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Review Article

Biological Weed Control - A Review

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ABSTRACT

Biological control of weeds involves the use of living organisms to attack a weed population to keep at or below desirable level without significantly affecting desirable plants. It includes use of insects, pathogens, nematodes, parasitic plants and competiting plants. Historically, biological control method has proved best on large infestation of a single weed species. These situations usually occurred in range lands or in water bodies. Biological control has also been successful into newly introduced weed area freed from its natural enemies. Unfortunately, biological weed control has not developed to the point that it has any appreciable impact on the production of agronomic crops. The more recent and much more successful importation of several pathogens into several countries have served to increase interest in the classical approach to biological control of weeds to such a point that several countries are now actively pursuing this approach. A large number of biocontrol agents are used in biological weed control measure. Some outstanding examples of biocontrol of weed are the use of insect to control Hypercium perforatum L., Opuntia sp. and Lantana camera L.

Keywords: *Biological control, Agronomic crops, Hypercium perforatum L., Lantana camera L.*

INTRODUCTION

The global need for weed control has been imposed mainly by the chemical industry. If herbicides are often effective and necessary to agriculture, yet pose some serious problems particularly if they are misused. For example, toxic and otherwise harmful compounds threaten animal and public health when they accumulated in food plants, ground waters and drinking water. They can also directly harm the workers who apply them. Even though chemical herbicides are found to be most cost-effective and efficacious in the management of weeds in crop field, growing political and environmental concerns have necessitated the search for alternatives. A key approach in all sustainable weed management system is to make the best possible use of the natural enemies of each weed a tactive known as biological control.

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When properly implemented, biological control had been to many spectacular successes against both insect pests and weeds generally by the introduction of natural enemies for the country of origin of a pest or weeds and also by avoiding unnecessary use of the chemicals (pesticide and herbicides) particularly those that possess a broad spectrum of activity (Julien, 1992).

I. BIOLOGICAL WEED CONTROL WITH PLANT PATHOGEN

Biological control of weeds by using plant pathogens has gained acceptance as a practical, safe, environmentally beneficial, weed management method applicable to agro-ecosystems. The interest in this weed control approach from public and private groups and support for research and development effort are the upswing (Charudattan, 2001).

The science of using plant pathogen to control weeds is almost as old as the science of plant pathology (Templeton et al., 1979; Wilson, 1969). Wilson (1969) described previous efforts to use pathogens for control of cactus, mistletoe, aquatic and agronomic weeds, and weedy trees that represent a continuous effort in biological control of weeds from 1890 through 1969. Cockayne (1910) reported that fungi had been investigated as “weed controllers” in many parts of the world but without success. Cunningham (1927) reported that “natural control” of weeds with plant pathogens had received “much attention in recent years” for eliminating weed without direct labour or monetary expense and described modest efforts to control weeds with pathogen in New Zealand. This type of control of weeds/plants by one sp. in agro-ecosystem now a day known as allelopathy for harmful as well as beneficial effects.

A. STRATEGIES FOR THE CONTROL OF WEEDS WITH PLANT PATHOGENS

i. The Classical Strategy: In this, a pathogen is simply released into weed populations (from one to many independent sites) and is expected to increase and disperse naturally throughout the entire weed population without significant subsequent annual release or augmentation of established population (Charudattan, 1984). The natural increase of disease on susceptible plants is relied upon to control weeds, either directly from plant death or indirectly through reduction of plant vigour and seed production, over broad geographical setting and within many ecological niches. The maximum degree of success (55.51%) by classical strategy in India has been achieved in aquatic weed followed by terrestrial weeds (23.8%) (Singh, 1995).

ii. The Bioherbicide Strategy: As bioherbicides (microbial pesticides), pathogen can be applied to control weeds within a specific geographical site (i.e., a single field) by inundative application of inoculum (Charudattan; 1984). This approach also referred to as the mycoherbicide approach (Templeton *et* a/., 1979). Inundative application of inoculum of pathogens, often to early stages of weed growth, results in the control of weed infestation without the disease developing beyond the initial lesion into epidemics. The initial lesion caused by the applied inoculum directly causes the death of infected weed seedings.

iii. The Augmentation Strategy: The augmentation strategy is similar to the bioherbicide strategy in that while there is direct human manipulation and distribution of inoculums, the inoculum is neither mass- produced nor applied as an inundative dose over large areas (Charudattan, 1984). Control of the weed results from and requires the increase of disease through many disease cycles to reach threshold levels that cause the death of infected plants within treated areas. These strategies permit the utilization of many different types of pathogens causing different types of diseases.

