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In Search of Allelopathy from Common Alliaceae Crops for Managing Weeds in Coriander: An Overview

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ABSTRACT

The need to reduce harmful effects from the indiscriminate use of herbicide has facilitated the development of weed management systems, which are based on ecological manipulations rather than agrochemicals. In this direction, utilizing allelopathic plants to suppress the weed may be the most cost-effective and environment-friendly method of weed control. In coriander, one of the popular seed spices, weed control is challenging as the crop is having a low degree of competitiveness against weeds particularly at the initial phases of its growth. Towards searching the allelopathic potential of some plants in managing the weeds of coriander, a few common *Allium* species like onion, garlic and leek are found effective as has been reported alongwith other crops in various parts of the world particularly due to their effects most often linked to volatile substances derived from sulphur amino acids. Reports are available on the allelopathic potential of wild onion (*Asphodelus tenuifolius*) on the germination and seedling growth of chickpea (*Cicer arietinum*). Welsh onion (*Allium fistulosum*) are found to exhibit distinct allelopathic effect on summer chrysanthemum by inhibiting rooting and early growth of the plants followed by wilting. *Allium ursinum* L. (wild garlic) is also found allelopathic for its phenolic acids and total phenolics content in the leaves, bulbs and soil. The present study is an attempt to search such potential allelopathic alliaceae crops which are very common, useful and substantiate the economy of the growers whenever grown alongwith the coriander crop.

Key words: Allelopathy, *Coriandrum sativum*, weeds, alliaceae, onion, garlic, leek

INTRODUCTION

Coriander (*Coriandrum sativum* L.) is an important spice crop which is popular in tropical and subtropical regions for its seeds as well as the tender leaves as a food additive. As an ingredient of mixed spice, the seeds of coriander is highly valued (Pariari *et al.*, 2003). For successful cultivation of this crop, weed management plays a predominant role. Coriander is considered to have a low degree of competitiveness against weeds and for this reason a weed-free field is generally recommended. One estimate found the crop yield was reduced by approximately 90% when a mixed stand of pigweeds (*Amaranthus* sp.), hogweed (*Boerhavis erecta*), spider plant (*Cleome viscosa*), purple nutsedge (*Cyperus rotundus*), barnyardgrass (*Echinocloa colona*), goosegrass (*Elucine indica*), bitter weed (*Parthenium hysterophorus*) and green foxtail (*Setaria viridis*) were allowed to interfere with the crop season-long (Morales-Payan *et al.*, 2000). Kothari *et al.* (1989) also reported that in India weed mixtures reduced the seed productivity by 40.4% and its seed oil yield by 37%.

Coriander and the related crops of the same family Apiaceae are known to develop their root system slowly, which retard their nutrient uptake from the soil and thereby making them a week competitor for nutrients compared to weeds. Increasing competition for light is also likely to occur due to the close proximity of weeds in the coriander field (Morales-Payan, 1995). Coriander may take 21 days to emerge after planting and does not compete well with weeds. Severe weed competition can occur unless the crop is seeded in clean fields. Some producers use a post planting application of glyphosate to control grassy and broadleaf weeds in the time period between planting and emergence of the coriander. Control of perennial weeds in the crop is very difficult and is best done in the year prior to planting coriander with a pre-harvest glyphosate treatment (SAKC, 2010).

With a view to overcome production limitations of coriander Hooper and Dennis (2002) studied and recommended precisely on their report for the RIRDC (Rural Industries Research and Development Corporation), Australia. Results from their herbicide trials have provided a greater clarity to herbicide choice and identified new options for broadleaf weed control in coriander. This is especially important since herbicide resistance and changes in weed spectrum are escalating coriander production costs from increased herbicide application rates.

In coriander, weed control by hand pulling and with small hand-cultivation tools are popular. Herbicidal suppression of grasses and broadleaf weeds can be done by atrazine, DCPA, fuchloralin, linuron, metribuzin, napropamide, oxadiazon, pendimethalin, prometrine, propanil and trifluralin (Kothari *et al.*, 1989; Zheljazkov and Zhalnov, 1995). Santos *et al.* (1997) also reported on the use of several other herbicides in coriander such as acifluorfen, bentazon, imazethapyr, linuron and oxyfluorfen.

