



Exploiting Microbial Phytotoxin As Bioherbicides Against Invasive Noxious Weeds Of India: Current Development And Future Scope

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ABSTRACT :

Weeds are a problem in a variety of land uses, associated with declines in crop yields, quality and health nuisance. One-third of global crop losses occur as a consequence of invasive weeds. An aggressive weed is a problem in Asian countries, particularly in India. These invasive weeds can be found in a large variety of environments. Native fauna is depleted and hydrology and bionetwork function are improved as a result of invasive species. The annual cost of dealing with invasive species is expected to be in billions of dollars, including management expenditures, poor health consequences, lost agricultural productivity and damage to ecosystem resources. Approximately 20-30% of all introduced species in the globe generate some sort of issue. The list of invasive alien weed species in India is well-documented and accessible to the general public. In India, 173 alien invasive species from 117 species of the genus and 44 families have been described, responsible for 1% of the available flora. In both cultivated and non-cropped conditions, different plant management methods are used to combat these weeds. None of the present solutions are sufficient to fully eradicate these weeds.

The herbicide resistance and chemical pesticides are the major issue for new generation due to strong support for developing a new novel compound to control weeds. Due to less user of chemical herbicide in current scenario, it is very important to develop a new class of bioherbicide with novel mode of action which is not previously developed. Considering the magnifying of yield fatalities instigated by these noxious weeds, an inclusive, reliable and widely adopted technology is urgently needed to address these issues. Development of ecofriendly weed control has shown a novel and innovative path to Scientist for developing a natural herbicide based on microbes. It is known that microorganism produce thousands of secondary products, many of which are phytotoxic and may potentially be used as herbicides or templates for the synthesis of new herbicides. The interest of researchers is therefore focused particularly on pathogen living on weeds. Microbial products are attractive candidate for potential use in agriculture. They are characterized by highly specific activity and high selectivity while at the same time they are readily biodegradable. They belong to very diverse groups such as polyketides, terpenoids, diketopiperazines, isocoumarins etc. of course, these compounds are too complex in structure to be used herbicide. However, secondary products of microorganism represent subject matter of wide research and supplement the organic synthesis in the development and extension of new biologically natural and cost-effective herbicides. This article attempts to summarize the current scenario of some Invasive noxious weeds in India, in particular, major types of weeds found in the region agricultural, ecological losses associated to it and popular physical, biological and chemical methods of their management. The noxious weeds are *Parthenium hysterophorus*, *Lantana camara*, *Xanthium strumarum*, *Cassia tora*, *Hyptis suaveolens*, *Sida actua* and *Antigonon leptopus*. The potential microbial marasmin to control some noxious important weeds is reviewed here. It is concluded that of this weed, best suited as targets for biological control using microbial metabolites. Potential opportunities and future prospective of effective as well as sustainable management are also briefly discussed

Keywords: Invasive Noxious weeds/ Microbial Phytotoxins/ bioherbicide/ Current Status/ Future Perspectives

INTRODUCTION :

A weed can be described as "an undesirable plant" from a human perspective, which usually means that a weed in one location might not be a weed in another. According to the European Weed Research Society, any herb or grass, except fungi, competing with people's priorities or requirements. Weeds are usually described by two characteristics: invasive or non-invasive, and noxious or not noxious. The species of animals, plants or microbes which poses threat to native biodiversity are known as Invasive species.

A weed is one that is unwanted, problematic, and hard to manage. The term "invasive" refers to a weed's unattractiveness as well as its difficulty in regulation. Weeds have a high rate of reproduction and spreading capability, and they use devious tactics to evade human control (Das, 2008). "Pernicious weeds" or "special problem weeds" are terms used to define invasive weeds. A invasive weed is a plant that has been declared by the government of a country as harmful to human health, agriculture, recreational, wildlife or land. A invasive weed is a crop that's cultivated in an appropriate region and is "competitive, recurrent and pernicious"⁶¹. Weeds that are cause important reduction in yield. Some weeds, such as *P. hysterophorus* used to flourish in uninhabited wilds are as rather than crop fields in the early years^{61, 77}.

