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Germination responses of wild mustard (*Sinapis arvensis*) to interaction effect of water potential and temperature

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Abstract

Wild mustard is one of the third common weed in wheat field of Iran. Knowledge of the germination requirements of wild mustard will help in determining the favorable conditions for germination and emergence and allow better management of this weed. This experiment was conducted to determine the effects of simulated dry conditions (use PEG) and temperature on seed germination of wild mustard (Sinapis arvensis). Over a 21d period, germination was studied in seven growth chambers with of 5, 10, 15, 20, 25, 30 and 35°C constant temperatures and water potentials of 0, -0.2, -.04, -.06, -0.8 and -1.0 MPa at seven temperatures. Seeds used in this experiment were harvested seeds from wheat field of Kermanshah-Iran. Result showed in all temperatures increase in water potential caused to reduce in final germination and germination index. More than 60% of the seeds germinated in first seven days at water potentials of 0.0 MPa when temperature was lower than 25°C and at water potential of -0.2 MPa when temperature was 20-25°C but the germination was reduced in solutions of lower than -0.4 MPa. The final germination was most at 10-20°C, intermediate at 5°C, and least at 30-35°C. If the growth condition is favorable, the finish germination seed of Wild mustard within 10 days.

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Introduction

Wild mustard (*Sinapis arvensis* L.) is a third common annual weed in the wheat field of Iran (Minbashi *et al.*, 2008) that is often controlled by herbicides (zand *et al.*, 2010). As a result, herbicide-resistant biotypes of *S. arvensis* have developed in many countries (Heap, 2013) and the increasing public pressure for more sustainable crop production methods have led to an increasing interest in integrated weed control strategies (Burki *et al.*, 1997) based on mechanical, physical, or biological control. However, the establishment of effective integrated weed management systems depends on a detailed understanding of weed biology and ecology (Siriwardana and Zimdahl, 1984). The ability to predict seed germination in response to environmental conditions is essential for better timing of mechanical and biological control treatments, thus reducing the need for herbicides. Germination is one of the important stages in plant life cycle (Windauer *et al.*, 2007). For control of weeds, predict time of weed seedling emergence is a critical step in developing simulation models that supplement integrated weed management (IWM) systems (Meyer *et al.,* 2000; Martinson *et al.,* 2007; Masin *et al.,* 2005; Gulden *et al.,* 2003; Schutte *et al.,* 2008; Batlla and Benech-Arnold, 2007) Also, understanding of germination and emergence of weed seeds would help to predict their potential spread into new areas (Ghersa *et al.*, 2000).

Each plant species has a specific range of environmental requirements necessary for germination (Baskin and Baskin, 2001). Seed germination is a complex biological process that is influenced by various environmental such as temperature, light, pH and soil moisture, and genetic factors (Shafii and Price, 2001; Chachalis and Reddy, 2000). Temperature is a major environmental factor that affects the seed germination capacity and germination rate (Kamkar *et al.*, 2012, Kebreab and Murdoch, 2000). Temperature has an impact on a number of processes that regulate seed germination, including membrane permeability and the activity of membrane-bound and cytosolic enzymes (Tlig *et al.*, 2008). Germination rate usually increases linearly with increasing temperature up to an optimum point, and then decreases linearly to a ceiling temperature (Steinmaus *et al.*, 2000; Bradford, 2002). Optimum temperature is a temperature that seed showed highest germination in minimum time (Alvarado and Bradford, 2002).

Too, germination of many plant was affected by water potential of soil that simulated by poly ethylene glycol (Rashed-Mohassel *et al.*, 2012; Biligetu *et al.*, 2011; Kazerooni Monfared *et al.*, 2012). Seeds must reach a critical water content to trigger cell elongation and initiate radicle emergence (Bradford, 1995). Seed germination rates generally decrease with decreases in water potential, which is always associated with failure of plant emergence (Willenborg *et al.*, 2005). In addition, water and temperature often interact in regulating seed germination. For example, seeds are capable of germinating at higher levels of water stress at optimum temperatures (Kebreab and Murdoch, 1999).

