Pests are easier to combat in habitats rich in species

April 1 2015

In habitats rich in different species, pests don't become resistant to chemical control agents as quickly. Credit: André Künzelmann, UFZ

A diverse and species-rich agricultural landscape is also beneficial to farmers. This isn't just because there are plenty of pollinating insects, creepy crawly pest controllers and other useful helpers. Scientists at the Helmholtz Centre for Environmental Research (UFZ) in Leipzig have come across another effect, which has thus far been unknown: in species-rich habitats, pests don't become resistant to chemical control measures so quickly, according to their publication in the scientific journal *Proceedings of the Royal Society B*.

Our opponents always seem to be one step ahead. Although pest controllers now have numerous chemical preparations available, allowing them to take action against unwanted insects, the species targeted are developing a resistance against the different active substances at a rapid pace. Often a single change in the organisms' genetic material is enough to do this. This means that scientists know more than 500 pests all over the world currently able to resist a total of 300 different insecticides. Many disease-transmitting mosquitoes defy any attempts to control them just as stubbornly as Colorado potato beetles and other agricultural pests.

On the other hand, other species that weren't being targeted actually suffered much more. Ultimately, pesticides don't just stay in one field, but end up in the bordering fields, woods and water. However, the insects living there develop much less resistance. "Over time, these species become two to four times more resistant to the pesticide used," stated Professor Matthias Liess, Head of the Department for System Ecotoxicology at the UFZ. Pests, on the other hand, manage to become between ten and a thousand times more resistant.

The researchers wanted to find out how this discrepancy comes about. "This is of interest from an agricultural point of view, as well as for nature conservation," emphasised Matthias Liess. That's because anybody that understands these processes better, has the possibility of slowing down the spread of resistance among our creepy crawly opponents. This wouldn't just enable us to combat them more effectively. It would also mean that less pesticides are required that are dangerous to other species.

So what makes pests of all things such adaptable survival artists? The researchers had their suspicions where that was concerned. It was typically the organisms that settled in new habitats and were able to multiply rapidly. Mass reproduction of pests in this way does, however, soon lead to intensive rivalry between the creatures. It's this rivalry that could encourage the development of resistance.

This is because pesticides don't just kill a proportion of the insects, but weaken those that survive as well. "That doesn't apply to resistant creatures though," explained biologist Jeremias Becker, "They now have the advantage over their weakened conspecifics and can take valuable resources away from them." That's why strong rivalry can mean that resistant pests supersede their susceptible conspecifics more quickly.

On the other hand, the situation is different for many insects, which live in the bordering fields or in the water, instead of in the crops themselves. They are part of a diverse community, in which they have other challenges to overcome too. Predators and rival species restrict multiplication and rivalry too as a result within one species. The creatures that are not resistant benefit from this according to the motto, "the enemy of my enemy is my friend." Therefore in a diverse community, resistant creatures can't play off their advantage over their susceptible conspecifics so well. "This means that the gap is constantly getting bigger," explained Matthias Liess. "The pests in the crops are becoming more and more resistant to pesticides, but their neighbours in the bordering fields and in the water aren't."

UFZ researchers have tested whether this theory is correct in laboratory trials using the mosquito species Culex quinquefasciatus. These relations to the common mosquito live in the tropics and subtropics and transmit diseases dangerous to humans and animals from avian malaria to the West Nile virus. "These creatures can be kept particularly well in the lab," explained Matthias Liess. "That's why they are often used as representatives for other mosquito species".

At the beginning of the trial, there were 400 larvae of these creatures swimming in the researcher's tanks at a time. Three-quarters of them contained the genetic material of one or even two copies of a pesticide resistance gene called ace-lR. The other quarter had to manage without this genetic information and were therefore not resistant. The individual populations were regularly treated with the insecticide Chlorpyrifos and also confronted with different living conditions. Four of them had to share their tanks with water fleas, which gave them competition and restricted the population growth. With four others, the researchers removed ten to twenty percent of the larvae twice a week, in order to simulate the influence of predators. The surviving mosquitoes in this population lived plentifully without having to grapple with other organisms. In the final four populations, the insects were allowed to multiply uninterrupted and soon faced intense rivalry. The researchers then observed how the frequency of resistance genes changed over six generations of mosquitoes – a process, biologists refer to as "microevolution".

As a result, the quickest transformation was experienced by the populations without predation and interspecific competition species. The proportion of mosquitoes with a resistance gene rose from 75 to 95 percent over the course of the trial. "In these populations, creatures only had to prevail against competition from their own ranks," explained Matthias Liess. Small differences in genetic material can bring crucial advantages, especially when resources are low. That's why rivalry among conspecifics accelerates microevolution. On the other hand, the situation looks very different when competing species like water fleas or predators such as researchers catching larvae come into play. In both cases, the resistance gene spread significantly more slowly in the populations under the influence of pesticide.

However, if there was no insecticide in the water, the same mechanisms ensured that the populations quickly lost their resistance gene again without enemy species. If they weren't confronted with the poisonous preparation at all, this genetic trait would ultimately bring them no benefits, only disadvantages, as resistance comes at a price. That means resistant creatures must invest in additional enzymes, for example, which are able to break down the pesticide. The energy they require for this is then lacking for other tasks. For example, it often leads to resistant creatures experiencing poorer growth. When there's stronger rivalry, only 40 instead of 75 percent percent of mosquitoes hold the resistance gene after six generations. However, water fleas and predators delayed this development too. Additional challenges like these really do seem to slow down microevolution.

The scientists anticipate that these effects constitute a fundamental principle and therefore apply to all habitats and species. "This could possibly result in new approaches towards pest control being deduced," said Matthias Liess. This means that the increase in biodiversity with competitors and predators of harmful organisms will reduce the development of resistance. If harmful organisms try to penetrate fields, they will therefore be easier to tackle using lower levels of pesticide. "Whether this will work in practice, however, must be investigated first," emphasised Matthias Liess. However, there is one thing he does not doubt: as well as bringing wide ecological advantages, species diversity also makes easier pest control.

More information: "Biotic interactions govern genetic adaptation to toxicants." *Proc. R. Soc. B* 20150071. rspb.royalsocietypublishing.or … nt/282/1806/20150071

Provided by Helmholtz Association of German Research Centres