There are some report (http://plantphys.info/research/allelopathy.html) that confirms coriander itself alongwith its other close members of Apiaceae family (such as fennel, cumin, caraway, celery, dill, anise, etc.) may inhibit the germination of lettuce at various seed densities. This inhibition is often termed as allelopathy which is defined as a process whereby plants provide themselves with a competitive advantage by putting phytotoxins into the near environment in the form of volatilization, leaching, root exudation and decomposition of plant residues (Lambers *et al.*, 1998). The study indicated the Apiaceae family generally has allelochemicals present in seed oils (viz., anethole, fenchone, allylanisole, camphene, α-phellandrene, α-pinene, p-methoxyphenyl acetone in fennel; cuminaldehyde, cuminylalcohol, p-cymene, α-pinene, α-phellandrene in cumin; anethole, p-allylanisole, p-methoxyphenyl acetone, anisaldehyde in anise; s-carvone, carveol, 2,3butanedione, furaldehyde, limonene in caraway; linalool, geraniol, α-pinene, p-cymene,limonene in coriander; s-carvone, limonene, α-phellandrene, α-pinene in dill and guaiacol, palmitic acid, limonene in celery, etc.) which inhibit germination and root hair elongation of reduce. So allelopathy in coriander can be studied further exploited from ecological to biological level for its sustainable production.

The immediate necessity towards sustainable coriander production is to find out possible allelopathic crops and their effects on weeds of the crop and the crop itself before finalizing the particular plant parts and detecting and/or quantifying the most active chemical present in it. Literature on allelopathic potential of crops especially in coriander is scanty. As reported by Chon and Nelson (2009), many compositae plants have allelopathic potentials and the activities, types and the amount of causative compounds differ depending on the plant species. Crops like *Allium* sp (onion, garlic, leek), may be tried as possible donor plants towards contributing allelochemicals to the unwanted weeds resulting in the desired shift of competition favouring the target crop of interest. This is based on the fact that these crops contain certain biologically active sulphur compounds which have proven insecticidal, fungicidal, acaricidal, nematicidal activities, if not demonstrable herbicidal activity (Auger *et al.*, 2004). The broad objective of this type of study should be to examine the role of these possible allelopathic plants in natural weed management by exploiting allelopathy as an alternate weed management tool for the production of coriander as a target crop against its associated weeds.

WHY ALLIACEAE FAMILY IN SEARCH OF ALLELOPATHY?

Since, antiquity, plants and plant products have shown to display pharmacological as well as biological properties. Among these interesting plants *Allium* sp. show pesticidal effects (Auger *et al.*, 2002) most often linked to volatile substances derived from sulphur amino acids. There are reports on the influence of sulphur (Maji and Sharangi, 2006; Das *et al.*, 2006) and phosphatic (Sharangi and Sahu, 2009) nutrients on yield and quality of onion and garlic. The chemistry of pungency on rupturing of cell membrane of the Allium is simple. On rupturing the amino acids, S-alk (en) yl-cysteine sulfoxides (RCSO) come into contact with the enzyme allinase present in vacuoles (Lancaster and Collin, 1981) which is cleaved to produce alk (en) yl sulphenic acids that rearrange to form unstable thiosulfinates (Ti) in all *Allium* sp. The alk (en) ylcystéine sulfoxides are four in number (Granroth, 1970): S-methyl-L-cysteine sulfoxide (MeCSO), present in small amounts in all but cultivated *Allium* predominant in some wild and ornamental, S-propyl-L-cystine sulfoxide (PrCSO), mostly present in the leek *Allium porrum,* S-1-propenyl-L-cysteine sulfoxide (PeCSO), predominant in onion *Allium cepa* and S-allyl L-cysteine sulfoxide (AlCSO) or alliin, in garlic *Allium* casting *sativum.* The proportions of these four compounds vary not only between species (Freeman, 1975), but also within a species depending on the organ, the variety, stage of development and environmental conditions considered (Boscher *et al.*, 1995).

