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The Effects of Salinity and Temperature on Some Germination Characteristics of *Salsola arbuscula*

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Abstract: Information on germination characteristics of plant species adapted to drylands and factors affecting on them are essential in reaching the best conservation and establishment of these multi-purposes plant species. Some germination traits such as Germination Percentage (GP), Coefficient of Velocity of Germination (CVG), Germination Index (GI), Vigor Index (VI), Radicle (R) and Plumule (P) Lengnth were investigated at three temperatures (10-20-30°C) and under six concentrations of NaCl and Na_2SO_4 (0-100-200-300-400-500mM) in *Salsola arbuscula*. Collected data were analyzed using a factorial experiment for salinity, temperature and interaction effects between salinity and temperature with four replicates. Temperature and different concentrations of NaCl significantly ($P<0.01$) affected various traits of germination except the effect of salinity on the CVG and temperature on the rate of P. The effect of Na_2SO_4 concentration and temperature on the rate of GP and GI, P, R and VI was significant ($P<0.01$). Seeds GP and GI were not affected by salinity up to a specific level and it would be neutral but the germination traits declined with the salinity increase more than the specified level (200mM NaCl, 100mM Na_2SO_4) and the optimum germination temperature was 20°C in both salts. The results suggest that *Salsola arbuscula* seeds are negatively affected by Salinity (NaCl and Na_2SO_4) and exposure to supra- or sub-optimal temperatures and higher salt concentrations (500 mM) not only provoke inhibition of germination but also decrease the rate of germination parameters (GP, GI, P, R, VI).

Key words: Salinity · Temperature · Germination · *Salsola arbuscula*

INTRODUCTION

About one-third of the world's land area is drought affected [1] with potential evapotranspiration rates exceeding precipitation [2], so dryland salinity is one of the most serious and significant environmental problems facing arid and semi-arid environments on a global scale [3]. Information on germination characteristics of plant species adapted to such environments and factors affecting on them are essential in reaching the best conservation and establishment of these multi-purposes plant species.

Germination is a crucial stage in the life cycle of individual plants inhabiting arid, saline environments [4]. Salt stress affects germination percentage, germination rate and seedling growth in different ways depending on the plant species [5, 6]. It was reported that maximum germination of the seeds of halophytic plants occurred in distilled water or under reduced salinity [6-8] and it has been found that germination percentage is reduced with a high NaCl concentrations [9-11]. Temperature is also an important factor influencing germination. Soil temperature and salinity are two important factors that control when and where seeds can germinate in arid, saline regions [12]. The effects of salinity and temperature on germination of many halophytic plants have been studied by several authors and response of the plants to temperature and salinity varies according to salinity response of the halophytic species [6,13-20]. Although high environmental salinity inhibits germination, the

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detrimental effects of salinity are generally reduced at optimum temperatures [16,21-24], with decreased germination noted in various species at either supra- or sub-optimal temperatures [25, 7].

The main objective of this paper is to determine the effect of salinity and temprature on some germination traits: Germination Percentage (GP), Coefficient of Velocity of Germination (CVG), Germination Index (GI), Vigor Index (VI), Radicle (R) and Plumule (P) Length in *Salsola arbuscula*.

MATERIALS AND METHOD

Plant Species Choice: The native and palatable species of *Salsola arbuscula* (Xerohalophyte [26] and Psammophyte [27] has been selected. This Irano-Turanian species of Chenopodiaceae family which is mostly characteristic for arid to semiarid and/or saline habitats have great importance in livestock grazing and also in salty and dry range improvement. It forms an important component of the flora and vegetation of desert environments. The species of chenopodiaceae are, however, taxonomically not well-investigated due to the limitation of practical taxonomical characters, the fleshy nature of many species, late flowering and fruiting time and the fact that they are aesthetically not attractive for most collectors and botanists [2, 28-37].