Invasive species are defined by IUCN as "an alien species that has established itself in a new natural or semi-natural habitat as an agent of change, threatening the survival of local biological diversity". Invasive weeds have been discovered by a number of internationally known invasion research

organizations. According to the GISP definition of invasive species, invasive alien species are non-native creatures that cause or have the potential to cause harm to the ecology, economy, or human health. Ignorance, mismanagement, or mistake are the most common causes of Invasive weeds entering an ecosystem. Weeds are seen as a major challenge in the ongoing struggle to provide enough food for the world's population.

Weeds have a negative impact on every agricultural enterprise and every aspect of our ecosystem.

They have always gotten in the way of human endeavours. One of the main biotic constraints in achieving optimal crop production has been weeds. Untimely and insufficient weed control results in the loss of a significant number of crop harvests per year. Weeds reduce crop production and efficiency, creating a danger to food Protection and environmental health. Crop yields are being reduced caused by many different types of weeds exist in severity dependent on the crop and the agro-ecological effects that are linked with it. Even with current crop conservation measures in place, weeds account for one-third of all agricultural product losses globally. It is estimated that the entire grain output lost due to just weeds is about 200 million metric tonnes, if we estimate a 10% yield loss from the work done at the FAO (Food and Agriculture Organization of the United Nations). Weeds cost India's agricultural industry more than around \$11 billion each year⁶⁴. In India, its presence decreases crop yield by 31.5 percent (22.7 percent in the winter and 36.5 percent in the summer), ensuing in an annual loss of Rs. 2799 crores⁶¹. Some of India's most common invasive weeds. *Parthenium hysterophorus* Linnaeus (Carrot grass), *Cyperus rotundus* (Nut grass), *Saccharum spontaneum* (Wild sugarcane), *Pluchea lanceolata* (Roshna), *Solanum elaeagnifolium* (Silverleaf nightshade), *Avena fatua* (Wild oat), *Chromolaena odorata* (Big sage)⁷⁷.

Losses due to weeds :

Thrashing of biodiversity from natural ecosystems, habitat modification, reduction in productivity and richness of fauna and flora, alteration of population structure, and many other losses are produced by invasive weeds⁶⁵. The threat is not restricted to loss of biodiversity; it also affects the climate, economic activities, and human health. Globalization has increased the possibility of foreign invasive weeds being introduced (trade, vacation industry and travel). The overall charge of invasive non-native species to the worldwide economy has been calculated at 5 percent of yearly output⁶⁶.

The cost of dealing with invasive species is expected to be in the hundreds of billions of dollars per year, including management expenditures, severe health consequences, and decreases in agricultural output and natural systems⁶⁷. The majority of calculations only consider yield losses. However, when weed control costs, decreased input usage efficiencies, quality losses, pests and disease occurrences (weeds are alternate hosts for many pests and diseases) are factored in, the figures may be very high⁶⁸. Invasive weed species were well-known and made publicly accessible in Australia⁶⁹, India⁷⁰, Malaysia⁶⁸, Indonesia⁷¹, China⁷², the Tropics⁷³, South and South East Asia⁷⁴ and the Pacific⁷⁵.

Several current studies have been undertaken to quantify the economic impact of INS (Invasive Non-Native Species) in a number of nations, and the findings reveal that the cost of INS to a country's economy can be very high, albeit estimates vary greatly^{63,76, 78}.

Various Types of Weed Management :

Weed management can be describe as a process of weed population and growth reduction below the economic injury level with minimum pollution. Various techniques have been used for weed control including Mechanical, chemical and biological weed control⁷⁷.

Mechanical /Physical Weed Control-

Mechanical control refers to procedures that kill or remove weeds by physically disturbing them. Excavation, discovery, tugging, ploughing and mowing are some of the tactics used. Primary and secondary tools, such as row growers and rotary horses, are used in the mechanical management of weeds, which begins with seed boing. Simplified breeding strategies for several vegetable crops were eventually established.