Reports are available on the allelopathic potential of wild onion (*Asphodelus tenuifolius*) on the germination and seedling growth of chickpea (*Cicer arietinum*). The seeds of chickpea were sown in sand and in each of the controlled, normal soil and the soil taken from the *A. tenuifolius*-infested field in petri dishes to record the length and weight of the roots and shoots 18 days after sowing. The mean germination time reached the maximum amount for the stem and fruit extracts. The fruit extract caused the most reduction in the germination index and the germination percentage of chickpea. The different wild onion organ extracts significantly reduced the root and shoot length and biomass of the chickpea seedlings compared with the distilled water. The fruit extract of wild onion proved to be the most detrimental to the root length, shoot length and dry weight of the chickpea seedlings. The soil beneath the *A. tenuifolius* plants significantly reduced the emergence, root length, shoot length, shoot dry weight and seedling dry weight but increased the root dry weight of the chickpea seedlings. It is suggested that *A. tenuifolius* releases phytotoxic compound(s) (Babar *et al.,* 2009).

In many countries welsh onion (*Allium fistulosum*) and rice are used as important components of cropping system. Usually, welsh onion are found to exhibit distinct allelopathic effect on summer chrysanthemum by inhibiting rooting and early growth of the plants followed by wilting (Choi, 1993; Choi and Song, 1993; Choi *et al.*, 1996). Choi *et al.* (1998) have also purified vanillic acid and beta-sitosterol from the ethyl acetate soluble fraction of welsh onion as growth inhibitors of Compositae plants. But in Korea, when rice is cultivated after welsh onion an enhanced productivity is found which has been confirmed by Choi *et al.* (1996) through pot experiments which paves the way to further purification and characterization of welsh onion (Goo *et al.*, 2001).

Macharia and Peffley (1995) also reported on this type onion with its allelopathic effect on weeds like *Amaranthus spinosus* and *Kochia scoparia*. They investigated on the suppression of these two weeds with evidence of competition or allelopathy in *Allium fistulosum*.

Garlic, another member of the Alliaceae family, is the second largest cultivated Allium species after onion (Rai *et al*., 2003). It is also tried for exploring its allelopathic potential by Shimabukuro and Haberman (2006) in addition to its medicinal properties (Blumenthal, 2000; Gardner *et al*., 2000). Of the six types of plant material tested by them (celery, broccoli, romaine lettuce, tomato leaves, carrot and garlic), only the garlic volatiles inhibited the germination and subsequent growth of lettuce seed indicating the presence of inhibitory volatiles having allelopathic effect. The possible mechanism of the allelopathy in garlic may be that allicin inhibits both the growth of microorganisms and seed germination. It also protects the damaged garlic from microorganisms and competition from other monocots for nutrients.

Djurdjevic *et al*. (2004) reported about *Allium ursinum* L. (wild garlic) which forms dense populations in which the other species are either sparsely present or absent. They studied its allelopathic potentials using both the seeds and seedlings of test plants (lettuce, amaranth and wheat) and by analyzing phenolic acids and total phenolics in the leaves, bulbs and soil. Aqueous extract and volatile compounds of the bulbs were found stronger inhibitors of seed germination and seedling growth compared to those of the leaves. The soil and phenolic-containing fraction of the soil under *Allium ursinum* also inhibited seed germination and growth of test plant seedlings. These results suggest that *A. ursinum* influences other herbaceous plants in plant community via soil and volatile compounds which inhibit seed germination and plant growth.

