Journal of Medicinal Plants Research Vol. 5(17), pp. 4065-4073, 9 September, 2011
Available online at http://www.academicjournals.org/JMPR
ISSN 1996-0875 ©2011 Academic Journals

Full Length Research Paper

Effect of NaCl and GA_3 on seed germination and seedling growth of eleven medicinal and aromatic crops

Aglaia Liopa-Tsakalidi[1], Georgios Zakynthinos[2], Theodoros Varzakas[2]* and Ioannis Nickolaos Xynias[3]

[1]Department of Mechanical and Water Resources Engineering, Technological Educational Institute of Messolonghi, Nea Ktiria, 30 200 Messolonghi, Greece.
[2]Department of Food Technology, Technological Educational Institute of Kalamata, Antikalamos, 24 100 Kalamata, Greece.
[3]Department of Plant Production, Technological Educational Institute of Kalamata, Antikalamos, 24 100 Kalamata, Greece.

Accepted 22 June, 2011

The effect of sodium chloride (NaCl) and gibberillic acid (GA_3) on seed germination and seedling growth of 11 medicinal and aromatic crops was studied under controlled conditions. For this various aqueous solutions of NaCl (0.05, 0.5 and 1.5 mol/l NaCl) and GA_3 (50, 100, 200, 400 ppm GA_3) were used solely or combined as germination and growth substrates. Two of the aqueous solutions of NaCl (0.5 and 1.5 mol/l NaCl) negatively affected seed germination of all 11 species even when combined with GA_3. One NaCl aqueous solution (0.5 mol/l) impeded germination of rosemary, dill, lavender and oregano seeds, whereas it did not affect germination of spearmint, anise, coriander, parsley, sage, basil and cress. The highest seed germination was recorded in cress and basil (6.6 and 5.7%, respectively) and the lowest in mint and rosemary (1.7 and 0.6%, respectively). The treatment with 0.5 mol/l NaCl significantly increased the seedling length in mint, oregano, coriander, parsley, dill, anise and lavender. The highest relative growth rate was observed in dill, rosemary, anise and parsley, and the lowest in mint, sage and cress. The results suggest that germination and seedling growth of the 11 species responded differently to low and moderate levels of NaCl.

Key words: Salinity, germination velocity, relative growth rate.

INTRODUCTION

Aromatic plants are staging a comeback and herbal ‘renaissance’ is happening all over the globe. The cultivation of these plants is urgently needed to ensure their availability to the industry as well as people associated with traditional systems of medicine. Systematic cultivation needs specific cultural practices and agronomical requirements. One-third of the total arable cultivation worldwide is considered problematic due to the poor water quality mainly in dry areas. It is imperative that improvement of tolerance to salinity of aromatic plants is carried out due to the large salinity problems caused by problematic soils. A study of the seed germination behavior of 11 aromatic species to salinity will contribute to find ways to use slightly saline water for their propagation/cultivation. Salinity is the major environmental factor reducing plant growth and productivity (Allakhverdiev et al., 2000). Seed germination and seedling growth are the most sensitive stages in the biological life cycle of plants and salt stress conditions are a serious factor limiting the instigation of plant growth (Khan and Gulzar, 2003). Irrigation of plants with salted water can decelerate the water absorption of seeds and consequently affect negatively all processes related to the use of nutrient reserves and embryo

*Corresponding author. E-mail: theovarzakas@yahoo.gr.

Abbreviations: **GA_3,** Gibberillic acid; **GP,** germination percentage; **RGR,** relative seedling growth rate; **s. e,** standard error; **ANOVA,** analysis of variance.

development (Al-Karaki, 2001; Miceli et al., 2003). Abiotic stress conditions during germination and early life stages of plant species result in altering plant hormone levels and in decreasing plant growth (Morgan, 1990).

Salinity affects the germination rate, percentage and seedling growth in different ways depending on the plant species (Murillo-Amador et al., 2000; Almansouri et al., 2001; EL-Keblawy and Al-Rawai, 2005). Giberillic acid (GA_3) is found to play an important role in the germination process (Ritchie and Gilroy, 1998) through a multiple regulatory mechanism (Fincher, 1989). However, the stimulating effects of Ga_3 on seed germination are not similar in all crop species (Bell et al., 1995). There are many reports on how the growth regulator GA_3 could influence the germination response in halophytes when grown under salt stress conditions. Thus, Khan and Ungar (1997) suggested that GA_3 could alleviate the germination process in the desert forb *Zygophyllum simplex* L., whereas, other researchers reported a positive affect of GA_3 on germination in *Atriplex triangularis* Willd., *Polygonum aviculare* (Khan and Ungar, 1985, 1997) and *Allenroflea occidentalis* (Gul and Weber, 1998). In contrast, other reports pointed out that there was no effect of GA_3 on germination of various species (Khan and Ungar, 2000; Gulzar and Khan, 2002; Khan et al., 2004). Finally, GA_3 has been also reported to promote growth in cotton, rice and in some halophytes when grown under saline conditions (Zhao et al., 1986; Lin and Kao, 1995). For this, the effect of the exogenous application of GA_3 on germination and seedling growth under salt stress conditions provides an attractive approach to encounter the effects of salinity. Despite the fact that response of agronomic crops to salinity is one of the most widely studied topics in plant physiology, there is relatively little information available on the performance of medicinal and aromatic crops under salt stress conditions.

This work was undertaken firstly to elucidate the performance of 11 medicinal and aromatic crops at different levels of salinity (NaCl), and secondly, to evaluate the effect of exogenous application of GA_3 on seed germination and seedling growth in medicinal and aromatic crops growing under salt stress conditions. The potential cultivation of these aromatic plants make imperative the need of such a study to optimize seed germination and seedling growth of medicinal and aromatic crops under the effect of salinity and GA_3.

