# Applications of Allelopathy in Crop Protection

[1]Ajayi, Oyinlola A [2]Akinola, Modupe O [3]Awodoyin Rasheed O

[1] Science Laboratory Technology, Federal Polytechnic, Ede, Nigeria [2]Cell Biology and Genetics Department, University of Lagos, Nigeria [3]Crop protection and Environmental Biology Department, University of Ibadan, Nigeria

mayomiakinola@gmail.com

## Abstract

Crop protection is an integral parts of crop production that requires multifaceted approach. Crop protection through the use of conventional methods had being 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 agroecosystems. 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 green house 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 being exploited in weed control by planting cover crops, applying residues and sraw 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 buts 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 literarily 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 interractions 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 aestvum*) 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 allelophatic 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 hederacead* 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

| **Allelopathic extract** | **Crop** | **Weeds controlled** | **Weed Control Efficiency (%)** | **Yield increase over the control** | **References** |
|---|---|---|---|---|---|
| *Sorghum bicolor* | Wheat | *Fumaria indica, Phalaris minor, Rumex dentates, Chenopodium album.* | 35.4-39.2 | 11.0-20.0 | Cheema and Khaliq (2000). |
| Sunflower | Wheat | *Avena fatua, Melilotus officinalis, Phalaris minor, Rumex obtusifolius* | 2.2-16.5 | 1.6-10.7 | Cheema *et al*., (2003). |
| Sunflower and Sorghum | Wheat | *Avena fatua, Phalaris minor*. | 10.0-62.0 | 18.55-62.0 | Jamil *et al*., (2009). |
| Sunflower | Wheat | broad leaf clock, swine cress, lambsquarters and fumitory | 21.0-61.0 | 7 | Muhammad *et al*., (2009). |
| Sorghum | Rice | *Echinocloa colonum, Cyperus rotundus, Cyperus iria* | 40.4 | 12.5 | Wazir *et al*., (2011). |
| Mexican Sunflower | Cowpea | *Phalaris minor, Chenopodium album, Tridax procumbens, Talinum triangulare, Amaranthus viridis, Chromolaena odorata.* | 59.26-69.92 | 65.32-66.45 | Ajayi *et al*., (2017b) |

## 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

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

## 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 pustles 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, Aspergilus alternate* and *Fusarium monilifrome*. 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 sclerotiorumin* 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*, *Alium 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, F*usarium solani* (Joseph *et al*., 2008).

Table 3: Disease Pathogen Control through Allelopathy

| **Allelopathic Plant Source** | **Pathogen** | **Percent Control** | **References** |
|---|---|---|---|
| Tomato | Flower thrip | 32.0 | Hongo and Karel (1986) |
| Neem | Root-knot nematode | 38.3-63.7 | Javed *et al*.(2008) |
| Neem | *Fusarium solani* | 53.2 | Joseph *et al*. (2008) |
| Eucalyptus | *Fusarium solani* | 46.7 | Joseph *et al*. (2008) |
| Rice | *Fusarium oxysporum* | 37.0-71.8 | Ren *et al*. (2008) |

## 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


Agarwal, A. Gahlot, A., Verma, R. and Rao, P. (2002). Effects of weed extract on seedling growth of some varieties of wheat. *Journal of Environmental Biology* **23**: 19-23.

Ahmad, A., Cheema, Z.A. and Ahmad, Z. (2000). Evaluation of sorgaab as natural weed inhibitor in maize. *Journal of Animal and Plant Science* **10**:141–146.

Ahmad, K., Adnan, M., Khan, M.A., Hussain, Z., Junaid, K., Saleem, N. (2015). Bioactive neem powder enhances the shelf life of stored mungbean grain and extends protection of pulse beetle. *Parkistan Journal of Weed Science Research* **21**:71-81.

Ajayi, O.A., Akinola, M.O. and Awodoyin, R.O (2017a). Allelopathic potential of sorghum residue in biological control of weeds in cowpea cropping system. *Journal of Physical Science and Environmental Studies*. **3**(2):18-24.

Ajayi, O.A., Akinola, M.O. and Awodoyin, R.O (2017b). Allelopathic potentials of aqueous extract of *Tithonia diversifolia* (Hemsley A.Gray) in biological control of weeds in cowpea cropping system .*International Journal of Agriculture and Economic Development*. **5**(1):11-28.

