

These trials were the largest and most thorough of their kind in the world. As never before, they have allowed researchers to observe how changing farm practices are affecting wildlife across the country.

The study set out to see if growing GMHT crops affected the abundance and diversity of farmland wildlife compared with growing conventional crops. Organised on an unprecedented scale, it cost the government around £5 million and lasted four years. The study was overseen by a Scientific Steering Committee composed of independent members drawn from the research and conservation communities. It involved 273 trial fields around England, Wales and Scotland. The sites that finally provided data for the study comprised 68 fields of maize, 67 fields of spring rape and 66 fields of beet (40 of sugar beet and 26 of fodder beet). Studies on another crop, winter-sown oilseed rape, are still underway.

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 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 managed the crops themselves, deciding how and when to plough the fields; and how and when to apply herbicides, pesticides and fertilisers as they would normally, following environmental regulations and the agrochemical manufacturers' specifications. Farmers mostly managed each half-field in the same way, apart from the choice and timing of herbicide applications. However, under certain conditions, for example, when there were more insect pests on one half than on the other, they were allowed to treat the halves differently. In practice, this happened rarely.

Were the trials fair?

Farmers in the trials knew which half-field was sown with GM crops and which was sown with conventional crops. They had to know so they could apply the correct herbicides properly. They were given some flexibility so they could apply more or less herbicide depending on weed levels. However, this flexibility brought a risk of bias. Could farmers have changed their crop management to favour one treatment in some way?

The scientific team is confident that the farmers were not biased. They monitored all advice given to the farmers, and audited the farmers' written records of crop management procedures. In particular, they checked that the farmers weren't using too much or too little herbicide compared with standard practices. Subsequent audits of the herbicides, and the rates and timings of applications showed that they compared well with current practice for both GMHT and conventional crops.

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 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

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 any departures from usual 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. For example, fields with GMHT and conventional spring oilseed rape were usually grown in fields that had contained cereal crops for the two preceding years. The intention was to replicate the normal way farmers would grow and manage conventional and GMHT 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.

What did the researchers investigate?

The researchers monitored plants and animals in the fields, and around the ploughed edges of the fields, called the field margins. This was done before, during and after the crops were grown and harvested. To collect all the necessary data, they visited each field between 15 and 20 times a year. After harvest, the GM crops were either buried in landfill, or, in the case of maize, ploughed into the ground of a nearby field.

The researchers looked at how weeds - both grasses and broad-leaved weeds - grew in and around the crops. Others studied the number of weeds in a certain area (plant density). They also calculated the weight of the dried weeds (biomass). This gives a good measure of the quantity of foliage, flowers and stems that were above ground and available for animals to eat, as well as how many seeds the weeds produced: generally, the greater the biomass of weeds, the more seeds they will produce.

Another useful measurement was the number of seeds that fell from the weeds on to the soil surface. Measures of this

'seed rain' allow researchers to predict whether the weeds would reproduce well and how many seeds would be available for insects and birds to eat. This is particularly important because populations of several species of farmland birds, which rely on weed seeds to eat in autumn and winter, have been declining in recent years. To assess if the herbicides affected the weeds' ability to grow again the next year, the researchers looked at the numbers of seeds left in the soil after harvest (the seedbank) and in the two following years. This store of seeds provides the weeds of the future. The team also measured the numbers of weeds emerging in the same field in the two following years.

The researchers monitored the numbers of insects in and around the crops, including butterflies, bees, ground beetles, springtails, true bugs, as well as spiders. (Here 'insects' includes spiders, although spiders are not scientifically classified as insects.) The teams did not study mammals or birds, as these require much larger areas of crop for assessment.

Fat Hen: a case study



For this study, the researchers looked at many weeds and wildflowers, including a common weed called fat hen (*Chenopodium album*) which is found in many arable fields and gardens. Fat hen is important for wildlife because it provides food for seed-eating birds and a variety of insects, but numbers in farmland fields have been falling in recent years.

