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BIOLOGICAL CONTROL OF WEEDS WITH PLANT PATHOGENS. PROSPECTUS – 1980

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ABSTRACT

Research on the use of plant pathogens for biological control of weeds increased dramatically during the past decade. Significant advances were made and the technology transfer stage reached in several operational and near-operational weed control programs. A broader informational base has also been established on which to formulate additional uses of plant pathogens alone and in combination with other methods. *Integrated pest management* (IPM) programs will be especially benefited by this increased usage.

INTRODUCTION

Prior to 1970, little concentrated research had been focused on the use of plant pathogens as biological control agents for weeds (Watson 1969, Zettler and Freeman 1972). However, during the decade of the 1970s, there was a dramatic increase in interest in this facet of plant pathology. No doubt, the factors that spurred much of this interest related directly to the increasing cost and decreasing availability of fossil fuels and to a heightened environmental awareness. Pesticides are related to both of these factors and biological controls offer an attractive alternative to fossil fuel based and environmentally criticized methods of chemical control using them. Hence, the rise in the popularity of so-called *integrated pest management* (IPM) programs which rely heavily for their success upon natural pest restraints, predominantly mediated through biological agents. Although advocates of IPM programs show a reluctance to use the term "biological control" because of unfounded fears conjured in the minds of many.

Plant pathogens are certainly viable candidates in any program relying on biological methods of weed control (Freeman *et al.* 1974, Zettler and Freeman 1972). They are numerous and diverse, easily propagated and disseminated and many are self-perpetuating and host specific. In addition, they are neither likely to infect or otherwise affect man and other animals, nor would they be likely to cause extinction of a target species. They are also compatible with other methods of control used in integrated programs. Therefore, it is not surprising that interest in their use as biocontrol agents has increased and will no doubt continue to do so. In this presentation, we will consider: the present status of the use of plant pathogens as biocontrol agents for weeds, the methodology of the approach to their use, and project future trends and needs.

PRESENT STATUS

Freeman *et al.* (1976) listed 27 aquatic and terrestrial plant species whose control with plant pathogens was being investigated (see Table 1). Investigations and the control of four of these species had reached the advanced stages. These

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Table 1. Compilation of weeds targeted for biological control with plant pathogens, after Charudattan (1978) and Freeman *et al.* (1976).

Weeds	
Charudattan (1978)	**Freeman *et al.* (1976)**
Aeschynomene virginica (L.) B.S.P.	*Acroptilon repens* (L.) DC.
Albizzia julibrissin Durazzini	*Aeschynomene virginica* (L.) B.S.P.
Alternanthera philoxeriodes (Mart.) Griseb.	Algae (Blue-Green)
Avena fatua L.	*Alternanthera philoxeroides* (Mart.) Griseb.
Cannabis sativa L.	*Ambrosia artemisifolia* L.
Cassia surrattensis Lamarck	*Brassenia schreberi* Gmel.
Chondrilla juncea L.	*Cassia surrattensis* Lamarck
Cyperus esculentus L.	*Chondrilla juncea* L.
C. rotundus L.	*Convolvulus arvensis* L.
Eichhornia crassipes (Mart.) Solms	*Eichhornia crassipes* (Mart.) Solms
Hydrilla verticillata (L. fil.) Royle	*Hydrilla verticillata* (L. fil.) Royle
Hydrocotyl umbellata L.	*Lantana camara* L.
Jussiaea decurrens (Walt.) DC.	*Morrenia odorata* Lindl.
Limnobium spongia (Bosc) Steud.	*Myriophyllum spicatum* L.
Morrenia odorata Lindl.	*Nuphar luteum* (L.) Sibth & Smith
Nuphar luteum (L.) Sibth & Smith	*Nymphaea odorata* Ait.
Panicum dicotomiflorum Michx.	*N. tuberosa* Paine
Populus spp.	*Nymphoides orbiculata* L.
Quercus spp.	*Oxalis* spp.
Sida spinosa L.	*Pistia stratiotes* L.
Solanum dulcamara L.	*Rubus constrictus* L. et M.
S. elaeagnifolium Cav.	*R. ulmifolius* Shott
Xanthium spinosum L.	*Rumex crispus* L.
X. strumarium L.	*Salvinia* sp.
	Sida spinosa L.
	Solanum elaeagnifolium Cav.
	Xanthium spp.

were: waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) with the fungus *Cercospora rodmanii* Conway (Conway 1976), nothern jointvetch, *Aeschynomene virginica* (L.) B.S.P., with a host specific strain of the fungus *Colletotrichum gloeosporioides* (Penz) Sacc. (Templeton *et al.* 1976), milk weed vine, *Morrenia odorata* Lindl., with the fungus *Phytophthora citrophthora* (Sm. and Sm.) Leonian (Ridings *et al.* 1976) and skeleton weed, *Chondrilla juncea* L., with the rust fungus *Puccinia chrondrillina* Bubak and Syd. (Cullen *et al.* 1973, Hasan 1974). The first three of these involve the use of endemic pathogens and the fourth is based upon the classical approach in that the biocontrol agent is exotic in nature.