Alam, S. M., Ala, S. A. Azmi, A. R., Khan, M. A. and Ansari, R. (2001). Allelopathy and its role in agriculture. *Journal of Biological Science* **1**(5):308 – 315.

Anjum, T., Bajwa, R. and Javaid, A. (2005). Biological Control of *Parthenium* I : Effect of *Imperata cylindrica* on distribution, germination and seedling growth of *Parthenium hysterophorus* L. *International Journal of Agric Biology* **7**(3):448-450.

Anjum, T. and Bajwa, R. (2005). Biological control of *Parthenium* II: Allelopathic effect of *Desmostachya bipinnata* on distribution and early seedling growth of *Parthenium hysterophorus* (L.) *International Journal Biology and Biotechnology* **2**:459-463.

Anjum, T and Bajwa, R. (2007) Field appraisal of herbicide potential of sunflower leaf extract against *Rumex dentatuse Field Crops Research* **100**:139 – 142.

Arif, M., Cheema, Z.A., Khaliq, A and Hassan, A. (2015). Organic weed management in wheat through allelpathy. *International Journal of Agriculture and Biology* **17**:127-134.

Ashraf, Z., Mashhadi, H. R. and Sadeghi, S. (2007). Allelopathic effects of barley (*Hordeum vulgare*) on germination and growth of wild barley (*Hordeum spontaneum*). *Pakistan Journal of Weed Science Research.* **13** (1-2):99-112.

Awan, F.K., Rasheed, M., Ashraf, M. and Khurshid, M.Y. (2012). Efficacy of brassica, sorghum and sunflower aqueous extract to control wheat weeds under rain-fed condition of Pothwar. *Pakistan Journal Animal and Plant Science*. **22**:715–721.

Bajwa, R., Khalid, A. and Cheema, T.S. (2003). Antifungal activity of allelopathic plant extracts III: Growth response of some pathogenic fungi to aqueous exrtract of *Parthenium hysterophorus*. *Pakistan Journal of Plant Pathology*. **2**(3):145-156.

Bertin C., Paul, R.N. Duke, S.O and Weston L.A (2003a). Laboratory assessment of the allelophatic potential of fine leaf fesues (*Festuca rubra* L.) *Journal of Chemical Ecology* **8**:1919-1937.

Bertin, C., Yang, X. and Weston, L.A. (2003b). The role of root exudates and allelochemicals in the rhizosphere. *Plant and Soil* **256**:67-83.

Bhowmik, P. and Inderjit, C. (2003). Challenges and opportunities in implementing allelopathy for natural weed management. *Crop Protection* **22**:661-671.

Cheema, Z.A. and Khaliq (2000). Use of sorghum allelopathic properties to control weeds in irrigated wheatin semi arid region of Punjab.*Agric Ecosystem Environs.* 79:105-112.

Cheema, Z. A., Sadiq, H.M.I. and Khaliq, A. (2000). Efficacy of sorgaab (sorghum water extracts) as a natural weed inhibitor in wheat. *International Journal of Agric Biology* **2**:144-146.

Cheema, Z. A., Khaliq, A. and Farooq, R. (2003). Effect of concentrated sorgaab alone and in combination with herbicides and a surfactant in wheat. *Journal of Animal Plant Science* **13**:10-13.

Cheema, Z. A., Khaliq, A. and Saeed, S. (2004). Weed control in maize (*Zea mays* L.) through sorghum allelopathy. *Journal of Sustainable Agric.* **23**:73-86.

Cheema, Z.A., Farooq, M. and Khaliq, A. (2012). Application of allelopathy in crop production: Success story from Pakistan in allelopathy: Currents trends and future application. In:

Cheema, Z.A., Farooq, M. and Wahid (eds). Springer verlag Berlin Heidelberg, Germany. 243pp.

Dang, Q.L., Lee, G.Y., Choi, Y.H., Choi, G.J. Jang, K.S., Park, M.S., Soh, H.S., Han, Y.H., Lim, C.H. and Kim, J.C. (2010). Insecticidal activities of crude extracts and phospholipids from Chenopodium ficifolium against melon and cotton aphid *Aphis gossypifolium*. *Crop Protection* **29**:1124-1129.

Farooq, M., Jabran, K. Cheema, Z.A., Wahid, A. and Siddique, K.H.M. (2011). The rolelof allelopathy in agricultural pest management. *Pest Management Science* **67**:493-506.

