INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES
IJPAES
Volume-4, Issue-3, July-Sept-2014
ISSN 2231-4490

Coden : IJPAES www.ijpaes.com
Received: 5th May-2014 *Revised: 26th May-2014* *Accepted: 7th June-2014*
Research article

ALLELOPATHIC EFFECTS OF EXTRACTS FROM TWO GROWTH STAGES OF WHEAT ON WILD MUSTARD GERMINATION CHARACTERISTICS

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ABSTRACT: A laboratory experiment was conducted to investigate the allelopathic effects of wheat extracts from two growth stages on germination indices of wild mustard, a common weed in agricultural lands. The experimental design was completely randomized with five wheat water extract concentrations (0, 25, 50, 75 and 100%), two growth stages of wheat (flowering and maturity) and three replications. The results showed that wheat plant extracts from both growth stages had significant allelopathic effects on germination indices of wild mustard. The extracts from flowering stage had more significant effects on suppressing the germination characteristics of wild mustard than maturity stage. In general, all concentrations had inhibitory effects on germination indices, however, there was no significant differences between 50% up to 100% concentrations. The results indicate that utilization of allelopathic behavior of wheat extract is an effective method for biological control of wild mustard.
Keywords: Allelopathy, Biological weed control, *Sinapis arvensis*, *Triticum aestivum*, Weed management

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's most important cereal crop and plays an important role in human nutrition. Appropriate agronomic management of wheat can greatly enhance its production. One of the effective ways to increase the production potential of wheat is scientific management of weeds [1]. Effective weed management is one of many critical components of successful wheat production. Weeds compete with wheat for light, nutrients, water, and space. Severe weed infestations can reduce wheat yields by as much as 70% if left uncontrolled, thereby reducing profits. In addition, weeds can attract harmful insects and diseases and decrease harvest efficiency. Wild mustard (*Sinapis arvensis*) is a weed in most parts of the world and are generally native to Europe and the Middle East and East Asia. This weed has been seen in 52 countries and in 30 crop. Wild mustard is a serious weed in cereal crops including wheat. Synthetic herbicides can control weeds effectively and reduce labor in weeding. However, in recent years, the increasing cost of herbicides and ecological and human health concerns, have renewed interest in exploiting non-chemical alternatives including allelopathy and crop competitiveness [2]. The use of allelopathy for biological control of weeds in agriculture has attracted the interest of many agronomic scientists. Allelopathy is direct influence of a chemical released from one plant in environment on the growth and development of another plant. This may provide a promising alternative to synthetic chemical weed control methods [3]. Many allelochemicals are secondary plant metabolites including alkaloids, phenoloids, flavonoids, and glucosionates, which are synthesized by the plants during their growth and developmental period [4]. Allelopathy in cereals (cultivated and wild plants of the Poaceae family) was attributed mostly to hydroxamic acids [5]. Leaves and its debris, radicles, pollen, flowers, stems, seeds and fruits have allelopathic properties after decomposing [6]. The use of plant extracts for controlling weeds have been reported with variable success [7-9]. In Pakistan, many plant species has shown allelopathic effects that could be successfully used for weed control in agricultural crops [10]. Also, studies have shown good potential of allelopathy for weeds control in wheat and as the best alternatives to the synthetic herbicides to control weeds [11, 12].

Although allelopathy has already contributed to some solution for biological control of weed problems in agriculture, but it is still considered a new concept [13]. Therefore more information and research is needed. The main objectives of this research is to investigate the allelopathic potential of wheat extract on germination of its main weed, wild mustard. Growth stage of wheat may have an effect on its allelopathy. Thus, another objective of this research is to evaluate the allelopathic potential of wheat at two growth stages. The results of this experiment can be used for better weed management of wheat crop fields.

MATERIALS AND METHODS

In order to determine the effects of wheat extract on germination and seedling growth of wild mustard (*Sinapis arvensis*), a factorial, completely randomized block design experiment with three replications was carried out in the Plant Physiology Laboratory of Shahid Chamran University of Ahvaz in 2012. The first factor was two wheat growth stages (flowering and maturity). The second factor was different concentrations of the wheat extract (0, 25, 50, 75 and 100 percent). One hundred grams of wheat powder were separately suspended in 2000 ml of distilled water and shaken for 48 hours by a horizontal rotary shaker in room temperature to obtain 100 percent concentration of aqueous extract. The solution was diluted appropriately with distilled water to give the other extract concentrations of 25, 50 and 75 percent.