B. CONTROL OF WEEDS WITH PLANT PATHOGENS

(i) Biological Control of Weeds with Microbial Pesticides: Three endemic fungal plant pathogen have been registered as microbial pesticides. One is soil born fungus, *Phytophthora,* while two are foliar pathogens in the genus *Colletotrichum.* The endemic fungal pathogen *Phytophthora palmivora* was first used commercially as DeVine in 1981 to control stranglervine (Milkweed vine), *Morrenia odorata* in citrus groves (Kenney, 1986).

Colletotrichum gloeosporiodes f.sp. *aeschynomene* was developed in United States and marketed as a microbial pesticide (mycoherbicide) in 1982 as collego for the control of northern jointvetch (NJV), A. virginica, in rice and soyabean in several states in the lower Mississippi River detla (Bowers, 1986). *Colletotrichum gloeosporioides* causes an anthracnose on NJV seedlings, infesting stems, petioles and leaflets (Daniel et al., 1973; Te Beest, 1988). Enlargement and coalescence of stem lesion result in the girdling and death of plant above the lesiones. The fungus sporulates profusely on the lesion surface, and rainfall contributes to dispersal of the fungus spores on the plant, increasing the severity of infection. The fungus also is dispersed by infected seed and by rain splash (Yang & TeBeest, 1992a). In the hands of growers, the commercial formulation of the fungus provides greater than 90% control of NJV when used according to label direction (Bowers, 1986). Collego has not been markated by the registrant since 1992.

A third mycoherbicide, BIOMEL, is composed of spores of C. *gloeosporioides* (Penz.) Sacc. f. sp. *malvae* and was registered in 1992 in Canada for the control of round leaved mallow *(Malva pusilla,* Sm.) in wheat (Mortenson, 1991). The fungus infects leaves, petioles, stems and crowns of this weed and kills the plant within a few weeks after application. The fungus infects several *Malva* species, velvet leaf *(Abutilon theophrasti* Medic.), and hollyhock *(Althea rosea* (L) Cav.), but the disease is severe only on *M.pusilla.* Though registered, BIOMAL has not been available commercially.

Work on mycoherbicides resulted in the identification of many new pathogens on *parthenium* in India. *Cryptosporiopsis* sp., *Altemaria zinniae* M.B. Ellis, *Phoma sorghina* (Sacc.) Boerema, Dorenb. and Kesteren and *Lasiodiplodia theobromae* (Pat.) Griffin and Maubi. were some of the hitherto unrecorded pathogens on the weeds (Kumar & Kumar, 2000; Kumar & Singh 2000). The most pathogenic isolate [WF (Ph)3; 1MI 378270] of *Cryptosporiopsis* sp., was evaluated further and found to be an ideal for mycoherbicide development (Evans et al., 2000).

The following examples of other fungal pathogens under investigation .illustrate the variety of targeted weeds and organisms that are being evaluated as biological control.

Ascochyta caulina is a plant pathogenic fungus which is specific to *Chertopodium album.* It has been suggested as a potential mycoherbicide to this weed, which is important and wide spread in arable crop throughout Europe (Netland et al., 2001).

Fungus *Stagonospora* convolvuli strain LA39, able to infect both field and hedge bindweed *(Convolvulus arvensis* and *Calystegia sepium,* respectively), was found in the UK and it's biocontrol efficiency improved by optimizing mass production, formulation and storage techniques. This fungus controlled bindweeds in both a cemetery and in maize crops (Defago et al., 2001).

