Applications of Allelopathy in Crop Protection

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Abstract

Crop protection is an integral part of crop production that requires multifaceted approach. Crop protection through the use of conventional methods had been effective but rather costly and problematic due to environmental pollution. Allelopathy may be employed for controlling weeds, insect pests and diseases. This paper reviewed various applications of allelopathy for crop protection in agricotsystems. The application of allelopathic water extracts in weeds and insects pest control were discussed. Sorghum was found the most potent allelopathic plant which had been used as mulch material, intercrop, and plant water extracts for weed management. Application of sorghum plant water extracts proved more effective in controlling weeds than all other strategies. Also, several other plants including sunflower, canola, rice, mulberry and several others had been evaluated. Although each of the allelopathic sources provided some control, mixtures of allelopathic water extracts were more effective than the application of single plant extracts. Allelopathy had also been effective in controlling stored grain and field crop pests in addition to several pathogens which may also be controlled by allelopathy. Allelopathy thus offers an environment friendly alternative to pesticides in crop protection

Key words; Crop protection, allelopathy, sorghum, pesticides and environmental pollution

1. Introduction

Allelopathy is a common biological phenomenon by which one organism produces allelochemicals that influence the growth, survival, development, and reproduction of other organisms. These allelochemicals may have beneficial or detrimental effects on target organisms (Kong et al., 2004). Allelopathy as a natural ecological phenomenon had been used in agriculture since ancient times. Allelopathy is a promising field with its wider applications in crop productions. Globally, work on allelopathy was initiated in the early 1970s with screening of local flora for allelopathic
potential in laboratory and greenhouse bioassays while field studies were taken up during the early 1980s.

The main purposes of research on allelopathy include the application of the pragmatic allelopathic effects to crop production, reduction of the input of chemical pesticides and consequent environmental pollution, and provision of effective methods for the sustainable development of agricultural production and ecological systems (Jabran et al., 2010). The exploitation of allelopathic crops in agriculture is currently being realized as components of crop rotations, for intercropping, as cover crops or as green manure (Cheema and Khaliq, 2000; Singh et al., 2003; Cheema et al., 2004; Reeves et al., 2006; Farooq et al., 2013; Arif et al., 2015). Also, allelopathy has been exploited in weed control by planting cover crops, applying residues and straw of allelopathic crop as mulches and foliar spray of allelopathic plant extract (Ashraf et al., 2007; Cheema et al., 2012. Allelopathic plants may also be considered as potential source of new molecules with herbicidal actions for the chemical industry (Anjum and Bajwa, 2005). Allelopathy has been recognized as a device in crop production but its application in crop protection has not been fully exploited. This paper critically reviewed practical applications of allelopathy in the control of weeds, insect and disease control. Also, the synthesis of novel agrochemicals from allelochemicals is discussed.

2. Application of Allelopathy in Weed Control

Allelopathy is derived from the Greek word ‘allelon’ which means ‘of each other’ and ‘pathos’ which means to ‘suffer’. Thus, allelopathy literally means the injurious effect of one upon the other (Rizvi et al., 1992; Iqbal et al., 2010; Awan et al., 2012). However, the term is now used in a wider sense. It is a phenomenon where a plant species chemically interferes with the germination,
growth or development of other plant species. It involves direct or indirect effect of one plant upon another through the production of secondary chemical compounds that technically escape into the environment (Cheema et al., 2000; Scheffler et al., 2001; Khaliq et al., 2002). Allelopathy can also be defined as the ability of plants to inhibit or stimulate growth of other plants in the environment by exuding chemicals. It plays an important role in agroecosystems and in the plant covers among the crop-crop and crop-weed interactions (Scheffler et al., 2001; Sadeghi et al., 2010). Currently, a more complete definition includes the positive and negative effects of chemical compounds produced mainly from secondary metabolism of plants, micro-organism, viruses and fungi that have an influence on the growth and development of agricultural and biological ecosystem (Rice, 1984; Seligler, 1996).

Allelopathic interactions among plants have been studied in both managed and natural ecosystems. In agroecosystems, allelopathic interactions could be part of the interference between crops and weeds that may affect the economical outcome of plant production (Alam et al., 2001; Agarwal et al., 2002; Ajayi et al., 2017a). Several researchers have suggested that allelopathy holds great prospects for finding alternative strategies for weed control in both natural and agroecosystems, hence it reduces reliance on synthetic herbicides (Quassem, 1995; Inderjit et al., 1999; Olofsdotter et al., 2002).