In this experiment, 30 seeds of wild mustard were placed on a filter paper in a clean and sterilized Petri dish, and 6 ml of final wheat aqueous extract concentrations were added to each petri dish. Petri dishes were transferred to a germinator set at 25°C and 70% relative humidity. They were inspected daily and the number of germinated seeds (growth of radicle by 2 mm) were counted, until the number of seeds germinated for three consecutive counts were the same. At the end of counting period, radicle and plumule lengths of wild mustard seeds were measured. Germination percentage (GP), germination rate (GR) and seed vigor index (VI) were also calculated according to the following equations [14].

$$GP = \frac{N_f}{N} \qquad GR = \sum \frac{N_i}{i} \qquad VI = \frac{SL \times GP}{100}$$

N, N_f and N_i are total number of seeds, number of seeds germinated and seeds germinate at the day i, respectively, and SL is radicle length plus plumule length. All the data were statistically analyzed by MSTATC statistical software.

RESULTS AND DISCUSSION

The results of analysis of variance showed that the effects of wheat growth stage, wheat extract concentration and their interaction on all germination traits measured were highly significant (Table 1).

Germination Percentage

Germination percentage (GP) of wild mustard was reduced significantly by all wheat extract concentrations from both growth stages as compared to control (Figure 1). The wheat extract from flowering stage was much more effective in reducing the GP than from maturity stage. The lowest GP in maturity stage treatment was in 75 and 100% concentrations, which were 41.1 and 43.3%. However, with the exception of 25% concentration, all other concentrations of wheat extract from flowering stage reduced GP to zero, thereby completely inhibiting wild mustard germination (Figure 1). This might be due to changes in enzyme activities that affect the translocation of metabolites stored during germination [15]. The germination, radicle and plumule growth and overall growth of tumbleweed (*Amaranthus albus*) was significantly reduced by application of 3 and 4% extracts of wheat residues [16].

Germination Rate

Germination rate (GR) is an indicator of the speed of seed germination (number of seeds germinated per day). GR of wild mustard was significantly reduced by all wheat extract concentrations from both growth stages (Figure 2). Although extracts from both growth stages were effective in reducing the GR of wild mustard, wheat extracts from flowering stage were significantly more effective than the extracts from maturity stage at all concentration levels. This indicates that the allelopathic chemicals are more concentrated, and therefore more toxic, at flowering stage of wheat than maturity stage. The 25% concentration of flowering stage reduced GR from 9.9 to 1.2 seeds germinated per day (an 87.9% reduction), and all the other concentrations reduced GR to zero (Figure 2). Considering these observations, it seems that allelopathic effects of wheat extracts, in addition to significantly reducing GP of wild mustard (Figure 1), has also delayed the germination of the seeds as well. This in turn can the main crop plants more advantages to compete with the weeds, particularly under moisture and nutrient stress conditions. The presence of the allelochemicals can reduce seed respiration and therefore, slow down the important metabolic activities and seed GR [17]. Leaf extracts from sunflower has also been reported to have allelopathic effects on white mustard seed by reducing its GR [18].

Radicle Length

Radicle lengths of wild mustard seedlings were significantly reduced by all wheat extract concentrations from both growth stages (Figure 3). Extracts from both wheat growth stages were effective in reducing the radicle length of wild mustard, but wheat extracts from flowering stage reduced this characteristic more significantly than the extracts from maturity stage at all concentration levels. The maturity stage extracts significantly reduced radicle length significantly only at 75 and 100% concentrations by 48.3 and 44.5 %, respectively. The 25% concentration from flowering stage significantly reduced mean radicle length by 77.1%, and all the other concentrations significantly reduced radicle length by 95.8% (Figure 2). The allelochemicals present in wheat residue extracts negatively affect mechanism such as cell division and proper functioning of growth hormones like giberelic acid, thereby reducing the growth and length of radicle [19]. Reduction in seedling lengths of tumbleweed (*Amaranthus albus*) by wheat residue extracts have been reported by other researchers as well [20, 21].

