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Effects of some environmental factors on annual weed shepherd's purse (*Capsella bursa-pastoris* (L.) Medik.)

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Abstract

Shepherd's purse (*Capsella bursa-pastoris* (L.) Medik.) is an annual weed species with a wide distribution in cereals of East Azarbaijan, Iran. Tow experiments were carried out based on randomised complete block design with four replications in Tabriz, Iran in 2014 to evaluate the effects of salinity and drought stress on shepherd's purse germination and early seedling growth. The salinity levels were included 0, 4, 8, 12, 16 and 20 dS m^{-1} (deci Siemens per meter) sodium chloride (NaCl). The drought stress levels were included 0, -0.4, -0.8, -1.2, -1.6 and -2.0 MPa osmotic potentials were obtained by polyethylene glycol 8000 as osmotica. Results indicated that the effect of salinity was significant on seed germination percentage and rate, seedling root and shoot length and seedling dry weight. The all traits reduced significantly by increasing the salinity level. In salinity of 20 dS m^{-1} the germination% of shepherd's purse was < 35 and the seedling dry weight reduced 65% in comparison with control (0 dS m^{-1}). Also the effect of drought stress was significant on seed germination, seedling length and seedling dry weight and all the traits decreased by increasing the osmotic potential. The germination% of shepherd's purse seeds in osmotic potential of -2.0 MPa was < 32 and the reduction in seedling dry matter was > 60%. Generally, it could be concluded that drought stress such as limited irrigation and salinity would be effective strategy for reduction in germination and early seedling growth of this annual weed species.

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Introduction

Crop growth and yield could be affected by weed species through allelopathy (Amini *et al.*, 2009) or competition (Amini *et al.*, 2014a). Shepherd's purse (*Capsella bursa-pastoris* (L.) Medik.) is a facultative winter annual plant that grows from a taproot (Hakansson, 1983). Small white flowers appear in terminal clusters. Siliqules are triangular with approximately 20 seeds each. Seeds are round to oblong and dull orange (Royer and Dickinson, 1999). Hurka and Haase (1982) recorded a minimum of 500 seeds per plant and a maximum of 90,000 seeds per plant. *Capsella bursa-pastoris* occurs in Africa, Asia, Australia, Europe, North America, and South America (Holm *et al.*, 1979). In East Azarbaijan of Iran, Shepherd's purse is most prevalent in winter crops such as wheat, barley, chickpea, lentil and oilseed rape (Shimi and Termeh, 2004).

Successful establishment of species is often dependent on the results of seed germination responses to environmental factors (Amini and Izadkhah, 2013; Amini *et al.*, 2014b). Germination and early seedling growth are the most critical factors for establishment of plant species (Bani-Aameur and Sipple-Michmerhuizen 2001). Environmental factors such as temperature, soil osmotic potential, pH, light, seed burial depth, crop residues and management practices affect seed germination and emergence of weeds (Luzuriaga *et al.* 2006; Mobli *et al.*, 2014; Ganepour *et al.*, 2014). Amini and Abdi (2014) observed that osmotic stress and salinity significantly reduced the germination and early seedling growth of common purslane (*Portulaca oleracea* L.). Baskin *et al.* (2004) found that most seeds of Shepherd's purse that mature in late summer do not germinate in the first autumn, but they may do so the following spring or in subsequent autumn.

In recent years *C. bursa-pastoris* has spread exponentially and is now a very important weed in winter crops such as wheat, barley and oilseed rape (*Brassica napus* L.) in the East Azarbaijan region of Iran. Assessment of germination behaviour of *C. bursa-pastoris* could play a crucial role in developing suitable management strategies for this winter weed species in the cropping systems. So, the present study was conducted to evaluate the effects of salinity and drought stress on seed germination and seedling growth of *C. bursa-pastoris*.