Germination Experiments [38]: Seeds were surface sterilized using the alcohol (70%) for 10 seconds followed by thorough rinsing with distilled water for three times and again sterilized using benomile fungicide (1/1000) for 20 minutes. Germination was carried out in 50×9 mm Gelman No. 7232 tight-fitting plastic petri dishes with 5 ml of test solution. Each dish was placed in a 10-cm diameter sterilized plastic petri dish as an added precaution against loss of water by evaporation. Four replicates of 30 seeds each were used for each treatment. The treatment solutions for salinity tests were distilled water (control), 100, 200, 300, 400 and 500 mM NaCl and Na_2SO_4. To determine the effect of temperature on germination, seeds were germinated in incubators at three temperature regimes (10, 20 and 30°C) and alternating light periods of 16-h light and 8-h dark. The rate of CVG, GI and VI were estimated using the following equations:

- Coefficient of Velocity of Germination=$\Sigma f_i/\Sigma f_i.x_i$) *100 [39]
- Germination Index= $\Sigma(_{fi}/_{xi})$ [40]
- Vigor Index= (Plumule Length (cm) * Germination Percentage)/100 [41]

Where f_i is the number of seeds germinating in a day, X_i is the number of days counted from the start of the experiment.

Data Analysis: All statistical analyses were conducted by SPSS Version 18 for Windows. Effects of salinity and temperature on germination traits were examined using a factorial experiment and the means were compared by DMRT method.

RESULTS AND DISCUSSION

The percentage of different traits showed different values with similar trends in both salts. Temperature and different concentrations of NaCl (0-500 mM) significantly ($P<0.01$) affected various traits of germination (GI, CVG, GP, P, R and VI) except the effect of salinity on the rate of CVG and the effect of temperature on the rate of P (Table 1). Although different results have been reported on the effect of salinity and temperature on the germination of halophyte seeds, however, halophyte seed germination has been reported to occur optimally under reduced salinity stress [6, 7, 11, 12-15, 18, 20- 22, 42, 43, 51, 52]. In this research, comparing with control condition, the rate of GI, GP, P, R and VI decreased with an increase in salinity (Fig. 1). However, the rate of GP in *Salsola arbuscula* was not inhibited by up to 200 mM NaCl. (Fig. 1). It can be concluded that the species are not affected by NaCl concentrations up to a specific level and the specified level of salinity would be neutral for them so the mentioned traits will decline with the salinity increase more than the specified level in all three species. So germination of *Salsola arbuscula* seeds was negatively affected by NaCl concentration. It agrees with the results obtained by Alsaeed [44]. Alsaeed [44] also reported that decreasing water potential as a result of NaCl concentrations increase caused a reduction in the rate of GP, CVG, P and R in *Salsola villosa*. Ajmal Khan *et al.* [45] also indicated that NaCl concentration increase inhibited germination in *Salsola iberica*. This trend has also been reported by Farkhah [46] studying *Salsola dendroides*, *Alhaji persarum* and *Aeluropus lagopoides* and Tajbakhsh [47] studying *Hordeum vulgare*. They concluded that higher NaCl concentrations caused germination traits (GP, GI, CVG, P and R) decrease.