Plumule Length

Plumule length of wild mustard was not significantly affected by any concentration of wheat extract from maturity stage (Figure 4). However, with the exception of 25% concentration, all other concentrations from flowering stage significantly reduced plumule length by 94.1%. These results confirm that allelopathic chemicals are more concentrated, and therefore more toxic, at flowering stage of wheat than maturity stage. Leaf extracts from sunflower has also been reported to have allelopathic effects on white mustard seed by reducing its plumule and radicle lengths [18]. Considering the results of radicle and plumule lengths (Figure 3 and 4), it seems that plumule growth of wild mustard was less affected by allelochemicals than radicle growth. In another study, increasing concentrations of water extracts from black mustard affected plumule growth of lentil less than radicle growth [21]. The results of this experiment showed reduction of radicle and plumule lengths (Figure 3 and 4). The delay in plumule and radicle growths will enhance the competitive advantages of main crop plants against their weeds.

Seed Vigor Index

Seed Vigor Index (SV) is one of the valuable characteristics for evaluation of seedling tolerance under stress conditions. The results showed that SV of wild mustard was significantly reduced by increasing wheat extract concentrations from both growth stages (Figure 5). Extracts from both growth stages were effective in reducing the SV of wild mustard, however, wheat extracts from flowering stage were significantly more effective than the extracts from maturity stage at all concentration levels. The 25% concentration from flowering stage reduced SV by 91.3%, while other concentrations reduced SV of wild mustard to the very low value of 0.2 (Figure 5). Significant reduction in SV of weed seeds will greatly enhance the competitive ability of the main crops against the weeds for water and nutrients, and thus will ensure better seedling establishment and final yield.

Table 1. Analysis of Variance test results for the characteristics measured in the experiment

Source of variations	df	Germination percentage	Germination rate†	Radicle length (cm)	Plumule length (cm)	Seed vigor
Replication	2	17.78 ^{ns}	2.44^{ns}	0.02 ^{ns}	1.60 ^{ns}	0.73 ^{ns}
Wheat growth stage (A)	1	9839.16**	74.2**	85.02**	45.48**	70.51**
Wheat extract concentration (B)	4	4333.46**	72.2**	29.80**	3.17**	59.03**
A×B	4	669.00**	5.80**	5.68**	3.55**	5.40**
Error	18	31.15	0.88	0.70	0.27	0.76
CV		14.19%	24.86%	25.20%	24.10%	25.10%

NS: Not significant **: Significant at 0.01 probability level.

† Number of seeds germinated per day

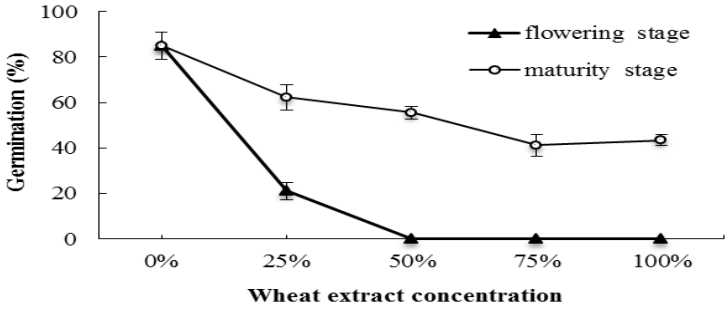

Figure 1. The effects of wheat extract concentrations and growth stage on germination of wild mustard. Vertical lines indicate standard errors.

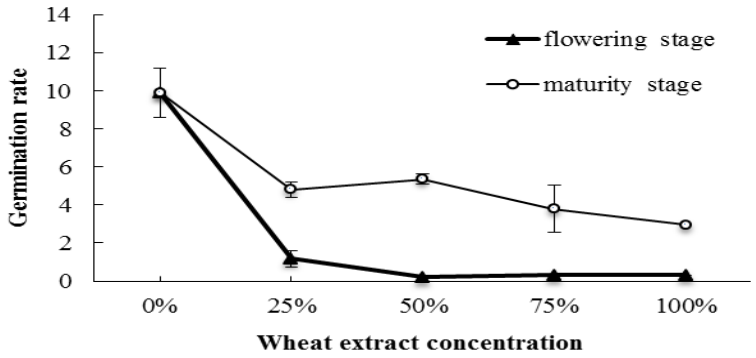

Figure 2. The effects of wheat extract concentrations and growth stage on germination rate (seeds/day) of wild mustard. Vertical lines indicate standard errors.

