Biocontrol of weeds using insects and fungi†

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Summary

The basic strategies of biocontrol of weeds are outlined. Examples of the use of insects and fungi in biocontrol are presented in an historical context. The success rate and the benefits derived from biological control suggest that a stronger commitment and further resources should be directed towards this many faceted method of weed control.

Introduction

Biological control of weeds can be considered in two main categories: Classical biocontrol, where releases are made of an imported natural enemy or inundative biocontrol where an agent (usually already occurring in the same area as the weed) is applied in heavy concentrations.

In classical biocontrol, the agent, once established, becomes self sustaining and reaches long-term equilibrium with its host. In inundative biocontrol the population of the control agent is not self-sustaining at levels which would control the host. The effects of inundative agents tend to be short term in much the same way as most chemical control methods. Sometimes an augmentation strategy to assist classical biocontrol agents persist in some areas if its host's range is used. This is referred to as augmentative biocontrol.

These basic strategies can be used in biocontrol programs using insects or fungi, however insects have usually been used as classical biocontrol agents.

Use of insects

The biocontrol of weeds in Australia did not begin as is often thought with *Cactoblastis* on prickly pear, but with four species of insects from Mexico via Hawaii to control lantana (*Lantana camara*). It is also noteworthy that this work was initiated by the Queensland Department of Agriculture and Stock. Since 1914, 23 species of lantana insects have been introduced into Australia. Fifteen of these have become established and, of these, two leaf mining beetles, *Octotoma scabripennis* and *Uroplata girardi*, first introduced in 1966, appear to be the most useful. They are in fact still spreading (Taylor 1989).

Tiger pear (*Opuntia aurantiaca*) is the major cactus pest in New South Wales. Control by the cochineal insect, *Dactylopius austrinus*, which was released in 1933, is adequate under dry conditions but the cactus grows rapidly in wet years. A limiting factor in subsequent control is the relatively poor dispersing ability of the insect. To aid in the control process *Dactylopius* is now artificially bred and redistributed in an augmentative biocontrol approach (Hosking 1984, 1985).

There have been a number of successful operations to control weeds by insects in Australia. However, possibly the most thoroughly researched of these, the control program for Paterson's curse *Echium* spp., is still underway.

This program formally began in CSIRO's research unit at Montpellier, France in 1972. Eleven insect species found in the western Mediterranean appear to have a major potential for biocontrol of *Echium* spp. (Delfosse 1985).

The program became the cause of a major conflict of interest issue which gave rise to the Biological Control Act 1984 (Commonwealth of Australia) (Cullen and Delfosse 1985). Since the resolution of this problem release of two of the chosen biocontrol insects have been made: *Dialectica scalariella*, the larval form is a leaf miner released in 1988 and *Ceutorhynchus larvatus* weevil, released in 1989.

These three examples illustrate that the biocontrol of weeds is not the simplistic picture of an early solution often painted in the popular media via the *Cactoblastis*/prickly pear story. In classical biocontrol, a major disadvantage is that the efficacy of the agent in a new environment cannot be predicted. For instance gall fly, *Procecidochares utilis*, which was introduced to control crofton weed, *Ageratina adenophora*, is parasitized by native wasps. In addition the fact that there is no location specificity in classical biocontrol as we have seen can lead to conflicts of interests.

However, it should be emphasised that in scientifically conducted releases for biocontrol of weeds there have been no major "accidents". Moreover, the success rate ("partial to good control") from such programs is about 30% (Lawton 1989), which compares extremely well with the search for new chemical herbicides and their cost of development. In addition the benefits of classical biocontrol are long term, environmentally safe and widely distributed. The benefit/cost ratio for the classical biocontrol of skeleton weed (see below) was estimated to approach 200/1 in 1976 (Marsden *et al.* 1980).

The use of fungi

The notion of using plant diseases to control troublesome plants is an appealing one. Fungi have been used in attempts to control weeds in various parts of the world since the 1950s. Initially researchers concentrated on native or naturalized fungi spreading them on to target weeds by various means. Results were generally unpredictable varying with time and location. One fungus to achieve success was the persimmon wilt fungus, *Acremonium diospyri*, which although not commercially available, has been used since 1960 to control persimmon trees in Oklahoma rangelands. The fungus is provided free to local landholders by a benevolent foundation. Suspensions of conidia provided in plastic 'squirt' bottles are applied to wounds made in the trees with a hand axe (G.E. Templeton, personal communication 1988).

A step forward was made in the Peoples Republic of China in 1963. A *forma specialis* of the fungus *Colletotrichum gloeosporioides* was developed by simple fermentation procedures into a product, "Lu-bao No. 1", used to control the parasitic weed dodder (*Cuscuta* spp.), in soybeans. It was applied in inundative doses of spores to create an artificial and localized epidemic. Although the original strain of this fungus has been replaced, the daughter product "Lu-bao No. 2", is still used. It is applied as a liquid suspension of spores like a conventional herbicide (Li, Y.H. personal communication, 1987). This type of product has become known as a "mycoherbicide".

