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Research Article

THE POTENTIAL FOR THE USE OF MYCOHERBICIDE TO MANAGE SOME NOXIOUS WEEDS IN INDIA

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ABSTRACT

Due to the recent trends in environmental awareness concerning the side effects of herbicides, public demands for development of safer, more environmental friendly approaches for weed control. The development of weeds resistant by the application of herbicides demands new alternate to cope with the problem since economic losses generated by weeds can be higher than those caused by other pests. The herbicide industry is continuously searching for identification and characterization of most effective, economical and environmentally safer synthetic herbicides by screening large number of synthetic organic molecules, synthesizing analogs of patent herbicides ,designing new herbicide molecules based on target site approach and screening of natural products for herbicidal activity. Eco-friendly trends in weed management force scientists to reach for innovative sources and tools. Fungi are well recognized for their ability to produce diverse biologically active metabolites including herbicides. Therefore screening for fungal products with herbicidal activity has been one of the most interested areas in weed management research. The herbicidal properties of fungi can be exploited successfully as a tool for the management of weeds. Large number of secondary metabolites produced by fungi provides eco-friendly, diverse and challenging chemical structures. The biological control of weeds by mycoherbicide (fungal weed pathogens and/their metabolites) have received considerable consideration. Mycoherbicides offer an innovative approach to the management of weeds using formulated fungal phytopathogen or their natural metabolite extracts would serve as an important component in integrated management strategy. In this review paper, we present the work for management of some noxious weeds of India viz. *Parthenium hysterophorus* L., *Lantana camara* L., *Xanthium strumarium* L., *Cassia tora* L., *Hyptis suaveolens* (L.) Poit. *Sida actua* Burm. f and *Antigonon leptopus* Hook. & Arn. with isolated indigenous fungal pathogens and by their metabolites.

INTRODUCTION

Long back Bailey (1906) has commented that nature know no plant as weeds. Man altered the earth's floral cover in his first efforts in agriculture and weeds were born. King (1966) has pointed out that perhaps the shortest definition of a weed is that attributed to Professor W J Beal who defined a weed as "Plant out of Place". Weeds are unwanted and undesirable plants which interfere with the utilization of and water resources and thus adversely affect human welfare. Whether a plant is considered a weed depends not only on its characteristics but also on its relative position with reference to other plants and to man. The same plant may be a weed in one environment and an economically important plant in another. More presence of one or few weed plants at a place is not of much concern but when their density increases they start interfering with main activities, becoming obnoxious and develop the status of a pest. In order to meet the objectives of good health and food, weeds must be controlled intelligently. The conventional methods of weed management are operative since long and played a significant role in weed management programme. However, the conventional methods of weed control have various drawbacks. Biocontrol of weed management is application of natural enemies to control the weed growth or suppress weed population. Generally two basic methods implement for weed control with pathogens. The application of foreign pathogenic organisms generally known as classical approach and where the pathogenic organisms are already present (native) known as bioherbicidal approach (Watson and Wymore 1990; Mueller-schaerer and Frantzen 1996; Mueller-Schaerer and Scheepens 1997). Such pathogens or biological agents are generally "manufactured", formulated, standardized, packed and registered like chemical herbicides (Auld and Morin 1995; Mueller-Schaerer and Scheepens 1997). One group of such biological agents with promising potential for weed control is mycoherbicide.

