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# Environmental maternal effects on drought and salinity tolerance of common plantain (*Plantago major* L.) at germination and seedling growth stage

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**Key words:** Population, chloride sodium (NaCl), polyethylene glycol (PEG), germination characteristics.

**Abstract**

Drought and salinity stresses are considered as limiting factors reducing crop production all over the world. In this experiment, resistance of common plantain to different level of drought and salt is screened at germination and seedling growth stages. To do this, an experiment with completely randomized factorial design, four replications in six salinity levels of Sodium Chloride (0, 100, 200, 300, 400 and 500 mM), and six level of drought with polyethylene glycol (0, -0.2, -0.4, -0.6 and -0.8 MPa) is performed in Research Laboratory of Agricultural University of Karaj. The results show that drought and salinity stresses leave adverse effects on the growth of the studied traits, i.e. germination rate, germination percentage, radicle length, and shoot length. The experiment shows that crops in Ahwaz are more resistant to drought and salinity stresses rather than Karaj's crops. Therefore, it is detected that plant's maternal environment significantly affect germination traits of the common plantain seeds which is needed to be considered in planning for common plantain growth control.

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## Introduction

Germination is the most significant process which determines the growth rate of weeds in cultivated areas and affected by different environmental factors (Chachalis and Reddy, 2000). Studies have shown that when species of a plant grow under different environmental condition, traits expressed in their offspring as well as their response to environment would be different (Roach and Wulff, 1987). Recognizing such different behaviors in growing weeds is very important since they help understanding patterns of weed adaptation to environmental conditions. Since germination and specific environmental condition of maternal plants are related and influenced by different biological carryover, such as temperature, light, photoperiod, nutrients, and growth substances, one species in different region may indicate different germination requirement and different reactions to imposed stresses (Abin and Eslami, 2009; Golzardi *et al.*, 2012). Adaptation to maternal environment influences on germination trait of the plants including: germination percentage, weight, length of Radicle or shoot, seed dormancy, seed coat thickness, seed chemical composition (Fenner, 1991a; Fenner, 1991b; Munir *et al.,* 2001). When opposed, environmental condition can affect seed germination (Khan and Gulzar, 2003). Seed germination and emergence are critical stages of plant growth when exposed to salinity and drought stress. Usually, if the plant can tolerate the stresses in the primary stages, it can also leave in later stages as well (Sathiyamoorty & Nukamura, 1995). Salt stress induces changes in the amount and type of metabolic materials and thereby affects the plant growth rate (Arshi *et al.,* 2002; Basra & basra, 1997). Salinity effects on hormone activity and reduces the growth rate while intensifies compound hindering production process. Generally, these changes slow down growth rate and development process (Arshi *et al.,* 2002; Taiz & Zeiger, 1991). Drought stress minimizes water absorption. To germinate, all the seeds require a minimum level of dehydration and protuberance; to achieve this, environmental potential should be lower than a certain considered level. The rate of water absorption slows down with decreasing osmotic potential which leads to reduced germiniability (Alizadeh, 1990). Salinity, on one hand, reduces water potential available for the plant Radicle, on the other hand, some ions leave adverse physiological and biochemical effects; either case leads to impaired nutrient absorption in the Radicle and deteriorates the plant growth (Fenando *et al.,* 2000).

In this investigation, the potential to alter seed germination characteristics through the maternal environment was quantified. We hypothesized that variable maternal environments differentially affect seed germination under drought and salt stress. Therefore, this research was conducted to study the effects of drought and salt stresses induced by PEG and NaCl on germination and early seedling growth of common plantain (*Plantago major* L.).

## Materials and methods

In order to do the experiment, we collected the seeds of common plantain, randomly, from bushes of farms and gardens of two regions, Karaj and Ahwaz. We performed a completely randomized factorial design with four replications. Carbendazim, a fungicide, is present to sterile the seeds in 1:1000 ratio for 5 minutes. After sterilization, the seeds are washed with distilled water and let stand for a while to be dried at room temperature. Different concentration of NaCI (0, 100, 200, 300, 400, 500 mM) is applied in the experiment to test the effect of salinity on germination. To study the effect of drought stress on germination, different levels of osmatic potentials are imposed (0, -0.2, -0.4, -0.6, -0.8, -1.0 MPa). Using the following equation, our desired solutions are prepared by dissolving appropriate amount of PEG 6000 in distilled water (Michel and Kaufmann, 1973).