Allelopathic effects are achieved due to the release of active biomolecules commonly called allelochemicals from allelopathic plants (Kruse et al., 2000; Bertin et al., 2003a; Anjum and Bajwa, 2007). Allelochemicals can be found in different concentrations in several parts of plants such as leaves, stems, roots, rhizomes, seeds, flowers and even pollen (Figure 1) (Bertin et al., 2003b). Numerous crops have been investigated for allelopathic activities towards weeds or other
crops (Table 1). Prominent among these are alfalfa (*Medicago sativa*), barley (*Hordeum vulgare*), rice (*Oryza sativa*), sorghum (*Sorghum* spp.), sunflower (*Helianthus annuus*), sweet potato (*Ipomoea batatas*), wheat (*Triticum aestivum*) and Mexican sunflower (*Tithonia diversifolia*) (Narwal, 2004; Anjum and Bajwa, 2005; Anjum and Bajwa, 2007; Ashraf *et al*., 2007; Hosseini 2011; Ajayi *et al*., 2017b).

Allelopathic crops can be used to control weeds by: planting crop cultivars with allelopathic properties; applying residues and straw of allelopathic crop as mulches; using allelopathic crop in a rotational sequence where the allelopathic crop can function as a smoother crop or where the residue are left to interfere with weed population of the next crop and foliar spray of allelopathic plant extract (Ashraf *et al*., 2007). Allelopathic plants may also be considered as potential source of new molecules with herbicidal actions for the chemical industry (Schuster *et al*., 1992; Bhowmik and Inderjit, 2003; Anjum *et al*., 2005; Anjum and Bajwa, 2005).

Iqbal and Anwar (2011) studied the allelopathic potential of *Sorghum halepense* on some wheat weeds. They discovered that shoot and inflorescence extracts have significant effects on the germination percentage and early seedling growth of two monocot and dicot weed species; however the effect was more pronounced on *Avena fatua* (wild oat) and *Cephalaria syriaca* than *Lathyrus sativa* and *Lolium temulentum* (Guad). It was also observed that sunflower water extracts (100%) inhibited weed growth of weed species such as broad leaf clock, swine cress, lambsquarters and fumitory by 24, 61, 31 and 21% and yield increase of wheat by 7% over the control (Muhammad *et al*., 2009). In another study, mulberry extract inhibited the seedling growth of Bermuda grass more than wheat seedling and interestingly, its foliar spray at 100% concentration significantly inhibited the growth of Bermuda grass and stimulated wheat growth
(Haq et al., 2010). Allelopathic potential of aqueous extract of leaves and root of Medicago sativa and Vicia cracca were studied in laboratory condition. It was discovered that 50% concentration of all the plants part significantly inhibited the germination and radical length of the four weed species (Amaranthus retroflexus L., Lolium perenne L., Ipomoea hederacea L and Portulaca oleracea L.) (Onur, 2007).

The possibility of using sorghum or sunflower residues for weed control in wheat was investigated by Hozayn et al. (2011). The study showed that sorghum and sunflower residues can suppress the growth of some weeds associated with wheat. The authors concluded that field studies are needed to evaluate suppressive efficacy of residues under natural conditions. Marzieh et al. (2013) assessed the allelopathic potential of Crocus sativus; Ricinus communis, Nicotiana tabaccum, Datura inoxa, Nerium oleander and Sorghum on germination and growth of field bind weed (Convolvulus arvensis). It was discovered that application of all the botanical extracts at 10 g/l significantly reduced all the measured growth parameters and that the aqueous extracts of these species could be used as post emergence bioherbicides against field bind weed. It was concluded that the impact of these plants on field bind weed control should be investigated on the field.