MATERIALS AND METHODS

Plant material

Eleven medicinal and aromatic crop species [that is dill (*Anethum graveolens*), basil (*Ocimum basilicum* L.), anise (*Pimpinella anisum* L.), rosemary (*Rosmarinus oficinalis* L.), spearmint (*Menta spicata* L.), cress (*Lepidium sativum* L.), coriander (*Coriandum sativum* L.), lavender (*Lavandula officinalis* L.), parsley *Petroselinum sativum* L.), oregano (*Origanum vulgare* L) and sage (*Salvia offficinalis* L.)] were used in this study. These crops were selected due to their agronomic importance.

Fifty seeds from each species were placed in 10 cm Petri dishes on filter paper and were covered with another filter paper. The dishes were moistened with 5 ml of distilled water (control) or with an equal quantity of the respective test solution. The following treatments were used: A) H_2O- distilled water (control), B) aqueous solutions supplemented with 50, 100, 200 and 400 ppm GA_3 respectively, C) aqueous solutions supplemented with 0.05, 0.5 and 1.5 mol/l NaCl respectively, D) aqueous solutions supplemented with 50 ppm GA_3 + 0.05 mol/l NaCl, 100 ppm GA_3 + 0.05 mol/l NaCl, 200 ppm GA_3 + 0.05 mol/l NaCl, 400 ppm GA_3 + 0.05 mol/l NaCl, E) aqueous solutions supplemented with 50 ppm GA_3 + 0.5 mol/l NaCl, 100 ppm GA_3 + 0.5 mol/l NaCl, 200 ppm GA_3 + 0.5 mol/l NaCl, 400 ppm GA_3 + 0.5 mol/l NaCl, F) aqueous solutions supplemented with 50 ppm GA_3 + 1.5 mol/l NaCl, 100 ppm GA_3 + 1.5 mol/l NaCl, 200 ppm GA_3 + 1.5 mol/l NaCl, 400 ppm GA_3 + 1.5 mol/l NaCl. The dishes were placed in a growth chamber at 16 h photoperiod, 12 klx light intensity, 22 ± 1°C temperature regime, and 70 ± 5% relative humidity (RH). Distilled water or test solutions were added to each Petri dish, during the experiment according to their water requirements. The number of the germinated seeds and length of seedlings were recorded every 3 days, starting from the third day after the seeds were initially placed in the Petri dishes. Seedling length was measured with a tape in mm with an accuracy of 1 mm.

The experiment consisted of three replications. Germination percentage is an estimate of the viability of seeds. The equation to calculate germination percentage is:

$$GP = \frac{\text{Seeds germinated}}{\text{Total seeds}} \times 100$$

Germination rate was estimated by using the modified Timson index of germination velocity: ΣG/t, where G is the percentage of seeds germinated after 3-days intervals and t is the total germination period (Khan and Ungar, 1984). Relative seedling growth rate (RGR) was calculated as $R = (\log_e L_2 - \log_e L_1)/(T_2 - T_1)$ where L is the seedling length at time $T_2 - T_1$ at 3-days intervals (Hunt, 1982).

Statistical analysis

Analysis of the data for seed germination and growth of seedlings of the eleven aromatic species was performed according to the randomized complete block design (RCB) (Steel and Torrie, 1960). Means of the examined traits were ranked according to Duncan's multiple range test and the Post Hoc comparison was used alternatively with the Student-Newman-Keuls (SNK), Dunnett and Tukey methods.

RESULTS

Seed germination

Seeds of the 11 aromatic crops germinated regularly when a 0.05 mol/l NaCl aqueous solution was used alone or combined with the various levels of GA_3 (Table 1). No seeds germinated in high salt concentrations (0.5 and 1.5 mol/l NaCl) when they were used either solely or combined with GA_3. The only exception was cress seeds that germinated in the presence of 0.5 mol/l NaCl when it

Table 1. Timson index germination velocity mean (± s. e.) in seedlings of 11 aromatic species grown in aqueous medium containing various levels of GA_3 (in ppm) and NaCl (in mol/l).