$$S= -(1.8\times10^{-2})\,C-(1.8\times10^{-4})C^2+(2.67\times10^{-4})\,CT+(8.39\times10^{-7})C^2T \qquad (1)$$

Where S is the solution potential in MPa, C is the concentration of PEG-6000 in g/kg $H_2O$, and T is the temperature. To assess germinability, 50 seeds are placed in a Petri-dish (8 cm) containing filter paper moistened with distilled water a desired salt concentration. Dishes are closed with parafilm to prevent evaporation of water. The petri dishes are placed in a germinator with 12 hour photoperiod and a room temperature of (18-25°C) (Pahlevani *et al.*, 2008). We observed germination daily for 14 days. In case of evaporation, some water may be added to petri dishes. The percentage germination is calculated from the total number of normal seedling from the number of seeds. Radicle and shoot length of germinated seeds are measured with a ruler after 14 days. The considered traits are calculated in the following way:

$$GP = 100 \times (N_i/S) \qquad (2)$$

Here, GP represents germination percentage, $N_i$ is the number of germinated seeds in $i^{th}$ day, and S is the total number of seedlings.

$$GR = \Sigma N_i/ T_i \qquad (3)$$

Where GR is germination rate, Ni is number of germinated seeds in the $i^{th}$ day, and Ti is number of days from start of experiment till $i^{th}$ counting.

After preliminary examinations, we tested the hypothesis of normal distribution of data. For data analysis and presentation, SAS 9.1 is used to compare means through Duncan's multiple range test and to draw charts excel software is used.

## Results and discussion

*The Effect of Salinity Stress on Germination Percentage*

Variance analysis indicates that salinity stress causes significant changes on two samples of common plantain. With increasing salinity level, germination percentage decreases (Table 1) (Fig 1). Common plantain leave germination of both samples stopped completely at 400 mM. By increasing NaCl concentration from zero to 300 mM, germination percentage of samples of Karaj and Ahwaz decreased to 94.44% and 83.33%, respectively; the rate declined from 90% to 5% in Karaj, and from 96% to 16% in Ahwaz (Fig 1). The results suggest that germinates of samples in Ahwaz are more resistant to salt stress. Golzardi *et al.* (2012), in a similar study, investigated the influence of maternal environment on germination percentage of Montpellier seeds under salinity stress and concluded that samples observed in Kerman are more resistant than samples treated in Karaj.

**Table 1.** The effect of salinity stress on germination percentage, germination rate, shoot length, and Radicle length of common plantain in two population.

| Radicle length (mm) | Shoot length(mm) | Germination speed (1/day) | Germination percentage (%) | Population | NaCl concentration (mM) |
|---|---|---|---|---|---|
| 3.45 a | 15.85 a | 13.95 b | 90 a | Karaj | 0 |
| 3.70 a | 18.70 a | 20.69 a | 96 a | Ahvaz | |
| 3.50 a | 8.70 c | 6.64 c | 40 c | Karaj | 100 |
| 3.75 a | 12.20 b | 15.72 b | 77 b | Ahvaz | |
| 3.40 a | 9.5 c | 5.58 c | 35 c | Karaj | 200 |
| 3.75 a | 8.55 c | 6.93 c | 37 c | Ahvaz | |
| 3.50 a | 3.5 d | 0.67 e | 5 e | Karaj | 300 |
| 4.05 a | 6.40 d | 3.08 d | 16 d | Ahvaz | |
| 0 b | 0 e | 0 e | 0 e | Karaj | 400 |
| 0 b | 0 e | 0 e | 0 e | Ahvaz | |
| 0 b | 0 e | 0 e | 0 e | Karaj | 500 |
| 0 b | 0 e | 0 e | 0 e | Ahvaz | |

Note: according to Duncan's test, means with common final letter in each column are not significantly different at 5%.