However, Ajayi et al. (2017b) in a field study, investigated the allelopathic potential of aqueous extracts of Tithonia diversifolia in weed control in cowpea cropping system, it was discovered that 10% and 7.5% (w/v) concentrations of the aqueous extract of Tithonia diversifolia leaf at 20 l/ha resulted in 65.49% and 62.05 reduction in weed density at 65 DAP while the weed control efficiencies were 66.45% and 65.32% respectively.
Table 1: Weed Control through Allelopathic Crop Extracts

<table>
<thead>
<tr>
<th>Allelopathic extract</th>
<th>Crop</th>
<th>Weeds controlled</th>
<th>Weed Control Efficiency (%)</th>
<th>Yield increase over the control</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum bicolor</td>
<td>Wheat</td>
<td>Fumaria indica, Phalaris minor, Rumex dentates, Chenopodium album.</td>
<td>35.4-39.2</td>
<td>11.0-20.0</td>
<td>Cheema and Khaliq (2000).</td>
</tr>
<tr>
<td>Sunflower</td>
<td>Wheat</td>
<td>Avena fatua, Melilotus officinalis, Phalaris minor, Rumex obtusifolius</td>
<td>2.2-16.5</td>
<td>1.6-10.7</td>
<td>Cheema et al., (2003).</td>
</tr>
<tr>
<td>Sunflower</td>
<td>Wheat</td>
<td>broad leaf clock, swine cress, lambsquarters and fumitory</td>
<td>21.0-61.0</td>
<td>7</td>
<td>Muhammad et al., (2009).</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Rice</td>
<td>Echinocloa colonum, Cyperus rotundus, Cyperus iria</td>
<td>40.4</td>
<td>12.5</td>
<td>Wazir et al., (2011).</td>
</tr>
</tbody>
</table>

3. Allelopathy for Other Pest Control

Apart from the applications of allelopathy for weed control, this ecological phenomenon could be employed in controlling insect pests and nematodes. The extracts of California pepper has suppressive effects on the elm leaf beetle by killing 97% of their population at 4.3 and 4.7 (w/v) concentrations (Huang et al., 2010). Farooq et al. (2011) reported that field studies have
established that *Crotalaria spectabilis* is very effective in reducing soil populations of wide range of parasitic nematodes. Mixed cropping of *Azadirachta indica* with several crop plants in India reduced the populations of six genera of parasitic nematode. Ahmad *et al.*, (2011) reported that application of neem based insecticide (Neemosal) may enhance the shelf life of stored mungbean grains. Iqbal *et al.*, 2011 discovered that extracts of orange peel was effective in controlling wheat aphids.

Neem (*Azadirachta indica*) produces allelochemicals, azadrachtin, salannin and nimbin (Farooq *et al.*, 2011). They inhibit or reduce the growth of different insect pests such as green cicadellid (*Jacobiasca lybica*) and whitefly (*Bemisia tabaci*). Similarly neem oil shows antifeedant action against strawberry aphids (*Chaetosiphon fragaefolii*). Some phenolics restrict wheat midge (*Sitodiplosis mosellana*). Some indigenous plants like bakain (*Melia azdarach*), habulas (*Myrtus communis*), mint (*Mentha longifolia*), harmal (*Pegnum harmala*) and lemon grass (*Cymbopogon citrates*) produce certain allelochemicals, which act as insecticide against rice weevil (*Sitophilus oryzae*) (Saljoqi *et al.*, 2006). It has been discovered that secondary metabolites from olive (*Olea europea*), tea (*Thea chinensis*), bhang (*Canabis sativa*), elephanta (*Elephantia* sp.), garlic (*Allium sativum*), black pepper (*Piper nigrum*) and red chillies (*Capsicum annum*) were effective against chickpea beetle (*Callosobruchus chinensis*) (Zia *et al.*, 2011). Also, Farooq *et al.* (2011) ascertained that allelopathic water extracts of sorghum, mustard, mulberry and sunflower were very effective in controlling aphids and sucking insects of *Brassica* spp.
Table 2: Pest Control through Allelopathy

<table>
<thead>
<tr>
<th>Allelopathic Plant Source</th>
<th>Pest</th>
<th>Percent Control</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot pepper</td>
<td>Pod borer</td>
<td>54.0</td>
<td>Hongo and Karel (1986)</td>
</tr>
<tr>
<td>Neem seed</td>
<td>Strawberry aphids</td>
<td>Not stated</td>
<td>Khalid et al. (2002).</td>
</tr>
<tr>
<td>California pepper</td>
<td>Adult elm leaf beetle</td>
<td>97</td>
<td>Huang et al. (2010).</td>
</tr>
<tr>
<td>Fig leaf</td>
<td>Aphid</td>
<td>47-86</td>
<td>Dang et al. (2010).</td>
</tr>
<tr>
<td>Orange peel</td>
<td>Aphid</td>
<td>65.69</td>
<td>Iqbal et al. (2011).</td>
</tr>
<tr>
<td>Garlic</td>
<td>Aphid</td>
<td>57.91</td>
<td>Iqbal et al. (2011).</td>
</tr>
</tbody>
</table>

