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Assessment of seed to seed allelopathic potential of Corn (*Zea mays* L.) on seed and seedling growth of some volunteer species

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Key words: Allelopathy, corn, germination, seedling growth, volunteer species.

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Abstract

The experiment was carried out to investigate the effects of interaction seed to seed between corn (*Zea mays* L.) with some of volunteer species like sainfoin (*Onobrychis sativa var. subinermis.), black cumin (Nigella sativa L.), bitter vetch (Vicia ervilia (L.) Willd.), proso (Panicum miliaceum L.)* and jimpson-weed datura (*Datura stramonium* L.) on seed and seedling growth factors. Results showed that *O. sativa* had inhibitory effect on *Z. mays* seedling growth, as shoot and root length and fresh weight of *Z. mays* by beside of this specie was significantly inhibited. In contrast, *V. ervilia* and *P. miliaceum* had stimulatory effect on seedling growth factors of *Z. mays*, as shoot and root length and fresh weight of *Z. mays* in the presence of these species was significantly increased. Seedling of *P. miliaceum* by beside of *Z. mays* had more germination percentage, shoot fresh weight and root dry weight in comparison with control. Less germination rate of *Z. mays* by beside of *N. sativa* was caused the reducing of shoot and root fresh and dry weight of this specie. Our results suggested that the seedling growth is suitable for potential testing of the allelopathic effect of the studied seed to seed interaction under laboratory conditions. In addition, the choice of vigorous seeds can be useful to alleviation of possible allelopathic risks.

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Introduction

Scientists have focused on the increase of food production needed for the fast expansion of the world's population. Weeds are the major problem in world agriculture because they cause losses in crop yields. Whenever two or more plants occupy the same niche in nature, they compete with each other for various life support requirements (Caton et al., 1999). Seed dispersal and seed germination are critical phases in the life-cycle of the plant during these phases the forces (biotic and abiotic stresses) have a maximum opportunity to exert their influence (Aliloo *et al.,* 2012).

A successful establishment of a weed in any ecosystem is attributed to several reasons, such as high growth rate, high reproductive potential, adaptive nature and above all interference by resource depletion and allelopathy (Kohil and Rani, 1994). Allelopathy concerns the effects of one plant on another due to chemicals released by them, or the breakdown products of their metabolites (Willis, 1994). The chemical interactions that occur among plants are known as allelopathy, and organic compounds that play a role in allelopathy are known as allelochemicals, and they become stressful when they are toxic and inhibit growth (Kocaçaliskan, 2006). Allelopathy is an ecological and chemical interaction characterized by stimulatory and inhibitory effects among different plant families. Worldwide, the inhibitory properties of the extracts and residues of many herbal species cohabiting with desired crops on the same field have been a major source of concern (Hussain *et al.,* 2007; Nazir *et al.,* 2007). The allelopathic properties of plants and their metabolites may be effectively used for biological weed management in crop production (Rice, 1984).

Allelopathic effects of shoot and root extracts on the seed germination and early seedling growth have been frequently reported (Tanveer *et al.,* 2008), however, few attentions have been given to seed-to-seed interaction. In the natural environment, many species shed their seeds to soil surface at same season. Hence, the seed-to-seed allelopathic effect may be one of the mechanisms involved in population establishment and community pattern allelopathic effects on each other. For this reason, the objective of the study was to distinguish allelopathic impacts of *Z. mays* on seed germination and seedling growth of some weed and crop species.

Material and methods

In order to determine the effects of interaction seed to seed between (*Zea mays* L.) with some of weed and crop species like sainfoin (*Onobrychis sativa var. subinermis.), black cumin (Nigella sativa L.), bitter vetch (Vicia ervilia (L.) Willd.), proso (Panicum miliaceum L.)* and jimpson-weed datura (*Datura stramonium* L.) on seed and seedling growth factors, an experiment was conducted under laboratory conditions in the University of Tabriz, Tabriz, Iran in 2012.