Fat hen fared best in the fields of conventional beet and oilseed rape crops. By the end of the growing season, there were fewer fat hen plants in the GMHT beet crop, and their biomass was ten times lower than in the conventional crop. Biomass is the weight of the dried weeds. A lower figure means the weeds had smaller quantities of foliage, flowers and stems above ground.

It was a similar story in the spring oilseed rape. There were fewer fat hen plants growing in the GM fields and biomass was nearly ten times lower.

The results were reversed for the maize crops. Few weeds survived in the fields of conventional maize where most farmers applied persistent herbicides early in the season. There were more weeds in the GM crop where farmers used broad-spectrum herbicides later in the season.

Spring-sown crops like beet and oilseed rape are important for weeds like fat hen 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. This store of seeds can then grow into the following season's weeds.

The researchers fear that that over several rotations seed stores of GMHT beet and maize could be severely depleted. Growing some GM crops without careful management could speed up the decline of this weed so that eventually it may become so scarce that it will no longer be a source of food and shelter for wildlife.

What did they find and why?

The researchers confirmed that the more weeds there are in a field, the more insects there are. The fields sown with conventional spring rape were the richest in plant and animal life. There were relatively more weeds and seeds in these fields, and bees and butterflies were more abundant, than in the GMHT spring rape fields.

In the GMHT spring rape and beet fields, there were fewer weeds and seeds than in the conventional spring rape and beet fields. There were 60% fewer weed seeds in GMHT beet fields and 80% fewer weed seeds in GMHT spring rape fields. However, the researchers can't be certain yet if these effects on seed stores persisted into the second year after harvest.

Bees and butterflies were less abundant in the GMHT beet crops than in the conventional beet because there were fewer nectar-providing weeds in the crop edges where bees and butterflies usually forage. One type of beetle that feeds on weed seeds was also less common in the GMHT spring rape and beet crops than in the conventional spring rape and beet as there were fewer seeds to eat.

However, there were some species, such as springtails and one type of ground beetle, that were more abundant in all the GM fields in the summer compared with their conventional equivalents. Springtails live in the soil and feed on decaying and dead weeds. The GM herbicides were used later in the season so the weeds were larger when they were killed, giving the springtails more to eat. The beetle probably did well because it feeds off springtails.

The fields sown with conventional maize were the poorest in plant and animal life. There were relatively more weeds, seeds (including those used by birds) and insects in the fields of GMHT maize.

The researchers believe the differences in results between GM and conventional crops are due solely to the different ways the farmers managed the conventional and GM crops. In almost half of the conventional crops, farmers applied specific herbicides to the field before either the crop or any weed had emerged. These 'pre-emergence' herbicides are designed to stay working in the soil for

longer and to prevent weed seeds from germinating. In nearly all conventional crop fields, the farmers then applied other herbicides after the weeds had emerged, but while they were still small. In contrast, farmers were able to leave weeds to grow around the GM crops before spraying later in the season because the broad-spectrum herbicides would kill most of the weeds even when they were quite large.

This strategy explains why conventional maize fields had the fewest plants and animals. Most maize farmers used atrazine, a powerful and persistent herbicide, before or just after weeds started to grow. The result was very few weeds, proving unattractive foraging grounds for most insects from very early in the crop's growth. By comparison, weeds were more abundant in GMHT maize fields because the GM herbicide was not applied until much later, allowing weed seeds to germinate and develop.

The researchers think that conventional beet and spring rape fields were richer in wildlife than their GM counterparts because the broad-spectrum herbicides used on these GM crops were more effective on weeds than the specific herbicides used on the conventional crops. The pre-emergence herbicides used on beet and spring rape are not as effective as atrazine at preventing weed seeds from germinating so the effect seen in conventional maize was not seen with conventional beet and spring rape.

