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Influence of seed pretreatments on growth and yield parameters of dill under salt stress

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Abstract

An experiment was carried out in 2015 at the University of Tabriz, Iran, to evaluate the effects of different seed pre-treatments (Control, 1 mM GA_3 and SA and polymer seed coating) on growth and yield parameters of dill (*Anethum graveolens* L.) under a non-saline and three saline (4, 8 and 12 dS/m NaCl) conditions. This experiment was arranged as factorial, based on RCB design with three replications. Means of plant height, shoot and root weight, plant biomass, umbrella number per plant, 1000 grain weight, grain yield and harvest index were statistically similar up to 8 dS/m NaCl salinities, but significantly decreased under 12 dS/m salinity. Seed polymer coating accelerated the deleterious effects of salinity and generally led to poor performance of plants under salt stress. However, most of the growth and yield parameters of dill were improved as a result of seed pretreatment by gibberellic acid (GA_3) and salicylic acid (SA). The highest grain yield per plant and harvest index were recorded for plants from SA treated seeds, followed by those from GA3 treated seeds.

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Introduction

Medicinal plants gained a considerable importance in agricultural production, pharmacy and exportation because of their use as a raw material for the pharmaceutical industry. Dill (*Anethum graveolens* L.) is widely used in the countries of the temperate and even of the cooler climatic zone. This plant has an attractive appearance, pleasant fragrance and a rich chemical composition. It is used as a popular aromatic herb, a vegetative and an inhibitor of sprouting in stored potatoes and an antispasmodic (Hassan, 2012). Dill is a tolerant plant to salinity, but most of the growing stage of this plant can be affected by salt stress (Shannon and Grieve, 1998).

Among abiotic stresses, salinity stress impairing crop production on at least 20% of irrigated land worldwide. Soil salinity may be the result of poor water management, high evaporation, heavy irrigation, and previous exposure to seawater. High salinity interferes with plant growth and development and can also lead to physiological drought conditions and ion toxicity (Zhu, 2002). General effect of salinity is to reduce the growth rate resulting in smaller leaves, shorter stature, and sometimes fewer leaves. Roots are also reduced in length and mass but may become thinner or thicker. The initial and primary effect of salinity, especially at low to moderate concentrations, is due to its osmotic effects (Daei *et al.,* 2009). The osmotic effects of salinity contribute to reduce growth rate, changes in leaf color, and developmental characteristics such as root/shoot ratio (Shannon and Grieve, 1998).

Yield is a complex entity and associated with a number of component characters. These characters are interrelated and such interdependence of the contributory factors often affects their direct relationship with yield. Each of these components however are affected differently by salinity and hence the need to determine how the individual components are affected by salinity. Reduction in crop yield as a result of salt stress has also been reported for different crops (Karimi *et al.,* 2009; Mahmood *et al.,* 2009; Bybordi, 2010).

Performance of plants may be improved by different methods. Seed priming and coating are good strategies for the possibilities to dwindle the negative effects of salt stress on plants. Priming is the soaking of seeds in a solution of any priming agent followed by drying, that initiates germination related processes without radicle emergence. Primed seeds can rapidly imbibe and revive the seed metabolism, enhancing germination rate and uniformity. Seed priming permits early DNA replication, increases RNA and protein synthesis, enhances embryo growth, repairs deteriorated seed parts and reduces leakage of metabolites (McDonald, 2000). According to Ghassemi-Golezani *et al.* (2013), percentage ground cover of borage (*Borago officinalis* L.) was improved as a result of seed priming. Ahmadian *et al.* (2010) suggested that seed priming increases germination and seedling growth under salt stress in cumin. One of the effective priming methods is pretreatment of seeds with plant growth regulators.

Plant growth regulators such as GAs and SA play critical roles in regulating plant responses to various stresses. Gibberellins (GAs) (especially GA_3) are tetracyclic diterpenoids that act at all stages in the plant life cycle by promoting germination, hypocotyl elongation, phase transitions, root, leaf, stem, and fruit growth, flower and seed development. GA_3 ameliorates the adverse effects of salt stress and restores normal growth and development of crops under salt stress, probably by regulating the level of other phytohormones and increasing stem growing (Hamayun *et al.,* 2010). The favorable effects of GA_3 have been shown to be through increasing the water status of the seedlings and partially by sustaining protein and RNA levels (Banyal and Rai, 1983). SA also has been known as an important molecular signal in the plant reaction for the response to environmental stresses (Senaratna, 2000) that have desirable effects on plant growth and development (Krantev *et al.,* 2008). It has been reported that SA significantly reduces ion leakage and toxic ions accumulation and lead to reducing environmental stresses and increasing plant growth via maintaining other growth promoters such as auxins and cytokinins (Shakirova *et al.,* 2003).

