Status of the Use of Plant Pathogens in the Biological Control of Weeds[1]

by

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It was only 7 years ago that C. L. Wilson (1969) reviewed the subject of biological control of weeds with plant pathogens for the *Annual Review of Phytopathology*. At that time, he chose to end his presentation with a commencement rather than a conclusion: ". . . to write a conclusion for this subject in its present state of growth seems premature. So let us consider where we might go from here." In this presentation we review where we have gone since then and how the plant pathologists' efforts now compare with those in other disciplines.

To say historically that our science is behind in biological control efforts, in general and against weeds specifically, is somewhat of an understatement. There are rumors, with some basis in fact, that plant pathogens were included in biological control studies for warfare purposes during and immediately after World War II. However, in the area of efforts to use diseases to benefit man, we are just beginning to see the first glimmer of a dawning. Wilson's reveiw came in 1969, significantly not until Volume 7 of *Annual Review of Phytopathology*. Thus, six volumes and 37 other reviews appeared before it. By this point in time, Sweetman's (1936) book on biological control of insects has been published for 33 years and revised (Sweetman, 1958) to include weeds for 11 years. In the revised edition, plant diseases were at least mentioned with a notation that a more careful study of their use is warranted. Also in 1969, Ryan's plan for biological control of cottony cushion scale was more than 80 years past and the prickly pear control board was established nearly 50 years before. The standard reference in the field was the book edited by DeBach (1964) on the *"Biological Control of Insect Pests and Weeds."* Out of the 884 pages in this book, less than one was devoted to agents other than insects. Included on this page was a mention of plant pathogens right alongside sheep, goats, geese, fish and snails. In DeBach's (1974) book, *"Biological Control by Natural Enemies,"* he simply states that "diseases offer great potential but there seems to have been a reluctance to try them."

DeBach is partially correct, but Wilson pointed out at least some areas in which diseases have been used and Sweetman (1958) noted the importance of diseases in assisting *Cactoblastis* control of the prickly pear. Today plant pathologists are becoming ever more aware of the potential of pathogens for biocontrol purposes. Let us explore briefly how this has developed.

In 1969, the American Association for the Advancement of Sciences sponsored a symposium (Huffaker, 1969) on biological control with a noticeable absence of plant pathologists on the program. However, in that same year, the First International Symposium on Biological Control of Weeds was held at the Commonwealth Institute of Biological Control Station in Delemont, Switzerland with one plant pathologist in attendance. The second symposium was held in Rome in 1971, with two plant pathologists present. In 1972, a scant 3 years after Wilson's review, Zettler and Freeman (1972) reviewed the potential use of plant pathogens for control of aquatic weeds. By this time, several ambitious biocontrol programs utilizing plant pathogens, both in the U.S. and abroad, were under way. In 1973, at the Second International Congress of Plant Pathology in Minneapolis, MN, a symposium session devoted to biological control of weeds was held. That same year, two plant pathologists attended the Third International Symposium on Biological Control of Weeds. At the 1974 meeting of the American Phytopathological Society a discussion session was held and an ad-hoc committee began an effort to establish a standing committee on biological control in that

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society. The Weed Science Society of America had an interdisciplinary ad-hoc committee to look into biological control efforts in North America in 1973. When the committee's findings were published in Weed Science (Goeden *et al.*, 1974), they showed 70 weed species were being investigated as targets for biological control agents. Out of these 70, only five were listed as targets for plant pathogens, but plant pathologists were beginning to awaken. The American Phytopathological Society has now established a standing committee on biological control. Approximately one-fourth of the over eighty in attendance at this IV International Symposium on Biological Control of Weeds are plant pathologists and their efforts are chronicled in this volume. Today there is a book on at least one phase of biological control written by plant pathologists (Baker and Cook, 1974) to go with all those written by entomologists. However, there is little doubt that entomologists have a headstart in this area of research; so much so that when biological control is mentioned, administrators and others who control funds frequently think only of entomology. Even the original term "biological control" is attributed to Professor H. S. Smith, an entomologist. But certainly plant pathogens qualify under his definition which simply stated is, "regulation of pest populations by natural enemies."