Farooq, M., Bajwal, A.A., Cheema, S.A. and Cheema, Z.A. (2013). Application of allelopathy in crop production. *International Journal of Agric Biology* **6**:1367-1378.

Haq, R.A., Hussain, M., Cheema, Z.A., Mushtaq, M.N. and Farooq, M. (2010). Mulberry leaf water extract inhibits bermudagrass and promotes wheat growth. *Weed Biology and Management* **20**:234-240.

Hassan, I., Nasir, M.A. and Haque, M.R. (1992). Effects of different plant extract on brown rust and yield of wheat *Journal of Agricultural Research*. 30:127-131.

Hongo, H. and Karel, A.K. (1986). Effects of plant extracts on insect pest of common beans. *Journal of Applied Entomology*. 102:164-169.

Hosseini. N. (2011). Allelopathic potential of sunflower on weed management in sunflower and wheat. *Australian Journal of Crop Science* **5**:1434-1440.

Hozayn, M., Abd El-Lateef E.M., Abd El-Monem, A.A. and Sharara, F.A. (2011). Potential uses of sorghum and sunflower residues for weed control and to improve lentil yields. *Allelopathy Journal* **2** (1):15-22.

Huang, H.C., Erickson, R.S. and Moyer, J.R. (2007). Effects of crop extracts on carpogenic germination of sclerotia, germination of ascospores and lesion development of *Sclerotina sclerotorum*. *Allelopathy Journal.* 20:269-278.

Huang, H., Morgan, C.M., Asolkar, R.N., Koivunen, M.E. and Mairone P.G. (2010). Phytotoxicity of sarmentine isolated frim long pepper fruit. *Journal of Agriculture and Food Chemistry* **58**:9994-1000.

Inderjit, S. Cheng, H.H. and Nishimura, H., (1999). Plant phenolics and terpenoids: Transformation, degradation, and potential for allelopathic interactions. In Inderjit, S. (ed.) *Principles and practices in plant ecology: Allelochemical interactions* CRC Press, Boca Raton, F.L. 266pp.

Iqbal, J., F. Karim, F. and Hussain, S. (2010). Response of wheat crop (*Triticum aestivum* L.) and its weeds to allelopathic crop water extracts in combination with reduced herbicide rates. *Pakistan Journal Agric Science* **47**:309-316.

Iqbal, M. T. and Anwar, O. G. (2011). The allelopathic potential of Jonson grass *Sorghum halepense* (L.) Pers. to control weed species. *Mesopotamia Journal of Agriculture* **40**(2):16- 23.

Iqbal, M., Kahloon, M., Nawaz, M. and Javid, M. (2011). Effectiveness of some botanicalson wheat aphids. *Journal of Plant Science*. **21**:114-115.

Jabran, K., Farooq, M., Hussain, M., Rehman, H. and Ali, M.A. (2010). Wild oat (*Avena fatua* L.) and canary grass (*Phalaris minor* Ritz.) management through allelopathy. *Journal of Plant Protection Research* **50**:41-44.

Jamil, M., Cheema, Z.A., Mushtaq, M.N., Farooq, M. and Cheema, M.A. (2009). Alternative control of wild oat and canary grass in wheat fields by allelopathic plant water extracts. *Agro. Sustain. Dev*. 29:475-482.

Javed, N., Gowen, S.R. Inam-ul-Haq, M. Abdullah, K. and Shahina, F. (2007). Systemic and persistent effect of neem (*Azadirachta indica*) formulations against root-knot nematodes, *Meloidogyne javanica* and their storage life. *Crop Prot.* 26:911–916.

Joseph, B., Dar, M.A and Kumar, V. (2008). Bioefficacy of plant extracts to control *Fusarium solani* f. sp. melongenae incitant of brinjal wilt. *Glob. J.Biotechnol. Biochem.* 3:56–59

Khaliq, A., Aslam Z. and Cheema, Z.A. (2002). Efficacy of different wheat management strategies in mungbean. *International Journal Agric Biology* **4**(2):237-239.

Kong, C., Liang, W., Xu, X., Hu, F.,Wang, P. and Jiang, Y. (2004). Release and activity of allelochemicals from allelopathic rice seedlings. *Journal of Agric. Food Chem.*52:2861-2865.

