Root parasitic weeds: Biology and control measures

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Biology of root parasitic weeds

Approximately 1% of flowering higher plants are parasitic plants that attach to other plants and deprive their hosts of water and nutrients. Some of them, facultative parasites, can survive without attaching to their hosts, but most of parasitic plants negatively affecting agriculture and forestry are obligate parasites that cannot live without connecting to their hosts. These plants can be classified into two groups according to the site of attachment. Mistletoes (*Viscum* spp.) and dodders (*Cuscuta* spp.) are stem parasites attaching to the stem (shoot) of their host, while sandalwood (*Santalum album*) and forest ghost flower (*Aeginetia indica*) are root parasites connecting to the underground roots.

Among root parasitic plants, witchweeds (*Striga* spp.) and broomrapes (*Orobanche* and *Phelipanche* spp.) are two most devastating weeds causing severe damages to agricultural production all over the world. Witchweeds are hemiparasites and have functional chloroplasts, but their photosynthesis cannot support their survival and thus they should parasitize host plants, mainly monocots; maize, sorghum, rice, and sugarcane. Broomrapes are holoparasites, lacking chlorophylls, and totally dependent on their dicot hosts; tomato, tobacco, oilseed rape, carrot, and legumes, for the supply of water and nutrients. Single root parasitic weed produces 10,000 to 500,000 dust-like tiny seeds which survive for more than 20 years in the soil. Therefore, potential host crops cannot be planted in the heavily infested fields for decades, leading to the abandonment of cultivation and the subsequent desertification.

Witchweeds (*S. hermonthica* and *S. asiatica*) are prevailing in sub-Saharan Africa, causing estimated annual loss of one billion US dollars in food crop production and threatening food supply for 300 million people. Broomrapes have been spreading from the Mediterranean countries to the rest of world and are now distributed widely.

The seeds of parasites germinate only when they perceive chemicals–termed germination stimulants–released from host roots. These chemicals are unstable and present only in the close vicinity to the host roots. Therefore, only the parasite seeds in the host rhizosphere, which can attach to the host roots after germination, will germinate; a sophisticated survival strategy of root parasitic weeds because their tiny seeds with limited food storage should connect to the host roots within a few days after germination or they will die.

As these parasites attach to the host roots, it is hard to detect parasitism in its early growth stage during which major damages to the hosts occur. In addition, any herbicides rapidly detoxified by and thus safe to host crops are not effective to the parasites which obtain water and assimilates only from the hosts through haustorium, an organ connecting the parasites to their hosts. These make root parasitic weed control very difficult.

Control measures

1) Breeding and/or selection of resistant/tolerant cultivars

Breeding and/or selecting crop cultivars that are resistant or tolerant to root parasites is the most economically feasible strategy. Prof. Gebisa Ejeta, 2009 World Food Prize laureate, produced sorghum cultivars resistant to *Striga*. A mutation of a gene, *LGS1*, changes the major strigolactone germination stimulant of sorghum from 5-deoxystrigol, which strongly elicits *Striga* germination, to orobanchol, a weak stimulant, and therefore these cultivars induce only negligible *Striga* germination. Other resistant mechanisms include inhibition of penetration of haustorium and its connection to conducive system of host roots. Unfortunately, in general, any single resistant mechanism has often been overcome by new biotypes of root parasitic weeds especially in the case of out-crossers like *S. hermonthica*.

2) Non-GMO herbicide resistant cultivars

For some types of herbicides like acetohydroxy acid synthase (AHAS) inhibitors and acetyl-CoA carboxylase (ACCase) inhibitors, it is rather easy to select herbicide resistant biotypes with target site mutations. In fact, rapid evolutions of resistant weed biotypes to these herbicides have extensively been reported. Maize seeds carrying such a herbicide resistant mutation treated or coated with an AHAS inhibitor imazapyr herbicide effectively control *Striga* and some other weeds. One possible drawback of this strategy would be the evolution of herbicide resistant biotypes of root parasitic weeds which produce huge number of seeds which may contain herbicide resistant mutants.

3) Cultivation method – Push-Pull

This method using a trap (pull) crop (Napier grass) and a repellent (push) fodder crop silverleaf desmodium (*Desmodium*) was originally developed for stemborer management in maze and then was found to be effective on *Striga* management. *Desmodium* spp. are legumes and thus non-host of *Striga.* Silverleaf desmodium plants planted in between the rows of maize produce strigolactone germination stimulants but at the same time they also release inhibitors of radicle elongation of germinating *Striga*. In addition, the legume plants improve soil fertility by nitrogen-fixation which also reduce strigolactone production and thus *Striga* germination. Accordingly, push-pull strategy effectively mitigates damages caused by stemborers and *Striga*.

4) Biological control

Microbes isolated from wilted *Striga* have extensively been examined for their potentials as biological control agents. Unfortunately, most of these pathogens (fungi) have been found to produce trichothecenes which are highly toxic to animals and humans. In general, pathogenic microbes are difficult to culture; 99% of soil microbes are unculturable. Difficulties in distribution, storage, and inoculation need to be overcome.

Toothpicks – Kenya approves Kichawi Kill^TM the first bioherbicide to combat Striga

Recently, a fungal pathogen *Fusarium oxysporum* fsp *strigae* was isolated from wilted *Striga.* The pathogen induces overproduction of specific amino acid only in *Striga.* Growing the pathogen on toothpicks which are then transported to villages. Growing the pathogen on cooked rice and then a cupful of inoculated rice is placed with each maize seed. The applied fungus kills germinating *Striga* seeds effectively. Some *Striga* may escape but they produce less flowers and seeds, resulting in a reduced subsequent infestation.

Conclusion

There are other control measures such as soil fumigation, crop rotation, hand and/or mechanical weeding. Hand and/or chemical weeding would be effective to remove resistant biotypes to a particular control measure. Anyway, a single control measure would not last long and thus combination of at least two or three different control measures shall be considered. In addition, further study on host-parasite interactions should lead to develop more economically feasible, and environmentally benign control measures.