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Conflicts in the Use of Plant Pathogens as Biocontrol Agents for Weeds

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Abstract

Theoretically, plant pathogens are ideal candidates as biocontrol agents for weeds. However, their use is subject to the same conflicts of interest that are encountered with other biocontrol agents. Namely, what will be the effects of their use on non-target species and what will be the eventual long-term influence on agro- and natural ecosystems. Despite their relatively recent usage as biocontrol agents, conflicts have already arisen and others, real or imagined, are certain to follow. Indeed, many of the same attributes, such as host range and reproductive capacity, that make pathogens ideal biocontrol agents can also serve to change them from friend to foe. Ironically, so can the whims of mankind. Examples of the types of conflicts of interest will be discussed in this presentation.

Conflits d'Intérêts Concernant l'Utilisation d'Agents Pathogènes pour la Lutte Biologique Contre les Plantes Nuisibles

De façon théorique, les agents pathogènes des plantes constituent des candidats idéals pour la lutte biologique contre les plantes nuisibles. Toutefois, leur utilisation soulève les mêmes conflits d'intérêts que lorqu'on emploi les autres agents biologiques: quels seront les effets de leur utilisation sur les espèces non visées et les répercussions à long terme sur les écosystèmes agricoles et naturels. Bien que l'utilisation des agents pathogènes en vue de la lutte biologique soit relativement récente, des conflits ont déjà surgi et d'autres, réels ou imaginés, vont certainement suivre. En effet, de nombreuses caractéristiques comme la gamme d'hôtes et la capacité de reproduction, qui font de ces agents pathogènes d'excellents agents de lutte biologique, peuvent également faire de ces amis des ennemis. Par ironie, les lubies de l'homme peuvent en faire autant. Les auteurs donnent des exemples du genre de conflits d'intérêts provoqués par les agents pathogènes.

Introduction

Plant pathogens have many desirable characteristics that make them ideal candidates as biocontrol agents for weeds (Freeman *et al.* 1974; Zettler and Freeman 1972). Therefore, it is surprising that prior to 1970, little concentrated research had been focused on their use for such purposes (Wilson 1969; Zettler and Freeman 1972). However, since 1970, there has been a dramatic increase in research efforts directed toward the incorporation of plant pathogens into biological control programs for both aquatic and terrestrial weeds (Charudattan 1978; Freeman and Charudattan 1981; Templeton 1982). As one would expect, with this increase there has also been increasing awareness of conflicts, both real and imagined, that may accompany their usage.

Andres (1981) discussed conflicting interests that may arise in the use of biological agents for weed control. He categorized them into economic, ecological, and aesthetic conflicts. Although his discussion dealt primarily with insects, use of plant pathogens as biocontrol agents is subject to the same categorical conflicts. Harris (1980) has pointed out that biological control research is still dependent upon an empirical element. Because of its more recent development, this is especially true in research on plant pathogens. The injection of such an element into scientific research certainly increases the potential for conflicts to arise — and they have. Some are imagined, but others are real. In addition, because of the potential for genetic diversity noted by Leonard (1982), conflicts may be even more frequent with the use of pathogens than other biotic agents. There are also other factors that form a basis for conflict. It is the purpose of this presentation to discuss the theoretical aspects that may lead to conflicts of interest in the use of plant pathogens in the classical and bioherbicidal approaches to controlling weeds biologically and to cite specific conflicts that have already occurred.

Conflicts in the Classical Approach

As defined by Tisdell *et al.* (1984) 'Classical biological control involves the release of a natural enemy (predator, parasite) of a weed or pest. The biocontrol agent is imported and once established, the population of the agent is self-sustaining and reaches a long-term equilibrium with that of its (weed) host'. Harris (1980) cites several examples, dating back to the turn of the century, of the use of insects in the classical approach to biocontrol of weeds. There have also been some notable successes with exotic plant pathogens. They are: the use of *Puccinia chondrillina* Bub. & Syd. (Uredinales) for control of *Chondrilla juncea* L. (Compositae) in Australia (Cullen 1974; Cullen *et al.* 1973; Hasan 1974), and the western United States (Emge and Kingsolver 1971; Adams and Line 1984); control of *Ageratina riparia* (Hyphomycetes) (Regel) R.M. King & H. Robinson in Hawaii with *Cercosporella riparia* (Trujillo 1976); and control of *Rubus* spp. (Rosaceae) in Chile with the rust *Phragmidium violaceum* (Schultz) Winter (Uredinales) (Oehrens 1977).