Seeds of *Z. mays* or weed/crop without another seeds as control were counted and 16 seeds of each species as separate placed within petri dishes which consisted of two layers of filter paper moistened with 4 ml of distilled water. For survey the effects of interaction seed to seed between Z. mays with some of weed and crop species, numbers of 16 seeds of each weed or crop species were regularly placed between the 16 wheat seeds. The distance between adjacent seeds was 1 cm, forming a grid of 4 rows by 4 columns of each species (*Z. mays* and each weed or crop species). Then, petri dishes were randomly incubated at 20±°C and germinated seeds (protrusion of radicle by 2 mm) were counted every day up to 9 days.

Rate of seed germination was calculated according to Ellis and Roberts (1981):

$$GR=\frac{\sum n}{\sum D.n}$$

Where n is the number of seeds germinated on day D, D is the number of days from the beginning of the test and R is the mean germination rate. Then percentage of germination was also determined.

At the end of test, length and fresh weight of root and shoot were measured. Root and shoot of each sample were then dried in an oven at 80 °C for 24 hours (Perry, 1977) and mean dry weight of root and shoot for each treatment at each replicate was determined. Percentage inhibition or stimulation of germination was calculated according to the following equation:

$$Inhibition\ (-)\ or\ Stimulation\ (+) = \frac{GST - GSC}{GSC} \times 100$$

Where GST is germination seeds in treatments (neighboring seed to seed) and GSC is germination seeds in control. All the data were analyzed on the basis of experimental design, using MSTATC and SPSS-16 softwares. The means of each trait were compared according to Duncan multiple range test at P≤0.05 and standard error values. Excel software was used to draw figures.

Results

The results revealed (Fig. 1a) that germination percentage (G %) of *Z. mays* was reduced by beside of *O. sativa, P. miliaceum* and *D. stramonium*. However, reduction in G% of *Z. mays* in the presence of the *O. sativa*, was not significant. In contrast, the highest G % of *Z. mays* was recorded in seeds by neighbored with *N. sativa*. Thus, the neighboring of *D. stramonium* and *N. sativa* caused maximum inhibition and stimulation in seed germination of *Z. mays*, respectively. The proximity of *Z. mays* had no effect on G% of all species. Nonetheless, G % of *P. miliaceum* by beside of *Z. mays* was increased (Fig. 1b). As a result, *Z. mays* had stimulatory effect on *P. miliacum*, but this weed specie had inhibitory effect on G% of *Z. mays* (Fig. 1a,b).

Fig. 2 clearly shows that germination rate (GR) of *Z. mays* was decreased in the presence of all species. However, alone this reduction was significant for *N. sativa*. As, GR of *Z. mays* in the presence of this specie was decreased from 0.30 up to 0.27 than control treatment. GR of all species was inhibited by beside of *Z. mays* in comparison with control. However, alone *N. sativa* was significantly affected by *Z. mays*. As, GR of this specie was 32% less than that of control (Fig. 2b). Hence, the neighboring of *Z. mays* with *N. sativa* had reciprocal inhibition for both species (Fig. 2a,b).

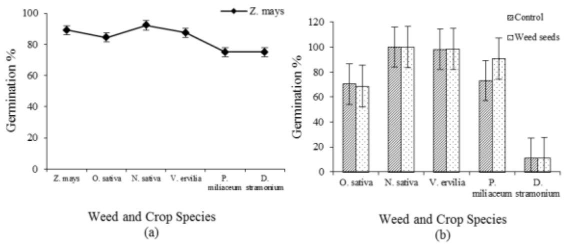

Fig. 1. Changing in germination percentage of *Z. mays* affected by some weed or crop species (a) and weed or crop species affected by *Z. mays* (b).

