DESERT

DESERT
Online at http://jdesert.ut.ac.ir

DESERT 13 (2008) 1-7

Phytotoxicity effects of soil amended residues of wild barley (*Hordeum spontaneum Koch*) on growth and yield of wheat (*Triticum aestivum L.*)

R. Hamidi[a*], D. Mazaheri[b], H. Rahimian[b], H. M. Alizadeh[c], H. Ghadiri[d], H. Zeinali[e]

[a] *Ph.D. Student, Faculty of Agriculture, University of Tehran, Karaj, Iran*
[b] *Professor, Faculty of Agriculture, University of Tehran, Karaj, Iran*
[c] *Assistant Professor, Faculty of Agriculture, University of Tehran, Karaj, Iran*
[d] *Professor, Faculty of Agriculture, Shiraz University, Shiraz, Iran*
[e] *Associate Professor, Faculty of Agriculture, University of Tehran, Karaj, Iran*

Received 2 August 2007; Received in revised form 5 May 2008; Accepted 5 June 2008

Abstract

Wheat (Triticum aestivum) growth and yield are depressed by physical and chemical interference of weeds. Recently, wild barley (Hordeum spontaneum) population has increased in wheat fields of many provinces of Iran. Since, little is known about the allelopathic effects of wild barley residues in soil, greenhouse studies were conducted to examine the effects of soil amended residues of wild barley at 0, 0.2, 0.4, 0.8, and 1.6 kg m-3, and its root exudates on growth and yield of wheat. There were no significant differences in wheat seedling height and FW when exposed to 0.2 and 0.4 kg m-3 , whereas, the two high residue levels, i. e., 0.8 and 1.6 kg m-3 significantly reduced these parameters. Two high residue levels also significantly reduced seedling and mature plant height fresh and dry weights, and yield of wheat. Root exudates that released from wild barley seedlings into the soil, did not affect wheat seedling height, whereas, those released from tillers significantly decreased seedlings and mature plants heights, FW and DW and yield of wheat.

Key words: Allelopathy; Soil amended residues; Wild barley; *Hordeum spontaneum*; Wheat growth; yield

1. Introduction

Interference can occur in a field by proximity to other plants. The growth and development of plants may be influenced by physical (competition for resources) and chemical (allelopathy) interference (Harper, 1977, Pope, 1984). In some cases, competition may be the dominant contributor to such interference, and in other cases, allelopathy may be the major contributor (Bais et al. 2003). However, in most cases, observed interference is a result of competition and allelopathy acting together (Jennings and Nelson, 2002, Rice, 1984).

Weeds have been a constant companion of crop plants in the field since man replaced native vegetation with his desired productive and economical plants (Shaw, 1982).

In natural plant communities the vegetation pattern is not solely explained by physical factors like availability of growth resources, but other mechanisms of interference such as allelopathy may have been involved (Blum et al., 1999). Allelopathy refers to the beneficial or harmful effects of one plant on another, both crop and weed species, by the release of chemicals from plant parts through leaching, root exudation, volatilization, residue decomposition and other processes in both natural and agricultural systems. Chemicals with allelopathic potential can be present in most tissues of all plant parts including leaves,

* Corresponding author. Tel.: +98 711 6138234;
fax: +98 711 2286134.
E-mail address: hamidi@shirazu.ac.ir

stems, flowers, roots, seeds and buds. Under appropriate conditions, these chemicals may be released into the environment, generally the rhizosphere, in sufficient quantities to affect neighboring plants (Rice, 1984). Natural soil concentrations of phytotoxic chemicals can provide evidence for release of allelopathic chemicals and demonstrating the movement of allelochemicals from the source plant to the rhizosphere of sensitive plant (Staman et al. 2000).