THE POTENTIAL OF ALLELOPATHY: SUCCESS STORIES FROM OTHER AREAS

The need to reduce harmful environmental effects from the indiscriminate and/or overuse of herbicide has encouraged the development of weed management systems, which are based on ecological manipulations rather than agrochemicals (Liebman and Ohno, 1997). During past four decades, the importance of allelopathy has been extensively explored in designing alternative weed management strategies. The reliance on synthetic herbicides could be reduced, resulting in economic and environmental benefits (Iqbal *et al*., 2004). Utilizing allelopathic plants to suppress the weed infestation is the most cost-effective and environment-friendly method of weed control (Kralova and Masarovicova, 2006). So far the assessments of allelopathy involve bioassays of plant or soil extracts, leachates, fractions and residues based on seed germination and seedling growth in laboratory and greenhouse experiments. Biological activities of receiver plants to allelochemicals are known to be concentration-dependent with a response threshold (An *et al*., 1998). Plant growth may be stimulated below the allelopathic threshold, but, depending on the sensitivity of the receiving species, severe growth reductions may be observed above the threshold concentration (Chon and Nelson, 2009). Several models have been proposed to describe dose-response relationships (Finney, 1979; Brain and Cousens, 1989; Wu *et al*., 2000; Dias, 2001; Liu *et al*., 2003; Liu and An, 2005). Allelochemicals released naturally have low bioactivity, are less specific and have a strong variability than commercial herbicides. Compared to the herbicides, allelochemicals are advantageous as they are biodegradable, having different chemical structures with different modes of action and weeds may not easily develop resistance to them (Reigosa *et al*., 1999, 2001). The allelopathic interactions between the vegetables and other crops/weeds/trees and the potential of vegetables for pathogen and nematode management/control has been extehaustively reviewed by Jacob *et al*. (2010). Composting of uprooted Parthenium, or use as a green manure and

Parthenium extract may reduce its spreading and inhibit the weed growth as well as menace of human health hazards worldwide (Kishor *et al.*, 2010). Jun *et al.* (2010) suggested that allelopathy plays a vital role in successful invasion of alien species in new areas. The allelochemicals of invasive alien species also serve as defence chemical weapons against native plant pathogen and herbivorous insects.

ALLELOPATHY VIS-A-VIS INTERFERENCE

In agriculture, various allelopathic effects have been illustrated viz., the effect among agricultural plants themselves (Young and Chen, 1989), the effect of agricultural plants against weeds (Harrison and Peterson, 1986), the effect of weeds on agricultural plants (Ito *et al.*, 1985) or even the effect among weeds themselves (Simkin and Doll, 1982). Weed interference has two components: competition and allelopathy. Both components can not be differentiated in the field (Radosevich *et al.*, 1997); however, *in vitro* studies can make it possible. In a pot and petridish assay study on nine weed and twelve crop species, cocklebar showed no allelopathic effect on *Daucus carota*, *Descurania sophia*, *Abutilon theophrasti* and *Lepidium sativum*. Whereas, the germination of *T. aestivum*, *Hordeum vulgare*, *L. perene* and *Avena sterilis* were being considerably inhibited (Kadioglu, 2004). According to Ongen and Nemli (1993) purple nutsedge, a common weed causing significant losses in summer crops, showed inhibition by decreasing germination rate and radicle length of tomato, eggplant and bean. The extent of interference was higher in light soils than in heavy soils. The leaves and rhizomes of mugwort (*A. vulgaris*), a common weed found worldwide (Holm *et al.*, 1996), affected the seedling growth of white clover, wheat, tomato and alfalfa. Moreover, the essential oils of mugwort inhibited white clover, green pepper, wheat, tomato, chinese cabbage, carrot, garden cress and alfalfa germination between 65 to 100% (Onen and Ozer, 1999, 2002). Studies were conducted by Morales-Payan *et al.* (2003) to determine the extent of full and partitioned interference of two nutsedge species with tomato. According to these results, shoot dry weight accumulation in tomato was affected to the same extent by belowground interference from purple and yellow nutsedge and the higher effect of full interference by yellow nutsedge may be attributed to increased aboveground competition between tomato and yellow nutsedge. Both the root and shoot extracts of the three allelopathic grasses viz., *Dicanthium annulatum* Stapf., *Cenchrus pennisetiformis* Hochest and *Sorghum halepense* Pers., reduced germination and suppressed early seedling growth of exotic weed *Parthenium hysterophorus* L. (Javaid and Anjum, 2006).

There are number of other factors than allelopathy which must be given due consideration before using allelopathy in weed management programmes especially in case of coriander, such as, varietal differences, specificity on allelopathic effects, autotoxicity, preceding and following crops, environmental factors, etc. In some cases, rhizosphere soil and microorganisms may decrease the phytotoxicity of allelopathic compounds, particularly phenolic acids. Soil microorganisms rapidly mineralize phenolic compounds because these compounds have greater energy/weight than simple sugars (Schmidt and Leh, 1999). Phenolic acids react with soil via sorption and oxidation, decreasing their phytotoxicity (Makino *et al.*, 1996; Ohno and First, 1998; Ohno, 2001). Potential exploitation of interference may, therefore, be an important tool for managing weeds in coriander.