Materials and methods

Plant materials

Experiments were carried out at the Weed Ecology Laboratory of the University of Tabriz, Tabriz, Iran in 2014. Seeds of *C. bursa-pastoris* were collected during May-June 2013 from a naturally occurring population in the wheat and barley fields of East Azarbaijan province, Iran (latitude 38.050 N, longitude 46.170 E, Altitude 1360 m above sea level). The climate of the location is characterized by mean annual precipitation of 245.75 mm, mean annual average temperature of 10°C, mean annual maximum temperature of 16.6°C, and mean annual minimum temperature of 4.2°C. Collected fruits of *C. bursa-pastoris* were dried at room temperature cleaning by hand-sorting, involving piece by piece removal of debris and rubbish produced a clean seed collection. The seeds were dried for several days at room temperature and then stored in paper bags under the same conditions until used in the experiments.

Salinity experiment

In this experiment, 50 selected ripened seeds were surface sterilized in 5.0% sodium hypochlorite solution for 5 min, and then were rinsed with distilled water thoroughly. Sodium chloride (NaCl) solutions of 4, 8, 12, 16 and 20 deci Siemens per meter (dS m^{-1}) were prepared to induce levels of salinity stress. Salinity of 0 dS m^{-1} was considered as control. The seeds were placed equidistant in covered Petri dishes (9 cm diameter) containing sterilized filter paper which was moistened with either distilled water or appropriate experimental solutions. The treatment solutions were drained off from the germination media and replaced with 5 ml fresh solutions at 2-day intervals to avoid the effect of seed leachates. The *C. bursa-pastoris* seeds were incubated for 14 d under conditions of 20/10°C in light / dark (12/12 h) period.

Drought stress experiment

The osmotic potentials including 0, -0.4, -0.8, -1.2, -1.6 and -2.0 MPa were obtained in solutions by dissolving appropriate amounts of polyethylene glycol 8000 (PEG- Michel 1983) in deionized water as osmotica. The *C. bursa-pastoris* seeds were incubated for 14 d under conditions of 20/10°C in light/dark (12/12 h) period.

Data collection and statistical analysis

Germination (protrusion of radicle by 1 mm) was recorded every day. Final germination percentage (G) was calculated as follows (Maguire, 1962):

$$G\ (\%) = \frac{G_s}{T_s} \times 100 \quad (1)$$

Where Ts is the total number of seeds and Gs is the number of germinated seeds at the end of the 14 d period.

Germination rate (S) was calculated as follows (Maguire, 1962):

$$S = \sum \frac{E_n}{N_n} \quad (2)$$

Where E_n is the number of seeds germinated in the n^{th} daily counting, and N_n is the number of days to germination in the n^{th} counting.

Also the seedling root and shoot length and seedling dry matter were recorded. All experiments were carried out twice as a completely randomized design with four replications per treatment. The data of the experiments were subjected to analysis of variance (ANOVA). The SAS Version 9.0.3 was used for ANOVA. The data that were used in ANOVA met the assumptions such as normality and homogeneity of variance and did not require transformation. The Duncan multiple range test was used to compare the means at $P \leq 0.05$

Results and discussion

Salinity stress

The results indicated that the effect of salinity was significant ($p \leq 0.05$) on seed germination (%) of *C. bursa-pastoris* (Fig. 1A). By increasing the salinity from 0 to 4 dS m^{-1}, the germination (%) of *C. bursa-pastoris* reduced significantly in comparison with control (0 dS m^{-1}) treatment. Increasing the salinity levels from 4 to 16 dS m^{-1} reduced germination percentage significantly in comparison with control. The salinity levels of 16 and 20 dS m^{-1} had the lowest germination percentage among the salinity levels.

The effect of salinity level was significant ($p \leq 0.05$) on seed germination rate of *C. bursa-pastoris* (Fig. 1B). By increasing the salinity from 0 to 8 dS m^{-1}, the germination rate of *C. bursa-pastoris* reduced significantly in comparison with control (0 dS m^{-1}). Increasing the salinity level from 8 to 20 dS m^{-1} reduced germination rate significantly in comparison with control. There was no significant difference among germination rate of 16 and 20 dS m^{-1} salinity levels. Similarly, germination of *Ipomoea purpurea* (Singh *et al.*, 2012) was also inhibited at salt concentrations ≥ 200 mM. Germination of texas weed (*Caperonia palustris*) was only 27% at 160 mM NaCl (Koger *et al.,* 2004). The same physiological mechanisms may facilitate rapid seed germination under salinity and water stress conditions (Foolad *et al.*, 2007).