The fate, activity and availability of allelochemicals in the soil are the function of microbial communities in the soil rhizosphere, leaching to soil layers below the roots, light decomposition and adsorption to soil particles (Inderjit, 1996). Many abiotic factors such as seasonal changes (DeScisciolo et al., 1990), stand variation (Lodhi, 1978), environmental factors including rainfall and temperature (Weidenhamer and Romeo, 1989) and also biotic factors such as plant density, growth stage, microbial population and age of donor plant (Rice, 1984) effect the availability and activity of allelochemicals in the soil. Williamson and Weidenhamer (1999) suggested that phytotoxicity is the function of static (i.e., the existing concentration in soil) and dynamic (i.e., the renewal rate) availability of allelochemicals. Inderjit (1996) reported that soil variables such as texture, pH, nutrients, organic matter, ion-exchange characteristics and oxidation state play an important role in the fate of allelochemicals in soil.

In conventional tillage systems, crop and weed residues return to the soil by plowing mechanisms. Many chemical substances directly release from the residues into the soil and together with toxins produced during microbial decay may cause phytotoxic effects on succeeding crops (Bowmick and Doll, 1982, Chou and Partrick, 1976, Kamsisky, 1981). Inhibitory effects on germination and establishment of crops caused by residues of either previous crops or weeds have lead to investigation of the possible release of toxic compounds from such residues (Kruse et al. 2000). Many studies showed the effects of residue extracts of weed on wheat germination and growth (Agarwal et al. 2002, Alam et al. 2002).

Soil amended residues with phytotoxic materials have often been tested for allelochemical activities (Inderjit, 1996). Bowmik and Doll (1982) reported that residues of common lambsquarters (Chenopodium album L.) incorporated in three different soil types reduced the height, and shoot fresh weight of both corn and soybean. In a field experiment, Roth et al. (2000) found that soil amended with sorghum residues delayed development of the subsequent wheat crop but did not affect its grain yield. Weidenhamer et al. (1989) demonstrated that soil amended with 100 and 200 μ g g-1 gallic acid and hydroquinone stimulated the growth of bahiagrass (Paspalum notatum L.) but amended soil with 400 μ g g-1 gallic acid and hydroquinone strongly inhibited the growth of bahiagrass. Bowmick and Doll (1982) and Drost and Doll (1980) observed that the foliage residues of yellow nutsedge (Cyperus esculentus L.) were very inhibitory to root and shoot growth of corn and soybean.

Allelopathic effects of genus of Hordeum have been known since 300 BC (Rice, 1984). The inhibitory compounds, coumarin, hydroxyl cinnamic acid and their derivatives, and vanilic acid have been shown to occur in barley plants and might be the responsible inhibitors (Overland, 1966). Liu et al. (2005) showed that the leachates of living cultivated barley (Hordeum vulgare L.) roots significantly reduced the total dry weight of white mustard (Sinapis alba L.) and reported that three allelochemicals, gramine (N, N- dimethyl- 3-aminomethylindole), hordenine (N,N-dimethyltyramine) and DIBOA (2, 4-dihydroxy-1, 4-benzoxazin-3-one) extracted from barley plants were effective in dry weight reduction.

There are many reports that show the effects of root exudation of one plant on another plant(s). Kossanel et al. (1977) found that root exudates of common lambsquarters in culture solutions retarded radicle growth of corn. Root exudates of Phalaris minor and Chenopodium murale decreased shoot and ear length and dry matter production of wheat (Datta and Ghosh, 1982). Root exudates of wild oats (Avena fatua L.) reduced growth of wheat shoots. The effect is often attributed to water soluble phytotoxins either leached from the residue or produced during microbial decay (Kimber, 1973). Pope et al. (1984) reported that root exudates of Portulaca oleracea significantly reduced soybean height. Root, leaf and flower extracts of Phalaris minor mixed with the soil were studied for their effects on rice root dry weight compared with the control. All Phalaris minor plant parts decreased rice root dry weight compared with the control (Bansal and Sing, 1986). Le Tourneau et al. (1956) found that water extract from 23 common weed and crop species inhibited germination and growth of wheat seedlings.