Efforts by the plant pathologist have developed along two lines: 1. Use of endemic pathogens as a type of biological herbicide; 2. Search for and introduction of exotic pathogens. This latter is the classical approach used very successfully by entomologists. The rationale behind its use is based on the simple fact that many of the more troublesome weeds are imported into an area presumbly minus their natural enemies. In many instances, this importation was accidental. In others, introduction was intentional but the plant escaped. Examples of both types of introduction can be found among aquatic weeds in North America. Alligatorweed [*Alternanthera philoxeroides* (Mart) Griseb.] was flushed from the ballast of ships arriving from South America whereas the waterhyancinth [*Eichhorniae crassipes* (Mart) Solm.] was brought from South America because of its showy flowers. At any rate, the fact that the weeds were imported dictated that a search be conducted for natural enemies in the plant's native habitat.

As noted earlier, there are several active programs in various stages of development involving over 20 weed species. These are listed in Table 1. For earlier studies, the reviews by Wilson (1969) and Zettler and Freeman (1972) should be consulted. There may be other programs not included either because we are unaware of them due to their formative stage or due to our oversight. References included are for keying purposes only and are not intended to be exhaustive. There are some programs that were intentionally deleted from the table because the present status is unknown. One of those concerns the proposed study of diseases of narcotic plants and their potential for biocontrol of these plants. This program was to be headquartered in California but its current status, if active, is unknown. The same is true of the program of brush control in conifer forests wtih the oak wilt fungus, *Ceratocystis fagacearum* (Butz) Hunt (French and Schroeder, 1969). Both of these programs are in sensitive areas of concern. The former by virtue of its international implications and the latter because of the potential spread of the pathogen to desirable oaks. Those studies dealing with biocontrol of parasitic plants, such as mistletoe and dodder, are also not included since these plants are plant pathogens themselves. However, in the broadest sense, some may consider them as weeds.

Of those programs listed in Table 1, four are much advanced over the others and are either approaching or at an operational stage. The most advanced of those using exotic pathogens is the one utilizing *Puccinia chondrillina* Bubak and Syd. for control of *Chondrilla juncea* L. in Australia. The rust and the weed are apparently native to southern Europe. Its biocontrol potential was established by the CSIRO group at their laboratory in Montpellier, France. After due consideration, the fungus was imported for release into Australia. It has become well established on *C. juncea* there and has rapidly spread in almost epiphytotic proportions. The rust is now beginning to exert considerable pressure on well established populations of the weed in Australia (Cullen *et al.*, 1973; Hasan, 1974a). This success has prompted consideration of the use of the pathogen to control skeleton weed in the western United States.

The other three advanced programs involve the use of endemic plant pathogens as a type of biological herbicide. Work in Arkansas (Daniel *et al.*, 1973; Templeton *et al.*, 1976) with the use of *Colletotrichum gloeosporiodes* (Penz.) Sacc. to control northern jointvetch [*Aeschynomene virginica* (L) B.S.P.] in rice fields is well advanced. The fungus has been made into a "product" which

Table 1. Present status of projects studying plant pathogens with biocontrol potential for aquatic and terrestrial weeds.

