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REVIEW

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ROLE OF BIOCONTROL AGENTS IN WEED MANAGEMENT – RECENT DEVELOPMENTS AND TRENDS

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ABSTRACT

Within integrated pest management programs, biological control of unwanted plants has remarkable capacity to provide viable, effective, and economic control of weeds. When using bio-herbicides, crop production and quality improve with virtually no damage to the ecosystem. Bioherbicides are target-specific, destroy only selected weeds that have been sprayed for and do not cause harm to non-target plants. Bio-herbicides can be quickly incorporated into weed control programs, which can reduce chemical herbicide dependence. We are also raising the chance of environmental pollution by pesticides. There are only a few bio-herbicides available on commercial bases although work began earlier in the 1940s. Sources of commercialized bioherbicides include *Phytophthora palmivora* (Devine), *Collectotrichum gleosporiodes* (Collego), *Colletotrichum gloeosporioides* (Binomial) and *Streptomyces viridochromogenes* (Bialaphos and Glufosinate). Virulence for pathogens and their environmental requirement are major constraints for bioherbicide development. Specific bio-herbicides should be useful in finding position in irrigated fields, wildlife while thriving weeds with pests or resistant weed control.

Key words: synthetic chemicals in weed control, pesticide toxification, residues in plant systems and soil, eco-friendly weed control technologies, bioherbicides, mode of action

INTRODUCTION

Weed is considered a nuisance plant, normally unwanted flora in human-made environments (e.g., greens, agricultural fields, grasslands, forests and parks) and natural areas [Ani et al. 2018]. Weeds absorb soil moisture and nutrients, and are competing with crops for sunlight and space [Leghari et al. 2016]. Rice weeds usually cause 10–40 % crop loss and often 100% loss [Rodenburg et al. 2016]. 20% profit loss in sugarcane and 40% profit loss in soybean. In developing countries, weeds on average cause crop losses of 20–30% [Abdul Rehman et al. 2015]. Problems related to field weeds include: reducing crop quality through product degradation and crop intrusion, producing biochemical ingredients that are allergic to individuals, fauna and crop plants, growing spikes and wooded branches that are a source of exasperation and livestock scuffing, obstructing roadside conspicuousness, interfering with the provision of community usefulness (telephone wires, power lines), impedes the flow of water in rivers and generates fire risks, increases the decline of public recreation areas, homes, space lots and vehicles, invades and displaces species in stable natural areas [Oerke 2006, Fantke et al. 2012]. Given the above evidence, there is an urgent need to upgrade existing technologies and establish new ways of managing unwanted plants that are environmental-

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ly and economically defensible. Biological control of unwanted plants has a remarkable potential to provide viable, efficient and economic control of weeds within Integrated Pest Management (IPM) programmes [Pal and Gardener 2006].

At national level, weed control loss exceeds 120 billions. According to a survey, the monetary value loss from weeds in Pakistan's major cereal crops falls within 30 billions for wheat, 40 billions for rice, 4 billions for maize and 5 billions for gram crops [Pakistan Agricultural Research Council Islamabad 2013]. Weeds are generally eradicated by cultural and chemical methods. The nutrient value of crops can be affected by chemical practices. Weeds are immune to herbicides now [Cordeau et al. 2016]. Environmental concerns over the use of pesticides, their residues in plant and soil environments and their harmful environmental consequences have drawn attention to the development of an eco-friendly solution to plant diseases and weeds. The situation demands the development of alternative weed control technologies.

DIFFERENT POLICIES ON WEED CONTROL

Weed control methods currently available include hand weeding, tillage, and herbicide use. Each technique has some benefits and some drawbacks [Mohammadi 2013, Sims et al. 2018, Beckie et al. 2019]:

1. Hand weeding is time consuming, expensive and especially difficult for toxic, spiny and perennial weeds.

2. Tillage is a mechanical method of weed removal. It controls weeds effectively, but tillage exposes the top fertile soil to water and wind erosion.

3. Herbicides provide effective weed control but affect the environment, reduce soil fertility, damage soil structure, contaminate water via surface run-off, kill non-target plant crops, can cause disease (e.g., cancer, Parkinson's disease, etc.)