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Mycoherbicide

Mycoherbicide have been defined as "plant pathogenic fungi developed and used in the inundative strategy to control weeds in the way chemical herbicides are used" (TeBeest and Templeton 1985) or as "living products that control specific weeds in agriculture as effectively as chemicals" (Templeton *et al*. 1986). Mycoherbicide are specifically formulated preparations of a living inoculum of a plant pathogen that is used for the control of a target weed. Usually they are applied in a manner similar to chemical herbicides by periodic dispersals of distinct doses of the virulent inoculum (Watson 1989; Watson and Wymore 1990). The concept of mycoherbicide was first introduced by Daniel *et al*. (1973), who demonstrated that an endemic pathogen might be rendered completely destructive to its weedy host by applying a massive dose of inoculum at a particularly susceptible growth stage. To render this approach a success, the pathogen must be culturable in artificial media; the inoculum must be capable of abundant production using conventional methods such as liquid fermentation; the final product must be genetically stable and specific to the target weed; storage (shelf-life), handling, and methods of application must be compatible with current agricultural practices; and the pathogen must be efficacious under sufficient different environment conditions to allow a feasible application window (Daniel *et al*. 1973; Templeton *et al*. 1979). The level of scientific activity in mycoherbicide research has increased tremendously and registered or unregistered uses of mycoherbicides have also increased worldwide. Likewise, the numbers of U.S. patents issued for mycoherbicidal use of fungi and mycoherbicidal technology have increased, perhaps foretelling an increased reliance on mycoherbicides in the future. Currently two mycoherbicides, DeVine® and Collego®, are used commercially in the United States to control, milkweed vine, Morrenia odorata in citrus groves of Florida and northern joint vetch, and Aeschynomene virginica in rice and soybean fields of Arkansas and neighboring states respectively (Templeton and Heiny 1988; Charudattan 1991; TeBeest *et al*. 1992). DeVine, marketed by Abbott Laboratories, is the first registered mycoherbicide. The mycoherbicidal product consists of a liquid concentrate of chlamydospores of pathotype of Phytophthora palmivora with a shelf life of six weeks in refrigerated storage (Woodhead 1981; Kenney 1986 Ridings 1986). Collego is applied post-emergence, aerially or with land-based sprayers. It is marketed as a dry formulation consisting of 15 % viable, dry conidia of Colletotrichum gloeosporioides f. sp. aeschynomene and 85 % inter ingredients. The mycoherbicide BioMal® (Colletotrichum gloeosporioides f. sp. malvae) has been registered in Canada and is used against round-leaf mallow, Malva pusilla (Auld and Morin 1995; Goodwin 2001). For control of sicklepod (Cassia obtusifolia), "CASST" is formulated as spores of Alternaria cassia in emulsifiable parafinic oil (Boyette *et al*. 1996). Several other candidates have undergone extensive testing for commercial development. These include Colletotrichum orbiculare for spiny cocklebur, Xanthium spinosum (McRae and Auld 1988; McRae *et al*. 1988; Auld 1993); Sclerotinia sclerotiorum for Canada thistle, Cirsium arvense (Brosten and Sands 1986); Colletotrichum coccodes for velvet leaf, Abutilon theophrasti(Wymore and Watson 1989); Colletotrichum malvarum for prickly sida, Sida spinosa(Kirkpatrick *et al*. 1982); Fusarium solani f. sp.cucurbitae for Texas gourd, Cucurbita texana (Weidmann1988; Weidmann and Templeton1988); Lasiodiplodia theobromae for Parthenium hysterophorus(Kumar and Singh 2000); Fusarium oxysporum for the narcotic plant coca, Erythroxylum coca (Gracia-Garzaand Fravel1998); and Phomopsis convolvulus for field bindweed, Convolvulus arvensis (Ormeno-Nunez *et al*. 1988; Morin *et al*. 1989 and 1990; Vogelgsang *et al*. 1994 and 1998; El-Sayed and Hurle 2001). Many other pathogens are under various stages of research and development.

Marasmins (Natural Product of fungi)

Fungal metabolites as herbicides have the obvious attraction that many of them produce phytotoxins. It has become increasingly evident that fungal phytotoxin are important disease determinants. Manipulation of the amount and type of phytotoxins synthesized by bio-control agents has been a strategy for improving the performance of such products (Cutler 1988; Froud-Williams 1991; Dayan *et al*. 2000). Tremendous effort has been expended in chemically characterizing thousands of these compounds, yet comparatively little effort has been made to determine their herbicidal potential. In only a few cases in which such compounds have been found to be phytotoxic has a mechanism of action been determined. In the few cases in which a molecular target site has been established, it has generally been one that has not yet been exploited by the herbicide industry (Duke *et al*. 1996). Phytotoxins also vary in host specificity, ranging from high host specificity to having no specificity whatever (Poole and Chrystal 1985; Froud-Williams 1991; Strobel *et al*. 1991). Non-host specific toxins are of considerably more interest because they often have the potential for killing a range of weeds without phytotoxicity to crops (Duke *et al*. 1991). An example of such phytotoxins is tentoxin (a cyclic tetrapep-tide) which is produced by several Alternaria species and causes severe chlorosis in many of the problem species associated with soybeans and maize without affecting either crop (Duke and Lydon 1987). The phytotoxin are biodegradable, microbially derived pesticides will be on the market within the next decade (Cutler 1988; Duke *et al*. 1996; Duke *et al*. 2000).