H. spontaneum, is the most original species of cultivated forms. The known distribution areas of this plant is Afghanistan, Turkey, Jordan, Syria, Iraq, Iran, Pakistan, individual parts of North Africa, Outer Caucasus, and the Southern part of Middle Asia. It normally grows from 350-1500 m above sea level (Shao et al., 1983). H. spontaneum has its center of diversity in the Fertile Crescent of Middle East where it colonizes a wide range of habitats from high rainfall to desert, from cool to hot areas and from sub-sea levels to altitudes in excess of 1700 meter (Harlan and Zohary, 1966)

Our previous laboratory studies showed the allelopathic effects of aqueous extracts of wild barley residue on germination and seedling growth of wheat (Hamidi et al., 2006), however, the objective of this study was to determine whether soil amended residues of this weed were phytotoxic to wheat.

2. Materials and Methods

Two separate experiments were conducted in the greenhouse under 16 h photoperiod, air temperatures of 25/15 °C (day/night), a relative humidity of 50 to 60% and a light flux density of 400 μ moles m-2s-1.

2.1. Experiment 1

Mature vegetative plant parts of wild barley were collected from the Experiment Station Farm, College of Agriculture, Shiraz University, located in Kushkak, 60 km northwest of Shiraz, Iran. All air dried plant materials were chopped by hand into small 1-cm long pieces and kept in paper bags until used. The soil was obtained from wild barley free area of the Experiment Station Farm, Faculty of Agriculture, located in Karaj, Iran, and air dried and sieved before use. Well decomposed manure was mixed with the soil in ratio of 50:50 and a complete fertilizer was applied in forms of urea (90 kg ha-1, pre-plant and 180 kg ha-1, broadcast), triple super phosphate (200 kg ha-1, pre-plant) and potassium sulfate (100 kgha-1, pre-plant). Three kgs of soil was placed in each of 25 cm-diameter uniform plastic pot. Prior to planting, dried and chopped residues of wild barley were added and thoroughly mixed with the soil at the rates of 0.2, 0.4, 0.8 and 1.6 kg m-3 of soil. A treatment with no residue was included to provide a base for comparing (control treatment). Ten vernalised wheat seeds (Triticum aestivum var. Pishtaz) were placed on the soil surface and covered with 200 g of dry soil to provide an appropriate and uniform planting depth. The field capacity of the mixed soil was measured (40% w:w) and pots were maintained at 80% FC throughout the experiment. All pots had draining trays to prevent loss of leachates. Appropriate additional nitrogen was added to each pot at early jointing stage. Immediately after emergence, seedlings were thinned to provide 5 plants pot-1. Two weeks after planting, shoot height, fresh (FW) and dry weights (DW); and at the end of the experiment, final plant height, plant fresh (FW) and dry weights (DW) and 1000 seeds weight were measured.

2.2. Experiment 2

This experiment was conducted to evaluate the probable involvement of allelopathy in the interference potential of wild barley through its root excudates. Ten non-dormant mature seeds of wild barley were planted in each pot. Immediately after emergence, seedlings were thinned to provide 5 plants pot-1. At 3-4-leaf and tillering stages, plants were cut from the soil surface. To prevent wild barley shoot re-growth after cutting at tillering stage, planting of wheat seed was delayed for 15 days and in this period the pots were not watered. Five newly germinating seeds of wheat were carefully placed into the 5-cm deep holes and covered with soil and all pots were watered to 80% FC soon after planting. A treatment with no wild barley was considered as control treatment. The pots were incubated as previously described in experiment 1. Collected data consisted of seedling and mature plant height, fresh (FW) and dry weights (DW), and weight of 1000 seeds of wheat. All other conditions were the same of the experiment 1.

Both experiments were conducted in a completely randomized design (CRD) with three replications. Data were analyzed by analysis of variance procedure and differences between means were subjected to Duncan's new multiple range test at the p=0.01 level.

