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Germination and early seedling growth of common purslane (*Portulaca oleracea* L.) affected by salinity and osmotic stress

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Abstract

Common purslane (*Portulaca oleracea* L.) is an annual weed species with a wide distribution in warm season crops in East Azarbaijan, Iran. Tow experiments were carried out based on randomised complete block design with four replications in Tabriz, Iran in 2013 to evaluate the effects of salinity and osmotic stress on *P. oleracea* germination and early seedling growth. The salinity levels were included 0, 5, 10, 15, 20 and 25 dS m^{-1} (deci Siemens per meter) sodium chloride (NaCl). The osmotic stress levels were included 0, -0.3, -0.6, -0.9, -1.2 and -1.5 MPa 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 25 dS m^{-1} the germination% of *P. oleracea* was < 40 and the seedling dry weight reduced 70% in comparison with control (0 dS m^{-1}). Also the effect of osmotic stress was significant on seed germination, seedling length and seedling dry weight and all traits decreased by increasing the osmotic potential. The germination% of *P. oleracea* seeds in osmotic potential of -1.5 MPa was < 35 and the reduction in seedling dry matter was > 80%. We can conclude that water limitation in the field 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

Weed species affect crop growth and yield by allelopathy (Amini *et al.*, 2009) or competition (Amini *et al.*, 2014a). Common purslane (*Portulaca oleracea* L.), is an annual herb with succulent, fleshy stems that may grow erect or prostrate, depending on light availability. It thrives in cultivated fields and gardens, barren driveways, waste places and eroded slopes and is considered a serious weed of 45 crops in 81 countries in the tropics and subtropics. *P. oleracea* is a principal weed of rice (*Oryza sativa* L.), corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), sugarcane (*Saccharum officinarum* L.) and vegetables (Holm *et al.*, 1991). In East Azarbaijan of Iran, *P. oleracea* is most commonly found in warm season crops such as corn, potato (*Solanum tuberosum* L.) and sunflower (*Helianthus annuus* L.) (Shimi and Termeh, 2004).
Germination and early seedling growth are the most critical factors for establishment of plant species (Bani-Aameur & Sipple-Michmerhuizen 2001). Successful establishment of species is often dependent on the results of seed germination responses to environmental factors (Chauhan *et al.*, 2006; Chauhan & Johnson 2010; Amini and Izadkhah, 2013; Amini *et al.*, 2014b). 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; DeCauwer *et al.*, 2014; Mobli *et al.*, 2014; Ganepour *et al.,* 2014). *P. oleracea* occurs in disturbed areas, temporary grasslands, and arable land. Temperature was a determinant factor in the germination of *P. oleracea* as 96% germination recorded under alternating day/night temperatures of 35/20C and 15% germination under 25/10C (Miyanishi & Cavers, 1980).

In recent years *P. oleracea* has spread exponentially and is now a very important weed in warm season crops and vegetables in the East Azarbaijan region of Iran. Assessment of germination behaviour of *P. oleracea* might play a crucial role in developing a better management strategy for this weed species in the cropping systems. Hence, the present study was undertaken to examine the effect of salinity and osmotic stress on seed germination early seedling growth of *P. oleracea*.

Materials and methods

Plant material

Experiments were carried out at the Weed Ecology Laboratory of the University of Tabriz, Tabriz, Iran in 2013. Seeds of *P. oleracea* were collected during September 2012 from a naturally occurring population in the 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 *P. oleracea* 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 3.0% sodium hypochlorite solution for 3 min, and then were rinsed with distilled water thoroughly. Sodium chloride (NaCl) solutions of 5, 10, 15, 20 and 25 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 *P. oleracea* seeds were incubated for 14 d under conditions of 30/20°C in light / dark (12/12 h) period.