Crop	H_2O	$50GA_3$	$100\ GA_3$	$200\ GA_3$	$400\ GA_3$	0.05 NaCl	$50\ GA_3$ + 0.05 NaCl	$100\ GA_3$ + 0.05 NaCl	$200\ GA_3$ + 0.05 NaCl	$400\ GA_3$ + 0.05 NaCl
Rosemary	$0.6^{a}\pm0.2$	$0.3^{b}\pm0.2$	$0.3^{b}\pm0.2$	$0.2^{c}\pm0.2$	$0.4^{a}\pm0.2$	$0.3^{b}\pm0.22$	$0.5^{a}\pm0.2$	$0.5^{a}\pm0.2$	$0.4^{a}\pm0.2$	$0.4^{a}\pm0.2$
Dill	$3.7^{b}\pm0.3$	$3.0^{c}\pm0.3$	$3.3^{b}\pm0.3$	$3.4^{b}\pm0.3$	$4.0^{a}\pm0.3$	$2.4^{d}\pm0.33$	$3.5^{b}\pm0.3$	$3.1^{c}\pm0.3$	$2.9^{c}\pm0.3$	$2.9^{c}\pm0.3$
Lavender	$2.7^{d}\pm0.2$	$4.1^{b}\pm0.2$	$3.9^{b}\pm0.2$	$4.1^{b}\pm0.2$	$3.9^{b}\pm0.2$	$1.7^{e}\pm0.2$	$2.4^{d}\pm0.2$	$2.8^{d}\pm0.2$	$4.4^{a}\pm0.2$	$3.7^{c}\pm0.2$
Oregano	$3.3^{a}\pm0.1$	$3.2^{b}\pm0.1$	$3.2^{b}\pm0.1$	$3.4^{a}\pm0.1$	$3.4^{a}\pm0.1$	$2.6^{c}\pm0.12$	$3.3^{a}\pm0.1$	$3.2^{b}\pm0.1$	$3.0^{b}\pm0.1$	$3.4^{a}\pm0.1$
Sage	$4.2^{bc}\pm0.2$	$4.2^{bc}\pm0.2$	$4.6^{a}\pm0.2$	$4.1^{c}\pm0.2$	$4.1^{c}\pm0.2$	$4.3^{b}\pm0.18$	$4.2^{bc}\pm0.2$	$3.4^{e}\pm0.2$	$3.8^{d}\pm0.2$	$3.8^{d}\pm0.2$
Basil	$5.7^{b}\pm0.0$	$5.7^{b}\pm0.1$	$5.7^{b}\pm0.1$	$5.7^{b}\pm0.1$	$5.8^{a}\pm0.1$	$5.8^{a}\pm0.05$	$5.8^{a}\pm0.1$	$5.8^{a}\pm0.1$	$5.7^{b}\pm0.1$	$5.8^{a}\pm0.1$
Spearmint	$1.7^{b}\pm0.2$	$1.6^{b}\pm0.2$	$1.7^{b}\pm0.2$	$2.1^{a}\pm0.2$	$2.3^{a}\pm0.2$	$1.7^{b}\pm0.16$	$1.3^{b}\pm0.2$	$1.8^{b}\pm0.2$	$2.0^{a}\pm0.2$	$2.2^{a}\pm0.2$
Anise	$4.0^{a}\pm0.2$	$3.5^{c}\pm0.2$	$3.2^{d}\pm0.2$	$3.4^{c}\pm0.2$	$2.9^{e}\pm0.2$	$4.1^{a}\pm0.20$	$4.0^{a}\pm0.2$	$3.4^{c}\pm0.2$	$3.7^{b}\pm0.2$	$4.1^{a}\pm0.2$
Coriander	$4.1^{b}\pm0.2$	$4.1^{b}\pm0.2$	$4.2^{b}\pm0.2$	$4.2^{b}\pm0.2$	$4.3^{a}\pm0.2$	$4.2^{b}\pm0.23$	$4.5^{a}\pm0.2$	$4.1^{b}\pm0.2$	$4.0^{c}\pm0.2$	$4.1^{b}\pm0.2$
Parsley	$4.2^{a}\pm0.1$	$3.9^{b}\pm0.1$	$3.8^{c}\pm0.1$	$3.8^{c}\pm0.1$	$4.0^{b}\pm0.1$	$4.1^{b}\pm0.10$	$3.7^{d}\pm0.1$	$4.0^{b}\pm0.1$	$3.7^{d}\pm0.1$	$3.8^{c}\pm0.1$
Cress	$6.6^{b}\pm0.1$	$6.8^{a}\pm0.1$	$6.7^{b}\pm0.1$	$6.8^{a}\pm0.1$	$6.7^{b}\pm0.1$	$6.7^{b}\pm0.07$	$6.7^{b}\pm0.1$	$6.5^{c}\pm0.1$	$6.6^{b}\pm0.1$	$6.6^{b}\pm0.1$

Means followed by different letters are significantly different at $p = 0.05$ level.

was solely used or was combined with the various levels of GA_3 (Table 2). The germination period for the 11 aromatic crops ranged from 14 to 34 days. The germination percentage in basil and cress was high (93 to 99), whereas in coriander and parsley it was relatively low (84 to 88%). In anise, oregano and sage germination percentage was moderate (54 to 74%) and in dill, rosemary and lavender it was very low (12 to 45) (Figure 1). The addition of 0.05 mol/l NaCl to the substrate had a positive effect on germination of sage and basil seeds resulting in significantly higher rates than those observed in the control (H_20, Figure 1). On the other hand, addition of NaCl hampered final germination in rosemary, dill, lavender, and oregano, but it did not affect mint, anise, coriander, parsley and cress seeds. The germination rate of the seeds in the last case was significantly lower (mint) or similar (anise, coriander, parsley and cress) to the respective rate observed in the control (Figure 2 and Table 1). The highest seed germination rate was observed in cress and basil (6.6 and 5.7%, respectively), and the lowest rate was recorded in mint and rosemary (1.7 and 0.6, respectively).

Aqueous solutions of GA_3 differently influenced seed germination of the crops studied. Thus, the seed germination rate was increased in lavender, when the aqueous solutions GA_3 were used alone or when the higher concentrations were combined with 0.05 mol/l NaCl (Table 1). A positive effect of GA_3 was observed in basil and cress in which the germination rate also increased when a higher and a lower concentration were respectively, when the hormone was used alone. The germination rate was also influenced positively in basil, when the two lower and the highest concentrations of GA_3 were combined with 0.05 mol/l NaCl, but it was not affected in cress, when GA_3 was used in the presence of 0.05 mol/l NaCl. In contrast, the aqueous solutions of GA_3, combined or not with 0.05 mol/l NaCl reduced seed germination in rosemary, dill (except when it was used alone in the higher concentration), anise, oregano and parsley (Table 1). No effect was recorded in the other crops.

Seedling growth

The growth period in dill seedlings ranged from 10 to 30 days. The maximum seedling length of dill, sage and cress was recorded on the 10th day in oregano and lavender on the 14th day, in basil, coriander, parsley and anise on the 17th day, in dill on the 24th day and in rosemary on the 27th day. Seedling growth in all aromatic crops was greater when the substrates were supplemented with the growth regulator GA_3 compared to the control (Figures 3 and 4A). The 0.05 mol/l NaCl treatment significantly decreased seedling length in seven (spearmint, oregano, coriander, parsley, dill, anise, lavender) crops compared to H_20.,

Table 2. Relative growth rate mean (±s. e.) in seedlings of eleven aromatic species grown in aqueous medium containing various levels of GA_3 (in ppm) and NaCl (in mol/l).