3. Results and Discussion

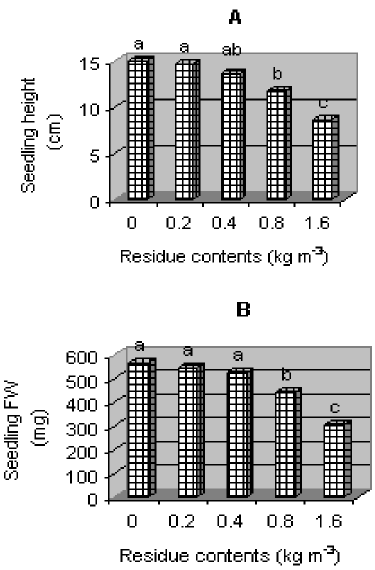
3.1. Experiment 1

There were no significant differences in wheat seedling height two weeks after planting, when exposed to 0.2 and 0.4 kg m-3 soil amended residues of wild barley. Only the two treatments of high residue levels (i.e., 0.8 and 1.6 kg m-3) significantly decreased wheat seedling height to the extent of 22.2 and 42.26% respectively (Fig. 1A).

Responses of wheat seedling fresh weight to different wild barley residues were similar to those of seedling height (Fig. 1B). The mean dry weight of wheat seedlings were 47.67, 42.67 and 31 mg plant-1 for the treatments of 0.4, 0.8 and 1.6 kg m-3, respectively, while there was not any significant difference between the lowest level residue and no-residue treatment (Fig. 1C).

At maturity stage of wheat, two higher residue treatments (i.e., 0.8 and 1.6 kg m-3) significantly reduced wheat plant height with greatest effect being recorded from 1.6 kg m-3 (Fig. 1D). Wheat plant FW and DW were also markedly decreased by the highest residue treatment by 51.29 and 33.67%, respectively (Fig. 1E and 1F). Similar effects were induced for weight of 1000 seeds of wheat at the two higher contents of residues (Fig.1G).

The presence of allelopathic substances in the soil is often determined by a number of important factors (DeSciscriolo et al., 1990, Inderjit, 1996, Lodhi, 1978, Rice, 1984, Weidenhamer and Romeo, 1989, Wiliamson and Weidenhamer, 1999). When conditions promote allelopaty, detrimental effects of allelpathic plants on their neighbors are characteristically exhibited (Liu and Lovett, 1993). The data obtained in this work demonstrate that wild barley has the potential to release water-soluble compounds to the soil either through its decomposed residues or live roots extracts (Liu et al., 2005) that would affect wheat seedling and mature plant growth. This is evident from the significant reduction in some wheat growth parameters at optimal level (in this study, 0.4 kg m-3) of soil amended residue treatment (Fig. 1C, 1E and 1F), and from the significant differences between control treatment and treatment in which wild barley plants were cut from the soil surface at tillering stage (Fig. 2).



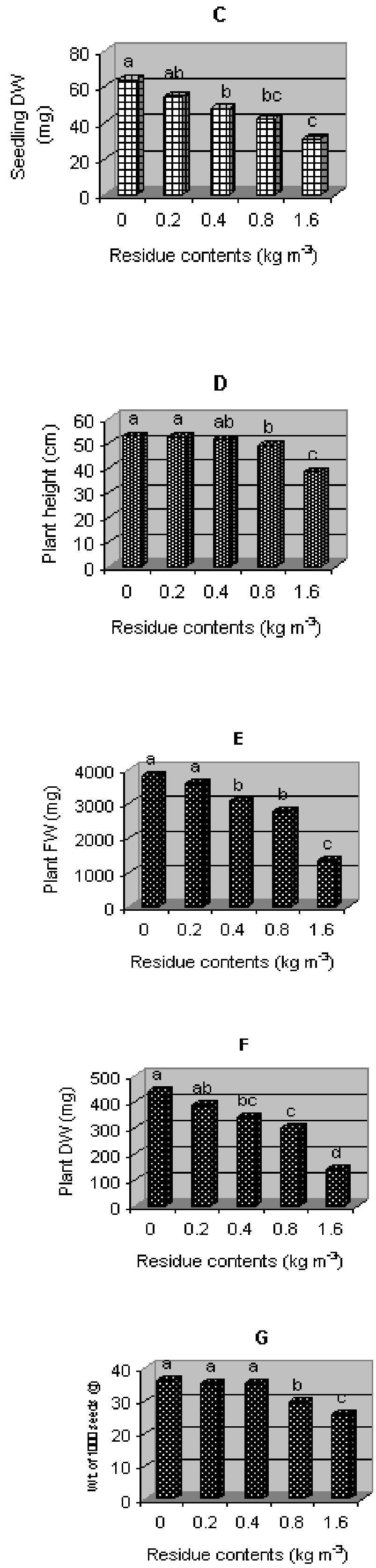
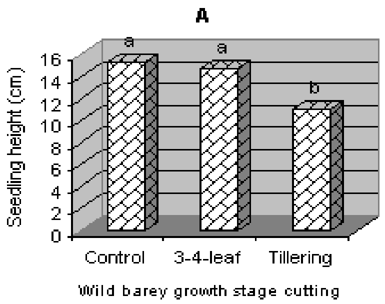