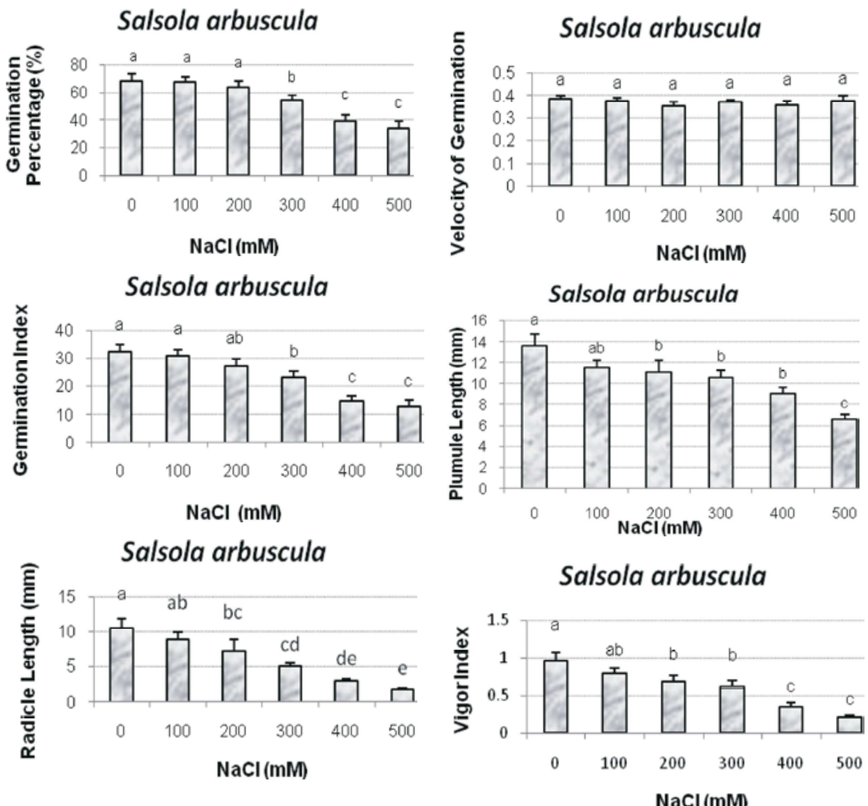

Fig. 1: The effect of NaCl concentrations on germination traits (P, R, VI, GP, CVG and GI) in *Salsola arbuscula*

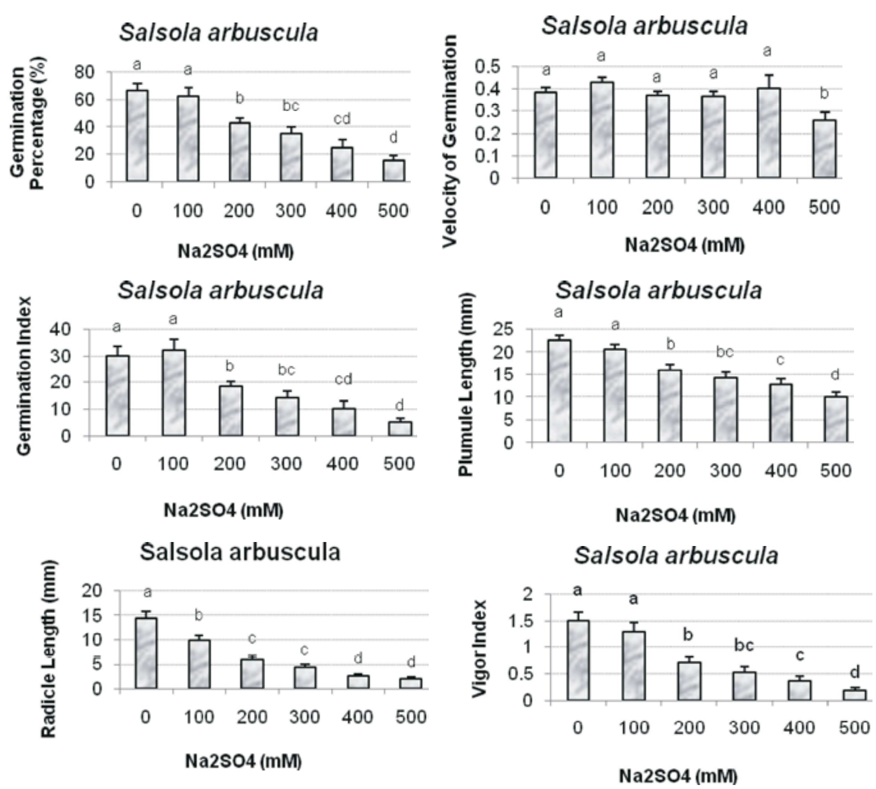

Fig. 2: The effect of Na_2SO_4 concentrations on germination traits (P, R, VI, GP, CVG and GI) in *Salsola arbuscula*

