Horizontal gene transfer: How fungi improve their ability to infect insects

March 8 2024, by Eva Sittig

The research team investigated genetic changes of Metarhizium fungi during infection of the invasive Argentine ant, shown here are its workers, on the right with brood. Credit: Sina Metzler & Roland Ferrigato, ISTA

Researchers at the Kiel Evolution Center have investigated for the first

time in detail how a fungus important for biological plant protection can pass on an advantageous chromosome horizontally, using a previously little-studied way of exchanging genetic information.

Sustainable plant protection measures that are not based on chemical pesticides rely on various organisms and biological agents to protect crops from pests. Such organisms used for biological plant protection are, for example, microscopic fungi of the genus Metarhizium, which can attack and kill a variety of plant-pathogenic insects and are used, for example, in South American sugar cane cultivation.

The molecular mechanisms of fungal infection and the immune response of insects are in an ongoing process of mutual evolutionary adaptation. In a joint project with colleagues from the Institute of Science and Technology Austria (ISTA), a research team from Kiel University investigated the genetic changes in the fungus during infection of the invasive Argentine ant (Linepithema humile).

The researchers examined the genomes of different strains of the fungi Metarhizium robertsii and Metarhizium brunneum from an earlier co-infection experiment in which ants had been infected with the fungus mix.

In the study, the outgrowing spores were used to infect new ants over 10 consecutive infection cycles. When analyzing the fungal genomes from these infection series, the fungal geneticist and first author of the study, Dr. Michael Habig from Kiel University, made an exciting observation: his analyses showed that a single chromosome was very frequently exchanged horizontally between two different strains.

This chromosome contains certain genes that the scientists suspect may give the fungus an advantage in infecting its hosts. The horizontal transfer of entire chromosomes has rarely been described scientifically

and has now been studied in detail for the first time. The researchers from the Kiel Evolution Center (KEC) and ISTA published their results in the journal *Proceedings of the National Academy of Sciences*.

Horizontal chromosome transfer detected in insect-damaging fungus

Scientists use the term horizontal gene transfer to describe how living organisms can transfer genetic material between different individuals, including those of other species. In this way, bacteria exchange extensive genetic information, often in the form of plasmids, in order to quickly adapt to changing environmental conditions or to adapt to the host. The rapid evolution of various pathogens is based on such mechanisms, among other things.

"In fungi and many other so-called eukaryotic organisms, however, horizontal gene transfer in the form of entire chromosomes is very rare and has hardly been researched to date," says Dr. Michael Habig, research associate at Kiel University.

"The analysis of the genetic information of the fungal strains shows that M. robertsii independently transferred a single chromosome a total of five times during the co-infection experiments, but no other genetic information from one strain to another via horizontal transfer," continued Habig.

Further analyses also indicated that the same chromosome can also be found in the distantly related, also insect-damaging fungus species Metarhizium guizhouense, whose common evolutionary origin with M. robertsii dates back around 15 million years.

"The chromosome in M. guizhouense is significantly less altered than

would be assumed for the long period of separate evolution of the two fungal species. The chromosome therefore also appears to have been passed on naturally between these different fungal species—and probably horizontally," says Habig.

Analysis of the chromosome indicates possible survival advantages for the fungus

The chromosome examined is a so-called accessory chromosome. This means that it does not occur in all individuals of a species and contains non-essential genetic information.

"The experiments showed that, under certain conditions, the fungus that had received the accessory chromosome had competitive advantages over fungi of the same strain that had not received the chromosome and were able to prevail against them. We want to investigate the details of these advantages in more detail in the future," says Habig.

The Kiel research team has already been able to derive initial indications from the analysis of the genes on the chromosome. "The chromosome contains hundreds of genes whose potential functions we will only be able to decipher in the future. However, we have already been able to identify 13 candidate genes that could presumably be responsible for so-called effector proteins, which can interact with the insects' immune system, for example," Habig continues.

The transfer of the chromosome may therefore have advantages for the fungus, the functional basis of which is still unclear. However, one plausible possibility is the transfer of certain genes that produce chitin-cleaving enzymes and can thus improve the ability to infect the insects.

"It is remarkable that we have found the genes of three such enzymes,

among others, which presumably play a role in the degradation of the chitin-containing cuticle of the host insect. This could influence a crucial step in the infection process, as the fungal spores are dependent on penetrating the protective exoskeleton of the host in order to infect it," says Professor Sylvia Cremer, last author of the study, from the Institute of Science and Technology Austria (ISTA).

Overall, the research work offers interesting new aspects on a way of exchanging genetic information that has been little studied in fungi to date.

"Our new work shows that horizontal chromosome transfer occurs regularly in fungi and that this mechanism can confer advantages to the recipient strain, at least in experiments under certain conditions," says Habig.

The Kiel research team and its collaboration partners from ISTA thus describe in detail for the first time a new aspect in the genome evolution of fungi, which may be able to use bacteria-like mechanisms of rapid evolutionary adaptation, for example to increase their virulence or harmfulness to their host organism and to transfer genetic information across species boundaries.

In the future, the researchers want to use the example of M. robertsii to investigate the relationships between horizontal chromosome transfer, possible fitness advantages and the mutual adaptation of fungi and insects in detail and thus gain further insights into this organism, which is important for plant protection.

More information: Michael Habig et al, Frequent horizontal chromosome transfer between asexual fungal insect pathogens, *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2316284121

Provided by Kiel University