Osmotic stress experiment

Osmotic potentials including -0.3, -0.6, -0.9, -1.2 and

-1.5 MPa were obtained in solutions by dissolving appropriate amounts of polyethylene glycol 8000 (PEG- Michel 1983) in deionized water as osmotica. The *P. oleracea* seeds were incubated for 14 d under conditions of 30/20°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):

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

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 *P. oleracea* (Figure 1A). By increasing the salinity from 0 to 5 dS m^{-1}, the germination (%) of *P. oleracea* reduced but was not significantly different with control (0 dS m^{-1}) treatment. The salinity levels higher than 5 dS m^{-1} reduced germination percentage significantly in comparison with control. The salinity of 25 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 *P. oleracea* (Figure 1B). By increasing the salinity from 0 to 5 dS m^{-1}, the germination rate of *P. oleracea* reduced but was not significantly different with control (0 dS m^{-1}). Increasing the salinity level from 5 to 20 dS m^{-1} reduced germination rate significantly in comparison with control. There was no significant difference among germination rate of 20 and 25 dS m^{-1} salinity levels. Similarly, germination of hairy *Biden spilosa* (Reddy and Singh 1992) and *Ipomoea purpurea* (Singh *et al.* 2012) were 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 ($P \leq 0.05$). Increasing the salinity stress from 0 to 5 dS m^{-1} reduced seedling root length significantly (Figure 1C). Also there was no significant different between seedling root length of *P. oleracea* in 10 and 15 dS m^{-1} salinity levels. The seedling root length was reduced as the salinity increased from 20 to 25 dS m^{-1} and the salinity level of 25 dS m^{-1} indicated the highest inhibition in seedling root length. The effect of salinity stress was significant on seedling shoot length ($P \leq 0.05$). Increasing the salinity level from 0 to 10 dS m^{-1} had no significant effect on seedling shoot length (Figure 1D). Increasing the salinity level from 10 to 25 dS m^{-1} reduced seedling shoot length of *P. oleracea* significantly. The seedling root length was reduced as the salinity increased from 20 to 25 dS m^{-1} and the salinity level of 25 dS m^{-1} had the lowest seedling shoot length.

The effect of salinity stress was significant on seedling dry matter ($P \leq 0.05$). Increasing the salinity level from 0 to 5 dS m^{-1} had no significant effect on seedling dry matter (Figure 1E). Increasing the salinity level from 5 to 15 dS m^{-1} caused significant reduction in seedling dry matter of *P. oleracea*. The seedling dry matter between 15 and 20 dS m^{-1} salinity level was not significantly different and the salinity level of 25 dS m^{-1} reduced the seedling dry matter of *P. oleracea* significantly in comparison with 15 and 20 dS m^{-1} salinity. 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.).

