Bioherbicides

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Bioherbicides

- Weeds are plants that create serious constraints in agricultural production.
- They compete with crops for water, gases, nutrients, space, light, and other growth resources, and can become hosts to pests and diseases.
- Herbicidal weed control creates spray drift and adversely affects the environment.
- Their residues (herbicides) in food commodities, directly or indirectly affect human health.
- These lead to the search for an alternate alternate method of weed management, which is eco-friendly.
- Biological weed control is a mechanism to suppress the germination and growth of weed populations to an economic threshold level by utilizing natural enemies, natural substances, or biotic agents.

Definition

- Bioherbicides consist of microorganisms such as pathogens and other microbes or phytotoxins derived from microbes, insects, or plant extracts that act as a natural means of weed control.
- Bioherbicides are made up of microorganisms (e.g. bacteria, viruses, fungi) and certain insects (e.g. parasitic wasps, painted lady butterfly) that can target very specific weeds.
- The microbes possess invasive genes that can attack the defense genes of the weeds, thereby killing it.
- Bioherbicides may be compounds derived from microbes or phytotoxic plant residues, extracts or single compounds derived from other plant species.
- A bioherbicide based on a fungus is called a mycoherbicide. In the industry, bioherbicides and other biopesticides are often referred to as "naturals".
- The first evidence of bioherbicide development was documented in the mid-1970s with the discovery of mycoherbicides.
- Since then, numerous bioherbicides have been registered and become available in the global market.
- The earliest bioherbicide project involved simply the application of *Fusarium oxysporum*, a fungus, against *Opuntia ficus-indica*.
- In the 1950s, the parasitic weed *Cuscata* spp. was controlled with *Alternaria cuscutacidae.*

Bioherbicides

- A bioherbicide is a preparation of living inoculum of a plant pathogen, formulated, and applied in a manner analogous to that of a chemical herbicide in an effort to control or suppress the growth of weed species.
- The use of bioherbicides is based on the fundamental epidemiological principles of plant pathology. Plant disease is the result of the interaction among the host plant, the pathogen and the environment, commonly referred to as the disease triangle.
- Although serious, devastating disease epidemics of crop plants occur, they are the exception rather than the rule and many factors can limit disease development.
- Pathogen factors such as:
  - low inoculum levels, weakly virulent pathogens,
  - poor spore dispersal mechanisms;
  - environmental factors such as unfavorable moisture and/or temperature conditions; and
  - plant factors such as low susceptibility of the host, and widely dispersed host populations

  often limit disease.

Advantages of bioherbicides

- high degree of specificity of target weed
- no effect on non-target and beneficial plants or man;
- absence of weed resistance development, and
- absence of residue build-up in the environment.

Microbial Herbicides

- The majority of biological herbicides developed to-date are mycoherbicides; however, several bacterial herbicides are under development as well.
- In the development of any new pest control strategy, safety and efficacy are the two primary concerns:.
  - safety (in relation to crop plants, the environment, and human health) and
  - efficacy (in relation to environmental tolerance, level of damage to the weed, and ability to be integrated within the crop production system) are the major criteria in the selection of suitable plant pathogens.
- The preferred characteristics of a potential bioherbicide pathogen:
  - growth and sporulation on artificial media
  - highly virulent
  - genetic stability
  - restricted host range
  - broad tolerance range
  - prolific propagule production
  - capacity to damage its host plant and
  - innocuous in ecological effects

Commercial bioherbicides first appeared in the market in USA in early 1980s with the release of the products:

- Devine : Developed by Abbott Laboratories, USA, the first mycoherbicide derived from fungi (*Phytophthora palmivora*).
  - Is a facultative parasite that produces lethal root and collar rot of its host plant *Morrenia odorata* (stangler vine) (control 95 to 100%), a problematic weed in citrus plantation of Florida.
  - It was the first product to be fully registered as a mycoherbicide.
- Collego: It is a formulation of endemic anthracnose fungus *Colletotrichum gloeosporioides* f. sp. *aeschynomene* (cga) was developed to control northern joint vetch (*Aeschynomene virginica*) in rice and soybean field.
- Biomal: It contains spores of *Colletotrichum gloeosporioides* f. sp. *malavae*. It is used to control *Malva pusilla* (round-leaved mallow) mallow) in Canada and USA.
- Dr. Biosedge: Further, the rust fungus *Puccinia canalicuta* is commercialized under the name Dr. Biosedge for control of *Cyprus esculantus* L. (yellow nut sedge).

