Allelopathy an Environmentally Friendly Method for Weed Control

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Abstract

Biological weed management is a system that incorporates the use of diverse biological organisms and biologically-based approaches including allelopathy, crop competition, and other cultural practices to significantly reduce weed densities in a manner that is similar to use of chemical herbicides alone. Interest in developing effective biological weed management systems continues to increase because of a growing awareness of problems associated with the constant and intensive use of chemical herbicides, which include surface- and groundwater contamination, detrimental impacts on nontarget organisms, development of weeds resistant to herbicides, and consumer concerns for residues on food. Among different biological methods of weed control, allelopathy could lead to reduced labour costs and increased efficiency, without any adverse effects on the environment. Many of the compounds produced by green plants that are not involved in primary plant metabolism are observed to function as chemical warfare agents against competing plants and pests. Many such natural compounds have the potential to be exploited as herbicides or as leads for discovery of new herbicides. The paper highlights the different concepts of using allelopathy for eco-friendly control of weeds.

Keywords: allelopathy, allelochemicals, natural compounds, weeds control

1. Introduction

The phenomenon of allelopathy, whereby a plant species chemically interferes with the germination, growth or development of other plant species has been known and documented for over 2000 years.

The term allelopathy, however, was first coined in 1937 by the Austrian Professor Hans Molisch from two Greek words: allelon 'of each other 'and pathos 'to suffer'and means the "injurious effect of one organism upon the other" [16]. Today, the term is generally accepted to cover both inhibitory and stimulatory effects of one plant on another plant [16]. In 1996, the International Allelopathy Society defined allelopathy as follows: "The science that studies any process involving secondary metabolites produced by plants, micro-organisms, viruses, and fungi that influence growth and development of agricultural and biological systems (excluding animals) "[24]. Nowadays, allelopathy has a significant role in research involving sustainable agriculture, like biological weed and pest control [3]. The current trend is to find a biological solution to minimize the perceived hazardous impacts from herbicides and insecticides in agriculture production. In this regards, the harmful impact of allelopathy can be exploited for pest and weed control [7, 20].

The chemicals responsible for the phenomenon of allelopathy are generally referred to as allelochemicals or phytotoxins [8]. Allelochemicals are usually classified as secondary metabolites and are produced as offshoots in the primary metabolic pathways of plants [9]. Many such natural compounds have the potential to induce a wide array of biological effects and can provide great benefits to agriculture and weed management [3, 10].

2. Allelopathy for Weed Management

The word weed means any wild plant that grows at an unwanted place for example in fields and interferes with the growth of cultivated plants [17]. Farmers must contend with approximately 30,000 plant species identified as weeds. Among them, 250 are really important and about 80 are known to reduce crop yield [8].

Weeds have substantially adapted characteristics (e.g. produce an abundance of seed, rapid seedling growth, quick maturation, dual modes of reproduction, environmental plasticity) that enable them to grow, flourish, invade and dominate an important part of natural and agricultural ecosystems [8, 25]. In agro-ecosystems, weeds compete with crop plants for resources, interfere in crop handling, reduce crop yield and deteriorate their quality, and thus result in huge financial losses [8] . Degree of loss depends on crop species present, timing and duration of competitive interactions, and resource availability [1]. Oerke et al. [12] reported that weeds, pathogens and animal pests cause a loss of around 13.2, 13.3 and 15.6% (totally 42.1%), respectively, in the eight most important food and cash crops, even when they are intensively controlled. However, if no physical, biological or chemical measures were used to protect crops, yield losses would be around 69.8%. So, losses prevented by crop protection measures are about 27.6% of attainable production. The only basis on which it is possible to calculate an overall figure for crop losses in all crops is financial one. In US agriculture, weeds cause an overall reduction of 12% in crop yields, and this represents approximately $32 billion in lost crop production each year (USCB 2007). In addition to the direct losses, approximately $4 billion is spent each year on herbicides used to control pest weeds. Thus, the total annual cost of introduced weeds to US agricultural economy is about $36 billion [13].

In light of these characteristics of weeds and their hazards, it becomes imperative to control them. Several techniques (e.g. mechanical and chemicals) are used for weed control. These techniques attempt to achieve a balance between cost of control and crop yield loss [8, 20]. Mechanical methods, such as hand weeding require enormous labour and time input. Nowadays, chemical method provides an effective strategy for weed control. Since their discovery in the 1950s, synthetic herbicides have developed as a major tool for weed management. Herbicides have helped farmers to increase yields while reducing labour. Indeed, without herbicides, labour would be a major cost of crop production in developed countries. Nevertheless, the indiscriminate use of herbicides has provoked an increasing incidence of resistance in weeds to some herbicides, changes in weed population to species more related to the crop, environmental pollution, and potential health hazards [10]. Overuse of synthetic chemicals for weed control worsens the quality of soil, water, other life support systems, human health and food [21]. Fast-developing herbicide-resistant ecotypes of weeds are also posing serious threats to agricultural production. So far, at least 334 weed-resistant biotypes belonging to 190 species (113 dicots and 77 monocots) toward herbicides have been identified (www. weedscience.com). Because of all these problems, efforts are being made to find out alternative low-input strategies for weed management. In this regard, much attention has been focused on the use of allelopathic plants and their products for managing weeds in a sustainable manner [21]. Natural products release from allelopathic plants may help to reduce the use of synthetic herbicides for weed management and therefore, cause less pollution, safer agricultural products as well as alleviate human health concerns [6]. So, it is worthwhile to explore the potential of plants with strong allelopathic activity for the management of agricultural weeds.