The study's results were consistent from year to year, and from area to area. This suggests that how farmers manage their fields will have more influence on animals and plants than environmental factors, such as soil type or weather. What's more, the success of some species depends strongly on others, for example insects will thrive if there are more weeds to feed from.

However, the researchers believe that the differences in wildlife between the GM and the conventional crops could be similar to those found if a farmer changed from growing one crop to another. These effects could have been happening with changes in growing practices anyway, but researchers have not looked for them before.

The actual effects of the GM cropping on biodiversity were remarkably consistent for each crop, even though the individual field sites showed a wide range of species and abundance, geographic location and crop management.

Les Firbank
Research Consortium Coordinator

What are the likely effects on farmland wildlife if GMHT crops were grown commercially in future?

There are several implications for wildlife, assuming that the trends observed in these trials continued in any large-scale farming and farmers used present herbicide regimes.

1. Growing GMHT beet and spring rape on a large-scale may disadvantage wildlife, particularly farmland birds, bees and butterflies. Fewer weeds may mean substantially fewer seeds important in the diets of some birds, especially breeding and wintering birds. Fewer flowering weeds also mean less nectar for bees and butterflies, especially in the GMHT spring rape fields.

2. Growing GMHT beet and spring rape on a large-scale may exacerbate long-term declines of flowering weeds, including those that are important food resources for seed-eating birds. Fewer fallen seeds and lower numbers of seeds left in the soil after harvest could influence future weed populations. At present, the researchers don't yet have enough data to know if these differences persist over several years, but they believe that they will

persist. If seedbanks did diminish, this would exacerbate the decline of some weeds, as well as making life harder for the birds and insects that feed off weeds and their seeds.

3. Growing GM rather than conventional maize on a large-scale may increase the abundance of flowering weeds. These weeds produced twice as many seeds in GM crops as in conventional crops, but surprisingly, there is little evidence to show that the size of the seedbank was affected.

4. 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.

5. Populations of springtails and their predators, such as beetles and spiders, might flourish in the short- to medium-term under cropping of GMHT beet and



GMHT spring rape. However, researchers speculate that this effect may be short-lived as, gradually, there could be fewer weeds left for the herbicide to kill, reducing the supply of rotting weeds for springtails to eat.

6. The extent of all these effects would depend upon when the farmers cultivated the fields and how they managed the yearly rotations of crops in the fields. Beet and spring rape are grown once every three or four years in rotation with cereal crops. Researchers would need to investigate further if growing GM crops in such rotations would produce any long-term changes in weed levels. If they found this to be the case, the consequences would be substantial because of the relatively large areas of land that might be involved.

7. The location and size of the cropped areas would also influence the significance of any differences between GM and conventional crops, if GM crops were grown commercially. For example, growing GMHT beet over a small area

may not affect insects and birds greatly if there are other areas close by, such as set-aside land, where they could find food and cover. But the negative impact on animal life would be more substantial if these crops were grown over large areas and in a region where there were few alternative supplies of food and habitats. When it comes to growing GMHT maize, the beneficial effects for animals may be high in certain areas if they are particularly dependent on arable crops and maize is grown over a substantial number of acres.

8. The UK researchers have demonstrated the best ways of assessing effects on biodiversity and set new standards for this type of research. These standards will prove invaluable for continuing research into biodiversity and will help researchers from other countries to assess the impact of growing GM crops in their own countries. Under new European Union regulations, companies wanting to market GM crops in future will have to fully assess the indirect effects of managing GM crops on biodiversity.

We are confident that our findings would represent what would actually happen under large-scale growing, unless the management regimes altered. For example, if changes in regulations meant that atrazine was banned on maize crops, or farmers were given incentives to delay herbicide applications to GM beet.

Les Firbank
Research Consortium Coordinator



What do the results of these trials mean for... ..bumble bees?