Mechanical control has a number of limitations to consider when designing and developing weed management systems. A rainy spell can decimate mechanical management alternatives and lead to weed competition because dry weather has such huge impact on mechanical management^{79,80}. Hand pulling and digging- Musk thistle, kochia and diffuse knapweed are among the biannual and annual weeds that respond well to this treatment. Annual weeds that grow upright and erect are efficiently controlled by hand digging, however straight, prostrate, rosette and straight weeds are pulled up by hand, they are frequently broken off at the base or at the soil surface, and they can regrow from tap roots left in the soil⁸¹.

Chemical Weed Control

All pesticides have the highest consumption, manufacturing, and market share. Herbicides are less expensive than manual and mechanical approaches, which are typically more expensive to use. Chemical farming may be less cost-effective for small dispersed farmer holdings⁸². The various types of chemical herbicide are used for invasive weed control. They are Dichlorophenoxyacetic acid (2,4-dichlorophenoxyacetic acid), Atrazine, Glyphosate SL, Metribuzin WP, Naphathelene acetic acid

Biological weed control-

Biological control described as 'management for a population below that which naturally happens when there is no introduced/employed organism employing a different live creature⁸⁴. Special bacteria and other types of microorganisms are typically used for this kind of thing, but they may be, if they suit, parasites, insect and mite predators, pathogens (such as fungi, bacteria and viruses), detectable rhizobacteria, herbivorous fish and more conventional animals (such as ducks, geese and snails)⁸³. Horses Grazing gives mowing-like outcomes and bacteria and fungi are rare in the use of harmful weeds. The most common term for biological control is 'insect biocontrol'⁸⁵. Biological control does not harm the environment because it leaves no pollution behind. Except for bioherbicide, it is self-sustaining and self-perpetuating. The introduction of bio-agents and bugs very year isn't necessary to conduct classical

biological control, making it more durable and long-lasting. Although the initial financial expenditure is considerable, it is cost-effective in the long term. Weed control via biological means/agents is not 100 percent successful, but it is still better than nothing because it helps preserve biodiversity. It works in locations that are inaccessible to humans. That weed is expected to be controlled by insect bio-agents wherever it is found, including deep forests and high mountains⁸⁶.

Mycoherbicide

Mycoherbicides are native pathogens, primarily fungi that are used as bio-herbicides. A number of inoculums, such as bacteria, fungi, parasitic, nematodes and viruses, that have been shown to control weed species can be used as herbicides. Every season, bioherbicides are sprayed on the selected weed in the crop field. The bio-agent is usually only extremely active on weed populations that are present at the same time.

Then, unlike in traditional bio-control, they wither away without any cyclic perpetuation. The pathogen may, however, continue to be active for 3–4 years in some circumstances, such as the soil-borne disease *Phytophthora citrophthora* (Sharma et al., 2014).

The invasive genes of microorganisms can attack the defense genes of the weeds and kills it. Microbial herbicide are natural compounds of fungi, bacteria, actinomycetes or protozoa. A bioherbicide based on a fungus is called a mycoherbicide. In the industry, bioherbicides and other biopesticides are often referred to as "naturals". The application of biobased products to achieving this goal has received increasingly great attention over the last three decades.

