BIOCONTROL OF WEEDS USING PLANT PATHOGENS

by

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Introduction

Since the late 1940s, synthetic herbicides have provided effective and economical control of many weeds. However, an excessive reliance on chemicals has created problems related to their overuse, such as toxic residues in plant and animal products and the pollution of soil and waterways. Furthermore, chemical herbicides fail to provide adequate control of some weeds, and increasingly stringent regulatory requirements for registration of new pesticides makes the development of new herbicides prohibitively expensive.

These factors have lead to an increasing interest in the use of biocontrol agents to replace or augment traditional weed management systems. Biocontrol agents have less adverse effects on non-target species and are perceived by many to be more environmentally friendly than synthetic herbicides. They are also likely to provide greater operator safety than most synthetic herbicides, some of which have been shown to be carcinogens or have other adverse effects (Brown, 1992).

There have been two main approaches to biocontrol of weeds using plant pathogenic fungi; the classical approach and the inundative (or bioherbicide) approach.

The classical approach

Classical biocontrol involves the importation and release of an exotic pathogen, usually from the region of origin of the target weed. As the introduction of an alien pathogen cannot be reversed, classical biocontrol agents are subject to stringent and extensive host range tests before they can be considered safe for importation and release (Shepherd, 1993; Charudattan, 1982). Once the introduced pathogen has become established it generally requires no further manipulation, relying on natural mechanisms of dispersal, infection and reproduction to reduce the target weed population. Therefore, an established classical biocontrol agent does not provide complete control of the host species, but exists in a state of equilibrium with the suppressed target weed population.

Perhaps the most notable example of classical biocontrol of a weed was the introduction of a rust fungus (*Puccinia chondrillina*) to control skeleton weed (*Chondrilla juncea*) in south-eastern Australia. A native of Mediterranean Europe, skeleton weed was introduced to Australia sometime before 1918. By 1971, it had infested over one million hectares of wheat and rangeland (Cullen, 1976). A virulent pathotype of a rust, *P. chondrillina*, was found in Italy as a result of a search for candidate pathogens and released near Wagga Wagga (NSW) in 1971. By 1972 the rust was widely distributed, with rust infection reducing the vigour, reproductive capacity and the spread of the target weed. By the 1978-79 season, the savings in reduced production losses were estimated at about $49 million (Cullen, 1985).

Classical biocontrol offers the potential for permanent and widespread control of weeds of rangelands, forests and waterways, where small residual populations of the host do not cause economic losses and other weed control practices are unjustified

(Templeton *et al.*, 1979). The responsibility for development of classical biocontrol agents is likely to remain with the public sector (eg. Departments of Agriculture, Universities) because the profit incentive for private industry is lacking (Emge & Templeton, 1981).

The inundative or bioherbicide approach

Whereas classical biocontrol involves a single introduction of an exotic pathogen and its natural spread, bioherbicides usually involve native or naturalised pathogens and are applied like conventional herbicides. Inoculum of the pathogen is huilt up on artificial media in a laboratory and the inoculum is then applied to weeds in inundative quantities when and where a weed problem occurs. Unlike chemical herbicides, bioherbicides are generally highly specific to the target weed and do not affect other plant species (Ayers and Paul, 1990). The pathogenic (ie. fungal or bacterial) component of the bioherbicide is usually not self-sustaining and as a result the control achieved is specific and short-lived. As bioherbicide agents do not need to co-exist in a stable equilibrium with their host, they are likely to afford much greater control rates than can be achieved with classical biocontrol agents.

Several bioherbicides have now been registered for use and have provided effective and economic control of several weed species. One of the first commercially viable bioherbicides went on sale in 1982 under the trade name Collego®. Collego® is a dry spore formulation of *Colletotrichum gloeosporioides* f.sp. *aeschynomene* that is applied as a post-emergent herbicide to control northern jointvetch (*Aeschynomene virginica*) in rice and soybean in the south-eastern United States (Bowers, 1986).