The effect of salinity stress was significant on seedling root length ($p \leq 0.05$). The salinity levels of 4 and 8 dS m^{-1} reduced seedling root length significantly (Fig. 1C). Also there was no significant different between seedling root length of *C. bursa-pastoris* in 8 and 12 dS m^{-1} salinity levels. The seedling root length was reduced as the salinity increased from 12 to 16 dS m^{-1}. There was no significant different between root length of 16 and 20 dS m^{-1}. The effect of salinity stress was significant on seedling shoot length ($P \leq 0.05$). Increasing the salinity level from 0 to 4 and 8 dS m^{-1} reduced the seedling shoot length of *C. bursa-pastoris* (Fig. 1D). Increasing the salinity level from 8 to 12 dS m^{-1} had no significant effect on seedling shoot length of *C. bursa-pastoris*. Increasing the salinity level from 16 to 20 dS m^{-1} had no significant effect on seedling shoot length of *C. bursa-pastoris* and the salinity level of 20 dS m^{-1} had the lowest seedling shoot length.

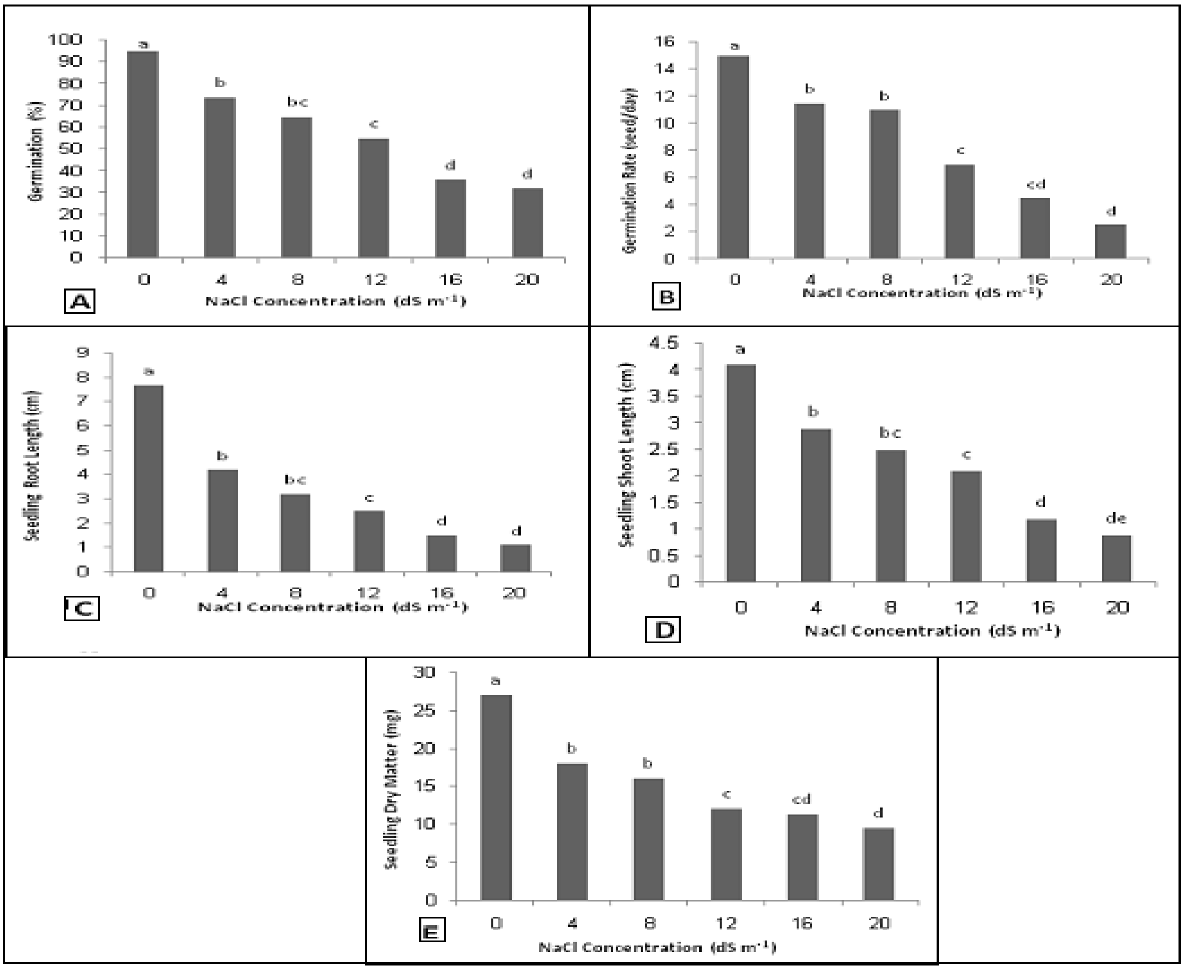

Fig. 1. Effect of salinity on seed germination (%) (A) germination rate (B), seedling root length (C), seedling shoot length (D) and seedling dry matter (E) of *C. bursa-pastoris*. Different letters indicate significant difference at $p \leq 0.05$.

The effect of salinity stress was significant on seedling dry matter ($p \leq 0.05$). Increasing the salinity level from 0 to 4 and 8 dS m^{-1} significantly reduced the seedling dry matter (Fig. 1E). Increasing the salinity level from 12 to 20 dS m^{-1} caused significant reduction in seedling dry matter of *C. bursa-pastoris*. The seedling dry matter between 16 and 20 dS m^{-1} salinity level was not significantly different and the salinity level of 20 dS m^{-1} had the lowest seedling dry matter of *C. bursa-pastoris* among the salinity levels. Ganepour *et al.