Thus far, no serious conflicts have arisen in the successes cited. True, the potential is there. For example, in Australia, three ecotypes of rush skeletonweed varying in their resistance to *P. chondrillina* apparently existed when the pathogen was released (Hull and Groves 1973). Following the successful establishment of *P. chondrillina* as a biological control agent, a decline in the numbers of the predominant host type that was susceptible to the rust and an increase in the numbers of two other resistant host types occurred in some areas where they were present (Burdon *et al.* 1981). Also, *P. violaceum* can affect cultivated *Rubus* spp. The present status of this pathogen in Chile is not known, but no adverse effects have thus far been reported.

Despite the lack of documented serious conflicts, there is an air of pathophobia that has brought to a virtual standstill the application of the classical approach in the use of plant pathogens for weed control. As far as we can determine, *P. chondrillina* is the first and the only exotic plant pathogen approved for release in the continental United States. In Florida, the proposed release of *Uredo eichhorniae* Gonz.-Frag. & Cif. (Uredinales) (Charudattan and Conway 1975), a rust pathogen of waterhyacinth (*Eichhornia crassipes* [Mart.] Solms-Laubach; Pontederiaceae) and Araujia mosiac virus (Charudattan *et al.* 1980) a pathogen on milkweed vine (*Morrenia odorata* [Hook. & Arn.] Lindl.; Asclepiadaceae), a serious weed in citrus groves, was rejected by the U.S. Department of Agriculture. The former because of lack of documentation of an alternate host, if one exists, and the latter because of an unsolvable conflict concerning its possible pathogenicity on certain 'endangered' species in the milkweed family (Asclepiadaceae) thought to occur in Florida. Prior to its disapproval, Charudattan *et al.* (1980) and Charudattan and Heron (1982) had tested the virus against 121 plant species in 25 different families. Only 10 species of milkweed, all vines, were susceptible. None of the herbaceous milkweeds tested was susceptible. Also, in the Florida program, two other exotic pathogens of waterhyacinth were tested and rejected by the investigators because of their wide host range. One was *Bipolaris oryzae* (previously identified as *B. stenospila* Drechs.; Hyphomycetes), isolated from waterhyacinth in the Dominican Republic (Charudattan *et al.* 1976) that was also pathogenic on rice (*Oryza sativa* L.; Gramineae), sugarcane (*Saccharum* spp.; Gramineae) and burmudagrass (*Cynodon dactylon* [L.] Pers.; Gramineae). Ironically, bermudagrass is listed by Holm *et al.* (1977) as the second most important weed in the world. Not so in Florida where tourists play millions of rounds of golf on more than 900 golf courses planted with bermudagrass. The second pathogen was a *Rhizoctonia* sp. (Hyphomycetes) from Panama (Freeman and Zettler 1971) that was also pathogenic to a large number of crop species. The work with this pathogen was suspended despite the fact that *Rhizoctonia* spp. are ubiquitous in soils throughout the world. *Rhizoctonia* sp. has also been reported to affect desirable aquatic plants (Bourne and Jenkins 1928). Hence, work with this exotic fungus was abandoned and was not resumed even when it was later found naturally occurring in the United States (Freeman *et al.* 1981).

To minimize conflicts that may arise in the use of exotic pathogens, two approaches have been taken to insure their safety. Australian efforts have been directed towards studying the host range and biocontrol potential of the organism in areas where it and the target weed are native. This approach is the safest in the initial phases. However, it has limitations in that it may not be possible to thoroughly test host range on plant species, biotypes, and varieties native to the target area. In the United States, pathogens have been introduced into quarantine facilities where their biocontrol potential and host range have been evaluated. This method has an advantage in that plants native to the target area can be more thoroughly tested. However, it has the disadvantage of the possibility of escape of the organism through human error or damage to the quarantine facility caused by natural disaster. Therefore, both approaches have limitations that could lead to unforeseen conflicts.