FUTURE GREY AREAS OF RESEARCH AND CONCLUSION

Allelopathy plays an important role in plant interactions in nature and in agriculture. Translating this growing knowledge to technology for managing weeds has been slow.

Notwithstanding the discovery of an allelochemical (leptospermone) leading to the development of a major class of herbicides (triketones) and the allelopathic cover crops used for weed management in other crops, as well as other cultural methods to employ allelopathy, there are still no cultivars of crops being sold with allelopathic properties as a selling point. Enhancement or impartation of allelopathy in crops through the use of transgenes could eventually be used to produce such a cultivar (Duke, 2010). Many new research efforts are on presently with the advancement of technology and tools producing many new explanations day by day. The dynamics of crop allelopathy, inducible processes and plant signalling is gaining growing attention (Belz, 2007). With conventional breeding being slow and difficult, more emphasis is laid on the use of modern techniques such as molecular markers and the selection aided by them (Singh *et al.,* 2003).

Weir *et al.* (2004) reported that specific plant response to the allelochemical triggers a genetically tractable cell-death cascade in susceptible plants. It indicates that chemical conformation of certain allelochemicals is very favorable for the manipulation of genetic cell-death cascades that are conserved among plants and, thereby, argues that allelochemicals may not necessarily be inherently toxic compounds but rather compounds that induce toxic responses.

Coriander being an important economic crop attracts attention in areas of plant protection like managing weeds as an essential option towards achieving goals of productivity both in quantitative as well as qualitative terms. Alongwith this the other concerns like possible impacts of chemicals in nature, soil, animals and human beings make the situation more complex in nature. Here comes the allelopathy with its unique opportunities and strength. All these opportunities in their right direction can help allelopathic weed control in coriander in spite of the fact that it is a relatively new concept and only waiting to be accepted by the large section of community dealing with protecting crops from weeds. On the other hand, coriander with its vast potential as a spice and medicine has already gaining spaces in the cultivation map around the globe. Finding suitable allelopathic crop towards managing weeds can not only make our objective of plant protection ecologically suitable but also make the growers economically well-off.

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REFERENCES

An, M., J.E. Pratley and T. Haig, 1998. Allelopathy: from concept to reality. Proceedings of the 9th Australian Agronomy Conference, August 1998, Wagga Wagga, Australia, pp: 563-566.

Auger, J., S. Dugravot, A. Naudin, Abo-Ghalia, Pieere D. and E. Thibout, 2002. Possible use of *Allium allelochemicals* in integrated control. IOBC Wprs Bull., 25: 295-295.

Auger, J., I. Arnault, S. Diwo-Allain, M. Ravier, F. Molia and M. Pettiti, 2004. Insecticidal and fungicidal potential of *Allium* substances as biofumigants. Agroindustria, 3: 5-8.

Babar, B.H., A. Tanveer, M. Tahir, A. Aziz, A.H. Ahmad, M.A. Nadeem and M.M. Javaid, 2009. Allelopathic potential of wild onion (*Asphodelus tenuifolius*) on the germination and seedling growth of chickpea (*Cicer arietinum*). Weed Biol. Manage., 9: 146-151.

Belz, R.G., 2007. Allelopathy in crop-weed interactions-an update. Pest Manag. Sci., 63: 308-326.

Blumenthal, M., 2000. Herbal Medicine Expanded Commission E. Monographs. 1st Edn., Integrative Medicine Communications, Newton, M.A. ISBN-10: 0967077214, pp: 519.

Boscher, J., J. Auger, N. Mandon and S. Ferary, 1995. Qualitative and quantitative comparison of sulphide and volatile flavor Precursors in different organs of Some wild and cultivated garlic. Biochem. System. Ecol., 23: 787-791.

Brain, P. and R. Cousens, 1989. An equation to describe dose responses where there is stimulation of growth at low doses. Weed Res., 29: 93-96.

Choi, S.T., 1993. Studies on the biologically active substances from *Allium fistulosum*. II. Allelopathic substances from *Allium fistulosum*. J. Kor. Soc. Hortic. Sci., 34: 355-361.