4. Allelopathy for Disease Control

Plants diseases constitute major cause of growth and yield reduction thus disease control is a integral part of crop protection. Bacteria, fungi, viruses and some nematode pathogens are major causal agents of different seed borne and soil borne diseases. Chemical control of diseases pathogens is not much effective (Farooq et al., 2011). Aqueous extracts of several allelopathic plants have been reported to exhibit antifungal properties. Hassan et al. (1992) reported that leaf extracts of jimson weed (Datura stramonium) reduced the development of rust pustules on the leaves of wheat. In another study, Bajwa et al. (2003) assessed the allelopathic potential of Parthenium against 3 pathogenic fungal species; Drechslera hawaiiensis, Aspergillus alternate and Fusarium moniliforme. It was discovered that 10-50% (w/v) concentrations of the extract suppressed the growth of the pathogenic fungi. Shaukat et al. (2001) investigated the impact of root leachates of Lantana camara against Meloidogyne javanica, the root-knot nematode. It was discovered that concentrated and diluted root leachate caused substantial mortality of M. javanica juveniles.
Allelochemicals have shown positive role in controlling plant pathogens by different means. Water extracts of different cereals, canola, sweet clover and lentil were very suppressive against fungus *Sclerotinia sclerotiorum* beans, when applied at low concentrations (Huang *et al.*, 2007). Two potent allelochemicals of rice; momilactone A and momilactone B have shown antifungal, antibacterial, antioxidant and anticancerous activities *in vitro* (Kong *et al.*, 2004). Some of the flavones and cyclohexenones from rice have suppressing potential against spore formation of *Rhizoctonia solani* and *Pyricularia oryzae* (Farooq *et al.*, 2011). Aqueous extracts of *Allium cepa*, *Allium sativa*, *Parthenium* and *Calotropis procera* have inhibitory effects on different fungal strains (Cheema *et al.*, 2012). Leaf water extracts of neem, eucalyptus and *Ocimum sanctum* can cause up to 50% reduction in growth of a fungus, *Fusarium solani* (Joseph *et al.*, 2008).

Table 3: Disease Pathogen Control through Allelopathy

<table>
<thead>
<tr>
<th>Allelopathic Plant Source</th>
<th>Pathogen</th>
<th>Percent Control</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Flower thrip</td>
<td>32.0</td>
<td>Hongo and Karel (1986)</td>
</tr>
<tr>
<td>Neem</td>
<td>Root-knot nematode</td>
<td>38.3-63.7</td>
<td>Javed <em>et al.</em>(2008)</td>
</tr>
<tr>
<td>Neem</td>
<td><em>Fusarium solani</em></td>
<td>53.2</td>
<td>Joseph <em>et al.</em> (2008)</td>
</tr>
<tr>
<td>Eucalyptus</td>
<td><em>Fusarium solani</em></td>
<td>46.7</td>
<td>Joseph <em>et al.</em> (2008)</td>
</tr>
<tr>
<td>Rice</td>
<td><em>Fusarium oxysporum</em></td>
<td>37.0-71.8</td>
<td>Ren <em>et al.</em> (2008)</td>
</tr>
</tbody>
</table>

5. Conclusion

The conventional methods employed in crop protection such as pesticide application, mechanical weeding and hand weeding are effective in crop production. However, there are many disadvantages associated with these methods, for example, the evolution of herbicide resistance in weeds, the negative impacts of herbicides on environmental, human and animal health, the cost of
herbicides, the losses in soil structure and the enormous labour requirements. Many of these problems can be minimized by creating diversity in crop protection practices with the application of allelopathy. Allelopathy has great potential for crop protection. It could be employed in organic agriculture for weed and other pest control as well as disease pathogens in order to protect the environment from the hazardous agrochemicals.

References