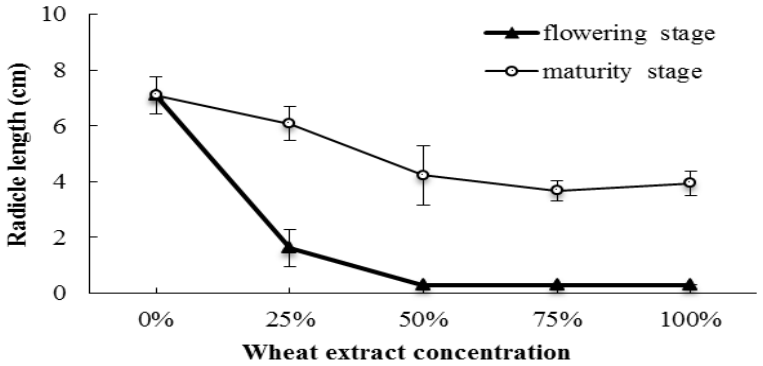

Figure 3. The effects of wheat extract concentrations and growth stage on radicle length of wild mustard. Vertical lines indicate standard errors.

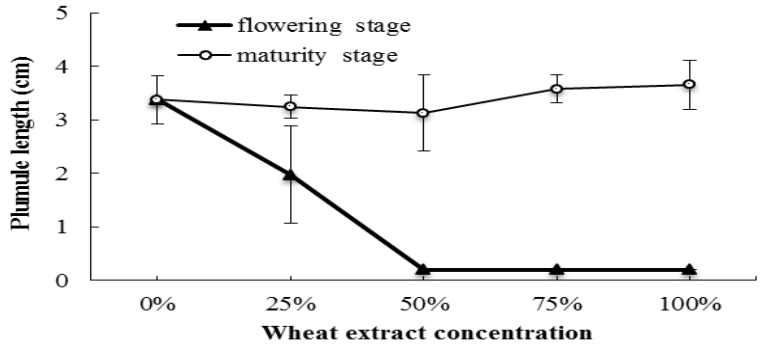

Figure 4. The effects of wheat extract concentrations and growth stage on plumule length of wild mustard. Vertical lines indicate standard errors.

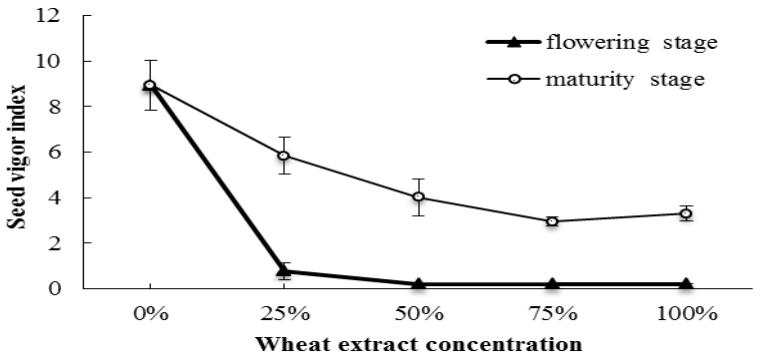

Figure 5. The effects of wheat extract concentrations and growth stage on seed vigor index of wild mustard. Vertical lines indicate standard errors. Vertical lines indicate standard errors.

CONCLUSION

The overall results of this experiment showed significant allelopathic effects of wheat plant extracts on germination indices of wild mustard, a common weed of wheat fields. The results confirm that concentration of allelopathic compounds in wheat plant water extracts, is different at flowering and maturity stages. Concentration of allelochemicals are significantly higher at flowering stage of wheat than maturity stage. Based on the results of this experiment, wheat maybe a useful crop in crop rotation programs for biological control of wild mustard weed. This is an environmentally friendly and ecologically important methodology for wild mustard control.

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