Bugs need symbiotic bacteria to exploit plant seeds

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The African cotton stainer (*Dysdercus fasciatus*) cultivates bacterial symbionts in its mid-gut that are necessary for growth and reproduction. Credit: Photo: MPI for Chemical Ecology/Kaltenpoth

Aggregations of the red and black colored firebugs are ubiquitous under linden trees in Central Europe, where the bugs can reach astounding population densities. While these insects have no impact on humans, their African, Asian, and American relatives, the cotton stainers, are serious agricultural pests of cotton and other Malvaceous plants.

Researchers at the Max Planck Institute for Chemical Ecology in Jena, Germany, recently discovered that these bugs need bacterial symbionts to survive on cotton seeds as their sole food source. By using high-throughput sequencing technologies, they found out that firebugs and cotton stainers share a characteristic bacterial community that colonizes a specific region of their mid-gut. Removal of the symbionts or reciprocal exchange of bacteria between firebugs and cotton stainers led to high mortality and low mating success, demonstrating the importance of the bacterial helpers for growth and reproduction. Thus, symbiotic bacteria constitute a key factor not only for the ecological success of firebugs but also for the pest status of cotton stainers. (Molecular Ecology, December 2012; Environmental Microbiology, in press)

With more than 80,000 described species, the true bugs represent one of the five megadiverse insect orders on earth. Many species are serious agricultural pests that are responsible for significant losses in crop production. Among these are cotton stainers, bugs of the family Pyrrhocoridae that damage cotton by feeding on the seed bolls and leaving indelible stains in the harvested crop. While previous research on sap-sucking insects demonstrated that they rely on microbial symbionts for nutrition, it remained unknown how cotton stainers and other seed-feeding bugs exploit Malvaceous plant seeds that are rich in toxic secondary metabolites, but poor in some essential nutrients.

This shows firebugs (*Pyrrhocoris apterus*). Credit: Photo: MPI for Chemical Ecology/Kaltenpoth

Scientists of the Insect Symbiosis Research Group at the Max Planck Institute for Chemical Ecology set out to address this question and elucidate the possible role of symbiotic bacteria in the nutrition of firebugs and cotton stainers. By using high-throughput sequencing technologies and deciphering almost 300,000 copies of bacterial 16S rRNA genes, they discovered that the bugs cultivate a characteristic community of three to six bacterial symbionts in a specific mid-gut region. "The symbionts are transferred to the eggs by female bugs, and the hatchlings later take them up by probing the egg surface," explains Sailendharan Sudakaran, PhD student in the Insect Symbiosis Group. "This guarantees that the bugs maintain the symbionts throughout their entire life and pass them on to the next generation." Bugs from different localities and even across different species showed very similar microbial communities, indicating that the bugs have been associated with their symbionts over millions of years.

To find out whether the bacterial symbionts help the bugs to survive on the plant seeds as their sole food source, the researchers performed a simple yet elegant experiment: They dipped bug eggs into bleach and ethanol and thereby killed the microbial community on the surface without harming the developing egg itself. Some of the eggs were then re-infected with a mixture of bacteria from an adult bug's gut, while others remained symbiont-free. Interestingly, the symbiont-free individuals showed markedly higher mortality, needed longer to develop into adults, and produced much fewer offspring than bugs with their native symbionts. "Symbiont-free bugs showed clear signs of malnutrition, although they were fed on the same plant seeds as their symbiont-bearing counterparts. This can only be explained by an important contribution of the bacteria towards host nutrition", says Hassan Salem, another PhD student in the group. Surprisingly, exchanging bacterial communities between firebugs and cotton stainers also resulted in reduced fitness of both species, indicating that – despite their similarity – the symbioses are highly specific.

The next important steps will be to find out whether the bacterial symbionts provide essential nutrients to their hosts that are lacking in the seed diet, or whether they help by detoxifying the noxious defensive chemicals of the plant. "Firebugs and cotton stainers are ideal model systems to address fundamental questions in insect symbiosis, because we can manipulate and exchange their microbial communities and then measure the fitness of the hosts," explains Martin Kaltenpoth, head of the Max Planck Research Group Insect Symbiosis. "Detailed knowledge on how insects interact with microbial symbionts is essential for an understanding of insect physiology, ecology, and evolution."

In the case of agricultural pest insects like the cotton stainers, this knowledge may also provide novel leads for biological control.

More information: Sudakaran, S., Salem, H., Kost, C. & Kaltenpoth, M. (2012) Geographic and ecological stability of the symbiotic mid-gut microbiota in European firebugs, Pyrrhocoris apterus (Hemiptera; Pyrrhocoridae). Molecular Ecology 21: 6134-6151. dx.doi.org/10.1111/mec.12027

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