Weed	Pathogen	Location	Status*	Reference
1. *Acroplilon* (=*Centaurea*) *repens* (L) DC (Russian knapweed)	*Paranguina picridis* Kirjanova & Ivanova	Canada	C,D	Watson, 1977
2. *Aeschynomene virginica* (L) B.S.P. (Northern Jointvetch)	*Colletotrichum gloeosproioides* (Penz) Sacc. f. sp. aeschynomene	Arkansas	E	Daniel *et al.*, 1973 Templeton *et al.*, 1976
3. Algae (blue-green)	Viruses (cynophages)	various	C	Jackson, 1970 Cannon, 1975
	Bacteria	Ohio	C	Brunbam, 1975
4. *Alternathera philoxeroides* (Mart.) Griseb. (Alligatorweed)	Virus	Florida	G	Hill & Zettler, 1973
	Alternaria sp.	Florida	B	Freeman *et al.*, 1976
5. *Ambrosia artemisiifolia* L. (Ragweed)	*Puccinia xanthii* Schu.	Russia	B,C,?	Kovalev, 1975
6. *Cassia surrattensis* Lamarck	*Cephalosporium sp.*	Hawaii	C,D	Trujillo & Obero, 1972 Trujillo & Obero, 1977
7. *Chondrilla juncea* L. (skeleton weed)	*Puccinia chondrillina* Bubak & Syd	Australia	E,F	Cullen *et al.*, 1973 Hasan, 1974a
		California	D	----------
	Erysiphe cichoracearum Dc. ex Merat	France (CSIRO)	C	Hasan, 1972
	Leveillula taurica (Lev. Arn.)	"	C	Hasan, 1972
	Virus (?)	"	C	Hasan *et al.*, 1973
8. *Convolvulus arvensis* L. (Field bindweed)	Various	Canada	A,B	Harris, 1976
9. *Eichhornia crassipes* (Mart.) Solm	*Acremonium zonatum* (Sawada) Gams	Florida	D	Freeman *et al.*, 1976
	Alternaria eichhorniae Nag Raj and Ponnappa	"	G	Nag Raj & Ponnapa, 1970
	Bipolaris stenospila Drechs.	"	C	Charudattan *et al.*, 1976b
	Cercospora piaropi Tharp.	"	C	Freeman & Charudattan 1974
	C. rodmanii Conway	"	E	Conway, 1976a Conway, 1976b
	Fusarium roseum (Lk) Sacc.	"	G	Freeman, *et al.*, 1976
	Myriothecium sp.	Indonesia	C	Setyowati, 1976
	Rhizoctonia spp.	Florida	D	Freeman, 1975 Freeman & Zettler, 1971
		Indonesia	C	Setyowati, 1976
	Uredo eichhorniae Fragoso & Ciferri	Florida	C	Charudattan & Conway, 1975
10. *Hydrilla verticillata* (L. fil.) Royle (Hydrilla)	*Sclerotium rolfsii* (Sacc.) Curzi	Florida	G	Charudattan, 1973
	Pythium sp.	Florida	C	Charudattan, 1973
	Penicillium sp.	"	C	Charudattan & Lin, 1974
	Aspergillus sp.	"	C	Charudattan & Lin, 1974
	Trichoderma sp.	"	C	Charudattan & Lin,
	Phytophthora parasitica Dast.	"	C	Freeman, 1976
11. *Lantana camara* L. (Lantana)	various	Australia Florida Brazil	A,B	----------
12. *Morrenia odorata* Lindl. (Strangler vine)	*Aecidium asclepiadinum* Spreg.	Florida	C	Charudattan *et al.*, 1976a
	Araujia mosaic virus	"	C	Charudattan *et al.*, 1976a
	Puccinia araujae Lev.	"	C	Charudattan *et al.*, 1976a
	Phytopththora citrophthora (Sm., Sm.)	"	D	*Burnett et al.*, 1974
13. *Myriophyllum spicatum* L. (Eurasian watermilfoil)	*Aphelenchoides fagariae* (Ritz-Box) Christie	Florida	G	Smart & Esser, 1968
	Virus (?)	Maryland	G	Bayley, 1970

Table 1. Continued.