Colletotrichum gloeosporioides is an indigenous pathogen, naturally producing low levels of disease on its host annually. Collego® is applied aerially, usually only once a season when the weed emerges above the rice canopy. The first symptoms of infection appear one to two weeks after spraying and the disease progresses to give approximately a 92% kill of the target weed, with the vigour of survivors heavily depressed (Ayers and Paul, 1990).

Other registered mycoherbicides include DeVine®, a liquid formulation of chlamydospores of *Phytophthora palmivora* used to control stranglervine (*Morrenia odorata*) in citrus in Florida. DeVine® provides up to 96% kill of stranglervine within 10 weeks of application with a broom spray and control persists for up to two years following a single application (Kenney, 1986).

In many areas, a number of environmental constraints need to be overcome for the successful use of bioherbicides. The most significant of these is the availability of water which, in the form of dew or high humidity, is essential for the infection process of many plant pathogenic fungi (Paul *et al.*, 1992). This may require the bioherbicide to be applied at dusk to utilise the high night-time humidity, or to keep the foliage wet using irrigation following mycoherbicide application. These limitations to bioherbicide use may be overcome by mixing the spores of the pathogen with humectants or by encapsulating spores in an emulsion of water in oil, tbus slowing evaporation of water droplets sufficiently to allow spore germination and infection of the weed host in otherwise dry conditions (Paul *et al.*, 1992).

The efficacy of bioherbicides may be greatly enhanced when integrated with each other and with conventional weed management systems. Synthetic herbicides have been shown in several cases to act in synergy with bioherbicides to provide greater weed control than either agent alone, and in some cases can greatly reduce the effective dose of the chemical (Paul *et al.*, 1992; Christy *et al.*, 1993). For example, a rust (*Puccinia canaliculata*) in combination with paraquat provided 99% control of yellow nutsedge (*Cyperus esculentus*) in trials in the United States (Phatak *et al.*, 1987). This compared with 60% control by the rust alone and 10% control with paraquat alone. In other studies, sublethal doses of glyphosate have been demonstrated to suppress the defence response of *Cassia obtusifolia* to a potential mycoherbicide, *Alternaria cassiae*, thus greatly enhancing virulence of the pathogen (Sharon *et al.*, 1991). Synergy has also been observed between different pathogens on the same host, with infection by one facilitating infection by the other (Morin *et al.*, 1993). Clearly, investigating the augmentation of a fungal pathogen with other pathogens and/or chemical herbicides will comprise an essential part of future bioherbicide development.

Nutgrass: a target for biocontrol

Nutsedge (*Cyperus rotundus*), commonly known in Australia as nutgrass, has been described as the world's worst weed (Holm *et al.*, 1977). In cotton crops, nutgrass competes for light, nutrients and water. It also reduces irrigation efficiency, pesticide penetration, harvesting efficiency, and contaminates lint (Keeley, 1987; Charles, 1991). Nutgrass has also been demonstrated to produce allelopathic compounds that may have the potential to further reduce cotton yields (Keeley, 1987). Charles (1991) conducted a grower survey in 1989 of weeds and herbicide use in the New South Wales cotton industry and found that on average, weed control costs the cotton grower $187/ha annually. The survey also reported that under current management systems, the occurrence of most weeds was found to be stable or decreasing. However, nutgrass, affecting 15% of the cotton area in 1989, was found to be escaping current weed management practices and rapidly becoming the principal weed problem in many fields (Charles, 1991). Overall, the survey found that growers were dissatisfied with the high cost of weed control and the ineffectiveness of control measures against weeds such as *Cyperus* spp. These factors make nutgrass an ideal candidate for a bioherbicide approach to weed control. Cotton Research and Development Corporation (CRDC)-funded research into the potential of developing a bioherbicide for use on nutgrass has commenced with a survey of pathogens of *Cyperus* spp. to identify potential biocontrol agents. Future work will attempt to incorporate the agent(s) into a bioherbicide formulation that will provide control of nutgrass without adversely affecting the cotton crop and then integrating the bioherbicide into conventional weed management practices.