Colletotrichum orbiculare (Berk, Mont.) v. Arx is being reevaluated as a biological control agent for Bathurst bur *(Xanthium spinosom* L.) in Australia, when applied as a mycoherbicide, the fungus controlled 50 to 100% of the seedlings in field tests conducted in 1987 and 1988. The highest levels of control, 98 to 100%, were achieved in a dryland grazing site' (Auld et al., 1990).

In Japan, two fungi, *Drechslera monoceras* and *Epicoccosorus nematosporus are* being investigated for control of two of the major weeds in rice fields in Japan which is to be very problematic. *Drechslera monoceras* has been reported to give excellent control of barnyard grass, *Eichinochloa* species, in greenhouse and field test (Gohbara & Yamaguchi, 1993). Combined use of this fungus and the herbicide pyrazosulfuron-ethyl controlled most of the weeds growing in paddy fields. Similarly, E. *nematosporus* has been repeatedly effective in controlling water chestnut *(Elocharis kuroguwai*) in green house and field tests (Gohbara & Yamaguchi, 1993). In China, *Exserohilum monoceras* and *Drechslera monoceras* were evaluated for their potential as biological control agents of barnyard grass *(Echinichloa crusgall).*

The soilborne fungus *Sclerotinia sclerotiorum* (Lib.) de Bary has been investigated for control of Canada thistle *(Cirsium arvense* (L.) Scop.}, spotted knapweed (*Centauria maculosa* Lam.), and dandelion *(Taraxacum officinale* Weber) (Brosten and Sands, 1986; Riddle et al., 1991). Population of dandelions in turf grass were reduced 80 to 85% following repeated applications of heat- killed perennial ryegrass seed infested with S. *sclerotiorum* (Riddle et al., 1991).

In the United States an endemic rust has also been evaluated for control of a weed utilizing the augmentative approach (Bruckart & Hasan, 1991) rather than a truly classical approach. *Puccinia canaliculata* (Schw). Lagerh has been evaluated for control of nutsedges, *Cyperus rotundus* L. and *C. esculentus* L, in the United States. When released early in the spring, the rust inhibits flowering and tuber formation (Callaway et al., 1985).

(ii) Control of Weeds With Classical Strategy: Pathogens used in the classical approach are expected to reduce weed populations to economically insignificant levels as a result of the natural epidemics they would cause. (Tempeton et al., 1979). The introduction of the rust fungus *Puccinia chondrillina* into Australia in 1971 from Mediterranean region for the control of rust skeletonweed *(Chondrilla juncea)* appears to constitute the first deliberate introduction of a pathogen for weed control in any country in what has become known as the classical approach to biological control of weeds with plant pathogens (Cullen et al., 1972). Two strains of P. *chondrillina* from Eboli, Itlay, were introduced into the United state in 1975. Within 2 years, the fungus caused severe infections of plants throughout populations of skeletonweed in California, Oregon, Idaho and Washington (Lee, 1986).

In 1975, *Entyloma ageratinae* was introduced into Hawai from Jamaica to control hamakuya pamakani (*Ageratina riparia* (Regel) K., & R.) (Trujillo et al., 1988). Weed population reduced from 80 to < 5% of the original population within 1 year.

(iii) Biological Control of Aquatic Weeds with Plant Pathogen: Several plant pathogens have been or are currently under investigation for biological control of aquatic weeds such as water hyacinth, water milfoil, duckweeds, alligator weed and water lettuce, in a variety of aquatic environments (Joye, 1990). Pathogens of aquatic weeds that have been tested as microbial pesticides include species of *Fusarium* and *Macrophomina,* on hydrilla and species of *Acremonium, Colletotrichum, Fusarium, Pythium* and *Phytopthora* for control of eurasian watermilfoil *(Myriophyllum spicatum* L.), but no promising control agents have been found among these isolates (Joye, 1990).

