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Review Article

WEED MANAGEMENT FOR SUSTAINABLE AGRICULTURE

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ABSTRACT
The objective of this chapter is weed management system which is difficult for farmers of this generation. For this, farmers often use weedicides to control the growth of unwanted plants, for which they use artificial weedicides which are harmful for the environment and human beings too. Bio-herbicides are environment friendly alternative to harmful herbicides. These are viruses, bacteria, fungi, protozoa, algae, other biological microorganism to kill weeds. Examples of bio-weedicides are 2,4-diethyl ester, neem extract, glyphosate. Bioherbicides do not have any side effects to the environment. Bioherbicides have selective response that only targets specific genes without damaging the crop plant.

Keywords: Weedicides, Bio-herbicides, Biological micro-organisms.

1. INTRODUCTION
In recent decades many measures had been taken to control the use of chemical-based herbicides, pesticides, fertilizers which have very adverse effect on the environment. It affects human health either directly or indirectly. This makes us to think for the alternate solution, but from where will this solution come? The report by the U.S Congress, office of technology assessment indicates that biologically based technology such as use of bio-herbicides, bio-pesticides, bio-fertilizers to control weeds and pests. Weeds are very irritating species in agricultural field. Weeds cause severe damage to the main crop plant, decreasing the crop production due to which there is increase demand for bioherbicides. Bioherbicides are eco-friendly and beneficial to the environment, and it's use have been increased from last three decades. The ban on artificial weedicides have created a strong impact to develop natural strategies to control the weeds. The application of bacteria, fungi, algae, viruses to achieve the goal to control the weeds have gained a lot of attention all over the world. Practicing such methods have benefited the environment, have reduced the cost of production to develop the natural weedicides as compared to the artificial chemical-based weedicides which have increased target specificity. They may also support populations of non-native animals and microbes and hybridize with native species subsequently altering gene pools [1-2]. Out of about 30,000 species widely distributed weeds, 1800 species cause yield loss by about 9.7% of total crop production every year in the world [3]. In 1980s, growers spent over $3 billions annually for chemical weed control, $2.6 billions for cultural, ecological and biological control method. Non-native weeds species are spreading and invading in United States and European wild life habitat at the rate of 7 lakhs ha/year and 1 lakh ha/year, respectively [4], changing the basic structure of wetlands. Weeds also serve as reservoir for plant pathogens that may cause significant economic loss in crop production.

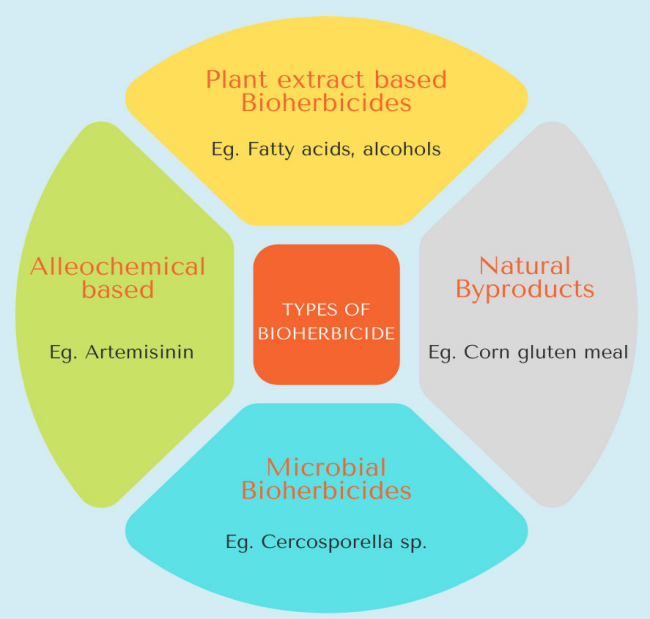

Fig. 1: Types of bioherbicides

2. PLANT BASED BIO-HERBICIDES

2.1. From plant-extract

Different metabolites like alcohols, fatty acids, phenolics, flavonoids, terpenoids, steroids secreted from plants have the ability to inhibit the growth, reproduction and development of weeds (Fig. 1). The specific receptors in weeds recognizes and reacts with these compounds, and in turn their population is reduced. Higher the concentration of seed extracts, more effective is the result. The plant extracts of *Juglans nigra* L. inhibits pre as well as post growth of weeds like *D. sanguinalis*, *Setaria italic* (L.) P. Beauv. Terpenoids from essential oils of *Cistus Ladanifer* L. inhibits chlorosis, plant growth, mitosis, decreases chlorophyll content, cellular respiration and damages leaves of *A. hybridus*, *Portulaca oleracea* L., *C. album*, *Conzya canadensis* [5].

2.2. From allelochemicals

These are secondary metabolites, also known as natures own herbicides. The diversity in chemical composition of allelochemicals has proved to be beneficial for the development of herbicides. They inhibit the seed germination of weeds. Allelochemicals disrupts photo-synthesis, water uptake, respiration, hormonal imbalance in weeds. Also, they have short half-life and thus are environment friendly. Herbicides such as cinmethylin, artemisinin, sarmentine, momilactones (Fig. 1) have been developed from plant allelo-chemicals [6].

3. BIOHERBICIDES FROM NATURAL BYPRO-DUCTS

Byproducts derived from natural sources have also found to be beneficial against weed control (Table 1, Fig. 1).