Crop	H_2O	NaCl	50 GA_3	100 GA_3	200 GA_3	400 GA_3	50 GA_3 + 0.05 NaCl	100 GA_3 + 0.05 NaCl	200 GA_3 + 0.05 NaCl	400 GA_3 + 0.05 NaCl
Dill	$0.444^{b}\pm0.09$	$0.367^{b}\pm0.08$	$0.595^{a}\pm0.08$	$0.146^{e}\pm0.08$	$0.182^{e}\pm0.08$	$0.150^{e}\pm0.08$	$0.184^{e}\pm0.08$	$0.188^{e}\pm0.08$	$0.213^{c}\pm0.08$	$0.196^{d}\pm0.08$
Rosemary	0.205±0.0					0.009±0.0			0.015±0.0	0.040±0.0
Anise	$0.118^{a}\pm0.03$	$0.139^{a}\pm0.03$	$0.093^{a}\pm0.03$	$0.065^{a}\pm0.03$	$0.089^{a}\pm0.03$	$0.055^{a}\pm0.03$	$0.127^{a}\pm0.03$	$0.106^{a}\pm0.03$	$0.159^{a}\pm0.03$	$0.114^{a}\pm0.03$
Parsley	$0.102^{a}\pm0.01$	$0.109^{a}\pm0.01$	$0.129^{a}\pm0.01$	$0.111^{a}\pm0.01$	$0.109^{a}\pm0.01$	$0.109^{a}\pm0.01$	$0.121^{a}\pm0.01$	$0.117^{a}\pm0.01$	$0.124^{a}\pm0.01$	$0.122^{a}\pm0.01$
Oregano	$0.056^{a}\pm0.01$	$0.053^{a}\pm0.01$	$0.049^{a}\pm0.01$	$0.049^{a}\pm0.01$	$0.049^{a}\pm0.01$	$0.041^{a}\pm0.01$	$0.061^{a}\pm0.01$	$0.062^{a}\pm0.01$	$0.062^{a}\pm0.01$	$0.065^{a}\pm0.01$
Lavender	$0.047^{a}\pm0.02$	$0.051^{a}\pm0.02$	$0.023^{a}\pm0.02$	$0.047^{a}\pm0.02$	$0.037^{a}\pm0.02$	$0.030^{a}\pm0.02$	$0.079^{a}\pm0.02$	$0.041^{a}\pm0.02$	$0.020^{a}\pm0.02$	$0.021^{a}\pm0.02$
Coriander	$0.037^{a}\pm0.02$	$0.054^{a}\pm0.02$	$0.036^{a}\pm0.02$	$0.039^{a}\pm0.02$	$0.022^{a}\pm0.02$	$0.022^{a}\pm0.02$	$0.076^{a}\pm0.02$	$0.061^{a}\pm0.02$	$0.061^{a}\pm0.02$	$0.062^{a}\pm0.01$
Basil	$0.034^{b}\pm0.02$	$0.024^{b}\pm0.02$	$0.031^{b}\pm0.02$	$0.023^{b}\pm0.02$	$0.023^{b}\pm0.02$	$0.008^{c}\pm0.02$	$0.015^{b}\pm0.02$	$0.008^{c}\pm0.02$	$0.057^{a}\pm0.02$	$0.044^{ab}\pm0.02$
Spearmint	$0.032^{b}\pm0.01$	$0.004^{d}\pm0.02$	$0.041^{b}\pm0.01$	$0.040^{b}\pm0.01$	$0.036^{b}\pm0.01$	$0.035^{b}\pm0.01$	$0.023^{b}\pm0.01$	$0.037^{b}\pm0.01$	$0.057^{a}\pm0.01$	$0.022^{c}\pm0.01$
Sage	$0.031^{c}\pm0.01$	$0.042^{c}\pm0.01$	$0.023^{d}\pm0.01$	$0.022^{d}\pm0.01$	$0.023^{d}\pm0.01$	$0.032^{c}\pm0.01$	$0.045^{c}\pm0.01$	$0.066^{a}\pm0.01$	$0.039^{c}\pm0.01$	$0.056^{b}\pm0.01$
Cress	$0.009^{c}\pm0.02$	$0.011^{c}\pm0.02$	$0.006^{cd}\pm0.02$	$0.006^{cd}\pm0.02$	$0.004^{d}\pm0.02$	$0.012^{c}\pm0.02$	$0.010^{c}\pm0.02$	$0.011^{c}\pm0.02$	$0.008^{c}\pm0.02$	$0.020^{b}\pm0.02$
							$0.048^{a}\pm0.02$	$0.020^{b}\pm0.02$	$0.004^{d}\pm0.02$	$0.005^{d}\pm0.02$

Means followed by different letters are significantly different at p = 0.05 level.

However, the reverse was noticed in rosemary, cress, sage and basil in which seedling length increased. Addition of GA_3 in 0.05 mol/l aqueous solutions of NaCl was found to be effective in promoting rate of seedling growth in seven of the aromatic crops. GA_3 accelerated their germination which was previously impeded by salinity (Figures 3, 4B1 and B2). The greatest relative growth rate was observed in dill, rosemary, anise and parsley, whereas the least relative growth rate was found in spearmint, sage and cress. Relative seedling growth rate in anise, parsley, lavender, coriander, sage and cress under NaCl treatment exceeded the respective rate in the control, although differences were not statistically significant.

Furthermore, no statistical differences were recorded when relative seedling growth rate in dill and parsley was compared respective of the control, even when NaCl solutions were supplemented with GA_3 (Table 2).

DISCUSSION

It is well established that NaCl inhibits seedling germination in two ways: (a) by causing a complete inhibition of the germination process at salinity levels that exceed the tolerance limits of a certain species, and (b) by delaying seed germination at salinity levels that cause some stress to seeds (Al-Karaki, 2001; Vicente et al., 2004). However, NaCl does not prevent germination. In the present study all higher NaCl concentrations (0.5 and 1.5 mol/l) inhibited the germination process in all eleven species, because they probably exceed each individual crop's tolerance limits (Belaqziz et al., 2009). The germination percentage in rosemary, dill, lavender and oregano seeds was reduced compared to that of the control at the level of 0.05 mol/l NaCl. It appears that the limit of seed tolerance during germination was lower in the aforementioned group of crops than in that of the remaining crops (spearmint, anise, coriander, parsley, cress, sage and basil) which exhibited a high percentage of germination (Figure 2). The study of salt tolerance during germination and seedling growth is important for determining saline limits at each developmental stage of the crop (Zapata et al., 2004). Some crops that have been classified as salt sensitive can germinate under high concentrations of NaCl (Kurt et al., 1986; Maas et al., 1983). However, other tolerant species (such as cotton) are more sensitive during germination (Kent and Laüchli, 1985). The reduction in germination percentage in dill with increasing salinity levels is reported by Ravender-Singh et al. (2000) and the greatest germination rate in basil seed by Simon (1985).