Experiments were conducted with potential commercial formulation of *Cercospora rodmanii* Conway for control of water hyacinth {*Eichhomia crassipes* (Mart) Solmes). This fungus has been released in South Africa for control of water hyacinth in the Crocodile river using a classical approach (Morris & Cilliers, 1992). Recently, *Microleptodiscus terrestris* (Gerdemann) Ostazeski was reported to have considerable impact on the population of milfoili in Florida tests (Joye, 1990). In recent work, Verma and Charudattan (1993) showed that this fungus was pathogenic to 3 (*Hydrilla verticilata, Myriophyllum aquaticum* and *Cereatophyllum demersum* L.) of 16 aquatic plant tested.

(iv) Biological Control of Weeds with Bacterial Plant Pathogens: Caesar (1994) suggested that strains of *Agrobacterium* *tumefaciens* (E.F. Smith and Town) isolated from important rangeland weeds may be effective as biological control agents for their respective hosts. Zhou and Neal (1995) compared strains of *Xanthomonas campestris* pv. *poannua* as biocontrol agents for annual and perennial subspecies *of* annual bluegrass (P. *annua* L.). Results of controlled growth chamber and field tests showed that two strains of this bacterium were similarly virulent in both tests. Johnson (1994) reported that three application of two strains of X. *campestris* pv. *poannua* controlled between 52 and 82% of the annual blue grass in dormant bermudagrass *(Cynodon transvaalensis* Burtt-Davy X C. dactylon (L) Pers.) field plots.

Begonia et al. (1990) have demonstrated in culture to be assemblies that isolates of Pseudomonas and *Erwinia herbicola* caused velvetleaf (*Abutilon theophrasti)* seedling to become chlorotic and develop abnormal root systems campared to non inoculated controls.

C. SYNERGISMS THAT MAY AFFECT THE EFFECTIVENESS OF MICROBIAL AGENTS

The term synergism is used loosely here to mean a combined use of insect, chemicals or pathogens that enable pathogens to control weed when the individual activities of the interactive participants and less effective.

(i) Synergism of Pathogens with Other Pathogens: Many examples have been reported in which pathogens incapable of causing significant levels of disease when infecting alone were more severe in combination with other pathogens. Dimock and Baker (1951) showed that *Fusarium roseum* infected snapdragon (*Antirrhinum majus* L.) through lesion caused by rust fungus *Puccinia antirrhini* D., & H. Apparently, *F. roseum* infected healthy tissue beyond the rust lesion and caused death of leaves and shoot or even entire plants whereas infection by the rust alone seldom caused death. Thus it appears that a facultative parasite incapable of infecting a plant alone, contributed to increased disease seventy by invading lesions produced by another pathogen. This phenomenon has been extended to biological control of weeds.

Mortality of groundsel infected by *P. lagenophorae* has been attributed to invasion of rust lesions by *Botrytis cinerea* Pers. (Hallet et al., 1990 a, b). Inoculation of healthy groundsel with *B. cinerea* caused only 10% mortality and only 40% mortality of abiotically wounded plants however, all plant previously infected by *P. lagenophorae* died after inoculation with Botrytis. Death of plants was attributed to growth of Botrytis into stems. The time necessary to kill plants was dependent upon several factors, including the inoculums concentration of Botrytis and initial pustule number of the rust (Hallet et al., 1990 a, b).

(iii) Synergism of Pathogens with Insects: Insects and plant disease may have played a role in the control of prickly pear *(Opuntia* sp.) in Australia and other countries (Wilson, 1969). Similarly introduction of the insect *Proceidorchares utilis* Stone into Australia from Hawaii in 1952 may have coincidentally introduced a pathogen, *Cercospora eupatorii*, that resulted in the buildup of a leaf spot disease of crofton weed, *Eupatorium adenophorum* Spreng. The combined effect of this insect and pathogen (with native insects) may have contributed to control of crofton weed (Dodd, 1961).

Yang and Te Beest (1992 b, 1994) found that green treefrogs *(Hyla cinerea Schneider)* and grasshoppers, *Conoccephalis* sp. and *Melanoplus differentiaiis* (Thos.), may be important vectors in the dispersal of inoculum and disease caused by C. *gloeosporoides* f. sp. *aeschynomene* on northern joint vetch.

