Asian lady beetles use biological weapons against their European relatives

May 16 2013

During spring and fall, mass occurrences of the Asian lady beetle can often be observed. Credit: Andreas Vilcinskas, Justus Liebig University, Giessen, Germany

Once introduced for biological pest control, Asian lady beetle *Harmonia axyridis* populations have been increasing uncontrollably in the US and Europe since the turn of the millennium. The species has been proliferating rapidly in Germany; conservationists fear that the Asian lady beetle will out-compete native beetle species.

Scientists from the University of Giessen and the Max Planck Institute for Chemical Ecology in Jena, Germany, have now found the reason why this animal is so successful. Apart from a strongly antibiotic substance – a compound called harmonine – and antimicrobial peptides, its body fluid, the hemolymph, contains microsporidia. These tiny fungus-like protozoa parasitize body cells and can cause immense harm to their host. The Asian lady beetle is obviously resistant to these parasites in its own body. However, transferred to native species, microsporidia can be lethal.

The Asian lady beetle – a model organism for studying biological invasions

Because of its delicate, yet extremely variable, patterning, the lady beetle species *Harmonia axyridis* is sometimes called Harlequin ladybird. However, this insect has no comical characteristics. At the end of the last century, the species – which is native e.g. in China and Japan and therefore called Asian lady beetle – was successfully used in European greenhouses to keep aphid populations in check: It can devour hundreds of aphids per day, as well as many bug species or insect eggs. Yet today, this "bio killer" has escaped from the greenhouses and is spreading massively, but: A rapid and successful propagation of a neozoon – the biological term for a species which is invading new habitats and ecosystems – is not just an inevitable matter of course. In most cases, such a neozoon species doesn't survive or else its population density remains very low, because original and adapted life forms usually prevail

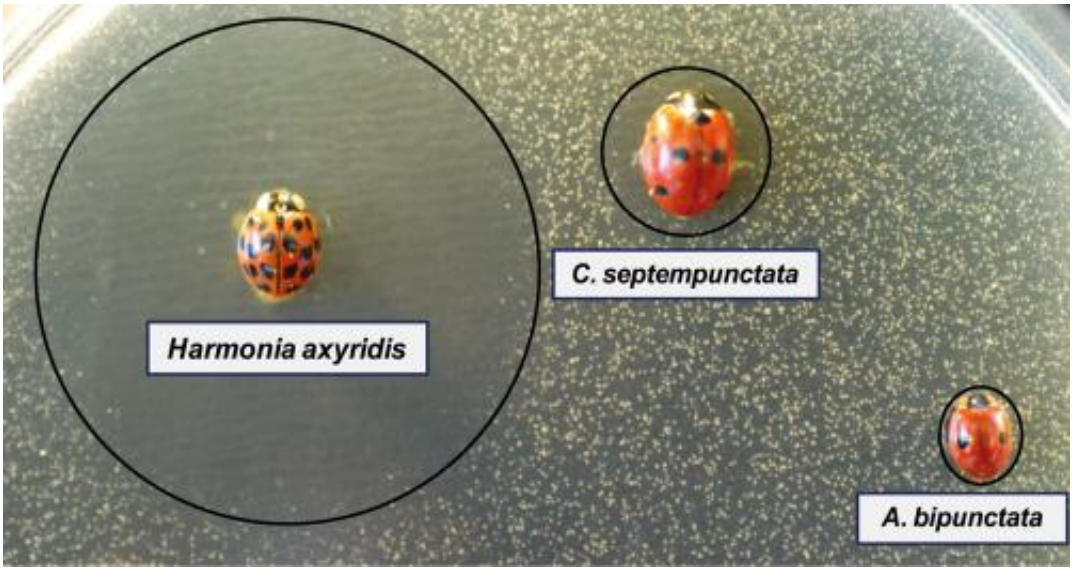
in their ecological niche and win interspecific competitions. However, as soon as *Harmonia axyridis* is released into nature, it invades all habitats, especially those occupied by beetle species that feed on aphids. Within a very short period of time, native beetles are out-competed and the intruders have taken over. During the fall, major congregations of Asian lady beetles can be observed as swarms of insects search for hibernation places in houses or other sheltered areas. They are not only a nuisance, they can also cause serious allergic reactions in humans. When prey becomes scarce, Asian lady beetles may feed on grapes as a substitute diet and hence, they are often found on grape-vines in vineyards in the fall. Once in the mash, the defensive chemical substances in their hemolymph negatively affect the taste of wine.