Zidan and Elewa (1995) mentioned that during germination, anise tolerated salinity up to 160 mM NaCl and coriander up to 200 mm NaCl. It is

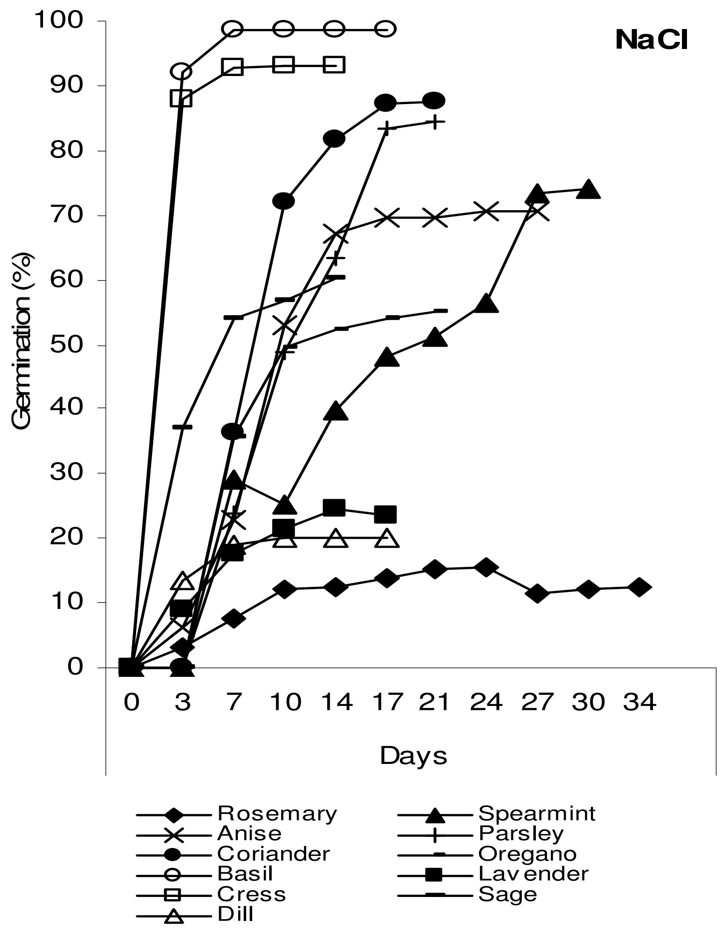

Figure 1. Effect of NaCl (0.05 mol/l) on germination (expressed as %) of the 11 medicinal and aromatics crops.

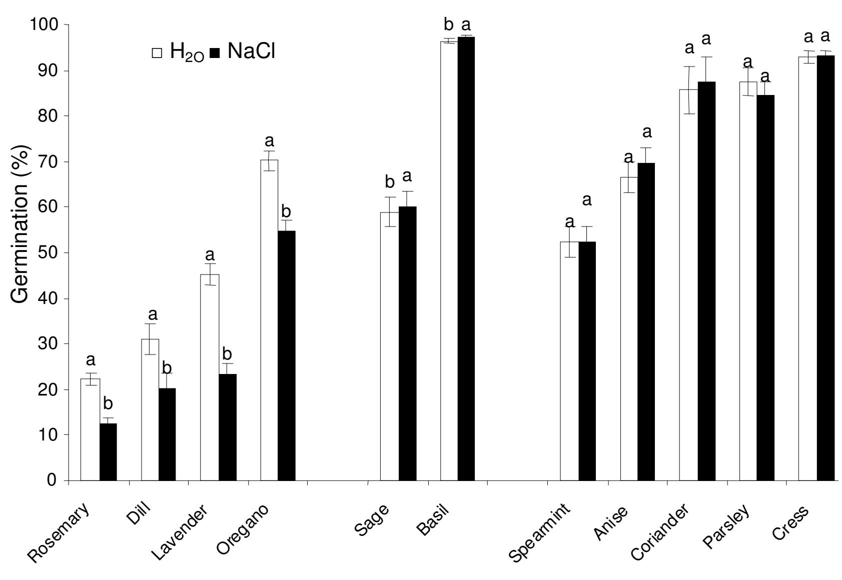

Figure 2. Final seed germination means (±s.e.) of the 11 medicinal and aromatics crops growing in aqueous medium supplemented with 0.05 mol/l NaCl. Columns followed by different letters are significantly different at p = 0.05 level.