Synergism of Pathogens with Chemicals: A promising consideration concerning possible chemical interactions with plant pathogens is the utilization of various chemicals, including herbicides, to increase the effectiveness of biological agents by weakening host resistance to infection by a pathogen (Charudattan, 1993).

Gobara and Yamaguchi (1993) showed that the combined use of herbicide pyrazosulfuron-ethyl and the fungus D. *mooceras* showed significant synergism in controlling barnyard grass in rice in Japan. Similarly, Scheepens (1987) showed that atrazin was synergistic with the pathogen *Cochliboius lunatus* for control of *Echinochloa crusgalli* (L). Beauv in Maize (*Zea mays* L.), in the Netherlands. In controlled experiments in a green house of growth chamber, barnyard grass seedlings could be controlled with the fungus after treatment with a sublethal dose of atrazine (dose of herbicide is reduced by 50 % to its normal recommendation).

(D) THE ENVIRONMENTAL IMPACT OF MICROBIAL HERBICIDES

On Non target Beneficial Plant Species

The ability of plant pathogens of weeds to infect cultivated and noncultivated plant species is a serious and important part of every effort to develop a commercial product for biological control of weeds. Almost without exception, these pathogens can and do infect cultivated and horticultural important plant species in controlled experiments.

Colletotrichum gloeosporioides f.sp. *aeschynomene* has been used in registered product, collego since 1982 to control a single weed species, *A. virginica,* in rice, *Oryza sativa* L., and soyabean, *Glycine max.* Merr., in the United States. This fungal pathogen infects several species within the genus *Aeschynomene.* However, it also infects species within eight other genera, including *Cicer, Indigofera, Lathyrus, Lens, Lotus, Lupinus, Vicia,* and *Pisum.* It is important to note, however, that the fungus is highly virulent only to *A. virginica* and *Lathyrus arboreus* L., although certain cultivars of *Pisum sativum* L. were also infected (Te Beest, 1988; Weidemann et al., 1988) Similarly, the host range of P. *palmivora,* the fungus formulated as Devine, includes species other than *M. odorata,* the intended target (Ridings et al., 1976). The host range of P. *palmivora* includes onion, cantaloupe, watermelon, okra, tomato, endive, cucumber, english pea, and carrot, and even certain citrus root stocks based on greenhouse tests of pre-emergence, post emergence and to foliage inoculation.

(II) BIOLOGICAL WEED CONTROL WITH BIOAGENT OTHER THAN PLANT PATHOGEN

A large number of biocontrol agents such as insects, mites, animals, fish, birds, and their toxic products have been identified for weed control. Among them, insects are one of the important groups. Certain species of insects have been introduced in the region where some weeds such as cactus, klamath weed, lantana, waterhycinth and parthenium have become a serious nuisance.

Outstanding Case of Biological control of weeds

(i) Lantana (*Lantana camara* L.): The first attempt of using insects to control weeds was done in the early 1920's to control *Lantana* sp. *Lantana camara* L. is the perennial shrub which is used as an ornamental plant throughout the world. This species became a menace in coconut plantation, rangelands and hindered reforestation. A seedfly (*Ophimoyia lantanae),* a lacebug (*Teleonania scrupulosa*) and butterfly (*Theola* spp.) have been used to control this weeds. Test conducted in 1920 and later showed that some of the insect were very effective in controlling Lantana. These insects include (a) larvae of *Crocidosema lantanae,* (b) larvae of *Agromyza lantanace* and (D) larvae of *Thecla echion* and *Thecla bazochi* (Thakur, 1992).

(ii) Pricklypear (*Opuntia* sp.): In Australia, the biological control of *Opuntia* by *Cactoblastic cactorum* transformed pricklypear territory of 24 million ha from a wilderness to a scene of prosperous endeavor. In India, 40,000 ha of land infested with *Opuntia dillenii* was recovered from the weed be releasing *Dactylopius tomentosus* cochineal scale insect as bioagent other species of *Opuntia* were not attacked by this insect (Narayanan, 1954). The primary damage to *Opuntia* with insects can be combined with secondary attack by bacterial and fungal parasites for eroding the weeds. These secondary bioagents are *Cleosporium anatum* E & E, *Phyllosticta concava* Seav and *Montegnella opuntiorum* Spera.

