Monarch Butterflies: If GM Bt doesn't get them, Roundup will

25 June 2013

Introduction

For many years scientists and others debatee whether or not pollen from GM Bt maize harms Monarch butterfly (*Danaus plexippus*) larvae as they feed on Milkweed (genus *Asclepias*) growing in and near GM crops. Studies now show that the threat to the Monarch from GM crops may be more serious. The use of the herbicide Roundup (active ingredient glyphosate) on Roundup Ready (RR) GM maize and soya has reduced the number of Milkweeds plants in fields, and the overall population of this iconic species has declined as a result.

This briefing looks at the evidence for the threats both to Monarch feed and habitat, and the current state of Monarch populations.

Monarch butterflies

Monarch butterflies are resident in North America and are strongly migratory. They are not a native species in Europe, but they sometimes appear as a rare passage migrant and have established small populations in southern Spain and some Atlantic islands as result of trans-Atlantic migrations. Monarchs are large compared to UK butterfly species (9-10 centimetre wingspan compared with the Peacock, *Inachis Io*, at 2.7-2.9 centimetre). The Monarch is an iconic species, so much so that seven US States have adopted the species as their "State butterfly".[1]

There are three distinct populations of Monarchs: Western, Eastern and Mexican residents.[2] The Western population migrates from British Columbia, Washington and Oregon to winter on coastal sites in California. The Eastern population breeds in Southeastern Canada, Eastern and Midwest US down to Texas and then overwinters in less than 20 hectares of the Oyamel forests in central Mexico (a journey of up to 2500 kilometres) – a site that was only found in 1975.[3] At this Winter hibernation sites in the forest the densities of adult butterflies can vary from 7 to 60 million per hectare.[4] The area of forest occupied by the hibernating adults has been used to estimate the overall population since 1976.

Monarch populations are also monitored throughout the breeding range by counting eggs, larvae, and an annual adult count takes place each 4 July using volunteers in the key States. A number of surveys of adults on migration in Canada, the US and Mexico also take place, for example the Autumn Southerly migration of the Eastern population is monitored every year on Lake Michigan.[5] In all there are seven programmes annually monitoring adult and larval Monarch populations.

Starting off just over the Mexican border the Eastern population flies North and East in the Spring and produces successive generations of offspring as it moves through the US into Eastern Canada.[6] A minority of adults reaching the Northern limits of the Monarch's range in Canada migrate the full distance before breeding, but 90% rely on successive broods to make the journey in stages.[7] In August adults stop reproducing and begin migrating back to their Wintering grounds. Stable isotope analysis estimates that half the overwintering adults in Mexico in 1997 came from the Midwest States, where 80% of US soya and corn crops were grown.[8]

The Western population (separated from the Eastern population by the Rocky Mountains) is monitored annually by the California State authorities in a two-week period around Thanksgiving (in November).[9]

Milkweed

Monarch larvae mainly feed on Milkweed, and a study in the early 1990s of overwintering adults in Mexico estimated that 92% of them had fed on the Common Milkweed *(Asclepias syriaca)* as larvae.[10] More recent research shows a significant positive correlation between Monarch egg production in the US Midwest on Milkweed and the overwintering population in Mexico.[11]

Common Milkweed (*Asclepias syriaca)* colonises disturbed soils and is found in agricultural fields and on roadsides. It has an extensive root system that can extend thousands of metres. It is pollinated by insects and produces fluffy seeds spread by the wind. It is considered a problem weed by farmers and gardeners. Other Milkweed species are also food plants for Monarch larvae, with 115 species found in North America and the Caribbean[12] in many habitats, including grassland and wetlands.

Milkweed produces a white sap that contains Cardiac glycosides, which are toxic to vertebrates. Monarch larvae and adults consuming milkweed are not affected by the toxin and are able to use it to protect themselves from predators, which learn that they taste unpleasant and are toxic, so avoid them.[13]

Monarch population trends

Data on Monarch populations dates back to the late 1970s, so long-term trends over more than 30 years can be observed.