Like most ladybug species, the Asian lady beetle reflexively secretes fluid from its hemolymph as soon as it is attacked by potential enemies. Hemolymph fluid contains toxins and is therefore defensive. Can the Asian lady beetle's secret of success be found in the hemolymph?

Microsporidia, tiny parasites present in the hemolymph of *Harmonia axyridis*, are the key to successfully out-competing native species

In comparison to other ladybug species, the hemolymph of *H. axyridis* contains a wide range of different antibacterial peptides – small proteins that insects use to fend off pathogens. Andreas Vilcinskas, Justus Liebig University in Giessen, Germany, and Heiko Vogel, Max Planck Institute for Chemical Ecology in Jena, Germany, studied the complex immune system of the insects and were able to isolate the genes that encode the enormous antimicrobial repertoire of *H. axyridis*. The hemolymph also contains a special substance, harmonine, which has a strongly antibacterial effect. Harmonine is only found in the hemolymph of *H. axyridis*, where is it abundant. Both the proteins and harmonine are of interest in medical research where they offer promising targets for the

development of novel antibiotics, potentially even those against malaria.



A Petri dish has been inoculated with *E. coli* bacteria -- indicated by the white dots -- and shows the enormous antibacterial potential of *H. axyridis*. Whereas native species *Adalia bipunctata* and *Coccinella septempunctata* have not or hardly formed a bacteria-free areola, *H. axyridis* has killed all bacteria in its surroundings. Credit: Andreas Vilcinskas, Justus Liebig University, Giessen, Germany

When *H. axyridis* and its relative *Coccinella septempunctata*, which is native to Germany, are infected with pathogenic bacteria, both beetle species produce antibacterial peptides. However, the Asian lady beetle switches from a general hygiene using harmonine to an effective defense strategy based on dozens of peptides. "This alone, however, does not answer our main question: Is such a strong immune system, capable of fending off pathogens, the sole reason why *H. axyridis* is conquering the habitats of other beetle species all over the world? Can *Harmonia* out-compete other species just because it is more resistant to pathogens and, as a consequence, has a better chance to survive – or do other important

factors play a role?" asks Heiko Vogel.

Although lady beetles generally compete for their common food source, aphids, some beetles also eat each other. This phenomenon, called intraguild predation, is an important factor in the competition among predating lady beetles – especially if they compete against the particularly aggressive invader *H. axyridis*. *H. axyridis* can feed on native lady beetles without harmful consequences. In contrast, native lady beetles that feed on *H. axyridis* die. How can that be?

A key experiment provided the answer to this question. The hemolymph of *H. axyridis* contains, apart from harmonine and antimicrobial peptides , a third defensive component: tiny biological weapons called microsporidia. These spores enable the invader to infect other beetle species, mainly because it is common among lady beetles to predate the eggs and larvae of other species. In their experiment, the scientists first injected harmonine into native *C. septempunctata* lady beetles, to establish whether this chemical substance harms the insects. In fact, the injection of hemolymph or purified microsporidia from *H. axyridis* had lethal consequences. A look through a high-resolution microscope revealed innumerable tiny spores in the hemolymph of the Asian lady beetle, spores that were even tinier than hemocytes. Microsporidic spores "germinate" and attack the cells of *C. septempunctata*; however, they do not germinate in *H. axyridis*. The Asian lady beetle can disable these biological weapons in its own hemolymph, but the spores become active as soon as they reach the body fluid of other beetle species. *H. axyridis*' very strong immunity against pathogens and the effect of the microsporidia may explain the ecological success of the Asian invader as it continues to out-compete native species across Europe. Now the researchers are interested in finding out how *H. axyridis* can disable the microsporidia in its own hemolymph. [JWK/AO]

More information: Vilcinskas, A., Stoecker, K., Schmidtberg, H.,

Röhrich, C., Vogel, H. (2013). Invasive harlequin ladybird carries biological weapons against native competitors. *Science*. May 17, 2013, DOI: 10.1126/science.1234032 dx.doi.org/10.1126/science.1234032

Schmidtberg, H., Röhrich, C., Vogel, H., Vilcinskas, A. (2013). A switch from constitutive chemical defense to inducible innate immune responses in the invasive ladybird Harmonia axyridis. *Biology Letters* 9: 20130006. dx.doi.org/10.1098/rsbl.2013.0006

Vilcinskas, A., Mukherjee, K., Vogel, H. (2013). Expansion of the antimicrobial peptide repertoire in the invasive ladybird Harmonia axyridis. *Proceedings of the Royal Society of London Series B* - Biological Sciences. 280: 20122113. dx.doi.org/10.1098/rspb.2012.2113

Provided by Max Planck Society