Klamath weed (*Hypericum perforatum* L.): This is considered as a noxious weed in the rangelands of Australia, New Zealand, Canada and USA. Two species of the leaf feeding beetle, *Chrysolina hyperici, C. gamellata* and a root borer, *Agrilus hyperici* have been used against this weed.

(iv) Aquatic weeds: Waterhyacinth (*Eichhornia crassipes*), a world wide aquatic weeds, infest transplanted paddy fields in many countries, including India. Most success in respect of biological control of this weed has been met in Florida (USA) with a hyacinthmoth, *Sameodes albiguttalis* B. Benner, which is a native of South America (Center, 1982). The bioagent exhibits its rapid reproduction ability in field condition its larvae feed upon young leaves and apical buds of waterhyacinth, rather severely. Success has been achieved also in the field of aquatic weed control by using the weevil *Neochetina bruchii, N. eichorniae* to control waterhyacinth and similarly grass carp fish *Ptenopharyngodon idealla* Vahl could control submerged aquatic weeds quite effectively (Gupta, 1987).

Salvina *(Salvinia molesta)* : In Kerala (India), fresh courses and paddy fields have been cleared from, noxious ferns, using curculionid beetle *(Cytrobagous salviniae)* as a very effective bioagent. The beetle in native of South America. The young larvae of the beetle damage the terminal buds, rhizomes, and petioles of salvinia.

(v) *Parthenium bysteropborus* (L.): This is an exotic noxious weed accidentally introduced in India in 1956. The mexican beetle *(Zygogramma bicolurata)* is found to have great potential to bring about permanent reduction in the density of P. *hysterophorus* in the parts of India experiencing moderate weather conditions. This beetle was found most active on *P. hysterophorus* during May to September in Uttaranchal, India (Pandey et al., 2001).

Dhileepan et al. (2001), Use light microscope, histochemical assay, gas exchange measurement and mineral estimation to determine response to galling in P. hysterophorus by Epiblema strenuana and Cantrachelas albocinereus. The ability of galls insect to alter the concentration of minerals such as magnesium, chloride and zinc in various part of the plant suggest that these galls act as “mobilizing sink”.

For the control of parthenium cacia cinacia another weed (legume) and cenchuras cilliaris (fodder grass) have been found suitable (Mahadevapa, 1997).

The genus *Zygogramma* is represented by 99 species in the nearctic and neotropical region but host plant of only 6 Zygogrammea species are known world over. The status of zygogramme sp. is present in Table 1.

Table 1: Status of Zygogramma sp. (Anonymous, 1993)

Name of the species	Status
Zygogrammma bicolorata	Feed on *P. hysterophorus.* Introduced in Australia and India
Z. disrupta	Introduced in USSR against rag weed *Ambrosia* sp.
Z. exclamationis	Feed on wild and cultivated sunflower plant in USA
A. suturalis	Introduced against rag weed *Ambrosia* sp. in USSR.
Z. tortuosa	Introduced against rag weed, *Ambrosia* sp. in USSR
	Feed on sunflower under laboratory condition
Z. conjuncta conjuncta	Culture destroyed in USSR for fear attacking sunflower
	Describe under genus *zygospila. Z. conjuncta* feeds on poverty weed Iva *axillaris* Pursh

(vi) *Ordbanche* spp.: Almost 50 insect are reported to feed on *Orobranche* sp. the only insect which selectively and effectively damage Orobranche is the fly *Phytomyza orobanchia* Kalt (Diptera : Agromyzidae) (Link *etal,* 1992).