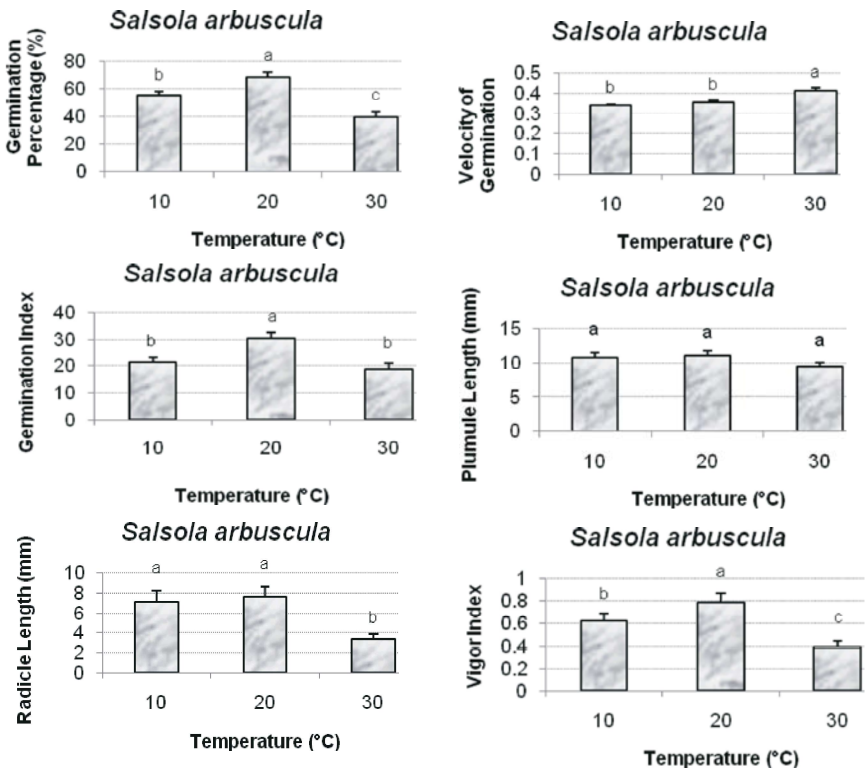

Fig. 3: The effect of temperature on germination traits (P, R, VI, GP, CVG and GI) in *Salsola arbuscula* under NaCl treatment

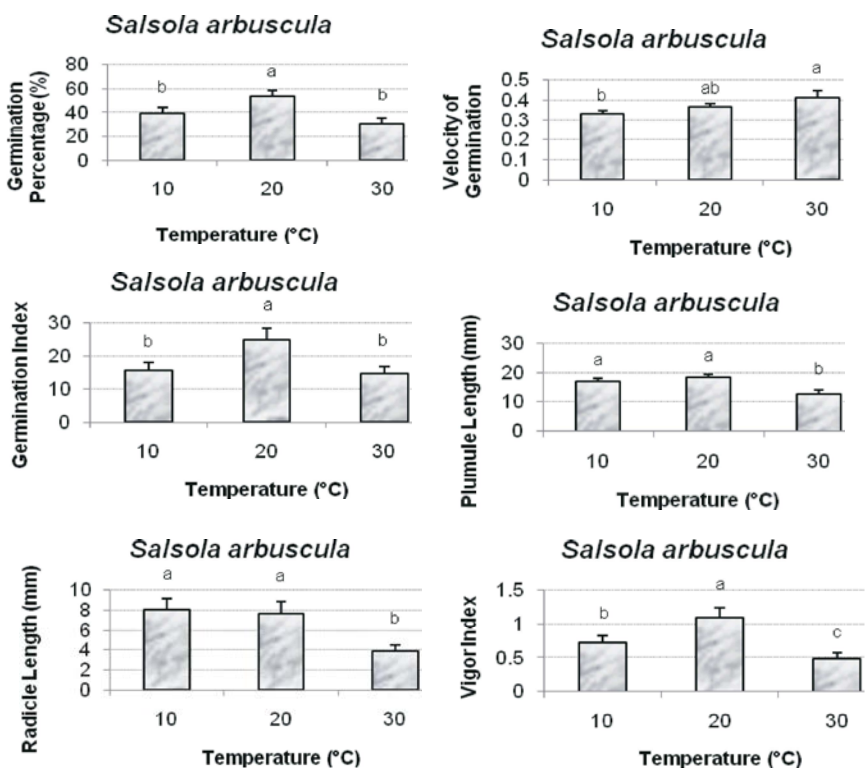

Fig. 4: The effect of temperature on germination traits (P, R, VI, GP, CVG and GI) in *Salsola arbuscula* under Na_2SO_4 treatment

Table 1: Results of analysis of variances for the effects of salinity (NaCl), temperature and their interaction on 6 germination traits of *Salsola arbuscula*

Source	df	P	R	VI	G	CVG	GI
Salinity	5	8.308**	18.614**	21.023**	22.008**	0.825^{ns}	19.807**
Temperature	2	2.449^{ns}	16.778^{**}	22.003**	40.461**	16.053**	20.934**
Salinity * Temperature	10	0.799^{ns}	1.9^{ns}	1.213^{ns}	0.37^{ns}	2.139^{ns}	0.837^{ns}