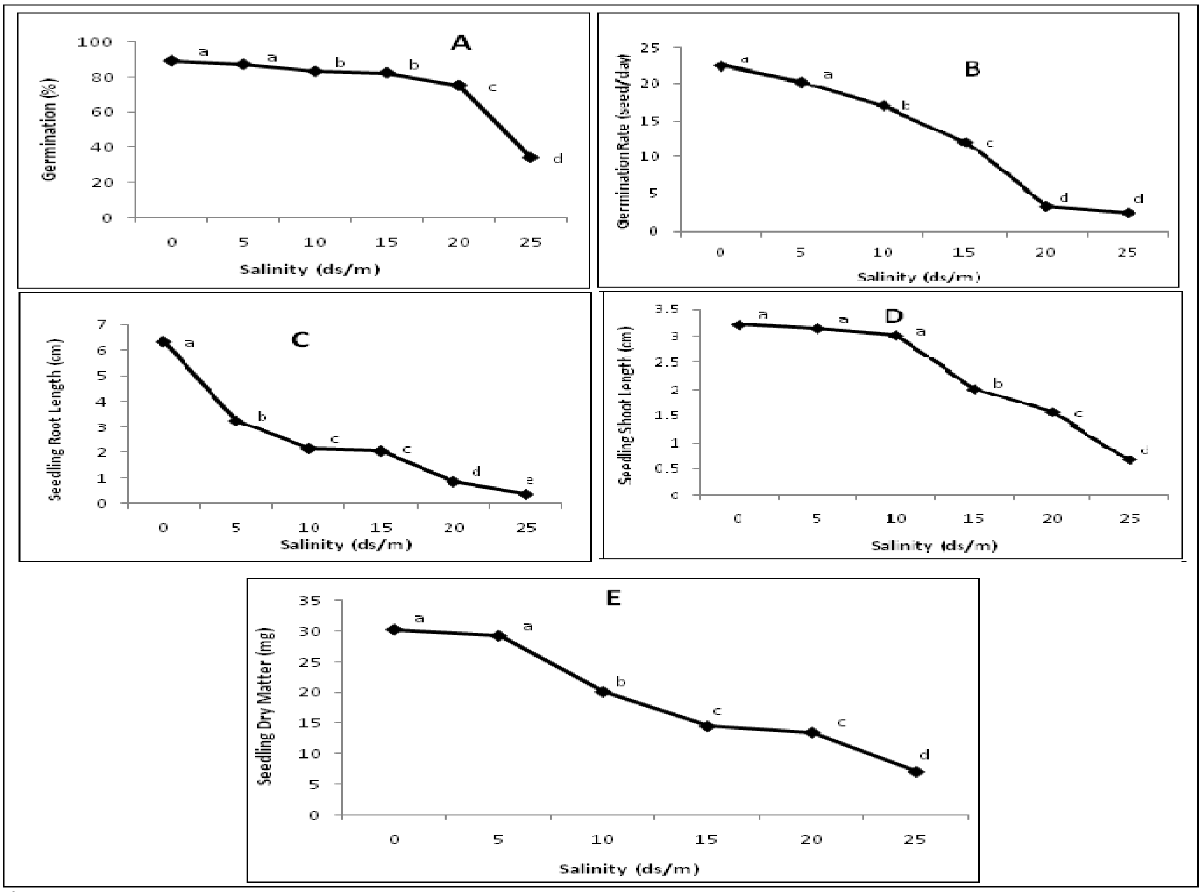

Fig. 1. Effect of salinity on seed germination (%) (A) germination rate (B), seedling root length (C), seedling shoot length (D) and seedling dry matter (E) of *P. oleracea*. Different letters indicate significant difference at $P \leq 0.05$.

Osmotic stress

Analysis of variance indicated that the effect of osmotic potential was significant ($P \leq 0.05$) on seed germination (%) of *P. oleracea* (Figure 2A). By increasing the osmotic potential from 0 to -0.6 MPa, the reduction in germination (%) of *P. oleracea* was not significant in comparison with control (0 MPa) treatment. Increasing the osmotic potentials from -0.9 to -1.5 MPa reduced germination percentage significantly in comparison with control. The osmotic potential of -1.5 MPa indicated the highest inhibition in germination percentage of *P. oleracea* among the osmotic potentials. The germination rate of *P. oleracea* was affected significantly by osmotic potentials ($P \leq 0.05$). By increasing the osmotic potential from 0 to -0.3 MPa, the germination rate of *P. oleracea* reduced but was not significantly different with control (0 MPa) (Figure 2B). By increasing the osmotic potential level from -0.6 to -1.2 MPa the germination rate reduced significantly in comparison with control (0 MPa). There was no significant difference among germination rates of -1.2 and -1.5 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). 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 (Van Den Berg and Zeng 2006). The tolerance of a particular weed species to water deficit may be related its distribution ecology (Chauhan *et al.* 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) and *Eupatorium compositifolium* (MacDonald *et al.* 1992) 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 -0.3 MPa had no significant effect on seedling root length (Figure 2C). Also there was no significant different between seedling root length of *P. oleracea* in -0.6 and -0.9 MPa osmotic potential. The seedling root length was reduced as the osmotic potential increased from -0.9 to -1.2 MPa. Also the -1.5 MPa osmotic potential showed the highest inhibitory effect on seedling root length.