Seed coating is a method of delivering chemical and biological substances with the seed, to benefit seedling survival and establishment in a cost effective manner. This technology has developed in order to improve seed performance (Sangamnathrao, 2009). Using seed coating with polyacrylamide may be effective in increasing water absorption and seedling growth (Taylor and Harman, 1990). Thus, the objective of this research is to evaluate the effects of different seed pretreatments on some growth and yield parameters of dill (*Anethum graveolens* L.) under salt stress.

Materials and methods

Experimental design and treatments

A Factorial experiment based on randomized complete block design with three replications was carried out to evaluate changes in some growth and yield parameters of dill (*Anethum graveolens* L.) plants under a non-saline and three saline (4, 8 and 12 dS/m NaCl) conditions in response to polymer seed coating and hormonal seed pretreatments. Seeds of dill were divided into four sub-samples, one of which was kept as control (untreated), two samples were primed with 1 mM GA_3 (GA_3) and SA (SA) for 4 hours at 25 ± 2°C under a dark condition, and then dried back to initial moisture content at a room temperature of 20-22°C. The other seed sample was coated with a water-absorbent polymer (SC). The hydrophilic polymer used for seed coating was polyacrylamide. Ten grams of seeds were soaked in 0.5% of Arabic gum solution and uniformly were coated with polymer.

Seed sowing and seedling establishment

Treated seeds were sown 1.5 cm deep in each pot filled with 900 g perlite, using 48 pots in general. Pots were then placed in a glass greenhouse under a natural light and a temperature of around 25±2°C. Tap water (EC = 0.59 dSm^{-1}) and saline solutions were added to the pots in accordance with the treatments to achieve 100% FC (Field capacity).

After emergence, seedlings were thinned to keep 10 plants in each pot. During the growth period, the pots were weighed and the losses were made up with Hoagland solution (EC =1.3 dSm^{-1} and pH= 6.5-7). Perlites within the pots were washed every 10 days and non-saline and salinity treatments were reapplied in order to prevent further increase in electrical conductivity (EC) due to adding the Hoagland solution.

Measurement of growth and yield parameters

At maturity, growth parameters such as plant height, shoot dry weight, root dry weight, and root/shoot (R/S) were determined. The dry weights of all plant samples were determined after oven drying at 80°C for 48 h. Five plants were then harvested and plant biomass, umbrella and grain numbers per plant, 1000 grain weight, grain yield per plant and harvest index were recorded. Analysis of variance of the data appropriate to the experimental design and comparison of means (Duncan multiple range test) at $p \leq 0.05$ were carried out, using SPSS16 software.

Results

Growth parameters

Salinity and seed pretreatments significantly influenced plant height shoot and root weights, but root/shoot ratio only affected by seed pretreatments ($p \leq 0.05$). The interaction of salinity × seed pretreatment for these traits was also insignificant. Plant height, shoot and root weights were not significantly changed up to 8 dS/m, but they were significantly decreased under severe salinity (12 dS/m). Plants from seeds treated with GA_3 were taller than those from other seeds Treatment of seeds with GA_3 and SA significantly improved shoot and root weight in comparison with plants from untreated and coated seeds. Seed polymer coating significantly decreased all these traits. The highest and the lowest root/shoot ratio were recorded for plants from GA_3 treated and coated seeds, respectively (Table 1).

Table 1. Means of some growth parameters of dill plants from untreated and pretreated seeds under non-saline and saline conditions.