The use of allelopathy for controlling weeds could be either through directly utilizing natural allelopathic interactions, particularly of crop plants, or by using allelochemicals as natural herbicides. In the former case, a number of crop plants with allelopathic potential can be used as cover, smother, and green manure crops for managing weeds by making desired manipulations in the cultural practices and cropping patterns. These can be suitably rotated or intercropped with main crops to manage the target weeds (including parasitic ones) selectively. Even the crop mulch/ residues can also give desirable benefits.

3. Allelochemicals as natural herbicides

There is increasing evidence that allelochemicals or natural plant products derived from higher plants/microbes can be ideal agrochemicals. Initially, the reason why plants devote resources to the production of these compounds was not understood as they were regarded as functionless waste products. It is now increasingly accepted, however, that these compounds function as defensive agents against pathogens, insects and neighbouring plants [11]. Many such natural compounds have the potential to induce a wide array of biological effects and can provide great benefits to agriculture and weed management [3, 10]. Evidence showed that higher plants release a diversity of allelochemicals into the environment. Despite so much chemical diversity, allelochemicals can be broadly characterized into phenolics and terpenoids. They are released by volatilization, root exudation, death and decay of plants, and leachation from living or decaying residues [1, 18]. After release, allelochemicals are involved in a variety of metabolic processes [18]. Several factors determine their toxicity such as concentration, flux rate, age and metabolic state of plant, and prevailing climatic and environmental conditions [18]. Their amount and production varies in quality and quantity with age, cultivar, plant organ, and time of the year. Einhellig [5] mentioned that both abiotic (temperature, nutrient amount, and moisture deficit) and biotic (disease and insect damage and interaction of plans with herbivory) factors enhance the amount and biosynthesis of allelochemicals in plants.

These allelopathic chemicals are produced by a 'donor' and transmitted to a 'receiver' that can either be 'injured' or 'stimulated'.

Allelochemicals act through direct interference with physiological functions of 'receiver' such as seed germination, root growth, shoot growth, stem growth, symbiotic effectiveness or act indirectly through additive or synergistic impact along with pathological infections, insect injury and/or environmental stress. Though many of these allelochemicals exhibit inhibitory response on various morpho-physiological functions of receiver plants and such responses being observed to be dose dependant in a linear fashion, their concentrations required for control of weeds on a field scale are impracticably higher.

4. Discussion

Despite herbicidal activity of allelopathic plants, to attain significant weed reduction under field conditions a large quantity of plant materials or pellets is required. This needs heavy field work. Therefore, the possibility of its periodical application for greater weed control should be further examined [14]. The various combinations of allelopathic plants and herbicides to reduce dependence on synthetic herbicides should be tested [15]. In addition, a combination of different allelopathic plant species with strong weed-suppressing ability, may be capable of controlling more weed species than a single allelopathic plant species. Another alternative to reduce field work is to select allelochemicals from various sources, such as plants or microorganisms, and use them as herbicides in place of synthetic chemicals [15] . This procedure can have desirable results, because most natural products are broken down rather rapidly by common microorganisms and thus are not persistent pollutants in the environment, as are many of the synthetic herbicides. Among the plant products as herbicides, juglone, isolated from walnut tree has been found effective against redroot pigweed, velvetleaf and barnyard grass [22, 23]. Caffeine derived from coffee showed considerable selectivity in inhibiting germination of *Amaranthus spinosus* L. at a concentration that has no effect on blackgram [17]. Strigol, a sesquiterpenoid derivative from cotton roots is a potent germination stimulant of witchweed (Striga asiatica L. Kuntz), an obligate parasite of maize, sorghum [2] and Orobanche minor [22]. Dhurrin (sorghum); gallic acid (spurge); Phlorizin (apple root); trimethylxanthene (coffee) and cinch (eucalyptus) are some other important plant products having promising herbicidal activity. I this regard continuous study on isolation and identification of allelopathic compounds in plants and rhizosphere should be conducted. Although many biologically active compounds have been found, we still need to explore new compounds from plants and microorganisms.

5. Conclusions

Increasing attention has been given to the role and potential of allelopathy as a management strategy for crop protection against weeds and other pests. Incorporating allelopathy into natural and agricultural management systems may reduce the use of herbicides, insecticides, and other pesticides, reducing environment/soil pollution and diminish autotoxicity hazards. There is a great demand for compounds with selective toxicity that can be readily degraded by either the plant or by the soil microorganisms. In addition, plant, microorganisms, other soil organisms and insects can produce allelochemicals which provide new strategies for maintaining and increasing agricultural production in the future.

6. References

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