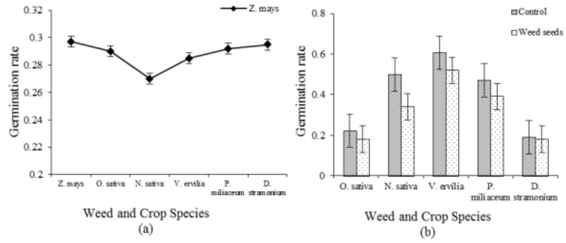

Fig. 2. Changing in germination rate of *Z. mays* affected by some weed or crop seed species (a) and weed or crop species affected by *Z. mays* (b).

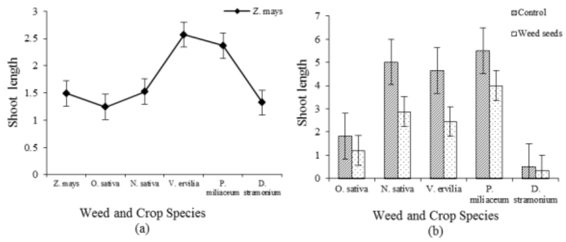

Fig. 3. Changing in shoot length of *Z. mays* affected by some weed or crop seed species (a) and weed or crop seed species affected by *Z. mays* (b).

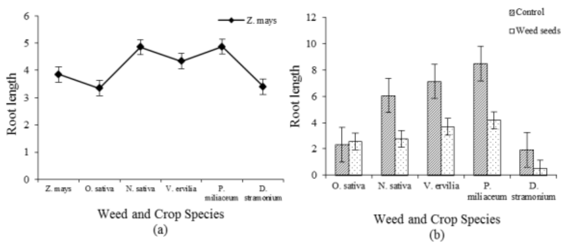

Fig. 4. Changing in root length of *Z. mays* affected by some weed or crop species (a) and weed and crop species affected by *Z. mays* (b).

Shoot length (SL) of *Z. mays* by beside of *O. sativa* and *D. stramonium* was inhibited. In contrast, SL of *Z .mays* in the presence of *V. ervilia* and *P. miliaceum* was significantly stimulated. As, SL of *Z. mays* was 42% and 34% more in compared to the control by beside of these species (Fig. 3a). Figure 3b shows that SL of all species was declined by beside of

Z. mays. However, this reduction was significant only for *N. sativa* and *V. ervilia*. As, the inhibitory effect of *Z. mays* on decrease shoot elongation of these species was 42% and 47% less than that of control. As a result, *V. ervilia* had the highest stimulatory effect on SL of *Z. mays*, while this crop had the highest inhibitory effect on SL of this specie (Fig. 3a,b).

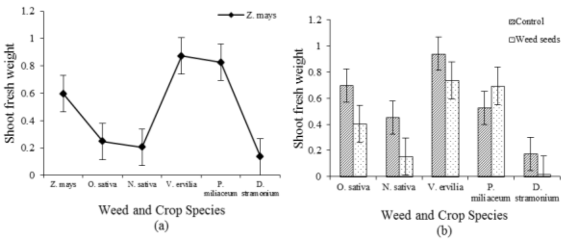

Fig. 5. Changing in shoot fresh weight of *Z. mays* affected by some weed or crop species (a) and weed or crop species affected by *Z. mays* (b).

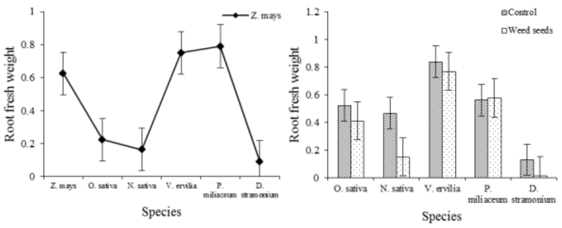

Fig. 6. Changing in root fresh weight of *Z. mays* affected by some weed or crop species (a) and weed or crop species affected by *Z. mays* (b).