Some Noxious Weeds of India and Development of Mycoherbicide

In India, there are number of weeds which are difficult to control using currently available management techniques. The chemical application have health and environmental problems, in order to reduce chemical application, we have to consider the use of alternatives to chemical herbicides. Under this condition, mycoherbicide and their metabolites are attractive alternative to chemical herbicides. The need to provide alternatives to chemical herbicides is being addressed in a various countries. I have initiated a research to investigate the potential for the use of mycoherbicide or their metabolites against some noxious weeds of Madhya Pradesh during my Ph D work. The weeds are included here because it is not only weed in India but they have presence worldwide.

Parthenium hysterophorus L

Parthenium hysterophorus L. (Asteraceae), a noxious plant, a weed of global significance responsible for severe human and animal health issues, such as dermatitis, asthma and bronchitis, and agricultural losses besides a great problem for biodiversity. According to Holm *et al*. (1997) this noxious invasive species is considered to be one of the worst weeds currently known. It inhabits many parts of the world, in addition to its native range in North and South America and the West Indies (Picman & Picman 1984). In India, the weed was first pointed out in Poona (Maharashtra) by Professor Paranjape, 1951, as stray plants on rubbish heaps and was reported by Rao (1956) as a new species in India, every since the weed became a menace around the globe including India. Various efforts have been made to manage the weed employing different methods such as mechanical, competitive replacement (allelopathy), chemical, and biological control methods. Mechanical control involves hand weeding, a time consuming and unpleasant job, made worse by the health hazards involved with handling Parthenium weed. Burning, another strategy employed to manage weed, is not a useful control strategy for Parthenium. This too has proved to be inadequate due to it requires large quantity of fuel and burning destroys all other economically important plants growing in its vicinity (Kushwah & Mauray, 2012; Ray & Gour, 2012). The application of chemical herbicides like atrazine 2, 4-D, metribuzin, paraquat (Gramoxone), trifluralin, diphenamid, and glyphosate have various environmental hazards and the development of weed resistance (Njoroge, 1991). Biological control is an environmentally sound and effective means of Parthenium control. Rajak *et al*., (1990) undertook a survey around Jabalpur (Madhya Pradesh) collecting diseased specimens of P. hysterophorus and isolated suspected pathogens. Out of the 25 fungal species identified, Myrothecium roridum showed most potential herbicide activity. Colletotrichum gloeasporides f. sp. parthenii isolated originally from diseased seedlings of P. hysterophorus, has shown very high mycoherbicidal potential (Rajak *et al*., 1990). Two species of Fusarium viz. F. oxysporum and F. solani were isolated from the infected root / stem of P. hysterophorus and evaluated for control. The pathogens exhibited considerable potential as biocontrol agents (Pandey *et al*., 1992; Singh 2007). Effects of types, concentrations and formulations of inoculum on the efficiency of two indigenous strains of Sclerotium rolfsii which incited collar rot disease in the seedlings of P. hysterophorus were determined. Maximum seedling mortality was recorded when actively growing mycelia propagules of S. rolfsii were used as inoculum (Pandey *et al*., 1998). Cell free culture filtrate of Phoma herbarum FGCC#75 was evaluated for its phytotoxic property against P. hysterophorus. The results of shoot cut, detached leaf and seedling bioassays revealed the presence of a toxic metabolite in the cell free culture filtrate that was responsible for toxicity against the target weed. The toxic metabolite was characterized after the CFCF extraction with butanol, hexane, chloroform, acetone and ethyl acetate. The phytotoxic compound obtained from ethyl acetate fraction was deduced to be 3-nitro-1, 2 benzene dicarboxylic acid (3-nitrophthelic acid) (Vikrant *et al*., 2006).