Eastern populations in Mexico are in a 15 year decline from 1996/97 to 2010/11,[14] with 2009/10 being the all-time low due to very severe weather. In 2011 Brower, et al, observed, "All of the past seven years have been below the 17-year average. We have analysed these data and found that the decline is statistically significant."[15]

The Western population appears more stable, although subject to periodic declines. In 2003 at one overwintering site the population fell to a low of 10,000 after a five-year decline. It made a seven-fold recovery the following year only to fall back to 45,000 in 2005 and recover again to 60,000 in 2006.[16]

Factors influencing Monarch populations

Several factors have been put forward as contributing to a possible reduction in Monarch populations:

- Illegal destruction of forests in Mexican hibernation grounds.
- Extreme weather conditions, especially in Spring and Summer 2009 due to abnormally cold conditions in Texas and the Midwest corn belt and at the hibernation sites in January-February 2010.
- Reduction in milkweed populations in the Midwest.
- Exposure of Monarch larvae to Bt toxins in pollen from GM Bt maize falling on Milkweed leaves.
- Urban development destroying habitat where Milkweed is found.

There is serious concern that a substantially reduced population of Monarchs will become far more likely to suffer collapses during extreme weather events at overwintering sites, along migration routes and at different lifecycle stages.[17]

Monarch populations in the Midwest soya and maize belt have been monitored a number of ways in the past, so using these data and more recent surveying it has been possible to assess the impact of changes in Milkweed abundance on adult populations. Similar historical data enables comparison of Milkweed populations.

In the 1970s and 1980s 10.5 million hectares of farmland had Milkweed in North Central States,[18] and the herbicide regime used then only gave partial control, so there were plenty of plants available for Monarch females to use to lay their eggs.

Aassessing the potential Monarch population in the Midwest requires data on Milkweed density in and out of agricultural fields, as well as data on the numbers of eggs and larvae found on each plant. Data on the number of eggs per plant is used to assess the potential Monarch population. Counts of adults and larvae are affected by many factors, such as predation and weather, and are not dependent on the availability of host plants. A survey in Iowa maize and soya fields showed a dramatic declined in the numbers of fields containing, and numbers of, milkweed in a decade when RR crops were cultivated:

> "An initial survey conducted in 1999 found that low densities of Common Milkweed occurred in approximately 50% of Iowa corn and soybean fields. In 2009 Common Milkweed was present in only 8% of surveyed fields, and the area within infested fields occupied by Common Milkweed was reduced by approximately 90% compared to 1999. The widespread adoption of glyphosate resistant corn and soybean cultivars and the reliance on post-emergence applications of glyphosate for weed control in crop fields likely has contributed to the decline in common milkweed in agricultural fields."[19]

An extensive study of Milkweed populations and the presence of Monarch eggs on the plants, plus analysis of historical data, has highlighted the importance of Milkweed in soya and corn fields as compared to other habitats before the introduction of RR maize and soya, "Egg densities on milkweeds in agricultural fields were significantly higher than on milkweeds in non-agricultural habitats in each year by an average factor of 3.89."[20]

The results of modelling based on field data of Milkweed density reveal that "milkweed numbers on the Iowa landscape… show that milkweeds declined in both agricultural fields and non-agricultural habitats from 1999 to 2010."[21] The decline on non-agricultural land in this period was 31%, compared to 81% in agricultural fields (58% overall). There has also been a decline in the relative importance of agricultural land Milkweeds to the total population during this period from 53% in 1999 to just 24% in 2010. If the intrinsically higher populations in fields is factored in, the decline is 72% during this period, and more than 90% of the loss can be attributed to reductions on agricultural fields rather than other land. Fewer Milkweeds present in fields also affects the egg laying efficiency of Monarch adult females because of the greater distance between plants.