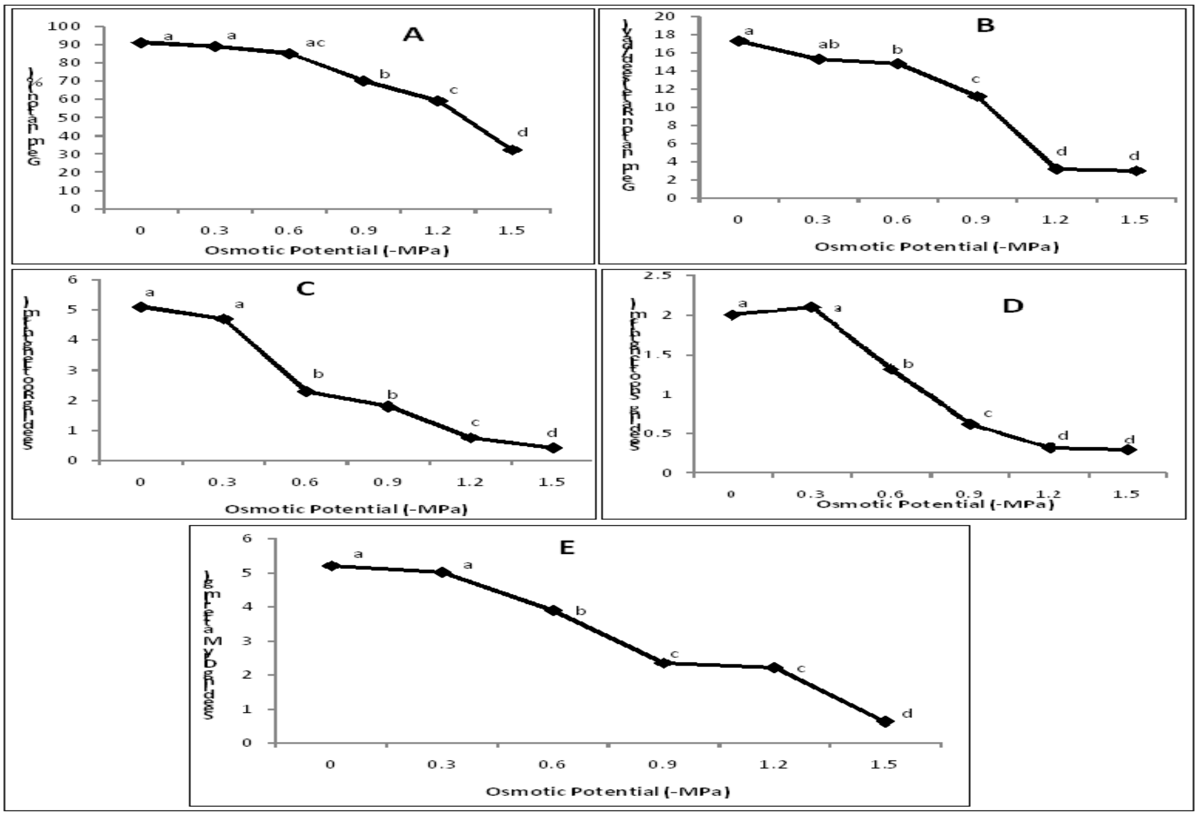

Fig. 2. Effect of osmotic stress on seed germination (%) (A) germination rate (B), seedling root length (C), seedling shoot length (D) and seedling dry matter (E) of *P. oleracea*. Different letters indicate significant difference at $P \leq 0.05$.

The seedling shoot length also was affected significantly by osmotic potential ($P \leq 0.05$). The seedling shoot length was not significantly different at osmotic potentials of 0 and -0.3 MPa (Figure 2D). The seedling shoot length decreased as the osmotic potential increased from -0.3 to -1.2 MPa. There was no significant different between seedling shoot length at -1.2 and -1.5 MPa osmotic potential.

The seedling dry matter of *P. oleracea* was affected significantly by osmotic potentials ($P \leq 0.05$). Increasing the osmotic potential from 0 to -0.3 MPa had no significant effect on seedling dry matter (Figure 2E). The seedling dry matter was reduced as osmotic potential increased from -0.3 to -0.9 MPa. The difference between seedling dry matter of osmotic potential of -0.9 and -1.2 MPa was not significant, but increasing the osmotic potential to -1.5 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.).

In our study, the magnitude of the adverse impact of salinity on germination of *P. oleracea* was dependant on NaCl concentration (Figure 1). In salinity of 25 dS m^{-1} the seed germination% was < 40 and the reduction in seedling dry matter was > 70%. 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 *P. oleracea* 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. The germination and early seedling growth of *P. oleracea* was affected adversely by increasing the osmotic stress as we observed that in osmotic potential of -1.5 MPa the seed germination% was < 35 and the reduction in seedling dry matter was > 80%. Therefore water limitation in the field such as limited irrigation would be effective strategy for reduction in germination and early seedling growth of this annual weed species. 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 osmotic stress. Our results will help growers to develop effective management strategies for this problematic weed species. The water limitation and salinity did not suppress germination and seedling growth completely; therefore, additional management strategies would need to be employed to achieve complete weed management. Also when we use salinity and drought stress for delaying in seed germination and seedling growth of *P. oleracea* in the fields, we should consider the crop growth and yield loss. Finally when we use these strategies for reduction in weed population and growth the need for herbicide application and tillage will be reduced that is consistent with sustainable agriculture and integrated weed management.

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