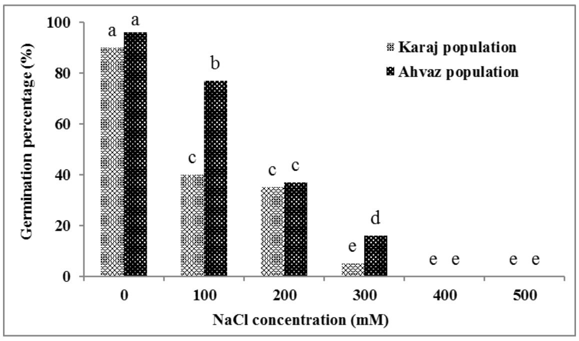


**Fig. 1.** The effect of salinity stress on germination percentage of two plantain populations.

*The Effect on Salinity Stress on Germination Rate*

Increasing salinity stress caused significant changes in germination rate of both samples of this study. Again, as far as germination rate is regarded, samples treated in Karaj seems to be more sensitive to salinity stress so that with increasing salt concentration from zero to 300 mM in both samples, germination rate declined to 95.20% and 85.11% in Karaj and Ahwaz, respectively (Fig 2). Higher germination rate of samples treated in Ahwaz demonstrate the potential of this region for planting when compared with Karaj. Abin and Eslami (2009) conducted a similar study to compare *Sonchius oleraceus* seed treatment in two regions of Ahwaz and Birjand and they observed that germination rate of both samples declines significantly as salinity stress increases. What is more, in all stress level, except for 240 and 320 mM, germination rate of samples treated in Birjand was significantly lower than Ahwaz. Gholami *et al.* (2010), carried out a test on *Vicia monantha* and reported that there is negative relationship between salinity level and germination rate.

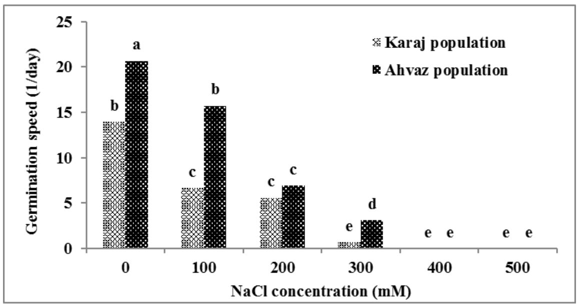


**Fig. 2.** The effect of salinity stress on germination rate of two plantain populations.

*The Effect of Salinity Stress on Shoot Length*

Increasing salinity stress significantly affects shoot length of both samples of this study. Similar to germination rate and percentage, samples treated in Karaj seems to have more reduction in shoot length so that with increasing salt concentration from zero to 300 mM in both samples, shoot length dropped to 77.92% and 65.78% in Karaj and Ahwaz, respectively (Fig 3). Maximum shoot length in both samples belongs to control treatment and minimum shoot length belongs to Karaj samples at 300 mM salinity level (Fig 3). A similar experiment on *Convolvulus arvensis* suggests that salinity stress leaves significant adverse effects on shoot length growth (Mostafavi and Golzardi, 2012).

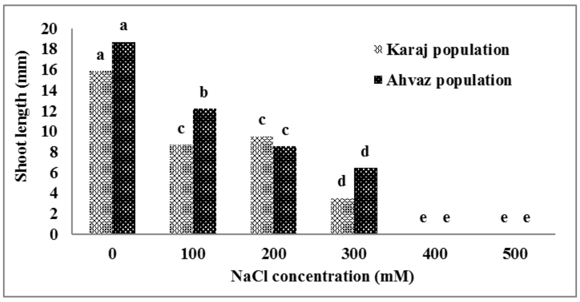


**Fig. 3.** The effect of salinity stress on shoot length of two plantain populations.

*The Effect of Salinity Stress on Radicle Length*

Salinity affects the growth of Radicle length in both observed samples but there is a difference between the samples with regard to the extent of influence and pattern of changes in Radicle length. At all salinity levels Radicle length of Karaj samples is less than Ahwaz. For both samples, the longest Radicle is observed at 100 mM concentration. While increasing salinity level, we observed that Radicle length of Karaj samples is more than control group at 100 and 300 mM but it is less than control group in 100 mM. In Ahwaz, the samples Radicle length exceeds the control group at 100, 200, and 300 mM (Fig 4).