It should be noted that plant pathogens throughout the ages have found their way from country to country and continent to continent. Just as with weeds, man is usually the culprit in their transportation from place to place. For example, *Puccinia xanthii* Schw. was accidently introduced in Australia from the United States. It became established in Australia on *Xanthium* spp. (Compositae), and has since been found to parasitize at least two varieties of sunflower (*Helianthus annus* L.; Compositae) (Tisdell *et al.* 1984). However, natural forces can also move pathogens. Coffee rust, *Hemileia vastatrix* Berk. & Br. (Uredinales), is believed to have been carried by wind currents from Africa to South America and annually cereal rust spores are carried by wind currents from Mexico and the southern United States along the 'puccinia pathway' into Canada. Thus, despite our most elaborate efforts, we must realize that movement of plant pathogens into new areas cannot be totally controlled.

Conflicts in the Bioherbicidal Approach

In view of the severe limitation placed on the use of exotic microorganisms, much of the work on weed control with plant pathogens is now concentrated on the use of endemic pathogens as bioherbicides. Both the augmentative and inundative approaches (Tisdell *et al.* 1984) are being used. The former is used primarily in areas where long range control is acceptable, such as rangeland and certain aquatic environments, while the latter is used where quick control is desirable, such as in annual crops. Both approaches use essentially the same methodology, differing only in intensity and frequency of pathogen application. Pathogens are grown in artificial culture, harvested and applied to the target plant at an optimal time for infection to occur. This approach has been very successful and two bioherbicides are already being marketed and others may be nearing the marketing stage.

Fungi make up the majority of the pathogen species used in biocontrol programs (Freeman 1980; Templeton *et al.* 1979, 1982). Those that have been used in the bioherbicidal approach are most frequently facultative parasites or, at best, facultative saprophytes. Therefore, they may not be as restrictive in their host range as are the obligate parasites that have been most often used in the classical approach. In fact, many weed-infecting pathogens, such as *Rhizoctonia* spp. (Freeman and Zettler 1971), *Sclerotium rolfsii* (Sacc.) Curzi (Hyphomycetes) (Charudattan 1973) and *Sclerotinia sclerotiorum* (Lih.) de Bary (Helotiales) (Brosten and Sands 1984) have extremely wide host ranges and could be used only under the most restrictive of conditions without causing serious conflicts. Others, including some of the more successful ones such as *Collectotrichum gloeosporioides* (Penz.) f. sp. *aeschynomene* (Melanconiales) (Templeton *et al.* 1978) marketed as Collego® for jointvetch (*Aeschynomene virginica* [L.] B.S.P.; Papilionaceae) in rice and *Phytophthora citrophthora* (R.E. Sm. & E.H. Sm.) Leonian (Peronosporales) (Ridings *et al.* 1972, 1982) marketed as Devine® for milkweed vine control in citrus are physiologically specialized races of these pathogens. It can be speculated that they probably arose as stable mutants, although recent research indicates that the pathovar of *P. citrophthora* from milkweed vines is actually a pathovar of *P. palmivora* (Butler) Butler (Fiechtenberger *et al.* 1981; Ridings *et al.* 1982). Nevertheless, its origin is probably also mutagenic in nature. Again, there is conjecture as to the origin of *Cercospora rodmanii* Conway (Hyphomycetes) (Conway 1976*a*, *b*), a biocontrol agent for waterhyacinth. It also probably arose as a variant of another *Cercospora* sp., *C. piaropi* Tharp., a species known to occur on waterhyacinth since 1917 (Tharp 1917).

The potential for genetic change affecting host range is present in pathogens used as bioherbicides. Certainly, the staggering numbers of propagules used in bioherbicidal applications increase the potential for mutants to occur. For example, *C. gloeosporioides* f. sp. *aeschynomene* has been applied at rates exceeding 150 billion propagules/ha (Templeton *et al.* 1978) and *C. rodmanii* was used at a rate of 40 billion propagules/ha in large-scale tests conducted by the United States Army Corps of Engineers in Louisiana (Theriot and Sanders 1980). Using such numbers certainly increases the possibility of disseminating a mutant with changed host range, although it is not certain that the mutant will survive and multiply. As Leonard (1982) has pointed out, changes in pathogenicity and host-specificity have occurred in certain species of plant pathogens, but experience indicates that such occurrences are rare.