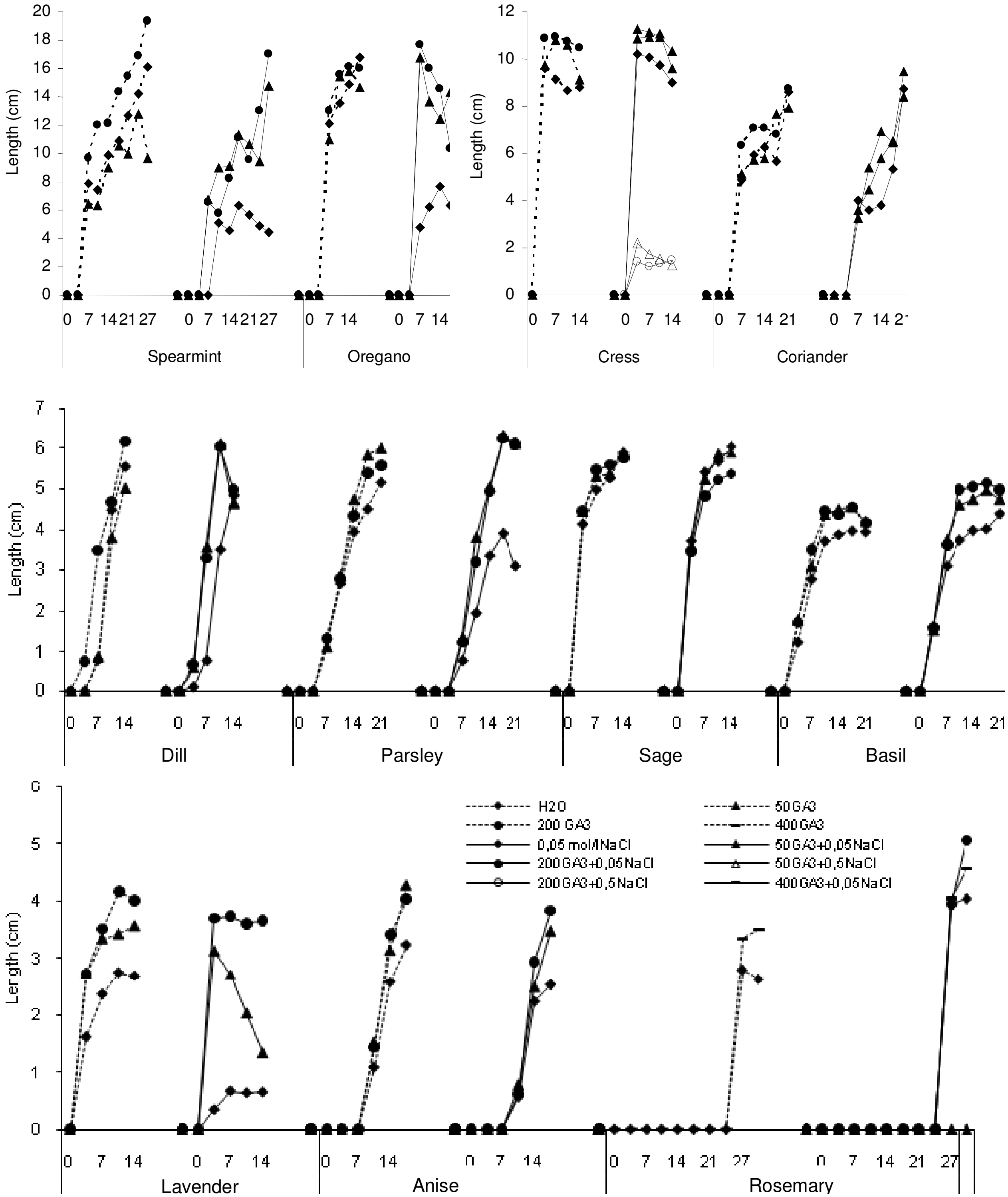

Figure 3. Effect of GA_3 and NaCl on the final length (±s.e.) of the 11 medicinal and aromatics plants.

difficult to quantify the genotypes per each plant species and the individual physiological responses induced by NaCl that are dependent on the stage of development and on various external factors in a way that could be extrapolated from species to species (Poljakoff-Mayber and Gale, 1975). All GA_3 concentrations combined with a 0.05 mol/l aqueous solution of NaCl were effective in alleviating NaCl stress in rosemary, dill, lavender and