This study was conducted to understand the effect of two environmental conditions on germination of wild mustard and predict seed germination of that in response to water potential and temperature and know better time to mechanical and biological control treatments, and after that reduce the need for herbicides.

The aim of this study was to identify wild mustard germination population from the Iranian wheat field, response to various temperature and water potentials.

Materials and methods

Seed source

Seeds of wild mustard were collected from irrigated wheat field (silty-clay soil) in Kermanshah (38°15' N., 68°91' W elevation 1333m), west province of Iran in spring 2012 and seed was stored at 5°C in a seed storage room prior to this study.

Germination test

Polyethylene glycol (PEG7000) was dissolved in distilled water to make 5 solutions that had the osmotic potentials of -0.2, -0.4, -0.6, -0.8 and -1.0 MPa, using the method described by Michel (1983). Distilled water was used as the control (0.0 MPa). Germination tests were done in darkness at range of temperatures include of 5, 10, 15, 20, 25, 30 and 35°C. A randomized complete block design with four replicates was used and replicates were placed into growth chambers. For each replicate, treatments of temperature and water potential were randomly applied to the experimental unit of 50-seed samples. Twenty five seeds were imbibed in 9 cm sterilized Petri dishes on top of two layers of filter paper (Whatman 597) that were moistened by adding 5 ml of distilled water or PEG solutions. The Petri dishes were enclosed and sealed in polyethylene bags to prevent desiccation. Germination counts were made daily for 21 days and germinated seeds were removed. Seeds with a radicle greater than 2 mm were considered germinated. For this study, an excellent fit was obtained using logistic model function to cumulative germination percentage in front of time (Kamkar *et al*., 2012).

$$G = \frac{G_X}{1+\exp[a(t-b)]}$$

Where, 'Gx' is the maximum germination percentage, 'b' is the time for 50% germination and 'a' is a parameter.

Statistical analysis

The germination speed (GS) was calculated as $GS=\sum Si/Di$ (Maguire, 1962) where "Di" is the number of days after sowing and "Si" is the number of seeds germinated on day "i". A two-way analysis of variance (ANOVA) was conducted for final germination and GS using the PROC MIXED procedure of SAS (Littel *et al*., 1996) with temperature, water potential, and their interaction as fixed effects, and replicate as a random effect. The means were compared by Duncan's Multiple Range Tests at 0.05 confidence level by the use of MSTAT-C computer programs.

Results

Result showed that requirement time to first germination was decreased by increase in temperature from 5 to 20°C, but by increase in temperature above 20°C, seed need more time to germination (Fig 1).

At 5°C, seeds germinated from first day in distilled (0.0 MPa) and in -0.2 MPa, and after 3 days in PEG solution of -0.4 MPa (Fig 1). The germination was delayed greatly when the water potential was -0.6 MPa, which the first germination occurred after 6 days. At 5°C, the final germination reached 76, 32, 13, 4%, respectively, in distilled water or PEG solutions of -0.2, -0.4, and -0.6 MPa. No germination occurred in -0.8 and -1.0 MPa solution at this temperature.

At 10°C, seeds germinated from first day in distilled (0.0 MPa) and -0.2 MPa, but in -0.4 and -0.6 MPa seed germinated after 3 days. In PEG solution of -0.6 and -0.8 MPa, first germination begun after 4 and 8 days respectively (Fig 1).The final germination was 86, 68, 33, 9, 3, and 2 respectively, in distilled water or PEG solutions of -0.2, -0.4, -0.6, -0.8 and -1.0 MPa (Fig 1).

At 15°C, germination occurred after only 1 day in distilled (0.0 MPa) and -0.2 MPa, after 2, 3, 8 and 5 days in -0.4, -0.6, -0.8 and -1.0 MPa respectively (Fig 1). The final germination percentages averaged across temperatures were 89, 73, 50, 19, 5 and 7%, respectively, in distilled water or PEG solutions of -0.2, -0.4, -0.6, -0.8 and -1.0 MPa (Fig 1).