* (2014) also observed that increasing the NaCl concentration from 0 to 30 dS m^{-1} significantly reduced the seedling length and dry weight of pepperweed (*Lepidium perfoliatum* L.).

Drought stress

Analysis of variance indicated that the effect of drought stress was significant ($P \leq 0.05$) on seed germination (%) of *C. bursa-pastoris* (Fig. 2A). By increasing the osmotic potential from 0 to -0.4 MPa, the reduction in germination (%) of *C. bursa-pastoris* was not significant in comparison with control (0 MPa) treatment. Increasing the osmotic potentials from -0.4 to -2.0 MPa reduced germination percentage significantly in comparison with control. The osmotic potential of -2.0 MPa indicated the highest inhibition in germination percentage of *C. bursa-pastoris* among the osmotic potentials. The germination rate of *C. bursa-pastoris* was affected significantly by osmotic potentials ($P \leq 0.05$). By increasing the osmotic potential from 0 to -0.4 and -0.8 MPa, the germination rate of *C. bursa-pastoris* reduced significantly in comparison with control (0 MPa) (Fig. 2B). By increasing the osmotic potential level from -1.2 to -2.0 MPa the germination rate reduced significantly in comparison with control (0 MPa). There was no significant difference among germination rates of -0.8 and -1.2 MPa osmotic potentials. Inhibition of germination at higher osmotic potentials may relate to the moisture deficit in the seeds below the threshold essential for germination (Everitt, 1983).