Weed	Pathogen	Location	Status*	Reference
14. *Nymphaeaceae* (Water lilies)				
A. *Brasenia schreberi* Gmel.	*Dichotomophothoropsis nymphaearum* (Rand)			
B. *Nuphar lutem* (variegatum?) Evgelm				
C. *Nymphaea odorata* Ait.				
D. *N. tuberosa* Paine		Minnesota	C,D	Johnson & King, 1976
15. *Nymphoides orbiculata*	*Puccinia scirpi* ?	Sweden	C	Nilsson, 1976
16. *Oxalis* sp.	*Puccinia oxalidis* (Lev.) Diet. & Ell.	France	C	Durrier, 1976
17. *Pistia stratiotes* L. (Water lettuce)	Virus	Africa	G	Pettet & Pettet, 1970
18. *Rubus constrictus* Lf. et m. and *Rubus ulmifolius* Shott (wild blackberry)	*Phragmidium violaceum* (Schulz) Winter	Chile	C,D,E	Oehrens & Gonzales, 1974
19. *Rumex crispus* L. (Curly dock)	*Uromyces rumicis* (Shum) Wint.	Italy Mississippi	G G	Inman, 1971
20. *Salvinia* sp. (Salvinia)	*Alternaria* sp. *Spicariopsis sp.*	Africa	G	Loveless, 1969
21. *Sida spinosa* L. (prickly sida)	*Collectotrichum malvarum* (A. Brown & Casp.) Southworth	Arkansas	C	Templeton, 1974
22. *Solanum elaeagnifolium* Cav. (Nightshade)	*Nothanguina phyllobia* Thorne	Texas	C	Orr *et al.*, 1975
23. *Xanthium* spp.	*Puccinia xanthii* Schw.	Australia	C,?	Alcorn, 1975 Hasan, 1974b

* A—planning, B—survey, C—laboratory and greenhouse studies, D—small-scale field studies, E—large-scale field studies, F—operational, G—inactive or unknown.

can be sprayed onto infested rice fields from airplanes. It is apparently a very effective control for jointvetch and its use may become widespread in the very near future. Two programs in Florida are also reaching maturity. One program involves the use of *Phytophthora citrophthora* (Sm., Sm.) to control strangler vine (*Morrenia odorata* Lindle.) in Florida citrus groves. This study is being conducted primarily by the Florida Department of Agriculture (Burnett *et al.*, 1974). The other concerns the use of *Cercospora rodmanii* to control waterhyacinths which is being researched by the University of Florida group (Conway, 1976a; Conway, 1976b). Both programs have reached the stage where a product form is being formulated and large scale field evaluations are planned for the near future. Both organisms are effective and appear host specific. *Phytophthora citrophthora* is a pathogen of citrus, however, the strain that attacks strangler vine does not affect citrus. *Cercospora rodmanii* has been shown not to attack over eighty plants of economic and ecological importance (Freeman *et al.*, 1976). A high degree of host specificity is also exhibited by *C. gloeosporioides* toward jointvetch. Thus, all three of these endemic organisms have been shown to be effective against the target weed and safe to use from the standpoint of presenting a hazard to other plants.

No doubt other programs will reach the status of the four above in the not too distant future and other new programs will be initiated. Certainly plant pathogens have many desirable characteristics as biocontrol agents (Freeman *et al.*, 1974; Freeman *et al.*, 1975; Zettler and Freeman, 1972). Therefore, it is not surprising that successes followed rapidly when a concerted effort to evaluate pathogens was made. The only surprise is that it took so long for plant pathologists to discover a potential that lay dormant, for the most part, on their doorsteps since the birth of the science. However, achievement of successes will not be without their problems. For example, in the United States, the Environmental Protection Agency (EPA) has taken a keen interest in the use of pathogens in the environment, especially in the aquatic environment. Even a large segment of the general public is affected with "pathophobia." Therefore, we will have to prove our case well and document, beyond any shadow of a doubt, the effectiveness and safety of pathogenic biocontrol. We may well have to meet registration requirements for pathogens similar to those needed to register a chemical herbicide. Such a requirement would definitely slow our progress; however, work in this area of research must be continued because the potential is too great to ignore. Fortunately plant pathologists have finally awakened to the task at hand. It is gratifying to those of us working in the field to note the increased interest in plant pathogens as biocontrol agents for weeds. Just as an example, today there are more plant pathologists in Florida working on biological control of weeds with pathogens than there were in the entire world less than 10 years ago.

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