Table 2: Results of analysis of variances for the effects of salinity (Na_2SO_4), temperature and their interaction on 6 germination traits of *Salsola arbuscula*

Source	df	P	R	VI	G	CVG	GI
Salinity	5	24.172**	72.045**	28.752**	19.432**	3.997**	18.773**
Temperature	2	24.172**	72.045**	28.752**	12.774**	3.528*	10.369**
Salinity * Temperature	10	0.745^{ns}	2.388*	0.869^{ns}	0.294^{ns}	1.943^{ns}	0.518^{ns}

The effect of Na_2SO_4 concentration and temperature on the rate of CVG, GP, GI, P, R and VI was also significant (P<0.01) (Table 2). However, the effect of Na_2SO_4 concentration on the rate of GP, GI, VI and P in *Salsola arbuscula* was not significant up to 100 mM, while salinity increase more than the specified level caused a significant decrease in the mentioned traits (Fig. 2). In this study, maximum rates of germination traits were obtained from non-saline control samples (0 mM NaCl and Na_2SO_4) (Fig. 1, 2). It was confirmed by Duan *et al.* [48]. Duan *et al.* [48] reported germination percentage decrease in *Suaeda salsa* because of salt stress (Na_2SO_4, Na_2CO_3, $MgSO_4$, NaCl and $MgCl_2$). Reddy and Vora [49] also indicated plumule and radicle length decrease caused by NaCl and Na_2SO_4 stress in millet and Makki *et al.* [50] showed GP decline in *Medicago sativa* seeds. Gulzar *et al.* [25] and Mauromicale & Licandro [51] also reported germination decrease as a result of salinity increase. Similar results were also obtained from *Prosopis juliflora* seeds [15]. Our results are also confirmed by those of Jeannette *et al.* [52] in *Phaseolus sp.*, Al-Khateeb [16] in *Panicum turgidum*, Zammouri *et al.* [53] in *Spartidium saharea,* Xue *et al.* [54] in *Hedysarum scoparium*. Optimal germination has been reported in non-saline conditions [55-59]. However, for *Chenopodium glaucum*, it was reported that seeds germinated better in low salinity stress [61]. In this study, the maximum rates of germination traits were observed in control treatments. This result substantiates several other studies that showed that halophytes and glycophytes, are especially sensitive to salt during the germination stage [9, 23]. It is assumed that in addition to toxic effects, higher concentration of salt reduces the water potential in the medium, which hinders water absorption by germinating seeds and thus reduces germination [53].

The highest rates of GP, GI, P, R and VI was observed when seeds were germinated at 20°C and the lowest rates of the mentioned parameters were observed at 30°C, while the highest rate of CVG was observed at 30°C in both salts (Fig. 3, 4). So the optimum germination temperature was 20°C in both salts and exposure to supra- or sub-optimal temperatures inhibited germination. Similar results have been reported by Xue *et al.* [54] studying seed germination of *Hedysarum scoparium* in 0-500 mM NaCl at 10-35°C and Khan and Ungar [61] studying the effect of Salinity and temperature on the germination traits of *Haloxylon recurvum*. Xue *et al.* [54] indicated that germination was inhibited at temperatures lower and higher than the optimum. Our results are confirmed with those of Zhang *et al.* [62] studying *Hordeum vulgare*. Zhang *et al.* [62] pointed to the velocity of germination increase and germination percentage decrease at higher temperatures. The reason is not clear. It might be due to the characteristics of these species or their hot and dry habitats. Decreases in germination have been attributed to increased evaporation of moisture at high temperatures, increasing salt concentration by capillary movement [61]. Although the specific reasons for reduced germination at low temperatures under salt stress are unclear, it may be that the physiological mechanisms involved in the ability to tolerate salt are less effective [62].

As a result, exposure to lower (10°C) or higher temperatures (30°C) and higher salt concentrations (500 mM) provokes inhibition of germination and similarly decrease the rate of germination parameters of *Salsola arbuscula* as a xerohalophyte species. It has to be mentioned that nature is unpredictable so observing unexpected trends is not impossible and there is the probability of observing various reactions of species [2]. Further investigations are essential to understand the eco-physiological strategies of plants for survival under natural stressful conditions.

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