Commercially Registered Microbial Bioherbicides

Pathogen	Weed host	Trade name
Colletotrichum gloeosporioides f. sp. aeschynomene	Northern jointvetch	Collego®
Colletotrichum gloeosporiodes f. sp. malvae	Round-leaved mallow	BioMal®
Colletotrichum gloeosporiodes	Silky Hakea	Hakatak™
Phytophthora palmivora	Stranglervine	DeVine®
Colletotrichum gloeosporioides	Dodder	LuBao
Chondrostereum purpureum	Black cherry	BioChon™
Cylindrobasidium laeve	*Acacia spp.*	Stumpout®
Colletotrichum coccodes	*Velvetleaf*	*Velgo®*

Pathogen	Weed host	Trade name
Cercospora rodmanii	*Water hyacinth*	*ABG-5003*
Alternaria cassiae	*Sicklepod, coffee* senna, and showy crotalaria	CASST™
Alternaria sp.	*Dodder*	*Smolder®*
Puccinia canaliculata	*Yellow nutsedge*	*Dr. BioSedge®*
Puccinia thlaspeos	Isastis tinctoria	Woad Warrior
Chondrostereum purpureum	Deciduous tree species	MycoTech™
Chondrostereum purpureum	Alders and Hard wood	Chontrol™ Ecoclear™
Xanthomonas Campestris	Annual bluegrass	Camperico®
Sclerotinia minor	Dandelion	Sarritor

Mechanism of microbial bioherbicides

- The proliferation of mycelium infects the vascular trachea to prevent the supply of food and nutrition.
- The phytotoxin α, β-dehydrocurvularin inhibits mitosis in root tip cells and halts seedling growth.
- Fungal pectinase penetrates the cell wall of the host by rupturing the polysaccharide layers and enlarging the pores in the wall and releases several signaling and toxic molecules in infected plant cells.
- The extracellular lipases of fungi utilize the lipids and proteins in the endosperm of weed seeds for growth.
- In addition, *Enterobacter* sp. secretes high concentrations of IAA and transfers it to weeds during their association, resulting in enhanced plant endogenous IAA and aminocyclopropane-1-carboxylate (ACC) synthase, which stimulates an increase of ethylene biosynthesis and causes a reduction in weed growth.
- Extracellular and hydrophilic phytotoxins, such as N2 -β-D-glucopyranoside, trans−4-amino-D-proline and aglycone of ascaulitoxin,are synthesized from a plant pathogenic fungus, *Ascochyta caulina*, which damage the plants and increase their mortality.
- Other bioherbicidal compounds,including α,βdehydrocurvularin, 24-kDa protein (Nep1), trichothecene, β−1,4-exoglucanase, β−1,4-endoglucanase, glucosidase, xylanase and pectinase, 3-nitro-1,2-benzenedi-carboxylic acid (3-nitrophthalic acid), macrocidins, diethyl 7-hydroxytrideca-2,5,8,11-tetraenedioate, cyclo-(ProPhe) and organic acids, are produced from bacteria and fungi to control the germination and growth of weed seeds .

Plant-Based Bioherbicides

- Plant extracts, which are traditionally used for medical or nutritional purposes, may serve as an alternative for developing bioherbicides for sustainable agricultural practices in weed management.
- Certain plant species have the capacity to secrete different metabolites known as allelochemicals, such as alcohols, fatty acids, phenolics, flavonoids, terpenoids, and steroids, that reduce the reproduction, growth, and development of adjacent vegetation, including weed species.
- Essential oils are natural volatile compounds derived from different plant parts, such as leaves, bark, flowers, fruits, seeds, roots, and also from the whole plant.
- Terpenoids (mainly mono and sesquiterpenes) are the main compounds of essential oils' activity which could be potential candidates for the development of new bioherbicides because they have a strong phytotoxic activity toward different weed species.
- The phytotoxic potential of essential oils involved:
    - chlorosis,
    - the burning of leaves, and plant growth reduction,
    - as well as mitosis inhibition,
    - membrane depolarization,
    - decrease of chlorophyll content,
    - cellular respiration, and
    - oxidative damage
- In the past, many herbicides such as Cinmethylin, AAL toxins, Mesotrine, Artemisinin, Biolaphes, Glufosinate, and Dicamba have been developed from plant allelochemicals.

Steps in bio-herbicide development

- Discovery:
  - The discovery phase involves the collection of diseased plant material,
  - isolation of the causal organism, demonstration of Koch's postulates,
  - identification of the pathogen,
  - culture of the pathogen on artificial media, and
  - maintenance of the pathogen cultures in short-term and long-term storage.
- Development:
  - The development phase involves the determination of optimum conditions for spore production,
  - determination of optimum conditions for infection and disease development,
  - determination of host range and elucidation of mechanism of action of the pathogen.
- Deployment
  - The final phase, deployment, often involves close collaboration between nonindustrial and industrial sectors through the formulation, scale-up, field evaluation, and marketing stages of commercialization process of a new bioherbicide product.