Marzieh, N. S.; Razmjoo, J.; Sharifnabi, B. and Karimmojeni, H. (2013). Assessment of allelopathic plants for their herbicidal potential against field bindweed (*Convolvulus arvensis*)**.** *Australian Journal of Crop Science* **7**(11):1654-1663.

Muhammad, N., Muhammad, A., Ansar, M., and Azar, M. (2009). Allelopathic effects of sunflower water extract on weed control and wheat productivity. *Pakistan Journal of Weed Science Research* **15**(1):107–116.

Narwal, S. S. (2004). *Allelopathy in crop production*, Scientific Publishers, Jodhapur, India. 342pp.

Olofsdotter, M., Jesen L.B And Courtois, B. (2002). Improving crop competitive ability using allelopathy: An example from rice. *Plant Breeding* **121**:1-9.

Onur, K. (2007). Allelopathic effects of *Medicago sativa* L and *Vicia cracca* L. leaf and root extracts on weed. *Pakistan Journal of Biological Sciences*.

Quassem, J.R. (1995). Allelopathic Effects of three *Amaranthus* spp (Pigweeds) on wheat (*Triticum*). *Weed Research* **35**:41-49.

Reeves, T. G. (2006). Effect of annual ryegrass (Lolium rigidum Gaud.) on yield of wheat. *Weed Research.* **16**:57 – 63.

Ren, L., Su, S., Yang, X., Xu, Y., Huang, Q. and Sheng, Q. (2008). Intercropping with aerobic rice suppressed *Fusarium* wilt in water melon. *Soil Biological Biochemistry*. **40**:834 844.

Rice, E.L. (1984). *Allelopathy*. Academic Press, Orlando, F.L. 422pp.

Rizvi, S. J. H., Haque, H., Singh, V. K. and Rizvi, V. (1992**.** A discipline called allelopathy. In: Rizvi, S. J. H. and Rizvi, V. (eds) *Allelopathy. Basic and Applied Aspects* Chapman and Hall, London. 231pp.

Sadeghi, S., Rahnavard, A. and Ashrafi, Z.Y. ( 2010). Response of wheat (*Triticum aestivum*) germination and growth of seedling to allelopathic potential of sunflower (*Helianthus annuus*) and barley (*Hordeum vulgare* L.) extracts. *Journal of Agricultural Technology* **6**:573-577.

Saljoqi, A.U.R., Afridi, M.K., Khan, S.A. and Rehman, S. (2006). Effect of six plant extracts on rice weevil *Sitophilus oryzae* in stored wheat grains. *Journal of Agric. Biological Science*. **1**:1-5

Scheffler, B.E., Duke S.O, Dayan, F.E and Ota, E. (2001). Crop allelopathy enhancement through biotechnology. *Phytochenistry* **35**:257-274.

Scheffler A.M. and Sharpe, W.E. (2003) Effects of lime, fertilizer and herbicide on forest soil and soil solution chemistry, hardwood regeneration and hardwood growth following shelterwood harvest. *Forest Ecological Management* **177**(1-3):471-484.

Schuster, A., Stokes, S., Papastergiou, F., Castro, V., Poveda, L. and Jakupovic, J. (1992). Sesquiterpene lactones from two *Tithonia* species. Phytochemistry **31**(9):3139-3141.

Shaukat, S.S. and Siddiqui, I.A. (2001). *Lantana camara* mediated changes in fungal community structure and its subsequent impacts on *Meloidogyne javanica* in mungbean *Phytopathologia mediterranea.*

Seligler, D. S. (1996): Chemistry and mechanism of allelopathic interactions. *Agronomy Journal* **88**: 876-885.

Singh, H.P., Batish, D.R., Kaur, S. and Kohli, R.K. (2003). Phytotoxic interference of *Ageratum conyzoides* with wheat (*Triticum aestivum). Journal of Agronomy Crop Science* **189**:341-346.

Wazir, I., Sadiq, M., Baloch, M.S., Awan, I.U.,Khan, E.A., Shah, I.H.,Nadim, M.A., Kwakwani, A.A. and Bakhsh, I. (2011). Application of bioherbicides for chemical control in rice. *Pakistan Journal of Weed Science Research* **17**: 245-252.

Zia, A., Aslam, M., Naz, F. and Illyas, M. (2011). Bio-efficacy of some plant extracts against chickpea beetle, *Callosobrucus chinensis* L. attacking chickpea. *Pakistan Journal of Zoology*. **43**:733-737