Bumble bees travel long distances to feed, seeking out nectar and pollen from crops, weeds and other wild plants. Bees are very good at moving pollen from flower to flower, playing a vital role in the reproduction of many species of plant. These plants need pollen from other plants to produce seed and healthy fruit.

Bumble bees thrive in areas where there are weeds, for example, around grassland and uncultivated areas of farmland. In arable fields, they are particularly attracted to the field boundaries, such as hedgerows, and the field margins, where there are more varieties and greater numbers of weeds.

As expected, this study found that numbers of bumble bees are generally low in arable fields, regardless of conventional or GM crop type. The numbers were so low that the researchers were often comparing counts of only two or three bees per field. The exception was the spring rape fields, where the flowering crops attracted much higher numbers.

The field margins are vital for bumble bees to forage for food in beet and maize fields, regardless of whether they are GM or conventional crops. The trials found more bumble bees feeding on weeds growing in margins of the beet and maize fields than in the fields themselves. There were no differences in the numbers of bumble bees on margins of conventional or GM crops, for beet, maize or spring rape.

But weeds in the margins may not be enough to allow a healthy bee population to flourish. Because cropped areas take up much more land than uncropped margins, weed populations in the cropped areas can be very useful to bees and may be very significant in helping these species survive.

Bumble bee numbers are unlikely to be affected by a lack of weeds in any one year because they will search elsewhere for food. But using GMHT beet and rape over many years and over large areas of arable land could have an impact by seriously depleting weed populations within fields, unless managed carefully. In landscapes where nectar resources are very meagre, such as in beet growing areas, any reduction in the long-term could exacerbate the current decline in bumble bee populations in the UK.

However, it looks likely that bumble bees will be more affected by the proportion of farmland growing different crops than whether fields contain conventional or GM crops. For example, large expanses of oilseed rape, which have copious nectar and pollen when in flower, will have a greater impact on bee numbers. These trials found at least five times as many bumble bees in the fields of spring rape crops (both GMHT and conventional) than in the beet or maize crops, which had very low numbers.



...a common butterfly?

The small tortoiseshell butterfly (*Aglais urticae*) is a common sight in the countryside. It is usually found around lots of flowering plants or stinging nettles, often near the edges of fields. The butterfly feeds off nectar in flowers on crops and weeds, and lays its eggs on nettles, which provide food for the caterpillars when they hatch.

These trials have found that growing GMHT spring rape and beet crops mean fewer weeds in the fields. Probably as a result, butterfly numbers were significantly lower around these field margins. However, it's unclear if this would have any long-term impact on the small tortoiseshell. Although there may be fewer flowering weeds, the highly mobile butterflies can fly on until they find the plants they need elsewhere. But the researchers point out that if weed populations decline over large areas over several years, the effects on butterflies' resources of nectar may become more important.

The scientific teams recorded the greatest numbers of the small tortoiseshell in July. At this time of year, the butterfly numbers in the

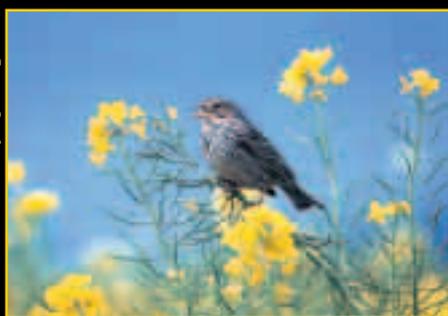
field margins of GMHT beet were almost a third lower than those in the conventional crop field margins. Numbers in the margins of GM spring rape fields were around a half of those found in the conventional crop fields margins. There was little difference in numbers between GM and conventional maize field margins in July.

The researchers also observed fewer flowers in the field margins of GMHT beet and spring rape during July, particularly within the area immediately adjacent to the crop. This 'tilled margin' is ploughed but not sown with crop and separates the crop from the field verge and outer boundary of the field, such as the hedgerow.