Biorationals

Biorational strategy has lot of advantage over chemical herbicide, it is ecofriendly, target specificity, less production costs compared to chemical herbicides and they have novel herbicidal mechanisms. The development of phytotoxins as weed biocontrol agents has been reviewed by various Scientist^{1,2,3}. Natural product of microbes provides good source of novel compounds for control of weeds. Some of the microbial phytotoxins are bialaphos produced by *Streptomyces viridochromogenens* and *S. hygroscopicus*⁴. The Bialaphos is a non-selective phytotoxin phosphinothricin and commercialized in the name of herbicide glufosinate. Its mode of action site is glutamine synthetase (GS). With similar mode of action, there are several natural products of microbes but they are not effective like glufosinate as a viable herbicide^{5,6}. The microbial natural product having variation in host specificity, some are host specific and some have no specificity are known as non host specific^{2,7,8}. Sometime nonspecific microbial toxins are advantage over host specific because they have potential to kill various range of weeds without phytotoxicity to crops⁹. The tentoxin (a cyclic tetrapeptide) 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 is the best example for non host specific toxin¹⁰. Only a small proportion of potentially useful microbial metabolites have been described herein, but examination of the structures leads to at least four conclusions. The first most example for this is a fermentation products having diverse features and possess unique control nature. The second most example are specific classes of compounds contain congeners that have dissimilar biological activity. The third example are some synthetic changes may be made to alter the biological properties of natural products without, apparently, destroying the bio gradable properties. The fourth properties is biologically active natural products offer unique and novel template for synthetic work to pesticide industry. They have lot of beneficial structures for the future development in microbial world and some are yet to develop. They are biodegradable in nature and microbes based herbicide will be on the great market in future generation^{1,4,6}.

Some Invasive Weeds of India and their management :

The Invasive weeds reviewed in this paper were chosen from recent survey and work done in weed control of Madhya Pradesh region during my PhD work. I have selected the weeds in this review are very noxious weed of world, it is not only weed for India. The details are mentioned below: -

***Parthenium hysterophorus*:**

A invasive and noxious weed *Parthenium hysterophorus* L. (Asteraceae) is a global presence and responsible for human and animal health problems like dermatitis, asthma and bronchitis. They have also causes agricultural losses and biodiversity. This noxious invasive species is considered to be one of the worst weeds as per Holm et al.²⁹. *Parthenium* weeds distribution is all over the world, in addition to its native range in North and South America and the West Indies³⁰. The weed firstly pointed out in Poona (Maharashtra, India) by Professor Paranjape, 1951. It was firstly reported by Rao³¹ as a new species in India. They have control by physical control which involves hand weeding but it is a time consuming and unpleasant job, causes health hazards to labours. Another physical approach is burning method. It is not a useful control strategy due to it requires large quantity of fuel and it destroys other economically crops growing near to it³². Another approach used for *Parthenium* control is chemical method but they have disadvantages causing environmental hazards and weed resistance for herbicides atrazine 2, 4-D, metribuzin, paraquat, trifluralin, diphenamid, and glyphosate^{33,34}. Application of biocontrol method is ecofriendly and effective for controlling weeds through the use of natural enemies likes insect and microbes. The application of microbes as herbicide Rajak et al.,³⁵ taken a survey around Jabalpur (Madhya Pradesh) to collect diseased specimens of *Parthenium hysterophorus* and isolated suspected pathogens. He has collected more almost 25 fungal species and identified, in which *Myrothecium roridum* has shown most potential herbicide activity. Out of 25 genera of fungi, *Colletotrichum gloeosporides* f. sp. *parthenii* isolated from diseased seedlings of *Parthenium hysterophorus*, has shown very high mycoherbicidal potential³⁵. The screening for bioherbicidal agent, two species of *Fusarium* viz. *F. oxysporum* and *F. solani* from he infected root / stem of *Parthenium hysterophorus*. these strains were evaluated, and they have caused severe wilting to fungi and shown good potential as biocontrol agents^{36,37}. There are various parameters are tested to develop a suitable bioherbicide from indigenous fungi *Sclerotium rolfsii* like types of media, concentrations of inoculum and formulations to the seedlings of *Parthenium hysterophorus*. Maximum seedling mortality were shown in which mycelia propagules were used as inoculum³⁸. The strain *Phoma herbarum* FGCC#75 Cell free culture filtrate were evaluated for its phytotoxic against *Parthenium hysterophorus* shoot cut, detached leaf and seedling bioassays. The result showed the presence of a toxic metabolite in the cell free culture

filtrate, have responsible for phytotoxicity for Parthenium weeds. The phytotoxic metabolite has characterized and extracted with butanol, hexane, chloroform, acetone and ethyl acetate. The ethyl acetate based fraction having phytotoxic compound 3-nitro-1,2 benzene dicarboxylic acid (3-nitrophthalic acid)³⁹.

