Genome reveals how Hessian fly causes galls in wheat

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A female Hessian fly dangles from a cardboard box. Fly larvae can decimate entire wheat fields by causing growth-stunting galls on seedlings. Credit: Purdue University / Tom Campbell

A team of researchers from 26 institutions around the world has sequenced the Hessian fly genome, shedding light on how the insect creates growth-stunting galls in wheat.

Hessian fly larvae can destroy entire wheat fields by injecting seedlings with potent saliva that "hijacks" the plants' biochemistry, irreversibly halting development and forcing the seedlings to produce a leaky tissue that contains nutrients for the larvae.

But how the insect is able to slip past plant defenses to create these galls - that is, the plant's stunted growth - has not been well understood.

The genome reveals that the Hessian fly has an extensive reservoir of rapidly evolving genes that code for effector proteins, molecules that control gene expression and cell signaling. The structures of these proteins are remarkably similar to proteins in plants, said study co-author Jeffrey Stuart, which suggests that they mimic normal proteins in the plant cell and use this disguise to manipulate wheat seedling biochemistry.

"The Hessian fly is basically a plant pathogen in the shape of an insect," said Stuart, professor of insect molecular genetics at Purdue. "If we have a deeper understanding of how the insect is attacking the plant and how it avoids detection, we may be able to develop new ways of making resistant wheat more durable and better advise growers on which varieties to plant."

Likely native to the Middle East, the Hessian fly is a pest of global importance. Wheat genetic resistance to the insect is particularly desirable in regions where cultural control methods, such as late planting, are not an option.

"In a few days, a single larva can transform a healthy wheat seedling into one that won't grow anymore," Stuart said.

But wheat is not without its own defenses. Stuart said at least 35 genes in wheat can detect and identify an effector protein injected by the Hessian fly and trigger a counterattack: The plant can thicken its cell wall, preventing fly larvae from extracting nutrients, and produce toxic substances to dispatch the pest. In the southern U.S., some growers use wheat with specific resistance genes to manage Hessian fly.

But the resistance typically fades after 5-10 years as Hessian fly populations that are unable to survive on resistant wheat die off and are replaced by populations with effector proteins that the plant cannot recognize.

Stuart said this "genetic arms race" between wheat and Hessian flies could explain two striking features of the fly genome: the large number of genes - more than 1,000 - that code for effector proteins and the distinctiveness of much of the Hessian fly genome. About 34 percent of the fly's genes bear no similarity to those in other sequenced insect genomes, suggesting that they are rapidly evolving in response to the insect's interactions with plant defense systems.

The reservoir of effector genes also contains the largest gene family discovered in an insect genome.

The next step in the research is to identify the individual proteins injected by the insect and how they work in plant cells, said Purdue doctoral candidate and study co-author Lucio Navarro-Escalante.

"We're just starting to understand how the insect and plant are interacting and which proteins the insect uses to avoid or overcome plant defenses," he said. "In the future, those effector proteins could be the basis from which we generate new ways of controlling the insect."

Stuart said some of the effector proteins closely resemble those in gall-forming bacteria, which could be an example of convergent evolution - a process in which unrelated organisms develop similar features.

Delving into the molecular mechanisms of how the Hessian fly manipulates wheat could help researchers create novel ways of engineering plants, he said.

"Insects have already figured out how to bioengineer plants to make tissues they would not normally produce. There is no reason why we could not mine the methods of insects to make plants do things for human consumption that they wouldn't normally do."

More information: The paper was published in *Current Biology* Monday (March 2) and is available at www.sciencedirect.com/science/… ii/S0960982214016959

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