Improper use or high doses of herbicides may cause crop damage, particularly if herbicide is applied during periods when the crop is sensitive to chemical exposure, which leads to unintended but economically significant crop damage [Thomas et al. 2004]. In addition, ecological possessions are linked by the practice of synthetic herbicides containing unintended impairment on spewed and offsite, e.g., by shifting the flora of treatment sites. Indirect impact of synthetic herbicide includes improvements in animal environment. It has particular significance for the use of herbicides in forestry. Nonetheless, it is from apprehensions about the harmful impact of herbicides that person distress which is directly exposed to these chemicals during pesticides spray or indirectly exposed to nutrition and biota or drift by their remains. Regardless of these issues, there are some critical thoughts about pesticides and herbicides being sprayed for transmission. Therefore, some new eco-friendly weed control techniques need to be built in order to address these limitations. The discovery of bio-herbicides has potential to overcome these constraints [Légère et al. 2000, Nazarko et al. 2005, Leeson and Thomas 2008].

THE BIOHERBICIDES

Bio-herbicides are biocontrol agents which are used for weed control. Bio-herbicides can contain biological components that can target specific weeds [Kremer 2019]. Nearly all weeds have some natural enemy that can help control its population. Bio-herbicides use these enemies that occur naturally, rather than rely on synthetic chemicals. Massive inoculum doses are applied to combat weeds [Hajek and Eilenberg 2018]. Much like chemical herbicides where a single herbicide is to be developed, some preparation for the use of bio-herbicides is required by broadcasting such organic complexes. Reviews on infections caused by weeds and the transmission of pathogens for their potential as bio-herbicides should be guided [Green 2003]. Reviews may be of indigenous region or innate varieties of unwanted plants in style, as well as traditional reviews of unwanted plants for organic control. The results of these studies indicate appropriate species for bio-herbicide advancement. The bio-herbicide pathogen may have the following characteristics: i) may grow on synthetic medium, ii) severe virulence, iii) genetic stability, iv) small congregational variety, v) broad tolerance range, vi) successful propaganda formation, vii) potential to harm host plants, viii) unharmful to the ecosystem [Bailey 2014, Saritha and Tollamadugu 2019].

Bio-herbicides are capable of controlling (i) unwanted plants infecting regions where herbs killing agents may be costly, (ii) unwanted plants have resistance to chemical agent regulation, (iii) crops alike agents (iv) parasite killing unwanted plants. Weeds which are not controlled for their control by traditional technologies are considered the ultimate objects for the use of bio-herbicide methodology [Shabana et al. 2010]. It is therefore important to understand that bioherbicide is not a chemical herbicide-equivalent type and therefore no presumptions of a bioherbicide would be prepared. In fact, bio-herbicides won't replace any other form of weed control. Less spending associated with bioherbicide expansion makes goods developed for the small marketplaces. Such marketplaces are not very financially useful for advancing traditional herbal killers or biological agent regulation. The bioherbicide mode of action is unique and distinct from chemical herbicides. Integrating biological control into other practices will enhance the capacity of growers to deal with herbicide-resistant weeds. Biological control can be used as a fragment of assimilated weed organization, supplementing herbicide rotations by providing new modes of action in the system [Beckie et al. 2007b, 2008b]. In fact, bio-herbicides won't replace any other form of weed control. Less spending associated with bioherbicide expansion makes goods developed for the small marketplaces. Such marketplaces are not very financially useful for advancing traditional herbal killers or biological agent regulation. The bioherbicide mode of action is unique and distinct from chemical herbicides. Integrating biological control into other practices will enhance the capacity of growers to deal with herbicide-resistant weeds. Biological control can be used as a fragment of assimilated weed organization, supplementing herbicide rotations by providing new modes of action in the system [Beckie et al. 2004]. Infection-causing harmful agents have genetic makeup specific for providing means to over-defense different forms of flora as they send guidance to microorganisms for attacking and infecting plant species. Corresponding to the gene requirement ensures harmful agents do not affect plants except that they are recognized by microbial genetic code. This selective reaction gives benefits to bioherbicides as they conduct some inquisitive weed plants with crop production without damaging crops. Bioherbicides mark one weed and give away the remaining unharmed surroundings [Charudattan 2001, Karen et al. 2015].

Brief history of bioherbicides

In the 1940s the use of mycoherbicides to combat the agronomic weeds began. In the beginning, work in Hawaii included merely the use of fungal species such as *Fusarium oxysporum* in *Opuntia ficus-indica* weed populations. After that in the 1950s, *Cuscata* spp. was introduced for *Alternaria cusutacidae* spores in Russia. In 1963, Chinese used same weeds for *Colletotrichum gloeosporioides* f. sp. *cuscutae*. It was renamed LuBao. There are only a few bio-herbicides available on commercial bases although work began earlier in the 1940s. Efficiency and protection are key apprehensions in promoting a creative method to manage pests [Watson and Wymore 1989, Auld et al. 2003, Harding and Raizada 2015, Pacanoski 2015]. In selecting pathogens for selected plants, crops, ecological and individual health protection and efficacy for weed control with potential to be incorporated into the crop manufacturing system are therefore requirements.