Lantana camara:

Lantana camara is native to tropical and subtropical America, it is considered as serious and one of the world's top ten weeds⁴⁰. From several years, survey of bioherbicidal agent for this weed were done in various country. The fungi collected during survey was *Aspergillus* spp., (*A. nidulans*, *A. niger*, *A. terreus*, *A. fumigatus* and *A. flavus*) cell free culture of 21 days old fermented broth has shown significant herbicidal property against *Lantana camara* shoot cut bioassay. It was observed that cell free culture filtrate of different species of *Aspergillus* had varied degree of toxicity against *Lantana camara*. There was significant reduction in chlorophyll and protein content reported by Pandey et al.,⁴¹. Saxena and Paney⁴² tested 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 *Lantana camara*. 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 invitro 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). Singh³⁷ has tested two species of *Fusarium* viz. *F. oxysporum* and *F. moniliforme* which is isolated from infected leaf of *Lantana*. These two strains have shown very good results and causes wilting of weeds within 7 days application. It has taken as potential as bio-control agents for *Lantana* weeds.

Xanthium strumarium:

Xanthium strumarium a annual Asteraceae family weeds invades roadsides, wastelands, riverbanks, farmland, overgrazed pasturelands. It is major weeds of maize, groundnuts, cotton and soya beans. It is toxic to animals. It is responsible for several agricultural, environmental and health problems in India⁴³. It grows luxuriantly and seriously in infested paddy, sorghum and other kharif annual crop fields in Andhra Pradesh, Maharashtra, Rajasthan and Madhya Pradesh⁴⁴. The weed is considered as one of the world's worst weed⁴⁰. All the parts of the weed are highly toxic and allergic to humans and animals⁴⁵. The major toxic substance in *Xanthium* is carboxyatractyloside which can kill hogs, cattle, goats, horses, sheep and poultry. Though the seed and seedlings contain the highest quantity of toxin, the whole plant can also be toxic⁴⁶. 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 lettuce⁴⁷. 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. *Curvularia lunata*, *Alternaria* spp., *Sclerotium rolfsii* and *Fusarium* spp., showed very high herbicidal potential⁴⁸. 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^{49, 50, 51}. 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:

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 America⁵² 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 cassia*⁵³ is already being evaluated as a mycoherbicide in the USA. Two species of *Fusarium* viz. *F. oxysporum* and *F. moniliforme* 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 biocontrol agents³⁷.

Hyptis suaveolens:

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 regions⁵⁴. There are some reports where alcoholic constituents of the weed cause allelopathic effect on higher plants⁵⁵. The spined burr catches in fur and clothing. Preliminary assessment of *Helminthosporium* sp. FGCC#74 as a potential mycoherbicide against *Hyptis suaveolens* was carried out by Pandey et al⁵⁶. 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. Singh³⁷ 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 *Hyptis suaveolens*. Significant herbicidal property of FGCCW#43 against *Hyptis* weed was seen in 21 days old fermented broth of cell free culture filtrate teste by shoot cut bioassay. It was observed that cell free culture filtrate of different species of *Fusarium* spp. have varied degree of toxicity against *Hyptis suaveolens*.

Sida actua:

It is a common wireweed, a species of flowering plant in the mallow family, Malvaceae. It is 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 areas⁴⁰. Survey has conducted to isolate a potential fungal strain from *Sida acuta* and collection of various strains has done during research. Singh³⁷ reported *Fusarium* sp. FGCC#55 was showing phytotoxic damage on target weeds.