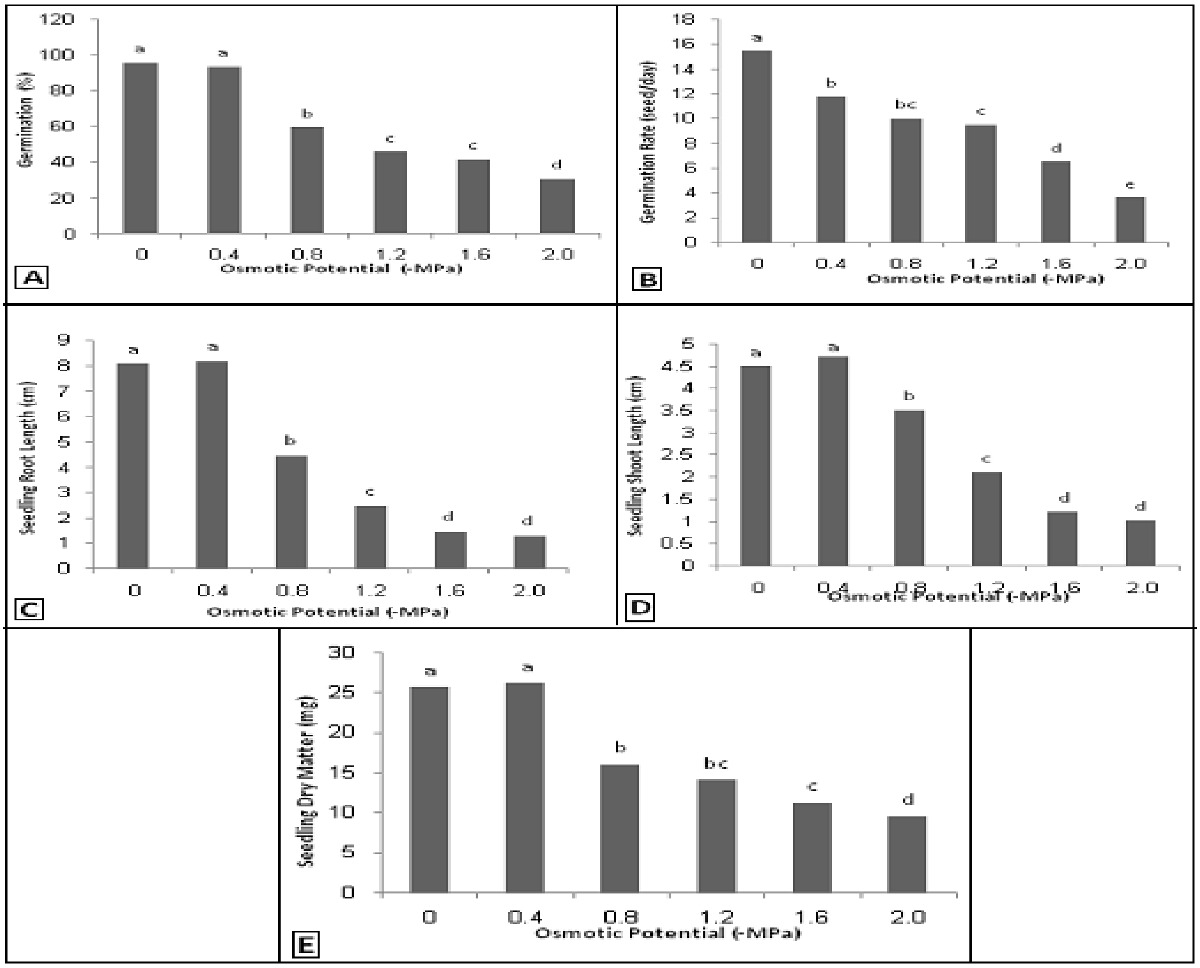

Fig. 2. Effect of osmotic potential on seed germination (%) (A) germination rate (B), seedling root length (C), seedling shoot length (D) and seedling dry matter (E) of *C. bursa-pastoris*. Different letters indicate significant difference at $P \leq 0.05$.

Germination inhibition under drought stress might be an important survival mechanism that ensures seed dormancy within the soil until sufficient water is available for successful seed germination (Chauhan and Johnson, 2009). The tolerance of a particular weed species to water deficit may be related its distribution ecology (Chauhan and Johnson, 2009). Zhou *et al.* (2005) reported that *Solanum sarrachoides* germination percentage was 93, 84 and 17 at osmotic potentials of 0, -0.3 and -1.0 MPa, respectively. Germination of *Caperonia palustris* (Koger *et al.*, 2004) seeds at a water potential of -0.8 MPa were only 9 and 10%, respectively.