Despite the potential dangers, in the United States the use of bioherbicides has been encouraged by a relaxation in the Environmental Protection Agency (EPA) guidelines for registration of biorational pesticides (Charudattan 1982). The prevailing EPA opinion is that biorational pesticides provide a safer alternative to the use of chemicals in the total environment. However, it should be noted that in view of recent court decisions, this relaxation probably will not apply to genetically engineered organisms should they be forthcoming. This is a serious conflict because of the great potential for tailoring an organism for biocontrol purposes through genetic engineering or mutations (Freeman and Charudattan 1981; Te Beest 1984). Apparently the curent view is that organisms selected through natural mutations are acceptable, but genetically engineered ones are not.

Few, if any, plant pathogens have ever been definitely proven to be pathogenic to either man, domestic animals, wildlife or fishes. In fact, in tests conducted in Florida by Conway and Cullen (1978), fish (*Gambusia*) utilized inoculum of *C. rodmanii* as a food source with no ill effects. However, certain fungi are known to cause allergic reactions in some individuals. This could possibly present a problem in the immediate area of inundative releases, but otherwise, the use of plant pathogens as bioherbicides should cause no conflict with human or other animals.

There are economic conflicts to consider. For example, waterhyacinth control with microbial agents is expected, rather unreasonably, to be as effective as chemical herbicides and as cost effective in practice as chemical herbicides to be accepted. Because this may not be the case, Abbott Laboratories have decided against commercialization of *C. rodmanii* as a bioherbicide based on marketing (economic) reasons.

The potential for toxin production by microbial biocontrol agents has discouraged many companies from entering this field. However, with relaxation of EPA registration requirements, several companies have renewed their search for toxins that may be potentially useful as pesticides. So, what used to be a conflict appears to be no longer a conflict.

Specific Conflicts

In addition to conflicts cited above, several other specific conflicts have occurred. Some of these relate to the fact that the weed is closely related to either a crop or an ornamental species. However, there are instances where the weed species *per se* is considered of economic value under some conditions.

Although it is one of the most important weeds in North America, Watson and Harris (1975) cautioned against the use of pathogens to control wild oats (*Avena fatua* L.; Gramineae) because of the close relationship to cultivated oats (*A. sativa* L.) and the commonality of their pathogens. In Louisiana, work on *Alternaria alternantherae* Holcomb & Antonopoules (Hyphomycetes) for control of alligatorweed (*Alternanthera philoxeroides* [Mart.] Griseb.; Amaranthaceae) was halted because of its pathogenicity on ornamental *Alternanthera* spp. (Holcomb 1978). Likewise in Florida, *Acremonium zonatum* (Saw.) Gams (Hyphomycetes) was purged from the list of potential controls for waterhyacinth because of its pathogenicity on ornamental and edible fig (*Ficus* sp.; Moraceae).

Lantana camara L. (Verbenaceae) is a pest in citrus groves in Florida, but it is also widely used in the State as an ornamental and the proposed use of a *Cercospora* sp. for its control met resistance. A similar situation occurred with alligatorweed in Louisiana where the plant is frequently used as a forage species. Biocontrol agents (insects and pathogens) have contributed to a significant reduction in the population of waterhyacinth. However, recently waterhyacinth has been targeted as an ideal candidate for biomass for the production of alternate sources of fuel. It is also being used to purify sewage effluents. Thus, a plant that was at one time considered the eighth worst weed in the world (Holm *et al.* 1977) is now of potential value.

Conclusion

Plant pathogens are suitable candidates as biocontrol agents for weeds. Although their use for this purpose can be generally safe as indicated by our experience (e.g. *P. chondrillina* in Australia and two mycoherbicides in the U.S.), it is not without potential for conflicts. As with any biological system, changes can occur with pathogens. Such changes may drastically alter the expected equilibrium of the ecosystem. The eventual effects on the agro- and natural ecosystem of the release of a plant pathogen as a biocontrol agent for weeds can be only suggested, never predictable with absolute certainty.

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