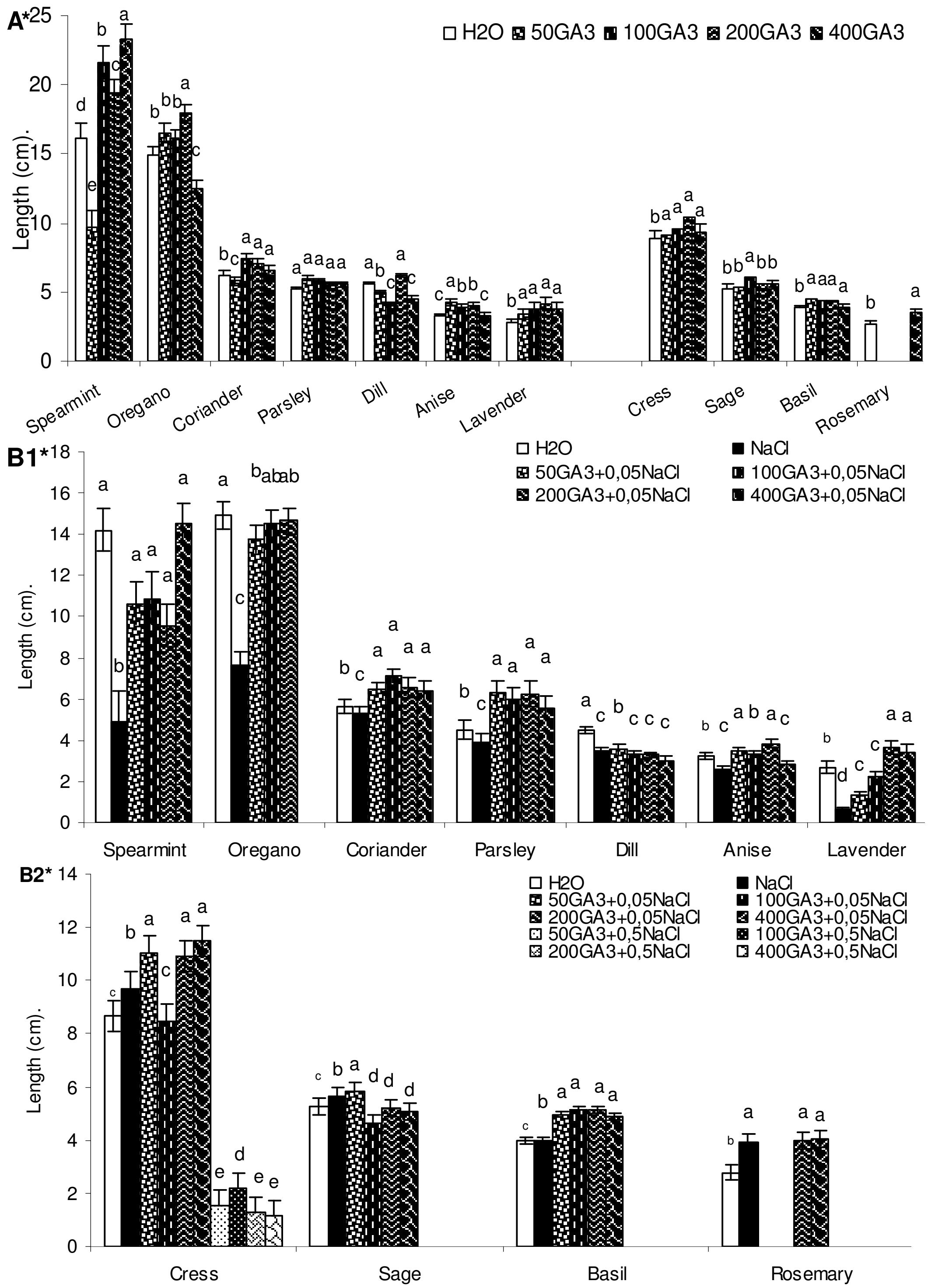

Figure 4. Final length means (±s.e.) of the 11 medicinal and aromatics crops in H_2O and 0.05 mol/l NaCl. Columns followed by different letters are significantly different at p = 0.05 level.

oregano. Addition of GA_3 increased their germination rate and as a result, their germination percentage compared to the 0.05 mol/l aqueous solution of NaCl (Table 1). The germination rate was estimated by using a modified Timson index, as a measure of the seed germination of the 11 aromatic crops (Zehtab-Salmasi, 2008). This index is a complete biological indicator considered as the most sensitive parameter used for evaluating the effect of

NaCl. The germination rate illustrates the possible cumulative effects of all the factors connected to the presence of NaCl that could possibly affect the plants (Zucconi et al., 1981). Chaudhuri and Webe (1968) reported similar results in wheat, where GA_3 improved salt resistance by increasing the germination percentage. The results of the present study indicate that germination in sage and basil was accelerated by the presence of NaCl (Figures 1 and 2). The same was concluded by Micelli et al. (2003) who reported that salinity has not significantly reduced germination percentages in basil. El-Darier and Youssef (2000) reported in cress that the maximum germination rate was attained at the 50 mM NaCl concentration level.

In the present study the germination rate in cress tolerated a higher concentration (0.5 mol/l NaCl) but only in the presence of GA_3. The final germination of three aromatic and medicinal crops (spearmint, coriander and parsley) was not affected by the presence of NaCl (Figure 2) whereas the final seedling length in seven of the crops was significantly reduced during growth (Figure 4B1). Similar results were reported by Mayer and Poljakoff-Mayber (1989) and Johnson (1990) who concluded that salt tolerance of seeds during germination is not related to the tolerance level during plant growth. Seedling length was reduced in cress at increased NaCl levels (Figure 3). This will inevitably result in smaller plants and it is in agreement with previous reports of Mohammad et al. (1998) and Meloni et al. (2001) who observed significant reductions in plant height in tomato and in cotton when they were grown under salt stress. The observed great influence of GA_3 treatment on seedling length increase in all the aromatic crops studied (Figures 3 and 4A) could be attributed to the inherent potential of gibberellic acid in promoting cell division and cell elongation (Scott, 1984). Gibberellic acid alleviated the negative effect of NaCl on seedling length growth in seven of the aromatic crops (mint, oregano, coriander, parsley, dill, anise and lavender). This is in agreement with the reports of Kabar and Baltepe (1990) and Ungar (1991) who suggested that high salt concentration could be alleviated by the presence of GA_3. The results of the present study suggest that germination of the medicinal and aromatic crops studied (except cress) is inhibited by NaCl concentrations higher than 0.5 mol/l. Lower than this level the performance of the crops is altered (some of them respond well while others do not). The response of the aforementioned crops to gibberellic acid was also a variable and the same was observed when it was used combined with NaCl. The view was similar in seedling length and some of the crops responded well by the presence of NaCl or GA_3 when they were solely or used on combination. However further research is needed to confirm the results of the present work.

REFERENCES

Al-Karaki GN (2001). Germination, sodium and potassium concentrations of barley seeds as influenced by salinity. J. Plant Nutr., 24: 511-522.

Allakhverdiev SI, Sakamoto A, Nishiyama Y, Inaba M, Murata N (2000). Ionic and osmotic effects of NaCl-induced inactivation of Photosystems I and II in *Synechococcus* sp. Plant Physiol., 123: 1047-1056.

Almansouri M, Kinet JM, Lutts S (2001). Effect of salt and osmotic stresses on germination in durum wheat (*Triticum durum* Desf.). Plant Soil, 231: 243-254.

Belaqziz R, Romane A, Abbad A (2009). Salt stress effects on germination, growth and essential oil content of an endemic thyme species in Morocco (*Thymus maroccanus* Ball.). J. Appl. Sci. Res., 5: 858-863.

Bell DT, Rokich DP, Mcchesney CJ, Plummer JA (1995). Effects of temperature, light and gibberellic acid on the germination of seeds of 43 species native to Western Australia. J. Vegetat. Sci., 6: 797–806.

Chaudhuri II, Wiebe HH (1968). Influence of calcium pretreatment on wheat germination on saline media. Plant Soil, 28: 208-216.

El-Darier SM, Youssef RS (2000). Effect of soil type, salinity, and allelochemicals on germination and seedling growth of a medicinal plant *Lepidium sativum* L. Ann. Appl. Biol., 136: 273-279.

El-Keblawy A, Al-Rawai A (2005). Effects of salinity, temperature and light on germination of invasive *Prosopis juliflora* (Sw.) D.C. J. Arid Environ., 61: 555-565.

Fincher GB (1989). Molecular and cellular biology association with endosperm mobilization in germination cereal grains. Ann. Rev. Plant Physiol. Plant Mol. Biol., 40: 305-346.

Gul B, Weber DJ (1998). Effect of Dormancy Relieving Compounds on the Seed Germination of Non-dormant *Allenrolfea occidentalis* under Salinity Stress. Ann. Bot., 82: 555-560.

Gulzar S, Khan MA (2002). Alleviation of salinity-induced dormancy in perennial grasses. Biol. Plant, 45: 617-619

Hunt R (1982). Plant growth curves. London, Edward Arnold. p. 248.