Summary

Biocontrol of weeds using plant pathogens can provide a viable alternative or addition to conventional weed management practices. Classical biocontrol aims to provide permanent suppression of weeds infesting large areas of land such as forests, waterways, and rangelands by the importation and release of a foreign pathogen. Bioherbicide biocontrol aims to provide short-term, high weed kill rate by the application of inundative quantities of an indigenous or naturalised pathogen specific to the target weed. As the action of the bioherbicide is restricted to sites of application and is not self-sustaining, bioherbicide development and commercialization can be economically viable. In the future, synergising bioherbicides with conventional

herbicides may enhance the effectiveness of both components and offers the possibility for controlling problem weeds that escape current weed management systems.

References

Ayers, P., & Paul, N. (1990). Weeding with fungi. *New Scientist*, 127 No. 1732, 28-31.

Bowers, R. C. (1986). Commercialization of Collego™- An industrialists view. *Weed Science*, **34**, 24-25.

Brown, J. F. (1993), Fungi as biocontrol agents. *University of New England 1992 Research Report*, p. 9-12.

Charles, G. W. (1991). A grower survey of weeds and herbicide use in the New South Wales cotton industry. *Australian Journal of Experimental Agriculture*, **31**, 387-392.

Charudattan, R. (1982). Regulation of microbial weed control agents. In R. Charudattan & H. L. Walker (Eds.), *Biological Control of Weeds with Plant Pathogens*, (pp. 175-188). New York: John Wiley and Sons.

Christy, A. L., Herbst, K. A., Kostka, S. J., Mullen, J. P., & Carlson, P. S. (1993). Synergizing weed biocontrol agents with chemical herbicides. *American Chemical Society*, **524**, 87-100.

Cullen, J. M. (1976). Evaluating the success of the programme for the biological control of *Chondrilla juncea* L. In T. E. Freeman (Ed.), *IV International Symposium of Biological Control of Weeds*, (pp. 117-121). Gainesville, U. S. A.:

Cullen, J. M. (1985). Bringing the cost benefit analysis of biological control of *Chondrilla juncea* up to date. In E. S. Delfosse (Ed.), *International Symposium on Biological Control of Weeds*, (pp. 145-152). Univ. British Colombia, Vancouver:

Emge, R. G., & Templeton, G. E. (1981). Biological control of weeds with plant pathogens. In G. C. Papavizas (Ed.), *BARC Symposium No. 5.*, (pp. 219-226). Allanheld, Osmun, Totowa:

Holm, L. G., Plucknett, D. L., Pancho, J. V., & Herberger, J. P. (1977). *Cyperus rotundus* L. In *The Worlds Worst Weeds; distribution and biology* (pp. 8-25). Honolulu: University Press of Hawaii.

Keeley, P. E. (1987). Interference and interaction of purple and yellow nutsedges (*Cyperus rotundus* and *C. esculentus*) with crops. *Weed Technology*, **1**, 74-81.

Kenney, D. S. (1986). DeVine®- The way it was developed - An industrialists view. *Weed Science*, **34**, 15-16.

Morin, L., Auld, B. A., & Brown, J. F. (1993). Synergy between *Puccinia xanthii* and *Colletotrichum orbiculare* on *Xanthium occidentale*. *Biological Control*, **3**, 296-310.

Paul, N. D., Ayers, P. G., & Hallett, S. G. (1992). Making biological herbicides more effective. *Journal of Biological Education*, **26**(2), 94-99.

Phatak, S. C., Callaway, M. B., & Vavrina, C. S. (1987). Biological control and its integration in weed management systems for purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*). *Weed Technology*, **1**, 84-91.

Sharon, A., Amsellem, Z., & Gressel, J. (1992). Glyphosate suppression of an elicited defence response. *Plant Physiology*, **98**, 654-659.

Shepherd, R. C. H. (1993). The theory and protocols for biological control of weeds. *Plant Protection Quarterly*, **8**(4), 144-147.

Templeton, G. E., TeBeest, D. O., & Smith, R., J. (1979). Biological Weed Control with Mycoherbicides. *Annual Review of Phytopathology*, **17**, 301-310.