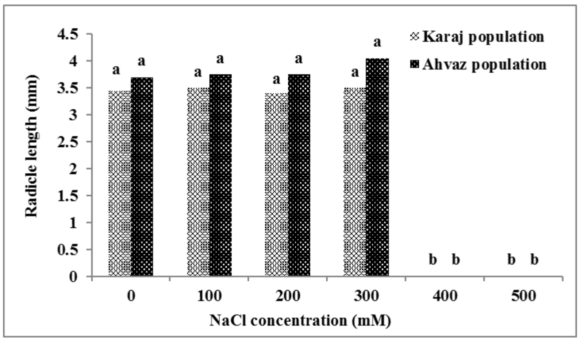


**Fig. 4.** The effect of salinity stress on Radicle length of two plantain populations.

*The Effect of Drought Stress on Germination Percentage*

Variance analysis indicates that drought stress causes significant changes on two samples of common plantain. With increasing drought stress, germination percentage decreases sharply (Table 2) (Fig 5). The highest germination percentage belongs to control groups of both samples. While water potential decreases (increased drought) from zero to -0.8 MPa, germination percentage of both sample seeds in Karaj and Ahwaz declined to 54.32% and 27.55%, respectively; i.e. water potential of samples in Karaj and Ahwaz decreases from 92.5% to 42.25% and from 98% to 71%, respectively (Fig 5). Common plantain leave germination of both samples stopped completely at -1. The results suggest that germinates of samples in Ahwaz are more resistant to drought stress. Golzardi *et al.* (2012), in a similar study, investigated the influence of maternal environment on germination percentage of Montpellier seeds under drought stress and concluded that samples observed in Kerman are more resistant than samples treated in Karaj and increased drought stress leads to decreases germination percentage. Abin and Eslami (2009) studied *Sonchius oleraceus* seed germination in two regions of Ahwaz and Birjand and they observed that Ahwaz samples are more resistant to drought stress than Birjand.

**Table 2.** The effect of drought stress on germination percentage, germination rate, shoot length, and Radicle length of common plantain in two population.

| Radicle length (mm) | Shoot length(mm) | Germination speed (1/day) | Germination percentage (%) | Population | Osmotic potential (-MP) |
|---|---|---|---|---|---|
| 3.48 a | 15.63 b | 16.14 b | 92.5 a | Karaj | **0** |
| 3.50 a | 18.40 a | 22.07 a | 98 a | Ahvaz | |
| 3.30 ba | 11.55 dc | 12.35 cb | 65.25 cd | Karaj | **-0.2** |
| 3.28 ba | 12.75 c | 20 a | 95 a | Ahvaz | |
| 2.98 ba | 10.78 dce | 9.75 cd | 57.75ecd | Karaj | **-0.4** |
| 3.03 ba | 10.88 dce | 16.20 b | 82 ba | Ahvaz | |
| 2.68 ba | 9.18 fe | 9.38 cd | 54.5 ed | Karaj | **-0.6** |
| 2.73 ba | 9.45 dfe | 13.06 cb | 74 bc | Ahvaz | |
| 2.28 b | 7.93 f | 7.09 d | 42.25 e | Karaj | **-0.8** |
| 2.53 ba | 8.03 f | 12.95 cb | 71 cd | Ahvaz | |
| 0 c | 0 g | 0 e | 0 f | Karaj | **-1** |
| 0 c | 0 g | 0 e | 0 f | Ahvaz | |

Note: according to Duncan's test, means with common final letter in each column are not significantly different at 5%.

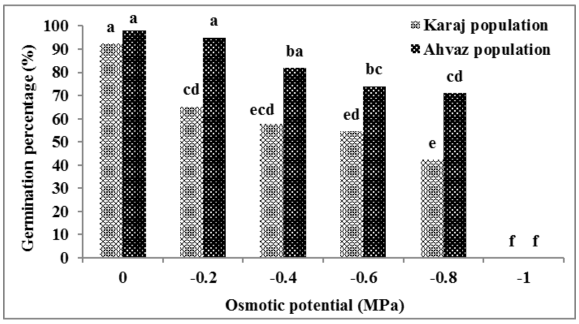


**Fig. 5.** The effect of drought stress on germination percentage of two plantain populations.

*The Effect of Drought Stress on Germination Rate*

Drought stress significantly affects germination rate of both samples of this study. Increasing drought stress caused significant decline in germination rate of both samples of this study. Again, like germination percentage, germination rate of samples treated in Karaj seems to be significantly more sensitive to drought stress so that when osmotic potential declines from zero to -0.8 MPa, germination rate of Karaj and Ahwaz decreases to 56.07 and 41.32, respectively (Fig 6). In addition, germination rates of Karaj samples are lower than Ahwaz at all level of drought stress. When compared with Karaj, higher germination rate and percentage of samples treated in Ahwaz demonstrate the potential of this region for planting in an environment with drought stress. Abin and Eslami (2009) conducted a research to compare *Sonchius oleraceus* seed treatment in two regions of Ahwaz and Birjand and they observed that in osmotic potential of -1, germination rate of samples in Birjand drops to zero and while in Ahwaz it declines sharply.