The potential of bioherbicides

Compared with chemical herbicides, bio-herbicides target fewer weeds. Marketplaces may not be large enough to support wild plant-based bioherbicide for control. Host option of plant pathogen is likely to increase. It enhances the herbicide-tolerant potential of wild plants to bioherbicides. They aid in monitoring herbicide-resistant wild plants, as there are less risks that multiple pathogenesis approaches would advance [Beckie 2011]. Preparation extracts can be used to increase mycoherbicidal host ability. *Alternaria cassiae* formulated, for example, has been shown to infect *Cassia obtustifolia* in water, which can increase host specificity [Amsellem et al. 1990]. The selection of weed regulators was increased by the combination of chemicals and bio-herbicides. It may also be helpful for genetic engineering approach. Through injecting genes via the processing of bialaphos, the virulence and effectiveness of the host range were modified [Charudattan et al. 1996]. Approaches to genetic manipulation may also be used to remove harmful pathogens.

One of the main drawbacks to the production of bioherbicides is the responsibility of pathogenic humidity. The major challenge to herbicide development is the ability to cope with pathogenic needs. Some beneficial effects were also obtained from the bio-herbicides. Prepared additives may be used to increase moisture by reducing the time for disease growth. These additives increase the entrance of pathogens and decrease their length i.e., enzymes and nutrients. They may be used to improve potency for the development of exciting enzymes and the use of pathogenic phytotoxins. Hence, preparations for bioherbicide to assemble the application of these approaches are important. Japanese product CanpericoTM should be used to ensure bluegrass power [Sporleder and Lacey 2013, Harding and Raizada 2015, Pacanoski 2015, Rehman et al. 2015].

Steps in developing a bioherbicide

The development of organic or natural herbicides includes three essential stages:

1. 'Detection stage' includes assembly of unhealthy flora, separation of underlying creatures, application of Koch' s hypotheses, pathogen recognition, pathogen cultivation on synthetic medium and maintenance of these crops for short-term or long-term storage.

2. 'Phase of progression' involves creating suitable conditions for spore growth, suitable conditions for contamination and progression of infection, assessing host range with exposure of pathogen exploitation appliances.

3. 'Stage of placement' includes close association between non-industrial and developed sectors through the growth, field assessment and publicization of phases of the bioherbicide production marketing cycle [Templeton and Heiny 1989].

Some commercially available bioherbicides

1. *Phytophthora palmivora* (Devine): It was developed by Abbott Laboratories, USA, the first mycoherbicide obtained from fungi (*Phytophthora palmivora*) which produces deadly root rot and collar rot of its host plant *Morrenia odorata* and survives in the soil for long ages of remaining turn. It was listed 1981 [Rao 2000].

2. *Collectotrichum gleosporiodes* (Collego): This is a preparation of the prevalent anthracnose fungus *Collectotrichum gloeosporioides* f. sp. *aeschynomene* which has been advanced in rice and soybean control of *Aeschynomene virginica*. It was also mycoherbicide first available on commercial bases for annual wild plants in crops with > 90 percent regulatory competence. It was named in 1982 [Boyette et al. 2012].

3. *Colletotrichum gloeosporioides* (Binomial): Philom Bios Inc., Canada has developed another *Collectotrichum*-based mycoherbicide Biomal successfully developed by Collego. It includes C-Spores. Sacc. f. sp. *Malavae Gleosporiodes* (Penz) This spps. were controlling the *Malva pusilla* [Xu et al. 2019].

4. *Streptomyces viridochromogenes* (Bialaphos and Glufosinate): The Japanese Bialaphos and glufosinate are internationally available. Bialophos is a by-product of *Streptomyces viridochromogenes* obtained through fermentation, while Glufosinate is phosphinothricin ammonium salt, which is an active component of bialaphos obtained from non-phytopathogenic *Streptomyces* [Carbonari et al. 2016].

Bioherbicidal characteristics

Bio-herbicides in culture produce durable and plentiful inoculae. They are cultivated by fermentation for obtaining large masses or for obtaining large yields that are active up to a few days (i). They are target-specific, destroy only selected weeds for which they were sprayed and do not damage non-targeted weeds (ii). They are genetically stable and they do not undergo mutations in adverse conditions in the natural world (iii). They destroy large portions of the population of weeds under various environmental conditions (iv) [Cai and Gu 2016].