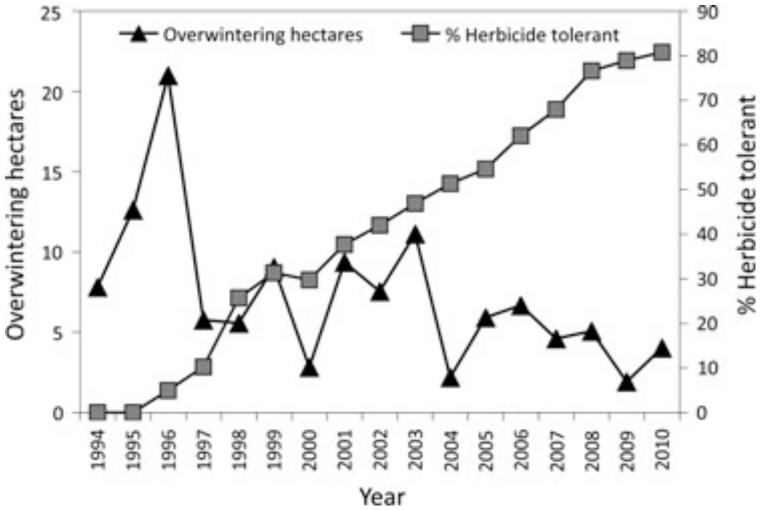
This has all impacted on the importance of agricultural land in producing new Monarchs, "The relative contribution of agricultural milkweeds to total monarch production went from 82% in 1999 to 55% in 2010."[22] The researchers on this project estimated that Monarch egg production in the Midwest declined by 81%. Egg laying on Milkweed in non-agricultural land has not increased to compensate for the reduced potential from agricultural land. The numbers of Monarch eggs in the Midwest correlate well with the overwintering population in Mexico.[23]

Researchers point to the introduction of RR soya in the Midwest in 1996 and RR maize in 1998 as critical factors in the decline of Milkweed and Monarch populations. One survey of Milkweed on agricultural land prior to RR crops being adopted on the farm was repeated after the GM crops were taken up from 2001, and a decline from 0.26 plants per square metre to zero was recorded.[24]

The relative importance of Milkweed decline to the variation in overwintering adults is put at 47%[25] Other factors include:

- The number of eggs surviving to adulthood
- A fluctuating contribution to the number of new adults from the Midwest each year
- Mortality of adults on migration
- Possible differences between Iowa Monarch and Milkweed data compared to other Midwest States

However the loss of potential breeding habitat in the Midwest due to the advent of RR crops and extensive use of Roundup, and subsequent reduction of Milkweed in fields, has been put at more than 100 million acres,[26] and the percentage of RR crops correlates closely with the decline in overwintering area in Mexico (see figure below[27]).



Bt maize and Monarch butterflies

Bt crops are genetically modified to produce toxic proteins throughout the plant designed to target specific pests. There are several types of Bt proteins, which were originally found in a soil bacterium (*Bacterium tumafaciens*). Different Bt proteins are either toxic to butterfly/moth larvae or beetle larvae. The toxic proteins work by destroying the larvae's midgut wall allowing the gut content to escape and to poison it. Other pest, such as aphids, are unaffected by the Bt gene and may still require chemical insecticide controls if present in high numbers on crops.

The GM Bt plant produces its own pesticide continuously, regardless of whether the target pest is present or not. However the production of the toxin is not always constant throughout the plant and can vary at different stages of the growing cycle. This was the case with early versions of Bt cotton.[28] GM plants failing to achieve sufficiently high levels of expression of the toxin in areas where the pest feeds (eg, leaves) increases the risk that the target insect pests will develop resistance to the toxin. Resistance to Bt toxins has been confirmed in GM cotton and maize in five places around the world.[29]

In 1999 researchers expressed that Bt maize pollen could be deposited on the leaves of Milkweed in and on the margins of fields and then be ingested by Monarch butterfly larvae feeding on the plant causing harm. Laboratory experiments confirmed this possibility.[30] For this to be repeated under field conditions several factors influencing toxicity are noted:

- The presence of the Bt toxin in the pollen needs to be sufficiently high to cause harm to the Monarch larvae.
- Sufficient pollen needs to be accumulated on the surface of Milkweed leaves preferred by larvae to deliver a high enough dose of toxin.
- Weather conditions (eg, rainfall can wash pollen off leaves).
- The production of the pollen needs to coincide with a period when larvae are actively feeding on Milkweed.
- The stage in the lifecycle at which larvae are exposed to Bt pollen (eg, early instars are more susceptible).
- The level of adoption of different Bt maize varieties could also have bearing on the overall impact on Monarch larvae numbers.