Table 1: Bioherbicides from natural products

Byproduct	Source	Targeted weeds
Distillers dried grains (DDGS)	Ethanol distillers	*Oxalis corniculata* L., *Stellaria media* L.
Corn gluten meal (CGM)	Wet-milling corn process	*C. album*, *S. nigrum*
Mustard seed meal	Mustard oil pressing	*Chenopodium album*

4. BIOHERBICIDES FROM MICROBES

Microorganisms are known to have positive relation with plant growth. But there are certain species which affects the plants growth and development by various mechanism. Metabolites produced from fungi and bacteria such as hydrogen cyanide, indolacetic acid, hydocinnamic acid and various others suppress weed growth. Pathogens like *Puccinia carduorum* Jacky, *Cercosporella* sp., *Septoria passiflorae* Syd, *Phragmidium violaceum* Winter (Fig 1) are few species that are used as bioherbicides to inhibit seed germination and growth of weeds [7].

5. EFFECTS OF BIOHERBICIDES ON WEEDS

5.1. Seed germination

Plant based herbicides releases biochemical substance, blocking hydrolysis of nutrient reserves and cell division in weeds. The process involves osmotic effects on imbibition rates, leading to inhibited germination and cell elongation. Essential oil damages DNA, mitosis, meristematic cells in weed [8]. The effect varies according with the size and seed coat permeability. Allelochemicals affects root surface rather than hypocotyls, due to thin cuticle layers, which results in altered cell cycle and division. Fungi enters the root hairs of a host, grows in intercellular space to reach root core. Proliferation infects vascular trachea and prevents food and nutrient supply thus inhibiting root growth [9].

5.2. Chlorophyll pigment

Chlorophyll is a green pigment, important for photosynthesis in plants. Phenolic compounds like ferulic, p-coumarin affects chlorophyll biosynthesis. Plant extracts inhibits chlorophyll associated enzymes and degrades chloroplasts and thylakoid membranes [10].

5.3. Photosynthesis

Plant extracts reduces the a/b chlorophyll binding protein by two folds, that eventually suppress chlorophyll synthesis and affects photosynthesis. Oxygen evolving enhancer protein 1 (OEE) is responsible for promoting the thioredoxin activity, release of oxygen by splitting water, protecting tetra-manganese cluster. Phytotoxic plant extracts and microbes reduces the OEE synthesis, which in turn affects gas and nutrients intake of weeds. Also, concentration of Mg is reduced, affecting chlorophyll synthesis in weed plants [11-12].

5.4. Plant hormones

Plant hormones are signaling molecules that regulate plant growth by various metabolic pathways. Gibberellin hormones play a major role in shoot development. *Sicyos angulatus* L. (allele-chemical), *Enterobacteria* sp. 1-3(pathogen), stimulates the accumulation of abscisic acid (ABA), jasmonic acid (JA), salicylic acid (SA). This leads to stomatal closing, lower rate of photosynthesis, increased plant senescence, further inhibiting plant growth and development [13-14].

6. ADVANTAGES AND DISADVANTAGES OF BIOHERBICIDES

Plant-based, phytotoxic microbial based bio-herbicides has proved to be a useful approach to control weeds. Bioherbicides are highly target specific and has no effect on non-target and beneficial plants. Bioherbicides usually have short half-life and thus poses no harm to environment and man-kind. The chemical structure of allelochemicals are more environment friendly than synthetic herbicides. Since, some allelochemicals are water soluble, they are easy to apply without adding surfactants. Multiple modes of action reduce the risk of herbicides resistance.

As we have seen there are plenty of benefits of bioherbicides in controlling weeds, but there are certain limitations that makes bioherbicides application less eligible than the current artificial herbicides. Structural complexity of many allelochemicals makes them too expensive for large-scale application. Example: cyclic tetrapeptide though being an excellent herbicide is expensive to use. Some phytotoxic natural products are poisonous to mammals. Ex: AAl-toxins. Bioherbicides have short half-life which is environmentally beneficial, but an effective herbicide must persist long enough to exhibit the desired effect. Due to this, natural phytotoxins are less preferred for weed management.

Table 2: Bio-herbicides from plant extracts and microbes with their respective weeds and modes of action

Plant/Microbes	Bioherbicide Source	Mode of action	Target weed	Reference
Matricaria chamomilla	Plant extract	Suppressed seedling and germination growth	*Phaseolus vulgaris*	[15]
Cleome rutidosperma DC	Methanol extract	Inhibit root and shoot growth	*Oryza sativa* f. spontanea Roshev	[16]
Sorghum	Water extract	Decreased leaf area index	*E. cruss-gali*	[17]
Leptospermum scoparium	Essential oil	Pre-emergent and control seed emergence	*P. oleracea*	[18]
Cercospora sp.	Spore	Inhibit weed growth and spread disease	Parthenium	[19-20]
Phoma macrostoma	Spore and culture	Inhibit growth, chlorosis, carotenoid biosynthesis	Chickweed, Wild Geranium	[21]
Epicoccum purpurascens	Spore	Inhibit seed germination, disease induction.	Echinochloa	[22]

7. CONCLUSION

Despite only few studies have been conducted to clarify physiological effects on weeds after herbicides application, but plenty of data is available about metabolic effects. Both plant-based and microbial bioherbicides inhibit weeds growth by releasing phytotoxic metabolites. Germination of weeds is controlled by stress mediated hormones, irregular activation of antioxidants, and other metabolites and thus weed population is suppressed. This article suggests that more studies need to be conducted to clarify biomolecular interactions between weeds and bioherbicides.

Conflict of Interest

Authors declare that there is no conflict of interest.

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