The least requirement time to germination occurred at 20°C, where seeds germinated after only 1 day in distilled (0.0 MPa) and -0.2 MPa PEG solution, after 2 days in -0.4 and -0.6 MPa PEG solution, and after 4 days in -0.8 and -1.0 MPa PEG solution (Fig 1). The most germination percentages was observed at 20°C where, in distilled water or PEG solutions of -0.2, -0.4, -0.6, -0.8 and -1.0 MPa final germination percentage was 93, 76, 54, 26, 12 and 7%, respectively, (Fig 1).

At 25°C, seeds germinated from first day in distilled (0.0 MPa) and -0.2 MPa, and after 3 days in PEG solution of -0.4 and -0.6 MPa (Fig 1). The germination was delayed greatly in -0.8 and -1.0 MPa, where first germination occurred after 5 and 8 days respectively. At this temperature, the final germination reached 78, 58, 38, 15, 3 and 1 %, respectively, in distilled water or PEG solutions of -0.2, -0.4, and -0.6 MPa.

At 30°Cseed germination from first day only in distilled (0.0 MPa) and in PEG solution of -0.2, -0.4, -0.6, and -0.8 MPa, first germination was observed after 2, 4, 4, and 5days (Fig 1). At this temperature, the final germination extremely decreased as final seed germination was 41, 27, 13, 10, 2respectively, in distilled water or PEG solutions of -0.2, -0.4, -0.6 and -0.8 MPa and no seed germination occurred in -1.0 MPa (Fig 1).

At 35°Cseeds of wild mustard showed the least seed germination power. In this temperature no seed germination occurred after1 day and germination started from second day in distilled water (0.0 MPa). In PEG solution of -0.2 and -0.4 MPa after 4 days and in -0.6 MPa after 6 days, first germination occurred (Fig 1). Also final seed germination was very low, as in distilled water or PEG solutions of -0.2, -0.4, and -0.6 MPa final seed germinations was 31, 16, 10, and 2% but no seed germination occurred in -0.8 and -1.0 PEG solutions (Fig 1).

Temperature, water potential, and their interaction had a significant effect (P<0.001) on final germination (percentage after 21 days), germination index and mean daily germination of wild mustard seeds (table 1).

Table 1. Analysis of variance of the traits under study.

treatment	d.f	Mean of Square	
		Final Germination	germination index
Water potential	5	4076.5**	8.26**
Temperature	6	21296.2**	45.81**
Interaction	42	495.2**	1.57**
Error	126	49.7	0.41

**: Significant at the 0.001 level of probability.

The final germination was most at 10-20°C, intermediate at 5°C, and least at 30-35°C. The final germination percentage decreased with the decrease of water potential, and this decrease was most significant at lower temperature of 5 (Fig 1). At all temperatures, germination percentage in distill water (0 MPa) and after that PEG solution of -0.2 MPa significantly were more than other PEG solutions and this objective in PEG solutions of -1.0 and -0.8 MPa were significantly less than other tested PEG solutions. Also difference between final germination of -1.0 and -0.8 MPa in all temperatures, expect 20 and 30°C, was not significant. The final germination averaged across temperatures were71, 50, 30, 12, 4 and 2%, respectively, in distilled water or PEG solutions of -0.2, -0.4, -0.6, -0.8, and –1.0 MPa (Fig 2) and the final germination percentages averaged across the PEG solutions were 21, 34, 40, 45, 32, 16 and 10%, respectively, in distilled water or PEG solutions of -0.2, -0.4, -0.6, -0.8 and -1.0 MPa (Fig 2).

Result showed that in all PEG water solutions, germination speed (GS) increased with the increase of temperature until 20°C but after that increase of temperature caused to decrease in GS. Also, at all temperatures, the maximum GS occurred in distill water and with the increase of water potential, GS decreased, as the least GS occurred in -0.8 and -1.0 MPa (Fig 2). Too, the effect of both temperature and water potential on GS was more severe than the effect of them on final germination.