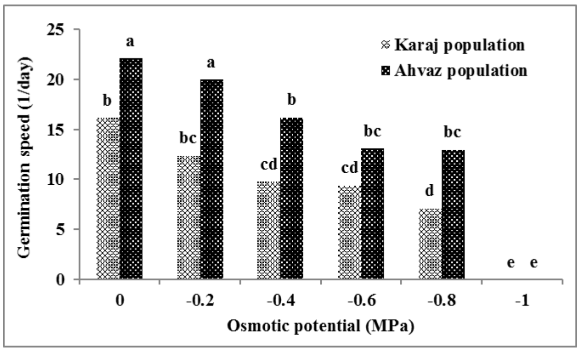


**Fig. 6.** The effect of drought stress on germination rate of two plantain populations.

*The Effect of drought Stress on Shoot Length*

At osmotic potential of –1 MPa, shoot length of both samples completely stops growing. Increasing drought stress significantly affects shoot length of both samples of this study. Although drought decreases shoot length of both samples, at all drought levels, shoot length of samples in Karaj are less than Ahwaz. While osmotic potential declines from zero to -0.8 MPa, shoot length of samples in Karaj and Ahwaz decreases to 49.26% and 56.36%, respectively (Fig7). Abin and Eslami (2009) studied two samples of *Sonchius oleraceus* and Mostafavi and Golzardi (2012) conducted an experiment on *Convolvulus arvensis* both of which ended in similar results.

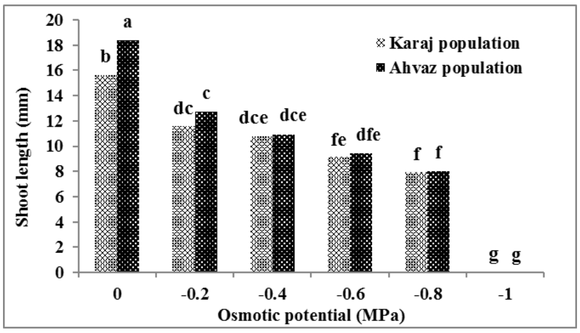


**Fig. 7.** The effect of drought stress on shoot length of two plantain populations.

*The Effect of drought Stress on Radicle Length*

With increasing drought, Radicle length decreases with a linear trend (Table 2) (Fig 8). As osmotic potential goes down from zero to –1 MPa, Radicle lengths of samples in Karaj and Ahwaz decline to 34.48% and 27.71%, respectively; i.e. Radicle length drops from 3.48 to 2.28 in Karaj and from 3.50 to 2.53 in Ahwaz (Fig 8). The results indicate that Radicle lengths of Ahwaz samples are more resistant to drought stress. Therefore, Ahwaz plants own more potential for growing in dry regions. Maximum Radicle length in both samples belongs to control group. Radicle length of both samples completely stops growing when osmotic potential is -1 MPa. Abin and Eslami (2009) reported that Radicle lengths of Ahwaz samples are more resistant to drought stress when compared with Birjand. Golzardi *et al.* (2012), in a similar study on two samples of Montpellier seeds under drought stress concluded that samples observed in Kerman are more resistant than samples treated in Karaj observing that Radicle length decreases with increasing drought level. Mostafavi and Golzardi (2012), after experimenting samples of *Convolvulus arvensis*, claimed that Radicle length decreases as drought level increases; however, decreasing rate varies based upon drought stress level.

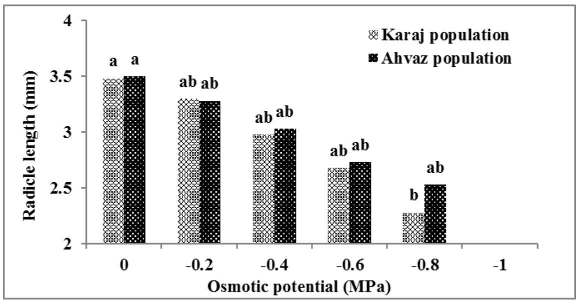


**Fig. 8.** The effect of drought stress on radicle length of two plantain populations.

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