The world of parasitic plants

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Most people are all too familiar with the idea of animal parasites, including tape worms, ticks and lice. But did you know that plants can also act as parasites, exploiting resources from unwilling hosts? Rather than being rare anomalies, however, there are over 4000 known species of parasitic plants, with representatives in 19 families of the plant kingdom.

Types of plant parasites

Plant parasites can be divided into two broad groups, hemi-parasites and holo-parasites. The former group is capable of photosynthesis and only extracts water from the host. Holo-parasites, on the other hand, completely lack chlorophyll and rely on their host for both sugars and water. Besides this, plant parasites can attach either to the stem or roots of the host.

Plant parasites encompass an extensive size range, including trees and the plant which produces the largest individual flower, *Rafflesia arnoldii*, a parasite of tropical vines. They also include the mistletoe family, which mainly act as hemi-parasites on tree and shrub species. The seeds are dispersed by birds feeding on the mistletoe berries; when the seeds are later excreted, they attach to the branches of trees due to a sticky, glue-like covering. This allows them to directly invade a new host. A common British parasitic plant species is Yellow Rattle *Rhinanthus minor*, a hemi-parasite which gets nutrients from the roots of plants close by. It has a useful role in creating wildflower meadows as it suppresses the growth of rapid-growing grasses that would otherwise dominate the ecosystem.

Rafflesia arnoldii *produces the world's largest flower, yet remains obscured for most of its life as a holoparasite of the vine* Tetrastigma *in the tropical forests of Sumatra and Borneo.* Rafflesia *does not form stems, leaves or roots and grows within the host as thread-like strands. During its reproductive phase, the parasite produces buds which break through the bark of the host.*

Beautiful parasite – the West Australian Christmas tree, Nuytsia floribunda *is a hemi-paraiste, sucking water from the roots of other plants.*

Common parasitic plant species include mistletoe (top) and Yellow Rattle (below).

Definitions

Epidermis: The outer layer of cells that cover an organism.

Root exudate: A substance made up of compounds secreted by plant roots into the soil. These can include organic acids, gases (e.g. CO_2), amino acids, sugars, inorganic ions and vitamins.

Marker assisted breeding: This uses molecular markers to determine if a plant carries a gene for a desirable trait. The 'markers' are specific genetic sequences closely associated with the gene of interest. A key advantage to this technique is that DNA can be isolated from seeds and screened to identify plants possessing a key trait without having to grow mature plants.

The invasion process

Plant parasite seeds can remain dormant in the soil for many years until stimulated to germinate by molecules released by host plants. Upon germinating, parasitic plants must rapidly locate a suitable host before their seed reserves are exhausted. This is helped by the parasite being sensitive to diffusible compounds released as airborne molecules or as part of host root exudates. Little is known, however, about the molecules which promote germination and directional growth in plant parasites.

Host contact triggers the development of a specialised invasive organ called the haustorium. This penetrates the epidermis of the host root or stem, growing between the cells to reach the xylem and/or phloem vessels. In the case of hemi-parasites, xylem vessels are entered via the pits within their walls; cells in the centre of the haustorium then differentiate into xylem vessels to ensure a continuous connection between host and parasite. Haustoria cells typically show high metabolic activity, with numerous mitochondria, which is thought to help water and nutrient uptake. Successful invasion results in greatly reduced growth of the host plant, as vital supplies are diverted to the unwelcome guest.

Dodder-laurel, seen here with its haustoria invading a black wattle

This photomicrograph shows a parasitic plant's haustoria (in black) invading the cells of a host plant.

Commercial implications

Parasitic plants have devastating effects on agriculturally important crops. Yields from timber tree species can be significantly reduced by mistletoe infestations. Meanwhile the genus *Cuscuta* contains over 150 species of holo-parasitic Dodder plants distributed worldwide, which infect both commercial crops (such as alfalfa, potatoes and tomatoes) and ornamentals.