Antigonon leptopus:

It is a perennial vine, lauded as an ornamental for its vigorous growth, and plentiful (usually) pink flowers, and even its ability to smother unsightly landscapes. When it is neglected, it can grow quickly over other vegetation, spreading beyond its area of introduction. Once established, it is difficult to eradicate because it produces many tuberous roots that can propagate vegetatively. Its fruits are buoyant, allowing for successful seed dispersal in water. Already it is classified as a Category II invasive^{57, 58, 59}. 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 it⁵⁷. The removal of aboveground tissue via cutting or mowing is not an effective method to eradicate plants because of the persistent, underground tuberous roots. To successfully control populations of this plant mechanically, the tubers need to be removed, and any resprouts repeatedly cut back⁶⁰. Tubers can be found as deep as 1 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 pathogen reported are *Colletotrichum*, *Pestalotia*³⁷. Significant herbicidal property in cell free culture filtrate obtained from 21 days old fermented broth of *Fusarium* sp. FGCCW#43 against *Antigonon leptopus* was recorded by employing shoot cut bioassay technique³⁷. It was observed that cell free culture filtrate of different species of *Fusarium* sp. had varied degree of toxicity against *Antigonon leptopus*.

Current Development and Future Scope :

Microbial Herbicides are part of modern agricultural production offer a cost effective, efficient and appropriate manner of weed control contributing considerably to production increase and stability. However synthetic herbicides have unfavorable toxicological characteristics, persistence and a potential environmental impact. The development of resistance and high costs has contributed to develop a new approach¹¹. On the other hand, bearing in mind side effects of pesticide on human health (chronic toxic effects of many compounds, reproduction, impact, mutagens, oncogenic effect etc) and contaminating residues in water and soil. The problems caused by excessive use of pesticide in conventional agriculture have initiated the development of a sustainable agriculture concept with special focus on alternative hazardous organism control in agroecosystems through implementation of biological control. Namely as it is generally known microorganism produce hundreds of thousands of secondary metabolites products many of which are phytotoxic and many potentially be used as herbicides or templates for the biosynthesis of new herbicides. These compounds are very diverse in structure, ranging from simple to complex molecules having very different molecular weights¹⁰. Advantages of natural products of microbes over synthetic herbicides:

- Investigations can be conducted with high investments
- No risk to human health and environments
- Highly selective toward plant species
- Registration of natural compounds is cheaper
- Shorter half life

Microbial herbicide prototype models and expectations :

There have been many articles reported by researchers on successful microbial agents with bioherbicidal potential, this has created the optimistic impression that additional bioherbicides are close to becoming commercially available. Also ,the expectation of weed mortality using terminology such as Microbial herbi-“cides” has generated the illusion that these organisms have or must possess identical features to chemical herbicides and will lead to the eradication or near-kill of weed populations^{12,13}. The fact that biological herbicides are not analogues to chemicals, lacking in some of the features of chemicals, has perhaps led to the opinion by some critics that this technology has failed to deliver the goods. But is this truly the case when in fact we are comparing the traits and benefits of biologically-based technology using the paradigm of chemically-based technology? The first generation of bioherbicides had a variety of characteristics that were comparable to those of chemical herbicides and deemed to be desirable for their commercial success^{14, 15, 16}. Successful bioherbicides were expected to provide high efficacy, often resulting in high weed mortality. Other traits considered in early bioherbicide development were host-specificity (i.e. preference for narrow host-range), ease of use, genetic stability, cost-effective mass production, and ability to provide rapid weed control with predictable field performance. While these characteristics are attractive, many biological herbicide candidates have fallen short of meeting these requirements. Both Collego® and DeVine® were considered great achievements because they provided at least 90% weed control that was effective and consistent¹⁷. However, their efficacy on single weed species has limited their commercial success, particularly when one considers that most agroecosystems are comprised of multi-species weed communities. It may be difficult to justify for many farmers to use or for industry to market a single product to control a single target weed. In addition, these two products have targeted weeds with specialized markets and limited profit margins¹⁸. On the other hand, a product such as Camperico®, with a single economic target, has a high value market in the golf course industry¹⁷. The development of *Chondrostereum purpureum* as a mycoherbicide has expanded its utility because of its broad-spectrum activity on a variety of woody tree species such as red alder (*Alnus rubra*), black cherry (*Prunus serotina*), white birch (*Betula papyrifera*), and aspen (*Populus* spp.). Other examples of bioherbicide candidates exhibiting a broad host-range include *S. minor* for dandelion and other broadleaved weed control in turf,