The seedling root length was affected significantly by osmotic potential ($P \leq 0.05$). Increasing the osmotic potential from 0 to -0.4 MPa had no significant effect on seedling root length (Fig. 2C). But by increasing the osmotic potential from -0.4 to -1.6 MPa the seedling root length of *C. bursa-pastoris* reduced significantly. Also the -2.0 MPa osmotic potential showed the highest inhibitory effect on seedling root length and was not significantly different with -1.6 MPa osmotic potential.

The seedling shoot length also was affected significantly by drought stress ($P \leq 0.05$). The seedling shoot length was not significantly different at osmotic potentials of 0 and -0.4 MPa (Fig. 2D) as it was increased in -0.4 MPa osmotic potential. The seedlings shoot length decreased as the osmotic potential increased from -0.4 to -1.6 MPa. There was no significant different between seedling shoot length at -1.6 and -2.0 MPa osmotic potentials.

The effect of drought stress was significant on seedling dry matter of *C. bursa-pastoris* ($P \leq 0.05$). Increasing the osmotic potential from 0 to -0.4 MPa had no significant effect on seedling dry matter (Fig. 2E). The seedling dry matter was reduced as osmotic potential increased from -0.4 to -0.8 MPa. The difference between seedling dry matter of osmotic potential of -0.8 and -1.2 MPa was not significant, but increasing the osmotic potential to -1.6 and 2.0 MPa reduced seedling dry matter significantly. Mobli *et al.* (2014) also reported that increasing the osmotic potential higher than -0.1 MPa significantly reduced the seedling length and seedling dry weight of hoary cress (*Lepidium draba* L.). The germination and early seedling growth of *C. bursa-pastoris* was affected adversely by increasing the drought stress as we observed that in osmotic potential of -2.0 MPa the seed germination% was < 32 and the reduction in seedling dry matter was > 60%. Therefore, water limitation in the field such as limited irrigation would be effective strategy for reduction in germination and early seedling growth of this winter annual weed species. Reduction of osmotic potential is the well-known result of combined salinity and drought stresses. This means that under both these abiotic stresses, the plant loses its internal osmotic potential (Yan *et al.*, 2012).

In the study, the magnitude of the adverse impact of salinity on germination of *C. bursa-pastoris* was dependant on NaCl concentration (Fig. 1). In salinity of 20 dS m^{-1} the seed germination% was < 35 and the reduction in seedling dry matter was > 65%. Ramirez *et al.* (2012) considered *Bidens alba* as a moderately-tolerant weed species to salinity stress. They observed that *Bidens alba* is able to germinate over a wide range of salinity stress (10 to 160 mM NaCl) but at 320 mM NaCl germination was completely inhibited. According to these results, it is likely that *C. bursa-pastoris* seeds could not tolerate high salinity stress at the germination and early seedling growth stage and this weed species infest the soils with low levels of salinity.

Haghverdi *et al.* (2011) reported a range of 7-27 dS m^{-1} salinity in East Azarbaijan soils. Therefore, it could be considered that weed species that did not germinate under salinity condition could not also tolerate low water potential and germinate under drought stress. The main challenge for the plant in saline soils is that, since the external osmotic potential is much less than in non-saline soils, high amount of osmotic substances must be augmented to obtain water potential slope which in turn facilitates transfer of water into the plant. On the other hand, increased concentration of ions in cytoplasm will eventually lead to toxic concentrations (Gulick and Dvorak, 2000; Gouia *et al.*, 2004).

Conclusion

The findings about the germination response of *C. bursa-pastoris* to salinity and drought stress will help growers to develop effective management strategies for this winter annual weed species in wheat, barley and oilseed rape. The drought stress and salinity could not suppress germination and seedling growth of *C. bursa-pastoris* completely; therefore, additional management strategies would need to be considered to achieve suitable and acceptable weed management.

When it uses these strategies in order to suppress the weed growth and development in the cropping systems, the need for chemical herbicide use and tillage will be reduced that will be consistent with sustainable agriculture and integrated weed management. Also when it uses salinity and drought stress for delaying in seed germination and seedling growth of *C. bursa-pastoris* in the cropping systems, it should consider the crop growth and yield loss, simultaneously.

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