Benefits of bioherbicides

Bioherbicides can be easily integrated into weed management systems, reduce dependency on chemical herbicides, reduce risk of contamination of pesticides in the environment, low maintenance and management, effective area is not limited, cheaper compared to synthetic pesticides, contribute to improving the effectiveness of weed management, reduce dependency on chemical herbicides, delays in the development of herbicide-resistant wild plants, decreases the risk of toxicity of pesticides in the environment, provides innovative management tools for crop producers, particularly organic growers, reduced or no use of chemical herbicides allow producers to meet the needs of markets where profit margins are often much higher [Beckie et al. 2007a, 2008a, Dash and Sethi 2016].

Limitations of bioherbicides

1. Products available on commercial bases such as Devine and Collego are useful for flooding conditions in citrus and rice, while humidity is a major challenge for bioherbicides while farming on dry land. For farms requiring control of weeds for agriculture, the most effective management technique is spray formulation in liquid form. Many suspensions are applied in combination with bioherbicides and presented later around potential "in principle" [Womack et al. 1996, Aneja et al. 2017].

2. Mass production: Collego, Biomal, and Devine spores are formed by inundated fermentation. For submerged fermentation in cultivation, all conditions in the bio-reactor including temperature, pH, and oxygen could be controlled. Nevertheless, the unsuitable formulation of plant growth which is not needed can pose difficulties. *Colletotrichum truncatum* studies have outlined the impact of the ratio of carbon and carbon to nitrogen (C : N) on propagule growth. Such ratios also affect appressoria germination and development, and consequent disease growth. Alternatively, definite N base arrangement advances conidia growth. One of the main constraints for processes in submerged environment using oxygen for cultivation is ~6 ppm. For submerged culture, the plant surfaces can also serve as support for providing a medium for spore formation. To this end, firm state fermentation from liquid culture which stimulates the spore formation process when dries. Many substrates such as wheat straw, oat grains and maize meal are used in the production of bioherbicides but comprehensive structures are not widely available in the modern world [Ortiz-Ribbing and Williams 2006, Yamane and Tanaka 2013, Berestetskiy and Sokornova 2018].

3. Genetic engineering and toxin production: Genetic coding could also be used as a useful method for the production of toxins by some infective factors. Nonetheless, the currently known cell-gene-generating phytotoxin are large gene collections of 25–35 kbp [Hoagland et al. 2007, Harding and Raizada 2015].

Overcoming the limitations

Virulence for pathogens and their environmental requirement are major constraints for bioherbicide growth. Targets for bioherbicide pathogens include expanding host selection, further development of toxins, increased virulence and more tolerance for formulating processes to enhance biotechnological methods. Although many microbes are very effective at low concentration and highly selective, pathogens with bioherbicides do not generate phytotoxins but may also contribute to the development of innovative wild plant control items. DNA approaches thrive on the development of prokaryotes, despite the fact that many bacteria are also being searched for as potential bioherbicides. Despite the fact that methods for fungi are not well developed, progress has been made in the last three to five years for genetic engineering of fungal pathogens [El-Sayed 2005, Hoagland et al. 2008, Pacanoski 2015].

Specific methods such as mutation, gene transfer, and recombination may be used for genetic alteration of the fungi. Methods such as transformation, gene replacement and incorporation to specific sites are mostly involved for the use of plant pathogens [Gelvin 2003]. The main limitation to the presence of recombinant techniques based on DNA is the lack of basic information about fungal pathogenesis. There is only minimal information available that refers only to crop pathogens and not to pathogens with bioherbicides. Different fungal genera have different pathogenicity mechanisms but few genes are considered available for incorporation into the pathogenic bioherbicide. Regular strain selection using standard methods may be useful for enhancing wild plant pathogens by optimizing the development of spores is important for prospecting success or failure of bioherbicides. Likewise, controlling nutrients for the fermentation medium, culture setting, and economic issues is crucial to effective bioherbicide progression. Similarly, there is a need to have more shelf-life for bioherbicide products that can survive under harsh conditions that are also the main constraint for bioherbicide progression. Progression has been made for the production as well as the implication of products that count the alginate gel method, invert emulsions and additives for improved germination, virulence efficiency [Singh et al. 2006, Dayan and Duke 2014, Gerwick and Sparks 2014, Masi et al. 2019].

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CONFLICT OF INTEREST

Authors declared no conflict of interest.

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