In fact, researchers believe that climate change may be a greater threat to the small tortoiseshell than a declining weed population, such as may happen if GM crops were grown extensively. Summer droughts damage the caterpillar's food plant, which reduces the butterfly's chances of survival.

...farmland birds?

Gerald Downey rspb-images.com



Numbers of many species of birds that live around farmed land, such as the skylark, corn bunting and grey partridge, have declined over the last three decades. As agriculture has intensified, there are fewer places for these birds to nest

and dwindling supplies of seeds and insects to eat.

These trials did not examine the direct effect on birds but their results can be used to indicate the likely impact of GM cropping on birds. For GMHT beet and spring rape, seed rain from broad-leaved weeds was reduced by 70% and 80%, respectively. Researchers know that some seed-eating farmland birds rely heavily on weed seeds for

their survival, especially over the winter. Consequently, they would probably suffer from a marked reduction in weed seeds.

In addition, for GMHT spring rape, the reduction in seed rain meant that while the seedbank doubled following conventional crops, it did not increase at all following GM crops. This suggests that GMHT spring rape cropping may exacerbate long-term declines in plants, some of which will be important in the diets of farmland birds.

The results from GMHT maize were quite different, with twice as much seed rain on the GM halves of the fields. This increased food resource may well be of benefit to seed-eating birds as maize tends to be grown in areas where there are few types of crops grown, so weed seeds tend to be scarce.

Some researchers had thought that GM cropping could help nesting birds because the broad spectrum herbicides are sprayed late, thus allowing weeds to live for longer, and providing birds with more insect food to rear their chicks during the breeding season. However, in this study there was no evidence that any of the GM crop fields recorded more insects during this period.

...a beetle?

Richard Revels rspb-images.com



Many species of ground beetle live in arable fields. Most of them can eat crop pests, such as slugs, and some can also climb weeds and feed on their seeds. As well as helping to control weeds and pests, these ground beetles are important

because they provide food for wildlife such as hedgehogs, shrews and farmland birds.

One species of seed-eating ground beetle, *Harpalus rufipes*, is very common in arable fields all over the UK. The study found that

large numbers of this species occurred when weed and seed numbers were highest. The beetle flourished in conventional spring rape and beet crops later in the season when weeds were producing lots of seeds. It did less well in the GM equivalents because there were fewer weeds and seeds. However, the researchers observed more beetles in GM, rather than conventional, maize crops.

So how would this beetle be affected if GM crops were grown commercially on a large-scale? The beetle is resourceful and able to move around exploiting different crops and areas of farmland. If areas of the countryside were set-aside to allow weeds to grow freely, or GM crops were a limited part of a patchwork of other crops, researchers believe the impact on populations of this beetle would probably be nothing to worry about. However, if GM crops were grown more extensively than conventional crops, the effect on populations over a number of years could be significant. This could be good for the beetle, in the case of GMHT maize, or not so good in the case of GMHT spring rape and beet.

Detailed results

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. Around 10,000 hectares of fodder beet are grown as food for livestock. It is grown particularly in western England, East Anglia and some parts of the north. The trials looked at both sugar and fodder beet.

Results

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 herbicides on the conventional halves of the field. However, applying *Roundup* 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. However, the researchers are collecting more data, which should produce some more conclusive evidence about the long-term trends in weed seedbanks.

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.

Implications

Applying broad-spectrum herbicides to GMHT beet reduces weeds, seeds and certain insects. Although the numbers of broad-leaved weeds were similar between field halves, the plants were smaller and less leafy in the GM crops, and there were 60% fewer seeds. In addition, there were fewer insects in the GM crop in August than there were in the conventional crop. This would not be good news for nature conservation, particularly because farmland birds may struggle to find as much to eat in the GM fields later in the year than they find in the conventional fields.

Growing GMHT beet is likely to affect the populations of weeds in the long-term as seed stores will shrink. The researchers think that weed seed reserves are unlikely to recover, even during cultivation of conventional crops in rotation with GM crops.