(III) BIOLOGICAL WEED CONTROL BY NATURALLY OCCURRING HERBICIDES

Concern about the environment hazards from, the herbicides has stimulated interest into the possible role of secondary plant product (allelochemicals) and microbial toxins as natural herbicides. Many of these chemicals have been found to possess good herbicidal activity. Biolophos is the first herbicide developed by this method, and is commercially marketed in Japan under the trade name Herbiace. It is isolated from the fermentation broths of *Streptomyces hygrocopicus* and S. *viridachromogenes* and exhibits herbicidal activity against wide spectrum of grasses and broad leaf weeds following foliar application. (Tachibana, 1987).

Table 2: Plant metabolites used for herbicidal activity (Tachibana, 1987)

Natural phytotoxin	Plant or microbial source
Anisomycin	*Streptomyces* sp.
Biolophos	*Streptomyces hygrocopicus, S. viridachromogenes*
Cercosporin	*Cercospora* sp. *Pseudocercosporilla capsuila*
Coffeina	Coffee plants
Dhussion	*Sorghum plants*
Tab toxin	*Pseudomonas tobaci*
Teu toxin	*Alternaria altemata*

Another approach is the biorational synthesis of more stable and selective analogues based on the novel chemistries provided by the allelochemicals and microbial toxins. Methoxyphenone, marketed in Japan (Nihon, Japan) as a selective herbicide for the control of barnyard grass {*Echinochloa crusgelli* (L.) Beauv.) in rice, is as synthetic analogue of the microbial toxin anisomycin (Munakata et al., 1973).

BIOLOGICAL WEED CONTROL THROUGH ALLELOPATHY

Green plant produces numerous secondary metabolites many of which are capable of inhibiting plant growing in a community. These chemicals have been designed as allelochemicals and the process as allelopathy. Several instance when such allelopathic phenomena is observed amongst the weeds themselves giving scientists opportunity to use it in allelopathic control of certain weeds using specific botanicals.

For instance, dry dodder *(Cuscuta* spp.) powder has been found to inhibit severely the growth of Waterhyacinth (*Bchhomia crassipa)* and eventually kill it. Like wise, dry carrot grass *(Parthenium hysterophorus)* powder was found detrimental to certain aquatic weeds. The presence of marigold *Tagetus* spp. plants exerted adverse allopathic effect on- P. *hysterophorus* growth. So was found true of the weed Coffeesena (*Cassia* spp.) which exerted suppressive allelopathic effects on *Pathenium* (Jay Kumar et al., 2001). The eucalyptus tree leaf leachates have been shown to suppress the growth of nutsedge (*Cyperus rotundus*) and bermuda grass (*Cynodon dactylon)* (Pandey et al., 2001).

Several plant spp. like *Cassia sericeae, Cassia tora, Cassia anrticulata, Ipomoea muricata, Amarantaus spinosus* and *Croton spaciflorus* have the potential to suppress the congress grass. C. *sericea* have proved a promising alternate to control carrot weed at Dharwar and Banglor in waste land and non cropped area (Mahadevappa et al., 1997).

Future research considerations for biological control of weeds:

- Prioritization of taxonomic survey, identification of species and biotypes and preparation of distribution maps of weeds.
- A high degree specificity for the target weed.
  No effect on non target and beneficial plant or man.
- Potential impact to biotechnological research and development.
- Natural enemies for most plants studied have been identified but whether these can provide the levels of controls, specificity and environmental safety required by today's standards, remain open to question.
- The role of bio-control in Integrated Weed Management System and the extent, to which it can help in controlling the numerous weed species, remain to be seen.
- Study of the biology of natural enemy and the weed-natural enemy relationships to determine how best they could be used to solve the problem.
- Increasing the effectiveness of the indigenous host specific natural enemies through different types of manipulations.
- Development of expertise through training.

CONCLUSION

There has been growing awareness and concern about environmental issues and the need to protect it for future generation. The indiscriminate use of broad-spectrum chemicals has resulted in reduction in biodiversity of natural enemies, out break of numerous weeds, development of resistance to herbicides, herbicides induce resurgence and contamination of food and ecosystem. For this, biological weed control measures have been systematically encouraged to bring down the use of toxic chemicals. Future research may discover specific biological control of organisms and combinations of organisms that an effective and safe and can be integrated with other methods of weed management in crops. There are not many now.

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