Lantana camara L

Lantana camara L. is a native of tropical America, and was introduced to India as an ornamental to be planted in gardens and hedges. Since then, the species has spread rapidly into both farm and forest lands, and is one of the most widespread, terrestrial invasive species in India today. It is considered as one of the world's 100 most invasive species, and among the world's 10 worst weeds. Lantana grows on all types of well-drained soils and in a wide rainfall range(from seasonal dry forests to rainforest) but is also very drought-resistant. It rarely invades undisturbed, closed-canopy forest but rapidly colonizes gaps, edges and disturbed or logged habitats. It produces large numbers of seeds that are dispersed by birds and the seeds germinate rapidly and easily. Lantana is a very efficient competitor against native species under conditions of high light, soil moisture and soil nutrients. It can become the dominant understory species in infested areas, blocking natural succession processes, and reducing biodiversity. It may be threatening the wildlife habitats in forests, and thereby threatening important wildlife populations. Present control methods are limited to physical removal and multiple application chemical herbicides. Plants larger than the fifth leaf stage are difficult to control with any of the commonly used herbicides. Significant herbicidal property in Cell free extract (CFE) obtained from 21 day old fermented broth of Aspergillus spp., (A. nidulans, A. niger, A. terreus, A. fumigatus and A. flavus) against L. camera was recorded by employing shoot cut bioassay technique. It was observed that cell free culture filtrate of different species of Aspergillus had varied degree of toxicity against L. camera. Twenty one days old culture filtrate of A. nidulans induced maximum toxicity in the target weed. It was followed by cell free culture filtrate obtained after 14 days of incubation. There was significant reduction in chlorophyll and protein content (Pandey *et al*., 2005). Saxena *et al*., (2001) while screening the herbicidal substances secreted by microbes found that the culture filtrate of an indigenous isolate of Alternaria alternata SSLC#103 exhibited marked phytotoxic effect against the weed L camera 41.62% and 52% change in biomass was recorded after 36 hours post-treatment and at 50% and 100% cell free filtrate concentrations respectively during the in vitro whole plant bioassay. Partial purification of the cell free culture filtrate yielded four fractions, of which phytotoxicity resided in the Fraction A and it was a fatty acid. The shoot cut bioassay of this fraction caused more prominent phytotoxic damage when compared to cell free culture filtrate (CFCF). Two species of Fusarium viz. F. oxysporum and F. monilifrome were isolated from the infected leaf of Lantana and evaluated for biocontrol potential. Both the species caused severe wilting. The pathogens exhibited considerable potential as biocontrol agents (Singh 2007).

Xanthium strumarium L

It is popularly known as Common cocklebur an exotic plant responsible for several agricultural, environmental and health problems in India. *Xanthium strumarium* is a coarse annual herb, belongs to family Asteraceae and is popularly known as common cocklebur, banokra, gokhru or chota datura. It is an extremely competitive weed creating several serious problems in agriculture and rangelands (Vargas, 1984). It grows luxuriantly and seriously in infested paddy, sorghum and other kharif annual crop fields in Andhra Pradesh, Maharashtra, Rajasthan and Madhya Pradesh (Deshpande, 1982; Kaul 1965). The weed is considered as one of the world's worst weed(Holm, 1977). All the parts of the weed are highly toxic and allergic to humans and animals (Kings, 1964; Parsons 1973). The major toxic substance in Xanthium is carboxyatractyloside which is capable of killing hogs, cattle, goats, horses, sheep and poultry. Though the seed and seedlings contain the highest quantity of toxin, the whole plant can also be toxic(Hatch *et al*, 1982). The allelochemicals produced from different parts of the weed also inhibit the seed germination and seedling growth of many crops viz. Wheat, maize, pearl millet, chickpea, rapeseed, tobacco and lettuce (Cutler, 1983). Due to non-acceptability of conventional methods of control, the possibilities of its management through an indigenous strain of Curvularia lunata had been explored. A total number of 15 fungi were isolated from different parts of the weed Xanthium strumarium. The pathogens incited moderate to severe infection and caused significant damage to the weed. C. lunata, Alternaria spp., Sclerotium rolfsii and Fusarium spp., showed very high herbicidal potential (Shukla *et al*., 2002). Preliminary evaluation studies viz. pathogenicity, herbicidal potential, safety to non- target organisms etc. carried out in laboratory conditions and the pathogen was found to have excellent mycoherbicidal potential against this weed. Similar results have also been reported by many other workers (Boyette & Wakler, 1985; Sharma & Gupta 1993; Thakur & Khare 1993) while evaluating the potential of Alternaria crassa for biological control of Jimson weed. Thus it can be boldly concluded that the mycoherbicidal agents can be applied in the field conditions for the biological control of weeds.