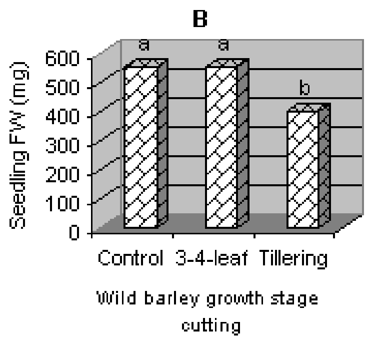
Fig. 1. Effects of different contents of soil amended residues of wild barley on wheat growth stages of seedling (A, B and C) and maturity (D, E and F), and yield (G)

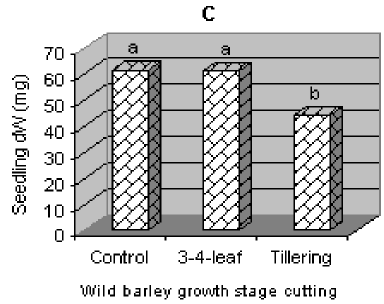
3.2. Experiment 2

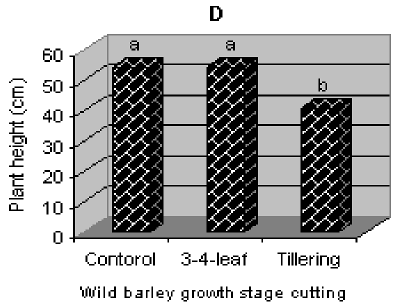
Figure 2 shows the phytotoxicity effects of wild barley roots that obtained by cutting of plants from the soil surface at 2 growth stages on wheat growth and yield. Root exuadates that released from wild barley seedlings into the soil did not affect wheat seedling height, whereas, those of released from tillers significantly decreased this growth parameter (Fig. 2A) Released root excudates from tillers significantly reduced FW and DW of wheat seedling to the extent of 27.7 and 28.03%, respectively, (Fig. 2B and 2C), whereas, these reduction for wheat plant FW and DW at maturity stage were 42.78 and 42.88%, respectively (Fig. 2E and 2F). Thousand weight seeds was also affected significantly by the treatment in which cutting of plants occurred at tillering stage (Fig. 2G).

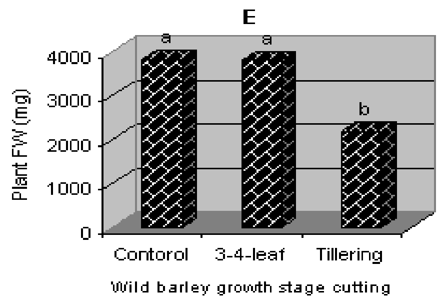
The absence of any inhibition in wheat seedling and mature plant growth parameters due to released exudates from living roots of wild barley seedlings (Fig.2) reflects a difference in exudates dosage, because at the early stage of wild barley growth, the plants were quite small and released insufficient amounts of root exudates to rhizosphere. As wild barley plants developed, exudates of living roots may have increased (Liu and Lovett, 1993) and accumulated in the soil (Lodhi, 1978). On the other side, after cutting of tillers from the soil surface, decomposition of dead roots in the soil by microorganisms may have caused additional release of toxic compounds (Kimber, 1973, Rice, 1984) and this trend was continued at a time period in which wheat plants were growing and developing.

