Potential for developing and marketing mycoherbicides

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Summary

Four mycoherbicides are currently being used to control weeds in annual crops, orchards, rangelands and forest and have shown to be commercially feasible. They usually perform as well as herbicides but often slower. They are especially attractive for hard-to-control weeds, herbicide resistant weeds and weeds closely related to the crops in which they occur.

Other mycoherbicides are approaching commercialization for use in comparatively dry climates and serve to illustrate the broader utility of mycoherbicides than originally thought.

Several mycoherbicides have been termed orphans because, even though they are biologically feasible, they are not considered to have sufficient commercial potential for industry investment. Creative marketing arrangements needed for these orphans are discussed.

Introduction

Mycoherbicides are environmentally benign biological control agents developed from indigenous fungi that normally incite weed diseases at endemic levels (8). Weed control is achieved by application of living spores of the fungus which have been produced and formulated in commercial fermentation facilities (7,21). Spore applications, either pre- or post-emergent depending upon the disease cycle, are made annually to specific weed populations in the same manner as chemical herbicides. Mycoherbicides thus have commercial potential in contrast to classical biological controls which rely on inoculative releases and self-perpetuation of exotic organisms (3).

Mycoherbicides are currently in use on a commercial scale for control of specific annual weeds in annual crops, perennial weeds in orchards, rangelands and forests and for a parasitic weed on an annual crop (6,10,19,20,23,30). Turfgrass weeds and waterweeds are obvious opportunities (6). The mode of action of mycoherbicides involves spore germination, penetration and establishment in the host. Pathogenesis leads ultimately to death of the specific host (25). Non-host plants and non-target organisms are not infected. If a spore does not impinge on its host it dies, deteriorates and becomes part of natural microbial degradation cycles without a distinctive residue in soil, water or the harvested crop (27).

Environmental and food safety issues are practical incentives for development of mycoherbicides, public perception of chemical pesticides being what it is (24,27). However development of all products to date has been driven by the need to control weed problems of limited extent that are not controlled by existing herbicides. These have resulted from research initiatives in university and government laboratories rather than industry (28). Industry has collaborated in many cases to provide expertise and resources for patents, fermentation scale-up, formulation, registration and marketing once biological feasibility was established (26). The low market potential, including lack of benchmark products against which to asses market potential have been disincentives to private industry. On the other hand, comparatively low development costs, improved regulatory climate, grower acceptance, and opportunities against herbicide resistant weeds provide increasing incentives and interest among conventional pesticide companies. A growing body of knowledge in public institutions on use of naturally occurring organisms for pest control and potential of recombinant DNA techniques to improve biological control organisms provides further incentives for private industry to invest in discovery and development of mycoherbicides (28).

In this paper I will present some examples of past successes with mycoherbicides, some potential mycoherbicides for the future and consider collaborative arrangements that might enhance growth of this relatively young branch of weed science.

Existing products

The mycoherbicide Collego® has been used for a decade in Arkansas rice and soybean fields to control the leguminous weed northern jointvetch (*Aeschynomene virginica*) (27). It is a two-component product consisting of Component A, a water-soluble spore rehydrating solution and Component B, a dry formulation consisting of 15% viable spores of a strain of *Colletotrichum gloeosporioides* and 85% inert ingredients. Each fermentation batch is assayed before packaging so each bag contains 7.54 x 10^{11} viable spores, the amount required to treat 4.05 hectares at the rate of 93.5 liters per hectare. On a dry-weight basis these rates range from (30-60 grams) product per acre depending upon germinability of the batch. Shelf-life of the dry formulation has exceeded one year in standard distribution channels and over three years in refrigerated storage. Weed control averaged 92% during field tests on 1991 hectares of rice treated during the development period 1972-1982 (3,21,25). Grower results since 1982 have been equally good and returns to growers have routinely exceeded four for one. No residual control in subsequent seasons has been detected. Collego® can be tank mixed with aciflurofen or bentazone (12,13,14,22) or other fungal pathogens. None of these have been registered.

Collego® is currently marketed by Ecogen Corporation and they anticipate re-registration of the product by EPA and continued marketing of the product for use in rice and soybeans. It is significant to note that this product is the first sold for use in an annual agronomic crop in the U.S.A.. It was developed in a collaborative research and development effort involving the U.S. Department of Agriculture, the University of Arkansas and the Upjohn Pharmaceutical Company with co-operating disciplines of weed science, plant pathology, veterinary science, fermentation science and registration and marketing personnel in industry (3,7,21,25). As a consequence, the cost of this pioneering effort has been difficult to establish. It has been estimated to be $2,000,000 but this should not be the basis for decisions on future opportunities with mycoherbicides. Much lower estimates could be developed now based on experience with Collego® and clearer registration guidelines would shorten development times.

The mycoherbicide Devine® has been used commercially since 1981 in Florida citrus groves to control milkweed vine, a perennial vine that canopies trees (19). It is marketed by Abbott Laboratories on a custom basis as a wet formulation of spores of a strain of *Phytophthora palmivora* (11). Shelf life currently is limited to six weeks in refrigerated storage. It is applied at the rate of 8 x 10^4 spores per square metre to the surface of moist soil under citrus trees. Label restrictions require a safety zone of 1.6 km be maintained between site of application and plantings of several susceptible vegetable crops and ornamental plants. Distribution and marketing of the relatively labile product is feasible because of the limited market area. Had it been a product that was to have been sold over a large area, improvement in formulation for longer shelf-life at ambient temperature would have been necessary (11).

No damage to non-target crops or citrus have been noted in the eleven years since first commercial use despite mild infection of citrus in controlled environments with high inoculum rates. In treated areas, there has been no detectable change in virulence of the pathogen or related pathogens with which it might cross. This affirms the original assertion that the fungus, although capable of interspecific hybridization in culture, does not do so in nature with sufficient frequency to create sustainable strains with undesirable traits.

