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the root of the problem

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There is not one living being on earth that doesn't need to eat. And we all go about it in the most ingenious ways. Humans go hunting in supermarkets. Dogs wait for food to appear in their bowls. Mosquitoes suck blood. Plants seep in light. Frogs await the passing fly. There are, however, organisms that go one step further in their quest for food, and that is to use another living being to produce what they need to eat. This is the realm of parasitism, some forms of which are particularly inventive. In this respect, one nematode, known as the soybean cyst nematode worm – or *Heterodera glycines* – is capable of taking advantage of soybean roots and modifying parts of them to erect the ideal feeding place. They do this by injecting effector proteins into the plant, a few of which are able to mimic plant proteins involved in plant development. These particular nematode proteins are known as CLE-related proteins and represent a very subtle way of twisting a host's welcome to their advantage.

Mongolian Death Worm by Pieter Dirkx (B)

Wikipedia

Nematode worms have been around for many many years and were no doubt swimming around in the primordial oceans. To date, about 28 000 nematodes have been described and it is likely that there is at least one million different species. In fact, scientists estimate that 4 out of every 5 animals are nematodes. There being so many, it is hardly surprising that they not only live all over the globe but are also marine, aquatic, terrestrial… and parasitic. The parasitic forms have had plenty of time to evolve into many interesting varieties of animal, plant and microbial parasites. In fact, out of the 28 000 nematodes, it is thought that about 16 000 are parasitic… The oldest description of nematodes is found in ancient Chinese literature dating back to 2 700 BC, and unsurprisingly relates their role in various human diseases. The first plant parasitic nematode worms were discovered in wheat seeds and reported in the 18th century. A century later, the discovery of root-knot nematodes on cucumber and cast nematodes on sugar beets paved the way for an emerging scientific discipline: plant nematology.

The soybean cyst nematode infects the roots of soybean, a characteristic of which is the visible formation of visible cysts that are full of eggs. These cysts are in fact the remnants of female nematodes that have died, leaving behind them a hardened cuticle full of progeny, typically 200 to 400 eggs per cyst. The eggs only hatch when the environment is favourable; a cyst can remain dormant in the soil several years – as long as it remains intact. When conditions are promising, an infected plant – or, worse still, an infected crop – can witness as many as three nematode life cycles per year.

How exactly does the nematode make its way into the roots of soybean in the first place? Nematodes go through four stages of development. During stage 2, the worm is able to penetrate the plant's roots and, literally, glide between the cells until it finds a patch which is close to the vascular system – the most fertile ground available. Once these parts are reached, it is thought that the worm uses its stylet to inject effector proteins into a cell's cytoplasm, proteins that are capable of inducing plant cell division. The end result is the formation of a large multinucleate cell, caused by the dissolution of the plasma membranes of neighbouring cells, whose nature have now become undifferentiated, until the nematode stops feeding. Hence, the nematode is not only capable of modifying the plant's root structure but also reprogramming its developmental stage – and transforming it into the ultimate dining room.

The actual cysts are caused by female nematodes that become so grossly oversized that their posteriors burst out of the root and become visible to the naked eye. This rather explosive stage does not stop the female from feeding more until she lays 200 to 400 eggs in a yellow gelatinous matrix inside her. She then dies, leaving a hardened cuticle behind, which forms the visible cyst.

The reprogramming of soybean root cells to design a multinucleated cellular trough for the benefit of worms is carried out by nematode proteins that, over time, have evolved to actually mimic specific developmental plant proteins known as CLE proteins. The nematode CLE-related proteins are moderate-sized proteins that carry two domains of importance: a variable domain (VD) and a short CLE domain. It is thought that inactive preproteins are injected into the root cells' cytoplasm where they then take advantage of the host's cell machinery for further modification. Thanks to the VD, the CLE-related preprotein is translocated to the extracellular space between the plant cell's membrane and the cell wall – a place known as the apoplasm – where it becomes active. The VD also seems to be important for host recognition; soybean cyst nematode CLE-related protein is, for instance, not compatible with any other host, such as Arabidopsis, which is infected by another variety of nematode.

As for the CLE domain, it is the part which mimics the CLE domain in plants. It is a short stretch of 12 amino acids which has a direct role in meristem differentiation, keeping the cells frozen in a stage which is just perfect for a nematode's dinner. The result is a specialised multinucleated feeding cell, or syncytium, which represents a food source for as long as is needed. However, though the CLE domain is crucial for root cell differentiation and meristem maintenance, it is not sufficient, implying that other parts of the protein are necessary for the successful growth of the nematode in host roots.

In a nutshell, VD is needed for host recognition and trafficking while the CLE domain is required for root cell reprogramming. Such findings are crucial not only in understanding how plant parasitic nematodes set out to survive and multiply, but also in which manner they attack plants, causing crop losses throughout the world. The soybean cyst nematode is guilty of crop destruction in South America, the US and Asia. It has been estimated that 77 billion dollars of damage occurs worldwide, every year. Which is a lot of money, and a lot of wasted food. Such research can help to develop pesticides that are specific and cause as little harm as possible to creatures that are otherwise harmless to crops. The better scientists understand how pathogenic nematodes take advantage of a host plant, the better they will be able to find ways of fighting it off. While saving the dinner of hundreds of thousands of people around the world. Every year.

Cross-references to UniProt

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CLE-related protein 2, *Heterodera glycines* (Soybean cyst nematode worm): Q86RQ1

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