Choi, S.T. and Y.Y. Song, 1993. Studies on the biologically active substances from *Allium fistulosum*. I. Effect of crude extracts on growth of Compositae crops. J. Kor. Soc. Hortic. Sci., 34: 344-354.

Choi, S.T., H.K. Ahn and Y.D. Chang, 1996. Effect of crude extracts and chopped shoot application of *Allium* spp. on rice growth. Kor. J. Crop. Sci., 41: 625-633.

Choi, S.T., H.K. Ahn, G.C. Gu, Y.D. Chang and K.S. Song, 1998. Allelopathic substances from *Allium fistulosum* inhibit the growth of Compositae crops. J. Kor. Soc. Hortic. Sci., 39: 333-337.

Chon, S.U. and C.J. Nelson, 2009. Allelopathy in compositae plants-A review. Agron. Sustain. Dev., 30: 349-358.

Das, R., A. Pariari, A.B. Sharangi, R. Chatterjee and D.K. Das, 2006. Response of onion (*Allium cepa* L.) to varying levels of sulphur of different sources. The Hort. J., 19: 351-353.

Dias, L., 2001. Describing phytotoxic effects on cumulative germination. J. Chem. Ecol., 27: 411-418.

Djurdjevic, L., A. Dinic, P. Pavlov, M. Mitrovic, B. Karadzic and V. Tesevic, 2004. Allelopathic potential of *Allium ursinum*. Bio. Syst. Ecol., 32: 533-544.

Duke, S.O., 2010. Allelopathy: Current status of research and the future of the discipline: A commentary. Allelopathy J., 25: 17-30.

Finney, Y., 1979. Bioassay and the practice of statistical inference. Int. Stat. Rev., 47: 1-12.

Freeman, G.G., 1975. Distribution of flavour components in onion (*Allium cepa* L.), leek (*Allium porrum*) and garlic (*Allium sativum*). J. Sci. Food Agric., 26: 471-481.

Gardner, C.D., L. Chatterjee and J. Carlson, 2000. The Effect of Garlic on Serum Cholesterol Levels. In: Phytochemicals as Bioactive Agents, Bidlack, W.R., S.T. Omaye, M.S. Meskin and D.K.W. Topham (Eds.). Technomic Publishing Co., Lancaster, P.A., pp: 199-212.

Goo, G.C., S.T. Choi, H.G. Ahn and K.S. Song, 2001. Growth promotion of rice seedlings by allelopathic polysaccharide from welsh onion. Biosci. Biotechnol. Biochem., 65: 1296-1301.

Granroth, B., 1970. Biosynthesis and decomposition of cysteine derivatives of onion and other *Allium* species. Ann. Acad. Sci. Fenn., 9: 154-160.

Harrison, H.F.Jr. and J.K. Peterson, 1986. Effect of sweet potatoes (*Ipomoea batatas*) on yellow nutsedge (*Cyperus esculentus*) and alfalfa (*Medicago sativa*). Weed Sci., 34: 323-327.

Holm, L.G., J. Doll, E. Holm, J.V. Pancho and J.P. Herberger, 1996. World Weeds: Natural Histories and Distribution. John Wiley and Sons Inc., New York, pp: 1129.

Hooper, P. and J. Dennis, 2002. Coriander-Overcoming Production Limitations: A Report for the Rural Industries Research and Development Corporation. RIRDC, Australia, ISBN: 0642585466.

Iqbal, Z., A. Furubayashi and Y. Fujii, 2004. Allelopathic effect of leaf debris, leaf aqueous extract and rhizosphere soil of *Ophiopogon japonicus* Ker-Gawler on the growth of plants. Weed Biol. Manage., 4: 43-48.

Ito, M., Y. Kamada and K. Ueki, 1985. Noncompetitive effects of *Mimosa pigra* L. Proceedings of the 10th Asian-Pacific Weed Science Society Conference, Nov. 24-30, Chiang Mai, Thailand, pp: 484-491.

Jacob, J., J. Shirmila, S. Sarada and S. Anu, 2010. Role of Allelopathy in vegetables crops production. Allelopathy J., 25: 275-311.

Javaid, A. and T. Anjum, 2006. Control of *Parthenium hysterophorus* L. by aqueous extracts of allelopathic grasses. Pak. J. Bot., 38: 139-145.