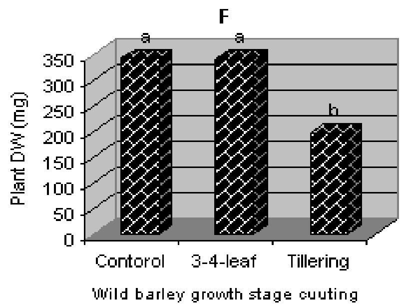












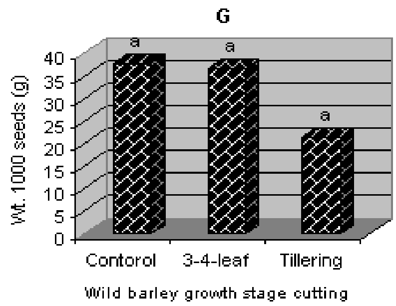


Fig. 2. Effects of wild barley root exudates on wheat growth stages of seedling (A, B and C) and maturity (D, E and F); and yield (G)

With regard to the fact that the activity and availability of allelochemicals in the soil depend on donor plant density (Rice, 1984), it would be expected that larger population densities of wild barley that usually occur in wheat fields, if its control does not take place, may be more effective to wheat growth and yield reductions than lower ones.

References

Agarwal, A.R., A. Gaholt, R. Verma and P.B. Rao., 2002. Effects of weed extracts on seedling growth of some varieties of wheat. J. Environ. Biol. 23: 19-23.

Alam, S.M., A.R. Azmi and S.A. Ali, 1990. Effects of purple nutsedge (Cyperus rotondus L.) leaf extracts on germination and seedling growth of wheat. Pak. J. Sci. and Ind. Res. 33: 235-239.

Bais, H.P., R.Vepachedu, S. Gilory, R.M. Callaway and J.M. Vivanco, 2003. Allelopathy and exotic plant invasion: From molecules and genes to species interaction. Science 301: 1377-1380.

Bansal, G.L. and C.M. Sing., 1986. Allelopathic effects of different parts of grassy weeds of wheat on the germination and growth of rice (Oryza sativa L.). Ind. J. Weed Sci. 18: 108-110.

Blum, U., S.R. Shafer and M.E. Lehman, 1999. Evidence for inhibitory allelopathic interactions involving phenolic acids in field soils: concepts vs. experimental models. Crit. Rev. Plant Sci. 18: 673-693.

Bowmick, P.R. and J.D. Doll, 1982. Corn and soybean response to allelopathic effects of weed and crop residue. Agron. J. 74: 601-606.

Chou, C.H. and Z.A. Partrick, 1976. Identification and phytotoxic activity of compounds produced during decomposition of corn and rye residues in soil. J. Chem. Ecol. 2: 369-386.

Datta, S.S. and K.N. Ghosh, 1982. Effects of pre-sowing treatment of mustard seeds with leaf and inflorescence extracts of Chenopodium murale L. Ind. J. Weed Sci. 14: 1-16.

DeScisciolo, B., D.J. Leopold and D.C. Walton, 1990. Seasonal patterns of juglone in soil beneath Juglans nigra (black walnut) and influence of J. nigra on understory vegetation. J. Chem. Ecol. 16: 1111-1130.

Drost, D.C. and J.D. Doll, 1980. The allelopathic effect of yellow nutsedge (Cyperus esculentus L.) on corn (Zea mays L.) and soybean (Glycine max L.). Weed Sci. 28: 229-233.

Hamidi, R., D. Mazaheri, H. Rahimian, H. M. Alizadeh, H. Ghadiri and H. Zeinaly, 2006. Inhibitory effects of wild barley (Hordeum spontaneum Koch) on germination and seedling growth of wheat (Triticum aestivum L.) and its own plant. Desert 11: (in press)

Harlan, R.J. and D. Zohary, 1966. Distribution of wild wheat and barley. Science 153: 1074-1080.

Harper, J.L., 1977. Population Biology of Plants. Academic Press, New York. 892pp.