Charudattan (1978) compiled the biological control projects being conducted by members of the American Phytopathological Society, which is international in scope. He lists 25 weed species whose control with plant pathogens was being actively researched (see Table 1). Based on his status data, research efforts on the same four species listed by Freeman *et al.* (1976) are still the most advanced.

The University of Florida has been granted a U.S. patent (Conway *et al.* 1978) for the use of *C. rodmanii* as a biological control agent for waterhyacinth. This fungus is currently being evaluated in a *Large-Scale-Operational-Management Test* (LSOMT) conducted by the U.S. Army Corps of Engineers in the State of Louisiana, U.S.A. (Theriot and Sanders 1980). The U.S. *Environmental Protection Agency* (EPA) has issued an experimental use permit for the utilization of *C. gloeosporioides* as a biological control for northern jointvetch in rice fields in the State of Arkansas, U.S.A. (Templeton *et al.* 1976). In actual use, spore suspensions of this fungus are applied to rice fields using fixed-wing aircraft. In Florida, U.S.A., large-scale field tests have been conducted to evaluate *P. citrophthora* as a biocontrol for milkweed vine in citrus groves (Ridings *et al.* 1976). These organisms are being researched in the U.S.A. by the Upjohn Co., and Abbott Laboratories, two pharmaceutical firms, in an effort to produce them into a commercial product form. They are well along in this endeavour, e.g., financial arrangements have already been made between Abbott and the University of Florida concerning royalties from the sale of *C. rodmanii* on the world-wide market.

In Australia, *P. chondrillina* has become well established after its introduction from southern Italy. It is beginning to exert considerable pressure on populations of skeleton weed and shows every indication of being successful in controlling this plant (Cullen *et al.* 1973, Hasan 1974). It also shows promise of success in the western United States where skeleton weed is a problem (Emge and Kingsolver 1971).

A recent significant event was the inauguration, in October 1978, of a regional cooperative research project on the use of fungal plant pathogens as weed control agents (Technical Committee 1978). Weed scientists and plant pathologists from the southern region of the U.S.A., which includes the States of Alabama, Arizona, Arkansas, Florida, Georgia, Kentucky, Lousiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia have agreed to work cooperatively on the project entitled 'Biological Control of Weeds with Fungal Plant Pathogens.' In this region of the U.S.A., weeds cause an estimated loss of $2.5 billion annually (Technical Committee 1978). A large portion of these losses is caused by the weeds targeted for research efforts under this project. They are: cocklebur, *Xanthium pensylvanicum* Wallr., morning glory, *Ipomoea purpurea* (L.) Roth and *I. herderacea* (L.) Jacq., prickly sida, *Sida spinosa* L., sicklepod, *Cassia obtusifolia* L., hemp sesbania, *Sesbania exaltata* Raf. Corry, Johnsongrass, *Sorghum halepense* (L.) Pers., nutsedge, *Cyperus esculentus* L. and *C. rotundus* L., alligator weed, *Alternanthera philoxeroides* (Mart.) Griseb., and waterhyacinth, *Eichhornia crassipes* (Mart.) Solms. The objectives of the project are twofold: 1) to identify and determine the distribution of fungi infecting weeds in the southern United States; 2) to evaluate the potential of fungal pathogens as biocontrol agents for reducing weeds problems. The original technical committee designated to conduct the research, consisted of 22 research scientists from throughout the region. The interest in the program is indicated by the fact that since its inception, several scientists have requested to be placed on the project, including some from outside the region. The project is an ambitious one that hopefully will finally establish that plant pathogens are viable control agents for noxious plant species.

METHODS OF APPROACH

Efforts by plant pathologists have developed along two lines: 1) The use of endemic pathogens as types of biological herbicides; and 2) the search for and introduction of exotic pathogens. The latter is the classical approach used successfully by entomologists, while the former is a somewhat newer concept that has been used more generally by plant pathologists. Both approaches have resulted in successes.

Notably among the successes with exotic pathogens, have been: the use of *P. chrondrillina* for *C. juncea* control in Australia as previously cited; control of *Ageratina riparia* in Hawaii with *Cerosporella riparia* n.s. introduced from Jamaica (Trujillo 1976); and control of *Rubus* spp. in Chile with the introduced rust *Phragmidium violaceum* (Schulz) Winter (Oehrens 1977). Using endemic pathogens, the most success has been achieved with the three weeds noted previously: jointvetch, waterhyacinth, and milkweed vine.