Cassia tora L

It is an obnoxious, aggressive, annual and herbaceous that grows in most parts of India as a weed. It belongs to the Leguminosae family. It is an annual herb, 30–90 cm high which occurs as wasteland rainy season wild plant in India. It is generally distributed throughout India, Sri Lanka, West Indies, china and tropics. It was introduced originally from Tropical America (Singh & Singh, 1967) and is a very common weed all over the area along roadsides and in wastelands. It occurs in South-east Asia and the South-west Pacific where it is an important weed of pastures. It is troublesome weed of row crops in the southern United States and causes problems in India, Malaysia, Java, the Philippines and some pacific islands. It is a major weed of groundnuts, soyabeans, sugarcane, tobacco and pastures. Biological control of *Cassia tora* is being attempted in the United States. The available information on the natural enemies of these weed fungus Alternaria cassiae (Jurair & Khan) is already being evaluated as a mycoherbicide in the USA. Two species of Fusarium viz. F. oxysporum and F. monilifrome were isolated from the infected leaf of *Cassia tora* and evaluated for biocontrol potential. The shoot cut bioassay of this fraction caused more prominent phytotoxic damage when compared to cell free culture filtrate (CFCF). Both the species caused severe wilting. The pathogens exhibited considerable potential as bio-control agents (Singh 2007).

Hyptis suaveolens (L) Poit

This weed belonging to Lamiaceae family is a native of tropical America and West Indies and was introduced in India as a Medicinal plant. It is a rigid herb of aggressive nature. This aromatic weed is now creating serious threats to biodiversity and resurgence of forest in Central India especially in Madhya Pradesh and Chattisgarh regions (Pandey and Pandey, 2008). There are some reports where alcoholic constituents of the weed cause allelopathic effect on higher plants (Totey, *et al*. 1994). The spined burr catches in fur and clothing. Preliminary assessment of Phoma sp FGCCW#54 as a potential mycoherbicide against H. suaveolens was carried out by Pandey *et al* (2006). It was observed that the pathogen incited severe infection in the seedlings and the disease was initially characterized by the appearance of necrotic patches on seedlings and finally seedlings died. Singh (2007) while screening the herbicidal substances secreted by microbes found that the culture filtrate of an indigenous isolate of FGCCW#43 exhibited marked phytotoxic effect against the weed H. suaveolens. Significant herbicidal property in cell free culture filtrate obtained from 21 day old fermented broth of Fusarium sp FGCCW#43 against Hyptis sp was recorded by employing shoot cut bioassay technique. It was observed that cell free culture filtrate of different species of Fusarium sp had varied degree of toxicity against H. suaveolens.

Sida actua Burm f

It is mallow family, malvaceae is common flowering wireweed, native to Central America, but today has a pantropical distribution and is considered a weed in various regions. It can tolerate drought as well as high rainfall conditions. They are erect perennial shrubs up to 1.5 m in height, occurring on a wide range of soil types. They have yellow flowers and reproduce by seed. It is weeds in disturbed and cultivated areas (Holm *et al* 1991; Parsons and Cuthbertson, 1992).Survey has conducted to isolate a potential fungal strain from S. acuta and collection of various strains has done during research. Singh (2007) reported Fusarium sp FGCC#55 was showing phytotoxic damage on target weeds.

Antigonon leptopus

It is a ornamental perennial vine having vigorous growth, and plentiful (usually) pink flowers, and even its ability to smother unsightly landscapes. It can growly quickly over other vegetation, spreading beyond its area of introduction when it is neglected. It is very difficult to eradicate when established, because it produces many tuberous roots that can propagate vegetatively. It's fruits are buoyant, allowing for successful seed dispersal in water. It is classified as a Category II invasive weed (Pichardoand Vibrans 2009; Raju *et al*. 2001). For now, the best means of control is a combination of mechanical and chemical methods. Mechanical control is an effective means of controlling this plant but will not eradicate it (Ernst and Ketner 2007). The removal of aboveground tissue via cutting or mowing is not an effective method to eradicate plants because of the persistent, underground tuberous roots. Tubers can be found as deep as1 m in soil; therefore, deep tillage is necessary to remove tubers. Burning likewise can control plants above ground, and plants will produce shorter shoots after regrowth, but this is not a viable long-term option for control. Chemical control is a more effective long-term approach of managing its infestations. The fungal pathogens reported are Colletotrichum sp and Pestalotia sp (Singh 2007). Significant herbicidal property in cell free culture filtrate obtained from 21 day old fermented broth of Fusarium sp FGCCW#43 against A. leptopus was recorded by employing shoot cut bioassay technique(Singh 2007). It was observed that cell free culture filtrate of different species of Fusarium sp had varied degree of toxicity against A. leptopus.