Discussion

In this study, the optimum temperature requirement for germination of wild mustard was constant temperature between 15-20°C. The germination recorded for the lower water potential in the present study was slightly lower than the response reported by Soltani *et al* (2013) using an ecotype from Gorgan, North city of Iran. Wild mustard is distributed in wide range of ecological territory and in wheat, rapeseed and barley field of Iran (Minbashi *et al.,* 2010). This diverse adaptation to soil and climate may result in variance of seed germination among ecotypes. The ecotype grown in a drier region has adapted to its environment and may have a greater germination capacity in low water potential (Biligetu *et al*., 2011).

In the semiarid Kermanshah western of Iran, low and erratic precipitation in combination with high transpiration rate contributes to extremely limited water availability most of the year. Seeds that are able to germinate during short term moisture availability increase the chance of greater seedling emergence. In the present study, more than 60% of seeds germinated within 96h, reaching maximum germination (over 90%) within 10 days under optimum temperature with adequate moisture availability. This suggested that the population can establish easily under favorable growth conditions. Even though the germination was reduced in solutions of water potential lower than –0.4 MPa, only 7% of Wild mustard seeds germinated at a low water potential of –1.0 MPa within 21 days at 15-25°C but at 5, 30 and 35°C, no germinated seed was showed. This indicates that this ecotype of wild mustard cannot germinate under low water availability.

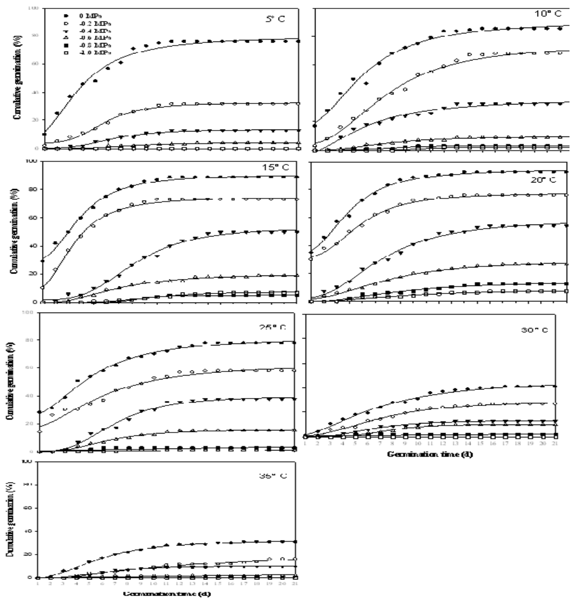

Fig. 1. Fitted (solidline) and observed germination (curves) of wild mustard (*Sinapis arvensis*) for temperatures 5, 10, 15, 20, 25, 30 and 35°C in water potentials of 0, -0.2, -0.4, -0.6, -0.8 and -1.0 MPa.

World have become warmer and drier over the last four to five decades and a further decrease of precipitation is predicted (Cutforth, 2000). The inability of wild mustard to germinate in warmer and drier condition suggests that this species cannot grow well under this changing environment.

This study has demonstrated that wild mustard cannot germinate under various temperature and water potential regimes, and have high germination in 15 and 25°C, and a water potential greater than –0.4 MPa is necessary to reach higher level of germination. We can use this result in no chemical control of this species and grow some species that resistant to drought stress and high temperatures in germination stage, for control of wild mustard.

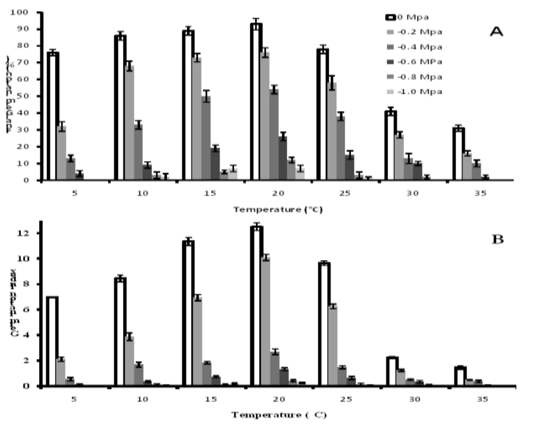

Fig 2. Final germination (A), Mean Daily germination (B) and Germination Index of wild mustard under different water potentials and temperatures. Error MPas represent ±SE of the mean.

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