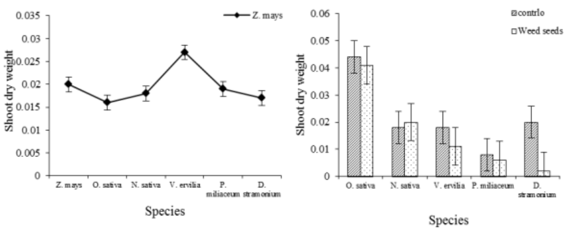

Fig. 7. Changing in shoot dry weight of *Z. mays* affected by some weed or crop species (a) and weed or crop species affected by *Z. mays* (b).

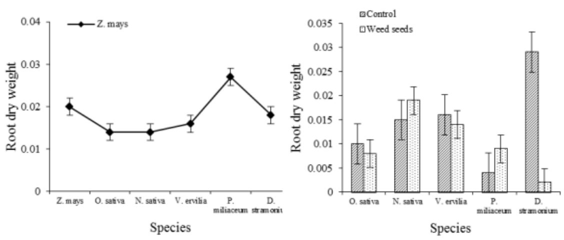

Fig.8. Changing in root dry weight of *Z. mays* affected by some weed or crop species (a) and weed or crop species affected by *Z. mays* (b)

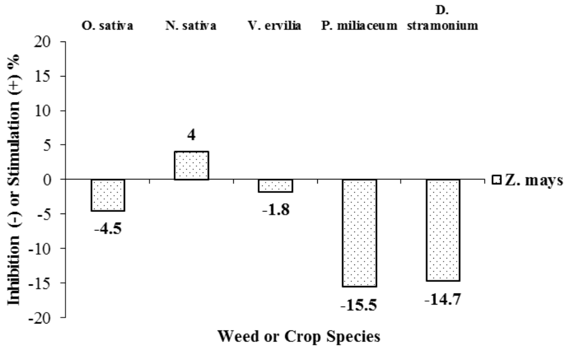

Fig. 9. Inhibitory or stimulatory effects of some weed or crop species on germination percentage of *Z. mays*.

Seedling of *Z. mays* by beside of *O. sativa* and *D. stramonium* was produced the lowest root length (RL). But, this specie in the presence of *N. sativa, V. ervilia* and *P. miliaceum* had the highest RL. As, RL of *Z. mays* by beside of *P. miliaceum* and *O. sativa* were 20.94% and 12.98% respectively, more and less than that of control treatment (Fig. 4a).

Fig. 4b indicates that RL of *N. sativa, V. ervilia* and *P. miliaceum* was significantly inhibited by beside of *Z. mays*. As, RL of these species were 54.69%, 48.03% and 50.58% less in comparison with control. According to this result, *N. sativa, V. ervilia* and *P. miliacum* had stimulatory effect on RL of *Z. mays*. However, *Z. mays* had inhibitory effect on RL of these species (Fig. 4a,b).

Shoot fresh weight (SFW) and root fresh weight (RFW) of *Z. mays* were significantly reduced by beside of *O. sativa, N. sativa* and *D. stramonium*. In contrast, SFW and RFW of this specie in the presence of *V. ervilia* and *P. miliacum* were significantly increased. As, these quality of *Z. mays* by beside of *V. ervilia* were 31.53% and 65.32% and in the presence of *N. sativa* were 16.66% and 20.88%, respectively more and less than that of control treatments (Fig. 5a & 6a). Seedling of *O. sativa* and *N. sativa* by beside of *Z. mays* had the least SFW. However, this quality of *P. miliaceum* in the presence of *Z. mays* was increased (Fig. 5b). Thus, the interaction of *Z. mays* with *P. miliaceum* had stimulatory effects on SFW for both species.

While, in neighboring of *Z. mays* with *V. ervilia*, this interaction was beneficial for *Z. mays* but was adversely for *V. ervilia* (Fig. 5a,b). As a result, the stimulatory effect of *Z. mays* on SFW of *P. miliaceum* was more than that of RFW of this specie.