DISCUSSION

Numerous microbial candidates exist, and preliminary research into biological characterizations has been conducted on these candidates for several decades. Despite all of this research and expense poured into development of microbial biological control agents, very few have been successful and fewer still have persisted in the marketplace. Many candidates have failed, and often for one of multiple common reasons;

production problems, lack of stabilization of high titers following fermentation, lack of adequate shelf life of formulations under warehouse temperatures, lack of an economic viable delivery system, or loss of virulence of the product before reaching the target. Therefore, there is a critical need to better understanding of the mode of action of mycoherbicide involved in host-pathogen interactions which consequently leads to enhance the virulence of pathogen and/or suppress the host plant's defense. Consequently, the environmental conditions play a basic role in guiding the mode of action of mycoherbicide microbial metabolites (marasmins) could represent important tools for improving, directly or indirectly, the efficacy of mycoherbicide. The availability of new methods of purification of toxin and their quantification, structure elucidation, fermentation processing, synthetic production, formulation, knowledge of biosynthetic pathways and molecular tools for their transformation could give further support to the use of these natural metabolites as "helpers" of biological control strategies. The knowledge of toxin structure can permit the preparation of appropriate derivates and/or analogues that are essential to studies of structure-activity relationships, to the understanding of the mechanism of action, to the determination of the active sites of the toxins, and eventually to the production of related toxins having different biological properties. Many studies have shown that changing the active sites of microbial metabolites changes their biological activity. Much work remains to be done in the use of fungi toxins for weed control. It is likely, with further refinement of techniques will provide fertile sources of alternative weed control methods. In addition, biological and cultural control were insignificant in reducing weed populations. The weed can significantly reduce crop yield and quality due to its aggressive growth habit, competitiveness and allelopathic interference. It is a difficult weed to manage, and a wide variety of methods, starting with prevention and containment, are necessary to reduce the incidence and spread of this weed. An integrated approach using cultural, physical, chemical and biological approaches are necessary for the successful management of this weed. Integrated approaches following different methods coupled with proper land management and best management practices can effectively control this weed. Despite the negative impact of this weed on the biodiversity, there is potential in exploring its beneficial properties as a mechanism of management.

CONCLUSION

There is no doubt the extraordinary fungal diversity in ecosystem and thus, each pathogen must be considered as unique and must be thoroughly studied in laboratory growth chamber or green houses to understand its disease cycle and potential as herbicide. The potential of particular genus as microbial herbicide can be obtained from knowledge about diseases of economic crops incited by other species or forms of the genus. Proper understanding of the disease cycle of a pathogen to be developed as mycoherbicides is very important step in a success of a programme. Unfortunately, many of the published reports that suggest specific fungi as potential mycoherbicides have not researched disease cycle or the weed biology adequately to make a definite judgment of the biological potential of a particular fungus (Templeton *et al*., 1998). A wealth of knowledge about disease cycles can also obtained with pathogens of economically important crops. Microorganisms specially fungi and actinomycetes are known to produce variety of phytotoxic metabolites with herbicidal properties (Abbas & Duke, 1997; Culter, 1998; Duke, 1986 a, b; Hoagland, 1990, 1999, 2000, 2001; Joseph *et al*., 2002). Still only few have been screened. Therefore, lot of opportunities exists in their integration with mycoherbicidal agents. Inadequacies discussed earlier may be amenable to correction either by advances in formulation technology for biological or by advanced molecular techniques (Yoder, 1983; Yoder & Turgeon, 1985). Mycoherbicides present suitable opportunities for return on investment from small market because the cost of developing them may be less than that for a chemical herbicide. Production technology is already available in fermentation industries, thus capital investment for production is low. Registration costs could be significantly less than for synthetic herbicides. Time required for research and development of a potential agent through registration and commercial use may be substantially less than for herbicides, and this would represent a significant saving of developmental costs (Templeton *et al*. 1986). Although, mycoherbicides have proved to be effective, but there is a need for technological improvement with chemical enhancer, by strain improvement or by combining fungi to increase the spectrum of weed control. Many fungal pathogens of weeds may be weed without additional technological improvement. Experience with Collego, Devine, Casst and Bio Mal leaves no doubt that mycoherbicides are effective and practical as weed control agents (Bowers 1986; Bowers 1982; Charudattan *et al* 1986; Kenney 1986., Ridings 1986., Ridings *et al* 1976; Smith 1982; Smith 1986; Templeton 1982; Walker and Riley 1982). The future direction of mycoherbicide will be influenced by current scientific, practical and government decisions. The future of mycoherbicide is bright and full of possibilities with the many novel, successful fungi and their metabolites being studied.

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