Grower acceptance of Devine® has been very good. Less than expected has been sold because of residual control by the fungus. Milkweed seedlings emerging under treated trees for up to five years after treatment have been killed by the fungus in some soils. It is expected that it will be re-registered by EPA, possibly with the addition of other hard-to-control weeds in the milkweed family.

A mycoherbicide to control persimmon trees up to 10 cm in diameter in rangeland in south-central Oklahoma has been used since 1960. It is provided free to ranchers by the Noble Foundation, near Ardmore, Oklahoma as a suspension of spores in plastic squirt bottles at the start of each growing season. Spores must be applied to wounds in the cambium of tree trunks made with a hand axe. All trees in a grove may be killed within three years following inoculation of 80% or more of the trees (10).

Loss of virulence during culture of the fungus has occurred frequently, necessitating isolation of virulent strains each season from diseased trees. The geographic separation and localized areas of use, plus the requirement for wound inoculation, has negated concern about the potential for conflicts of interest with economic persimmons in forest or home gardens. It is thought that a formulation of this fungus with good shelf-life and stable virulence would have greater utility and market potential over a much wider area (26).

The mycoherbicide Lubao® is used in the People's Republic of China to control dodder parasitic on broadcast-planted soybeans. It is a strain of *Colletotrichum gloeosporiodes* used since its discovery in 1963 for practical control of this parasitic weed. In the late 1970s, some 670,000 hectares of soybeans in 10 provinces were treated and control averaged greater than 85% (30).

Spores are provided to growers in fresh solution and sprayed at concentration of 20 million spores per ml with hand sprayers until runoff. Best results are obtained when spraying is done at 1600 to 1700 hours on days when humidity in high, usually in late July to early August.

Limited shelf life and technical problems in fermentation and formulation have reduced its use in recent years but there are two county factories in the Nigxia autonomous Region that still produce a granular form of the product. A preliminary evaluation of this mycoherbicide in the U.S. suggests that existing or improved strains may have potential on dodder species in high value crops, and that the existing technology for production and formulation of Collego® would also be appropriate for this mycoherbicide (5).

Potential products

A mycoherbicide for the control of a weedy prunus species in forests in the Netherlands is available from Koppert Biological Control (19,20). It is a native fungus strain of *Chondrostereum purpureum* and, like persimmon wilt, requires wound inoculation to initiate the disease. Weed trees and sprouts are cut mechanically and the cut surfaces of the stump are painted or sprayed with mycelial fragments in agar suspension. Mycelial concentration equivalent to 20 to 200 μg dry weight per stump are effective, and applications made in spring or autumn are similarly effective in removing prunus saplings from reforestation plantings.

Fructification and sporulation of the fungus on naturally infected and treated trees and stumps may provide periodic inoculum threats to certain cultivated *Prunus* within a 5 km radius during pruning seasons. The low risk to non-target native trees and fruit trees is believed to be acceptable to the Dutch Plant Quarantine Authority because of separation of forest plantations and fruit growing regions. Registration in the Netherlands was applied for in 1991 for restricted use of this wet product with a shelf-life of about two months. Low market potential is a deterrent to commercialization. But the ease with which the organism can be produced and marketed in a localized area raises expectation that it will be available commercially (9,20). The relatively broad host range of *Chondrostereum purpureum* provides added incentive to use it as a management tool in Western Canada reforestation projects to remove unwanted alder and other hardwood species (29).

A mycoherbicide with considerable market potential is being developed in New South Wales, Australia, for control of spiny cockleburr (Bathurst burr) in sheep ranges and in irrigated cotton and soybean fields (1,2,16). It is a strain of the fungus *Colletotrichum orbiculare* that incites a burr anthracnose and appears to have excellent potential for control of this serious weed despite the comparatively dry climate of the region (2).

Effective control can be achieved by timing application to take advantage of dew or rainfall and by formulations that enhance efficacy where climatic moisture is erratic. The relatively high market potential of this mycoherbicide is an incentive for commercialization and the possibility that additional cockleburr and other weedy species may be controlled by it, is an added inducement to develop this product for use in Australia and other countries (16).

Biomal® is a mycoherbicide being commercialized by PhilomBios., Saskatoon, Saskatchewan, Canada for control of round-leaved mallow in lentil, flax and wheat fields in the prairie provinces of Canada and the northern plain states of the U.S.A. (15,17,18). It is a dry formulation of the fungus, *Colletotrichum gloeosporioides* and is expected to be marketed in Canada in 1992 and in the U.S.A. in 1993. It gives reliable control in the comparatively dry climate of the prairie by careful timing of application to take advantage of moisture that favours infection and disease development. The effectiveness of this mycoherbicide in a characteristically dry region, like the burr anthracnose in Australia illustrates the fact that endemic diseases persist within climatic constraints of regions where they occur. Thus pathogens have windows of opportunity when they can be successfully used as mycoherbicides regardless of the general climatic averages of the region.

Several other mycoherbicides have been shown to be adequate biologically but not to have adequate market potential to warrant registration and development costs. They are termed "orphaned" mycoherbicides. Most of these are strains of *Colletotrichum gloeosporioides* and appear to have been sufficiently researched for production, formulation and registration. Consequently it would seem feasible to use existing technology and registration data to achieve this commercial status. However because they are for niche markets often widely dispersed, creative marketing strategies will be required to make them available. Collaboration between academic and federal laboratories with industry will continue to be necessary and use of local institutions such as grower co-operatives, large food processing industries or even government agencies as exclusive distributors is needed to make possible opportunity for public benefit with these orphans.

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