Shoot dry weight (SDW) of *Z. mays* was inhibited by beside of *O. sativa, N. sativa* and *P. miliaceum*. In contrast, SDW of this specie was enhanced in the presence of *V. ervilia*. As, *Z. mays* in the neighboring of this specie had 25.92% more SDW, compared to the control (Fig. 7a). Seedling of *O. sativa, V. ervilia, P. miliaceum* and especially *D. stramonium* was showed less SDW than that of control by beside of *Z. mays*. However, *N. sativa* in the presence of this specie was indicated more SDW than that of control (Fig. 7b).

Fig. 8a shows that root dry weight (RDW) of *Z. mays* in the presence of *P. miliaceum* and *D. stramonium* was significantly increased. This specie by beside of *P. miliaceum* had 25.92% more RDW in comparison with control (Fig. 8a). In contrast, RDW of *D. stramonium* in this interaction was 93.10% less than that of control (Fig. 8b). Also, this quality in *O. sativa* and *V. ervilia* was declined by beside of *Z. mays*. As a result, *Z. mays* had the highest inhibitory effect on SDW and RWD of this weed specie.

In general, seeds of *O. sativa, V. ervilia, P. miliaceum* and *D. stramonium* had inhibitory effect on germination percentage of *Z. mays*. In contrast, *N. sativa* had stimulatory effect on germination of this crop. Thus, in weed control or crop rotation management, it needs to increase precision in selective of crop. Our results indicated that existing seeds of *N. sativa* by beside of *Z. mays* may be beneficial for *Z. mays* in germination phase (Fig. 9).

Discussion

The interaction among *Z. mays* with some of weed or crop species shows that germination percentage and especially germination rate of *Z. mays* and some of these weed species significantly decreased (Fig. 1 & 2). Reduction in seed germination might be due to presence of allelochemicals that inhibited the processes of seed germination. According to El-Khatib (1977), an indirect association between lower seed germination and allelophatic inhibition may be the consequence of the inhibition of water uptake. Lower seed germination was recorded partly due to the fact that the presence of the some allelochemicals in the seed prevented the growth of seed embryo or caused its death. Allelochemicals are found to be released to environment in appreciable quantities via root exudates, leaf leachates, roots and other degrading plant (seed) residues, which include a wide range of phenolic acids such as benzoic and cinnamic acids, alkaloids, terpenoids and others (Rice, 1995). These compounds are known to modify growth, development of plants, including germination and early seedling growth.

Fig. 3-8 indicates that moreover seed germination percentage and rate, seedling growth was also affected by allelochemicals that produced in interaction between *Z. mays* and some of weed or crop species. This effect was as inhibitory or stimulatory mood. The mechanism of inhibition on the seedling growth caused by allelochemicals can be the result of reduced cell division and/or cell elongation (Iman *et al.,* 2006).

Few studies have been reported that legumes crop residues have been stimulatory effects on studied crops. For example, Gill *et al.,* (2000) have reported stimulatory effect of mungbean, sesame and soybean residues on wheat, chickpea and lentil at lower concentration. Improvement in corn yields following legume crops has also been reported (Phetchawee *et al.,* 1985)

Phenolic allelochemicals from *O. sativa* can inhibit amino acid transport and protein synthesis, and the subsequent growth of treated plants. All phenolics could reduce integrity of DNA and RNA (Zeng *et al.,* 2001). In addition, aqueous extracts of *O. sativa* can increase indoleacetic acid oxidase activity of receptor plants, and then reduce the level of indoleacetic acid (Zeng *et al.,* 2001).

Einhelling (2002) reported that individual compounds can have multiple phytotoxic effects on a plant. There was a reduction in radicle growth of the germinating seeds because the seeds allelopathic might have contained allelochemicals that affected the enzymes responsible for plant hormons synthesis (Fujii *et al.,* 1991). There is an inhibitory effect on root elongation when the root comes into contact with the matter with inhibitory chemicals as described in early works with various crops and weeds (Qasem, 1995).

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