Johnson DW (1990). Stress productivity in alfalfa: Selection under saline and non-saline environmental conditions. Ph.D. Thesis (Diss. Abstr. 9103038), University of Arizona, Tucson.

Kabar K, Baltepe S (1990). Effect of kinetin and gibberellic acid in overcoming high temperature and salinity (NaCl) stresses on the germination of Barley and Lettuce seeds. Phyton. Int. J. Exp. Bot., 30: 65-74.

Kent LM, Laüchli A (1985). Germination and seedling growth of cotton: salinity–calcium interactions. Plant Cell Environ*.,* 8: 155-159.

Khan MA, Gul B, Weber DJ (2004). Action of plant growth regulators and salinity on the seed germination of *Ceratoides lanata*. Can. J. Bot., 82: 37-42.

Khan MA, Gulzar S (2003). Germination responses of *Sporobolus ioclados*, a saline desert grass. J. Arid Environ., 55: 453-464.

Khan MA, Ungar IA (1984). The effect of salinity and temperature on the germination of polymorphic seeds and growth of *Atriplex triangularis* Willd. Am. J. Bot*.,* 71: 481-489.

Khan MA, Ungar IA (1985). The role of hormones in regulating the germination of polymorphic seeds and early seedling growth of *Atriplex triangularis* Willd, under saline conditions. Physiol. Plant, 63: 109-113.

Khan MA, Ungar IA (1997). Alleviation of seed dormancy in the desert forb *Zygophyllum simplex* L. from Pakistan. Ann. Bot., 80: 395-400.

Khan MA, Ungar IA (2000). Alleviation of salinity-enforced dormancy in *Atriplex griffithii* Moq. var. *stocksii* Boiss. Seed Sci. Technol., 28: 29-37.

Kurt E, Jensen A, Epstein E (1986). Resistance of fully imbibed tomato seeds to very high salinities, Plant Cell Environ*.,* 9: 667-676.

Lin CC, Kao CH (1995). NaCl stress in rice seedlings, starch mobilization and the influence of gibberellic acid on seedling growth. Bot. Bull. Acad. Sin., 36: 169-173.

Maas EV, Hoffman GJ, Chaba GD, Poss JA, Shannon MC (1983). Salt sensitivity of corn at various growth stages, Irrig. Sci., 4: 45-57.

Mayer AM, Poljakoff-Mayber A (1989). The Germination of Seeds. 4th Ed. Pergamon Press, Oxford, p. 270.

Meloni DA, Oliva MA, Ruiz HA, Maretinez CA (2001). Contribution of proline and inorganic solutes to osmetic adjustment in cotton under salt stress. J. Plant Nutr., 24: 599-612.

Miceli A, Moncada A, D'anna F (2003). Effect of Water Salinity on

Seeds-Germination of *Ocimum basilicum L.*, *Eruca sativa L.* and *Petroselinum hortense Hoffm.* Acta Horti., 609: 365-370.
Mohammad M, Shibli R, Ajlouni M, Nimri L (1998). Tomato root and shoot response to salt stress at different levels of phosphorous nutrition. J. Plant Nutr., 21: 1667-1680.
Morgan P (1990). Effects of abiotic stresses on plant hormone systems. In, Alscher R. G. and Cumming JR (eds) *Stress responses in plants, adaptation and acclimation mechanism*. New York, Wiley-Liss. Phyton. pp. 113-146.
Murillo-Amador B, Troyo-Dieguez E, Jones, HG, Ayala-Chairez F, Tinoco-Ojanguren CL, Lopez-Cortes A (2000). Screening and classification of cowpea genotypes for salt tolerance during germination. Phyton Int. J. Exp. Bot., 67: 71-84.
Poljakoff-Mayber A, Gal J (1975). Plants in Saline Environments. Ecological Studies 15. Berlin, Heidelberg, New York. Springer, pp. 193-199.
Ritchie S, Gilroy S (1998). Gibberellins, regulating genes and germination. New Phytol., 140: 363-383.
Scott TK (1984). Hormonal regulation of development. II. The functions of hormones from the level of the cell to whole plant. In Encyclopaedia of Plant Physiology. New Series. Berlin, Springer-Verlag, pp. 180-185.
Simon JE (1985). Sweet Basil, a production guide. Purdue University Cooperative extension service, HO-189, 3 P.
Singh R, Kundu DK (2000) Soil salinity effect on germination of wheat (*Triticum aestivum* L.), castor (*Ricinus communis*), safflower (*Carthamus tinctorius*) and dill seed (*Anethum graveolens*) in Vertic Ustochrept of Bhal region of Gujarat. Indian J. Agric. Sci., 70: 559-560.
Steel RG, Torrie JH (1960). Principles and procedures of Statistics. McGraw-Hill Book Company, Inc., p. 481.
Ungar IA (1991). Ecophysiology of Vascular Halophytes. CRC Press, Boca Raton, FL., p. 209.
Vicente O, Boscaiu M, Naranjo MA, Estrelles E, Bellé JM, Soriano P (2004). Responses to salt stress in the halophyte *Plantago crassifolia* (*Plantaginaceae*). J. Arid Environ., 58: 463-481.
Zapata PJ, Serrano M, Pretel MT, Amoros A, Botella MA (2004). Polyamines and ethylene changes during germination of different plant species under salinity. Plant Sci., 167: 781-788.
Zehtab-Salmasi S (2008). Effects of salinity and temperature on germination of dill (*Anethum graveolens* L.). Plant Sci. Res., 1: 27-29.
Zhao KF, Li ML, Liu JY (1986). Reduction by GA_3 of NaCl-induced inhibition of growth and development in *Suaeda ussuriensis.* Austr. J. Plant Physiol., 13: 547-551.
Zidan MA, Elewa MA (1995). Effect of salinity on germination, seedling growth and some metabolic changes in four plant species (*Umbelliferae*). Ind. J. Plant Physiol., 38: 5-12.
Zucconi F, Pera A, Forte M, De BM (1981). Evaluating Toxicity of Immature Compost. Biocycle, 22: 54-57.