Pseudomonas syringae pv. *tagetis* on Canada thistle and other Asteraceae weeds and *Sclerotinia sclerotiorum* for control of Canada thistle, dandelion, and diffuse and spotted knapweeds^{16,23}. While broad-spectrum activity is viewed as an advantage for a commercial product, whether it is biologically or chemically based, many chemical herbicides exhibiting this feature may be restricted as to application at particular growth stages of the crop without causing a certain level of crop injury²⁴. Some of the host specificity traits of many biological herbicides may be advantageous since there is a greater assurance that nontarget and beneficial plant species will not be damaged and the bioherbicide can be applied at any growth stage of the crop without injury^{14,24}. One of the benefits of DeVine® was that it persisted in the soil to provide long-term and residual activity; however, this same trait could also be considered a disadvantage if it creates problems for crop rotations where the crop may be a susceptible target to the bioherbicide pathogen. In addition, from an industry perspective, long-term residual effects can lead to reduced demand for repeat product sales, which can be exacerbated by the fact that the product has a small market potential in the first place²⁴. These issues also hold true for chemical pesticides. In addition, DeVine® must be refrigerated and the product must be made-to-order 30 to 60 days prior to its intended use due to its low stability and thus has limited shelf life^{24,25}.

From a technological perspective, Collego® is capable of being economically mass produced in liquid culture fermentation at a commercial scale, but other fungal bioherbicides have not seen this same achievement since many of the prospective fungi cannot readily produce spores in liquid, but sporulate more readily in solid-substrate fermentation¹⁸. Unfortunately, high labour costs, inability to control cultural conditions and maintain sterile conditions have been associated with solid-state fermentation²⁶. BioMal® was not commercialized in Canada due to technical difficulties to mass produce it cost-effectively²⁷. Unreliable field performance, a reason for the lack of success of many post-emergent bioherbicides, has often been the result of the requirement for long periods of dew or leaf wetness by the microbial pathogen^{12,14}. Although Collego® and DeVine® perform consistently and with high efficacy in the field, these early prototype models were used under relatively conducive conditions and thus required very simple formulations. Collego® was effective because the target weed inhabits rice paddies where high humidity is normally present²⁸. In the case of DeVine®, it is a soilborne pathogen and subjected to less fluctuating temperature and humidity.

CONCLUSION :

There are many chances to design weed management strategies that are both sustainable and effective, despite the fact that weeds present a difficulty in the farming systems that are now in use in India. There is a need for additional research on the ecology and biology of weeds, particularly with the process of understanding the seed bank dynamics in various locales and cropping systems. For efficient weed management, a deeper comprehension of the germination process of weed seeds is required. As a result, the evaluation of the impact of different agronomic approaches has to be the primary focus of study in the future (i.e. cultural weed control methods, such as narrow rows, high seeding rates, weed-competitive cultivars etc.) on weed management and crop yield in various places, particularly those with restricted access to herbicides or ones with lower levels of effectiveness.

Various microbial agent exists and preliminary research for metabolites characterizations has been conducted on various agent for two decades. Despite all this research and expense for development of microbial agent, there are very few have been successful and very few in the market. Lot of microbial agent did not success due to some reasons viz 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. To develop a better microbial herbicide, there is basic need to understand mode of action of bioagent or their products which is involved in host-pathogen interactions. They have leads to enhance the virulence of pathogen or suppress the host plant's defense. There are other factors like environmental conditions which is also play a basic role in the action of spores and products. The action of microbial metabolites (marasmins) could represent important in this condition. The availability of new methods for purification and quantification of product, 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 derivatives 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. With the development and correction of fewer techniques will provide good sources of microbial herbicide alternative for future generation weed control.

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