Jun, X.L., Z.R. Sen, B.H. Hong, S.Y. Yuan and W.R. Long *et al*., 2010. Allelochemical mediated invasion of exotic plants in China. Allelopathy J., 25: 31-50.

Kadioglu, I., 2004. Effects of hearleaf cocklebar (*Xanthium strumarium* L.) extract on some crops and weeds. Asian J. Plant Sci., 3: 696-700.

Kishor, P., A.K. Ghosh, S. Singh and B.R. Maurya, 2010. Potential use of parthenium (*Parthenium hysterophorus* L.) in agriculture. Asian J. Agric. Res., 4: 220-225.

Kothari, S.K., J.P. Singh and K. Singh, 1989. Chemical weed control in Bulgarian coriander (*Coriandrum sativum* L.). Int. J. Pest Manage., 35: 2-5.

Kralova, K. and E. Masarovicova, 2006. Plants for the future. Ecol. Chem. Eng., 13: 1179-1207.

Lambers, H., F.S. Chapin and T.L. Pons, 1998. Plant Physiological Ecology. 2nd Edn., Springer, New York, USA., pp: 540.

Lancaster, J.E. and H.A. Collin, 1981. Presence of allinase in isolated vacuoles and of alkyl systeine sulfoxides in the cytoplasm of bulbs of onion (*Allium cepa*). Plant Sci. Lett., 22: 169-169.

Liebman, M. and T. Ohno, 1997. Crop Rotation and Legume Residue Effects on Weed Emergence and Growth: Applications for Weed Management. In: Integrated Weed and Soil Management, Hatfield, J.L., D.D. Buhler and B.A. Stewart (Eds.). Ann Arbor Press, Chelsea, MI., pp: 181-221.

Liu, D.L., M. An, I.R. Johnson and J.V. Lovett, 2003. Mathematical modelling of Allelopathy. III. A model for curve-fitting allelochemical dose responses. Nonlinearity Biol. Toxicol. Med., 1: 37-50.

Liu, D.L. and M. An, 2005. Implementation of CARD: Curve-fitting Allelochemical response data. Nonlinearity Biol. Toxicol. Med., 3: 235-244.

Macharia, C. and E.B. Peffley, 1995. Suppression of *Amaranthus spinosus* and *Kochia scoparia*-evidence of competition or allelopathy in *Allium fistulosum*. Crop Prot., 14: 155-158.

Maji, M.K. and A.B. Sharangi, 2006. Influence of sulphur nutrient on yield and quality of garlic (*Allium sativum* L.) for sustained productivity. The Hort. J., 19: 285-288.

Makino, T., Y. Takahashi, Y. Sakurai and M. Nanzyo, 1996. Influence of soil chemical properties on adsorption and oxidation of phenolic acids in soil suspension. Soil Sci. Plant Nutr., 42: 867-879.

Morales-Payan, J.P., 1995. Growing cilantro, cilantro and parsley width. Agricultural Development Foundation. Technical Bulletin No 25. Santo Domingo, Dominican Republic, pp: 26. http://www.rediaf.net.do/publicaciones/guias/download/cilantro.pdf.

Morales-Payan, J.P., B.M. Santos, W.M. Stall and T.A. Bewick, 2000. Influence of nitrogen fertilization on the competitive interactions of cilantro (*Coriandrum sativum*) and purple nutsedge (*Cyperus rotundus*). J. Herbs Spices Med. Plants, 6: 59-66.

Morales-Payan, J.P., W.M. Stall, D.G. Shilling, R. Charudattan, J.A. Dusky and T.A. Bewick, 2003. Above- and belowground interference of purple and yellow nutsedge (*Cyperus* spp.) with tomato. Weed Sci., 51: 181-185.

Ohno, T. and P.R. First, 1998. Assessment of the folin and ciocalteu's method for determining soil phenolic carbon. J. Environ. Qual., 27: 776-782.

Ohno, T., 2001. Oxidation of phenolic acid derivatives by soil and its relevancy to allelopathic activity. J. Environ. Qual., 30: 1631-1635.

Onen, H. and Z. Ozer, 1999. Some plants, germination and seedling maturation Culture dry wormwood (*Artemesia vulgaris* L.) leaves and rhizomes of a research on the effects. Turk. Herboloji J., 2: 22-30.