Another important development in weed control with fungi took place in 1971. A strain of *Puccinia chondrillina*, a rust fungus and an obligate parasite, was introduced to Australia from Italy via France to control skeleton weed (*Chondrilla juncea*) a major weed of cereals. This fungus has dry spores which are naturally dispersed by wind, unlike most fungi used in the mycoherbicide approach, which are wet-spored and spread by rain splash in nature. *P. chondrillina* was allowed to spread naturally; this approach is referred to as "classical" biological control. Until this time it was more usual to use exotic insects as bio-control agents for weeds. *P. chondrillina* spread rapidly (Cullen *et al.* 1973) and proved highly successful on the most widespread of three forms of this weed. Subsequent releases of additional strains of the fungus from Italy and Turkey have been made.

Mycoherbicides

In the 1970s a number of USA research labs concentrated on developing pathogens which were already present in the USA. This led to the release of two commercial mycoherbicides in the early 1980s. DeVine® was produced in a cooperative venture between the Florida Department of Agriculture and Consumer Services and Abbott Laboratories

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(Ridings 1986). DeVine® is a formulation of chlamydospores of *Phytophthora palmivora* used to control strangler vine (*Morrenia odorata*) a weed of citrus groves in Florida. Although mass production of chlamydospores by fermentation was possible, long shelf life for the product could not be achieved. DeVine® is handled like fresh milk through its distribution system; it has an expiry date of 6 weeks (Kenney 1986). It is feasible to distribute and market this relatively labile produce because of a limited target area.

The second product, Collego®, was developed as collaborative effort between a group at the University of Arkansas led by Professor George Templeton, the US Department of Agriculture and the Upjohn Company. Collego® is a formulation of the pathogen *Colletotrichum gloeosporioides* f.sp. *aeschynomene* which is used to control northern jointvetch (*Aeschynomene virginica*) a weed of rice. Although production of spores by submerged fermentation and drying spores for shelf life was relatively easily achieved on a small scale for research purposes, improvements were required for commercial production.

The development of Collego® and DeVine® stimulated widespread research interest in mycoherbicides. The result of this activity led to several potential new products. Below are three examples.

BIOMAL(TM) is a potential mycoherbicide for control of round-leaved mallow (*Malva pusilla*) in wheat (*Triticum aestivum*) and lentils (*Lens culinaris*) in Manitoba and Saskatchewan, Canada, and northern wheat-producing areas in the USA. It is a selected strain of *Colletotrichum gloeosporioides* f.sp. *malvae* applied in spore suspensions. Control of round-leaved mallow has been achieved in field tests (Makowski and Mortensen 1989).

A mycoherbicide for control of American blackberry (*Prunus serotina*) in pine forests in The Netherlands is being developed with a strain of the fungal pathogen *Chondrostereum purpureum* (Scheepens 1980). Like the persimmon wilt disease, it requires wound inoculation to initiate the disease development. Weed trees are cut mechanically, and the cut surfaces of the stumps are painted or sprayed with mycelial fragments in agar suspensions in the same manner as the "cut-stump" herbicidal control method.

In our own research program at the Agricultural Research and Veterinary Centre, Orange, the current emphasis is the control of the widespread weed Bathurst burr, (*Xanthium spinosum*) by the fungus, *Colletotrichum orbiculare* (Auld *et al.* 1988). The work has included discovering the most strongly pathogenic isolates, defining optimal conditions for disease development (McRae and Auld 1988), fermentation and formulation research and field tests. We are currently working with a commercial partner in scale-up production studies and further field tests.

The development of Collego® took about ten years and although there are several promising potential products nine years after the release of Collego® none have yet reached the market. This again emphasizes the need for a long term commitment to biocontrol research, whether it be for classical biocontrol or inundative biocontrol with commercial products.

There appears to be considerable potential for the mycoherbicide technique of weed control (Templeton 1987). Costs of production and research and development for mycoherbicides about $2 million (in the early 1980s) are relatively low compared with conventional herbicides around $100 million. Moreover the market necessary to offset these development costs for conventional herbicides resides in the six major world crops: wheat, corn, rice, soybean, cotton and sugarbeet. Thus mycoherbicides may have an increasing role in smaller total value crops. Combinations of fungi could be formulated to overcome the commercial disadvantages of a product being limited to a specific weed. In addition, where pathogens are not sufficiently virulent, research has already shown that they can be combined with very low rates of conventional herbicides.

Conclusions

Biocontrol of weeds is a many faceted approach which requires a long term commitment by research policy makers, researchers and funding bodies. However the success rate and the long-term benefits from biocontrol suggest that stronger commitment and further resources should be directed towards biocontrol of weeds.

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