Following the initial research tests were carried out on various Bt crops. Pollen from Syngenta's GM maize Bt176 (containing the Cry 1Ab toxin) was confirmed as toxic to Monarch larvae, and it also produced sub-lethal effects in the Black Tailed Swallowtail butterfly larvae (*Papilio polyxenes).* This GM maize variety was abandoned in the early 2000s. Research involving other Bt traits with Cry1Ab toxin (Bt11 and MON810) found them to be less toxic than Bt176 because of lower levels of Bt expression in the pollen.

The overall conclusion of several studies is that the risk to Monarch larvae from Bt pollen in the field is low.[31] However all the studies reported on were published in the early 2000s, a time when only single-trait Bt maize varieties were being cultivated in the US. Since then there has be a tendency to "stack" multiple Bt traits in single GM crops (ie, newer GM varieties may contain two or more Bt genes coding for different toxins either to provide protection against more than one type of pest or as part of a strategy to slow the development of pest resistance).

Dow and Monsanto have now introduced SmartStax maize, which contains six Bt traits all coding for different Bt toxins targeting 13 maize pests.[32] The Bt toxins include three that are active against moth and butterfly larvae (Cry1A.105, Cry2Ab2, Cry3Bb1) that could potentially impact on Monarch larvae. According to the US Environmental Protection Agency it is "unlikely that direct or indirect harmful effects to non-target organisms" are caused by SmartStax maize and "no synergistic or antagonistic effects were observed in several combinations of the individual events". However it should be remembered that the data used to assess the safety of the individual proteins is supplied by the applicants, rather than independent scientists, and it excludes the impacts of sublethal effects from low-level exposure. SmartStax maize is also tolerant to the herbicides glyphosate and glufosinate ammonium, which means it has the potential to hit Monarch populations in two ways – by possible toxic effects of Bt on larvae and by killing off larval food plants in and around crops. The current trend is toward more stacked varieties in an attempt to slow resistance development in weeds and pests. Future RR crops may include herbicide tolerance genes of 2,4-D, dicamba and glufosinate ammonium[33] to allow farmers to control weeds resistant to glyphosate.

Conclusion

If the present use of GM RR and Bt crops continues or increases pressure on Monarch populations will grow either through further loss of Milkweed plants or possible sublethal or lethal effect of Bt maize pollen. The continued use of stacked RR and Bt genes will further diminish Milkweed numbers in fields leaving Monarch adults no option but to lay their eggs on plants in non-agricultural land, which ironically would reduce their exposure to the Bt toxins in SmartStax maize. The resulting smaller populations of Monarch would be far more vulnerable to steep declines due to severe weather or further loss of habitat in Mexico and the US. Human beings have the power to do something about this situation by changing agriculture practices and preventing forest destruction and further urban encroachment into habitats.

Sustainable alternatives to GM RR and Bt crops involve a move away from arable monocultures by diversifying crops and varieties, adopting longer rotations and managing the land to allow species that biologically control pests to flourish. In such systems Milkweed could form part of wildflower margins around fields to build populations of crop parasite predators near fields.

The European Union has yet to license any RR crops for cultivation, but 14 are in the application pipeline, including soy, maize, and sugarbeet. Although the Monarch does not live in the EU it is essential that lessons are learned from experience in the Americas. Many of our butterflies and moths are already forced to coexist with intensive arable production, and there is an overall decline in abundance and distribution in butterflies in the UK.[34] The picture is similar for larger moths, with "two thirds of 337 common and widespread" species having declined in the last 40 years.[35] The last thing the European farmland species need is RR crops with added Bt to increase potential risk.

Notes

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