Onen, H. and Z. Ozer, 2002. Studies on the allelopathic influence of BeifuB (*Artemisia vulgaris* L.) crops. J. Plant Dis. Protect., 18: 339-347.

Ongen, N.Y. and Y. Nemli, 1993. Buckthorn (*Cyperus rotundus* L.) in some vegetables on the allelopathic effects of germination and radicle development. Proceedings of the Turkey lnci Herboloji Congress, Feb. 3-5, London, pp: 211-216.

Pariari, A., A.B. Sharangi, R. Chatterjee and D.K. Das, 2003. Effect of Boron and Zinc on growth and seed yield of coriander. Hort. J., 16: 89-93.

Radosevich, S., J. Holt and C. Ghersa 1997. Weed Ecology: Implications for Management. 2nd Edn., John Wiley and Sons, New York, ISBN: 978-0-471-11606-6.

Rai, D.K., R. Chatterjee, A.B. Sharangi, A. Pariari and P.K. Chattopadhyay, 2003. Performance of garlic (*Allium sativum* L.) cultivars in new alluvial zone of West Bengal. The Hort. J., 16: 71-75.

Reigosa, M.J., A.M. Sanchej and L. Gonjalez, 1999. Ecophysiological approach to allelopathy. Crit. Rev. Plant Sci., 18: 577-608.

Reigosa, M.J., L. Gonjalez, A.M. Sanchej, B. Duran, D. Puime, D.A. Fernadez and J.C. Bolano, 2001. Comparison of physiological effects of allelochemicals and commercial herbicides. Allelopathy J., 8: 211-220.

SAKC, 2010. Saskatchewan committed to a thriving agriculture community. Saskatchewan Agriculture Knowledge Centre, Tuesday, September 07, 2010. http://www.agriculture.gov.sk.ca/Default.aspx?DN=bbd5605d-c129-478d-bde3-bbd6da56aa34.

Santos, B.M., J.P. Morales-Payan and W.M. Stall, 1997. Tolerance of cilantro (*Coriandrum sativum* L.) to postemergence herbicides. Proc. Caribb. Food Crop Soc., 33: 333-339.

Schmidt, S.K. and R.E. Ley, 1999. Microbial Competition and Soil Structure Limit the Expression of Allelochemicals in Nature. In: Principles and Practices in Plant Ecology: Allelochemical Interactions, Chester, L.F. and K.M.M. Dakshini (Eds.). CRC Press, Boca Raton, pp: 339-351.

Sharangi, A.B. and P.K. Sahu, 2009. Effect of placement and dose of phosphatic fertilizers on onion. J. Plant Nutr., 32: 1901-1913.

Shimabukuro, M.A. and V. Haberman, 2006. An aromatic adventure with allelopathy: Using garlic to study allelopathy in the classroom. Am. Biol. Teacher, 68: 242-247.

Simkin, G.S. and J.B. Doll, 1982. Effect of annual weed residues on the growth of yellow nutsedge. Possible role of allelopathy in the competition between tomato, *Senecio vulgario* L. and *Chinopodium album* L. Weed Res., 29: 349-356.

Singh, H.P., D.R. Batish and R.K. Kohli, 2003. Allelopathic interactions and allelochemicals: New possibilities for sustainable weed management. Critic. Rev. Plant Sci., 22: 239-311.

Weir, T.L., S.W. Park and J.M. Vivanco, 2004. Biochemical and physiological mechanisms mediated by allelochemicals. Curr. Opin. Plant Biol., 7: 472-479.

Wu, H., J. Pratley, D. Lemerle and T. Haig, 2000. Laboratory screening for allelopathic potential of wheat (*Triticum aestivum*) accessions against annual ryegrass (*Lolium rigidum*). Aust. J. Agric. Res., 51: 259-266.

Young, C.C. and S.H. Chen, 1989. Continuous Cultivation of Asparagus and the Allelopathic Effect. Food and Fertilizer Technology Centre, Canada, pp: 9.

Zheljazkov, V. and I. Zhalnov, 1995. Effect of herbicides on yield and quality of *Coriandrum sativum* L. J. Essent. Oil. Res., 7: 633-639.