Inderjit, 1996. Plant phenolics in allelopathy. Botanical Review 62: 186-202.

Jennings, J. and C.J. Nelson, 2002. Zone of autotoxicity influence around established alfalfa plants. Agron. J. 94: 1104-1111.

Kamisky, R., 1981. The microbial origin of the allelopathic potential of Adenostoma fasiculatum L. Ecol. Monogr. 51: 365-382.

Kimber, R.W.L., 1973. Phytotoxicity from plant residues: II. The effect of time of rotting of straw from some grasses and legumes on the growth of wheat seedling. Plant and Soil 38: 347-361.

Kossanel, J.P., J. Martin, A. Annelle, M. Peinot, J. K. Vallet and K. Kurenj, 1977. Inhibition of growth of young radicles of maize by exudations in culture solution and extracts of ground root of Chenopodium album L. pp. 77-86. In: A. M. Grodzinsky (ed.), Interactions of plant and microorganisms in Phytocenoses. Naukova, Dumka, Kiev.

Kruse, M., M. Strandberg and B. Strandberg, 2000. Ecological effects of allelopathic plants- a review. NERI Technical Report, No. 315, 46pp.

Le Tourneau, D., D. Failes and H.G. Heggeness, 1956. The effects of aqueous extracts of plant tissues on germination of seeds and growth of seedlings. Weeds 4: 363-368.

Liu, D.W. and J.V. Lovett, 1993. Biologically active secondary metabolites of barley. I. Developing techniques and assessing allelopathy in barley. J. Chem. Ecol. 19: 2217-2230.

Liu, D.L., M. An, I.R. Jhonson and J.V. Lovett, 2005. Mathematical modeling of allelopathy: IV. Assessment of contribution and competition and allelopathy to interference by barley. Nonlinearly in biology, Toxicology, and Medicine. 3: 213-224.

Lodhi, M.A.K., 1978. Allelopathic effects of decaying litter of dominant trees and their associated soil in a lowland forest community. Amer. J. Botany 65: 340-344.

Lovett, J.V., A.H.C. Hoult and O. Christen, 1994. Biologically active secondary metabolites of barley. IV. Hordenine production by different barley lines. J. Chem. Ecol. 20: 1945-1954.

Overland, L., 1966. The role of allelopathic substances in the "smother crops" barley. Am. J. Botany 53: 423-432.

Pope, D.F., A.C. Thmpson and A. W. Cole, 1984. Biological activity of weed root exudates. Proc. Southern Weed Sci. 37th Annual Meeting. Pp. 120.

Rice, E.L., 1984. Allelopathy, 2nd edition, Academic Press, Inc. Orlando. 318 pp.

Roth, C.M., J.P. Shroyer and G.M. Paulsen, 2000. Allelopathy of sorghum on wheat under several tillage systems. Agron. J. 92: 855-860.

Shao, Q., L. Chang-sen and B. Chiren, 1983. Origin and evolution of cultivated barley: wild barley from Western Szechuan and Tibet, China. Barley Genetics Newsletter 12: 37-42.

Shaw, W.C., 1982. Integrated weed management systems technology for pest management. Weed Sci. 30: 2-15.

Staman, K., U. Blum, F. Louws and D. Robertson, 2000. Can simultaneous inhibition of seedling growth and stimulation of rhizosphere bacterial population provide evidence for phytotoxin transfer from plant residues in the bulk soil to the rhizosphere of sensitive species? J. Chem. Ecol. 27: 807-829.

Weidenhamer, J.D. and J.T. Romeo, 1989. Allelopathic properties of Polygonella myriphylla: field evidence and bioassay. J. Chem. Ecol. 15: 1957-1970.

Weidenhamer, J.D., D.C. Hartnett and J.T. Romeo, 1989. Density-dependent phytotoxicity:

distinguishing resource competition and allelopathic interference in plant. J. Appl. Ecol. 26: 613 – 624.
Williamson, G.B. and J.D. Weidenhamer, 1999. Bacterial degradation of Juglone: evidence against allelopathy. J. Chem. Ecol. 16: 1739-1742.