One of the most notorious parasitic plants however is the hemi-parasite *Striga hermonthica*, also known as 'witchweed' due to the devastating losses it causes in plants of the grass family (*Poaceae*) and some legumes. It is a particularly acute problem in Sub-Saharan Africa, where it infects the major crop staples rice and sorghum. Striga is estimated to cause global losses of $7 billion and to be the main limiting factor for food security in Sub-Saharan Africa. As Striga is a root parasite, a farmer cannot tell if his field is infected until the purple flowering stems emerge from the soil, by which point it is too late. By diverting valuable water supplies from the host, Striga causes the crop plants to be stunted, resulting in overall yield reductions of 20-100%. Furthermore, each plant can produce up to 50 000 seeds, which can remain viable in the soil for 20 years until stimulated by host compounds. This makes it extremely difficult to control Striga once fields become infected. Applying nitrogen fertiliser can reduce infestation, as the parasite prefers nitrogen-deficient soils, but this option is too expensive for most subsistence farmers, who have to rely on cruder methods such as hand weeding.

The devastating parasitic weed Striga

A farming family inspect their maize crop, devastated by Striga, accompanied by a researcher from the International Institute of Tropical Agriculture.

Science to the rescue?

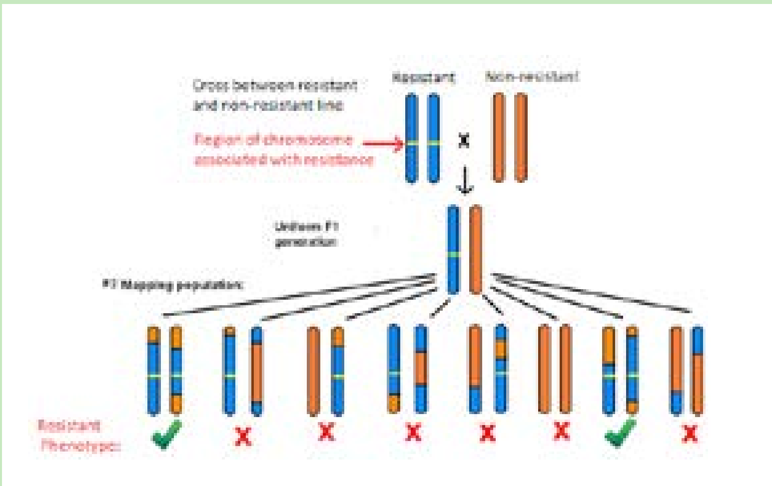
Scientific research has yielded some small successes in identifying ways to supress Striga infestations. These include the use of trap crops (or 'false hosts'), such as cotton, which produce molecules which stimulate Striga seeds to germinate. These plants, however, cannot themselves be infected, causing the young Striga plants to die. This can reduce the resident seed population within the soil before the main crop is planted.

Other strategies include using species that naturally produce compounds which repel Striga. An example is the legume *Desmodium uncimatum*. When this was planted together with maize (a technique known as 'intercropping') in field trials this reduced Striga infestation levels by 40 times.

Meanwhile, researchers are hoping to identify strains of crop plants showing natural resistance to Striga, which can then be interbred with high yielding lines. To identify areas of chromosomes associated with resistance, a mapping population is first created by breeding a resistant and non-resistant line together to generate a homogenous F1 (first generation) population (see Box below). Breeding together the F1 offspring promotes recombination events during meiosis, where sections of DNA are exchanged between the parent chromosomes. This can separate the region associated with resistance from the rest of the parent genome.

By screening each successive generation for resistance, the relevant genetic locus can be mapped with increasing precision. Once the area is identified, this can be used in marker assisted breeding programmes. Continuing this research will be important in the efforts to secure a sustainable food supply for future generations.

A mapping population is used to identify genetic loci (places) associated with resistance. A resistant line is interbred with a non-resistant line, generating a uniform heterozygote F1 population. When the F1 plants are bred together, sections of parental DNA are recombined during meiosis, which can separate the region containing the resistance genes. F2 offspring which are homozygous (both loci the same) for these genes will display the resistant phenotype. The DNA can then be tested with markers that distinguish between the parental genotypes to determine which parts of the genome originated from the resistant parent. The process can be repeated, breaking up the parental genomes further, to locate the resistant loci with greater precision.



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