However, GMHT beet might provide some benefits to the environment. Populations of springtails and some of their predators may flourish, at least in the short-term, compared with those found in fields treated with conventional herbicides.

Some researchers had thought that GMHT beet cropping might help nesting birds but this was not the case in this study. The theory was that the weeds that grow before herbicide application would provide birds with more insect food to rear their chicks in during the breeding season in May and June. However, in this study there was no evidence of more insects during this period. It may be that these potential benefits would only be observed if the herbicides were applied differently, for example, if farmers sprayed even later in the season, but this would reduce the crop yield.



Detailed results

GMHT Spring oilseed rape

Spring-sown oilseed rape is grown in many regions of the UK, but is particularly popular in the north of the country because it will grow in cool, damp weather. In any one year, spring rape can cover 60,000 hectares.

Results

Like the beet, the farmers treated almost half of the conventional spring rape crop with pre-emergence herbicides in March so weed density was, on average, higher in the GM fields until farmers applied *Liberty*. Then, weed density fell drastically, particularly of broad-leaved plants. This is probably because the herbicide 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% lower biomass in the GM crops. Seed rain was also lower, with 80% 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. Like in the

beet fields, 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 was also more frequent in the conventional beet fields because there were more seeds for them to eat.

Implications

Applying broad-spectrum herbicide to GMHT spring rape reduces weeds, seeds and some insects. As butterfly numbers were lower in GM fields, the findings suggest that growing conventional rather than GMHT spring rape may be important for butterflies in regions where there are not many suitable flowers in the field margins and hedgerows. These crops may also have a valuable role in replenishing the stocks of weed seeds that may be an important food resource for animals.

Farmland birds may struggle to find as much to eat in the GM fields later in the season than they find in the conventional fields. They would probably find similar numbers of insects to feed on in both fields but may well find fewer seeds in the GM fields. Weeds including those used by birds for food were smaller and less leafy in the GM fields because they had germinated after the herbicides had been applied. Flowering and seed-producing plants were also fewer in the tilled margins of GM crops than in the margins of the conventional crops.

Of all the crops, growing GMHT spring rape produced the strongest effects on weeds. The researchers aren't sure yet whether these differences in weed numbers will persist after several years of cropping with cereals, but they think that they will result in more rapid declines in broad-leaved weeds, in particular.

Growing GMHT spring rape might provide some benefits to the environment. Populations of springtails and some of their predators may flourish, at least in the short-term, compared with those found in fields treated with conventional herbicides.

GM cropping may also encourage farmers to do less ploughing. Turning over the soil is a way to control weeds, but it is not particularly environmentally friendly. It kills animals that live in the soil and buries weed seeds keeping them out of the reach of insects and birds. If the farmer knows he can kill weeds effectively anyway with the broad-spectrum herbicide, he has less need to plough.

Detailed results

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 spring rape, can be grown continuously in the same field.

Results

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 in August there were 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; and fewer spiders in the GM crop margins.

Implications

Growing GMHT maize would be an option for farmers wanting to replace more intensive and persistent herbicides, such as atrazine. For wildlife, this would be good news. Even though there weren't large numbers of weeds growing in the GMHT maize fields compared with GMHT beet and spring rape, there were more than in the conventional maize fields.

More weeds and seeds were produced in the GM fields suggesting that birds looking for food over the autumn and winter might well benefit, as well as small mammals such as mice, that feed on weed seeds. This might be important because maize is often grown in areas where there are few other arable crops.



Glossary

ACRE

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)

Researchers have manipulated the DNA of a crop to produce a certain effect, such as making it resistant to a particular insect or herbicide.

Herbicide

A chemical that kills plants like weeds, wildflowers or grasses. Many herbicides only kill a few kinds of plants.

Herbicide-tolerant crop, or GMHT

A crop that has been genetically modified to be resistant to a particular herbicide.

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.

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