Despite about equal numbers of successes, the emphasis in recent work appears to be slanted toward the use of endemic pathogens using the bioherbicide strategy (Templeton *et al.* 1979); e.g., the Southern Regional Project is heavily weighed in favour of endemic fungal pathogens. Part of the reason for the popularity of this approach was noted by Freeman *et al.* (1976); namely, regulations preventing the importation and use of pathogens brought on, in part, by 'pathophobia'. In general, it is much easier to import a macroorganism than it is a microorganism. However, of probably more importance prompting their use in this manner is the fact that they can be produced and disseminated in large quantities. This is one of the factors that made them viable candidates for biocontrol to begin with. Commercially produced inoculum of *C. rodmanii* contained in excess of 10^6 propagules per gram of dry weight (Freeman *et al.* 1979). Templeton *et al.* (1976) reported that they had obtained 95 to 100 per cent kill of jointvetch in 17 rice fields, totalling 240 ha, by dispersing *C. gloeosporioides* on the field by airplane, at the rate of 1.5×10^6 spores per ml in 96 litres of water per ha. That comes to a staggering 144 billion potentially infective units per ha. In addition, most of the organisms being researched incite compound interest diseases (Van der Plank 1975); i.e., disease increase progresses at an expotential rate due to subsequent inoculum production. This subsequent inoculum production can be exceedingly high; e.g., at the height of a *C. rodmanii* epidemic in waterhyacinth, Freeman *et al.* (1979) reported trapping over 900 spores per m^3 of air in a 24-hour period. Only with microorganisms could such tremendous inoculum potentials be realized. Therefore, the bioherbicide tactic, which permits the utilization of endemic plant pathogens, is a workable alternative to the classical approach using exotic pests.

FUTURE CONSIDERATIONS

Templeton *et al.* (1979) have pointed out some of the constraints to the use of mycoherbicides. These include such factors as host resistance, environment, and spatial isolation of the host. In addition, narrow environmental requirements for infection, spore dormancy and long incubation period are factors that may be operative. All of these constraints would be especially important using mycoherbicides to control weeds in annual crops, such as jointvetch in rice. They may be less of a factor in control with a longer range timetable, such as weeds in rangelands and aquatic environments. However, Baker and Cook (1974) as well as Snyder *et al.* (1976) have expressed pessimism about the effectiveness of fungi as biocontrol agents. In fact, Baker and Cook (1976) consider them to be third in potential importance behind Actinomycetes and bacteria. It should be noted, however, that these authors are generally referring to their use as biological control agents for other pathogens. Nevertheless, many of the constraints they noted, such as competition, predation and parasitism, would be the same for their use in weed control. Freeman (1980) considered overcoming these constraints as not an insurmountable task. He notes however, that there may be other disadvantages that may not be definable in light of present knowledge. These are the questions that haunt proginators of biocontrol programs. Namely, what are the long-term effects on nontarget species and what will be the eventual influence on the total agro and/or natural ecosystems?

In view of the above, plant pathologists should expand their search to include other potential groups of organisms. To date, most efforts have been expended on fungal pathogens with only a small amount of research directed toward nematodes (Watson 1978, Orr *et al.* 1975) and viral pathogens (Charudattan *et al.* 1976). Presently, noone is looking at bacterial pathogens. Certainly members of this latter group have great potential when one considers the importance of soft-rot bacteria in the successful control of *Opuntia* in Australia and Hawaii (Dodd 1927, Fullaway 1954). In addition, there are entirely new groups of pathogens, such as mycoplasma, viroids, rickettsia, etc. that have only recently come to light. All of these other groups of pathogens need to be researched in future efforts.

There is also a need for more basic studies in the host-pathogen interaction, especially as it relates to epidemiology. Berger (1977) outlined the epidemiological strategies needed to achieve economic plant disease control. They were: 1) reduce initial inoculum; 2) slow the rate of disease increase; and 3) shorten the time of host exposure to the pathogen. He advocates the use of modelling techniques and computer simulation to simplify the assessment of specific epidemiological events. The practicing artisan of biocontrol can use the same techniques to determine the underlying basis for disease occurrence. He can then use this knowledge in his efforts to induce epidemics rather than control them. Some work has been conducted on epidemiological aspects of biocontrol with pathogens (Freeman 1980, Te Beest *et al.* 1978), but more is needed. In fact, it is imperative that this aspect be thoroughly researched. It is especially important in the application of the bioherbicide tactic.

More futuristically, the pathologists should begin to think in terms of conventional, mutation, and recombinant DNA genetics. Using such techniques, it is theoretically possible to 'taylor-make' a biocontrol agent to fit any set of conditions. Admittedly, such research would be painstakingly slow, expensive, and subject to controversy. However, the rewards could be great.

The use of plant pathogens in IPM should be explored to the fullest. Plant pathogens are usually considered enemies in such programs, but they can also be allies if used properly.

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