Treatments	Plant height (cm)	Root weight (g)	Shoot weight (g)	Root/Shoot ratio
Salinity				
Non-saline	86.30 a	1.93 a	4.61 a	0.416 a
4 dS/m	85.43 a	1.90 a	4.51 a	0.418 a
8 dS/m	83.84 a	1.90 a	4.51 a	0.418 a
12 dS/m	77.41 b	1.68 b	3.97 b	0.421 a
Seed pre-treatment				
Control	82.66 b	1.65 b	3.99 b	0.413 c
GA_3	92.16 a	2.22 a	4.99 a	0.445 a
SA	86.25 b	2.13 a	4.92 a	0.432 b
SC	71.91 c	1.42 c	3.70 c	0.384 d

Different letters in each column indicate significant difference at $p \leq 0.05$.

Yield components

Interaction of salinity × seed pretreatments for umbrella number per plant was significant ($p \leq 0.01$). Umbrella number in plants from pretreated and untreated seeds up to 4 dS/m salinity was not changed significantly, but it was reduced under moderate and severe salinities. The highest number of umbrella per plant under 0, 4 and 8 dS/m salinities was recorded for plants from GA_3 treated seeds, followed by those from SA treated seeds, but no significant advantages of these treatments were observed under 12 dS/m salinity. Plants from polymer coated seeds had the lowest umbrella number per plant under all levels of salinity (Fig. 1).

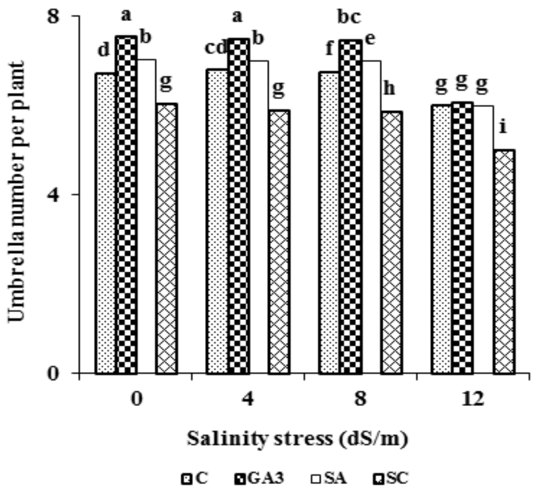

Fig. 1. Umbrella number of dill plants from untreated and pretreated seeds under non-saline and saline conditions.

The effects of salinity and seed pre-treatments on grains per plant and 1000 grain weight were significant ($p \leq 0.05$).

Grains per plant deceased with increasing salinity, with no significant difference between 0 and 4 dS/m and also between 4 and 8 dS/m salinities. 1000 grain weight did not change significantly up to 8 dS/m, but significantly reduced under 12 dS/m.

The number of grains per plant was comparatively higher for plants from GA_3 treated seeds, but the largest grains produced by plants from SA treated seeds (Table 2).

Plant biomass and grain yield

Plant biomass, grain yield and harvest index significantly affected by salinity and seed pre-treatments ($p \leq 0.05$).

All these traits were not influenced by salinities up to 8 dS/m, but significantly decreased under 12 dS/m. The highest plant biomass was recorded for plants from GA_3 treated seeds, followed by plants from SA treated seeds.

However, the highest grain yield and harvest index were achieved by plants from SA treated seeds, followed by those from GA_3 treated seeds. The least of all these traits was observed in plants from polymer coated seeds (Table 2).

Table 2. Means of yield components, plant biomass, grain yield and harvest index of plants from untreated and pretreated seeds under non-saline and saline conditions.

Treatments	Grains per plant	1000 grain weight (g)	Plant biomass (g)	Grain Yield (g)	Harvest index (%)
Salinity					
Non-saline	2320.3 a	1.46 a	7.92 a	3.36 a	29.68 a
4 dS/m	2081 ab	1.60 a	7.81 a	3.29 a	29.49 a
8 dS/m	1814.7 b	1.66 a	7.75 a	3.02 a	27.64 a
12 dS/m	1461.5 c	1.08 c	7.12 b	1.47 b	16.65 b
Seed pre-treatment					
Control	2023.3 b	1.37 b	7.84 b	2.83 b	25.88 b
GA_3	2345.4 a	1.31 b	8.35 a	3.03 ab	26.06 b
SA	1873.9 b	1.79 a	8.01 b	3.32 a	28.94 a
SC	1435.0 c	1.33 b	6.40 c	1.97 c	22.59 c

Different letters in each column indicate significant difference at $p \leq 0.05$.

Discussion

Reduction in plant height, root and shoot weights under severe salinity (Table 1) were likely related with retardation of cell division and expansion as a result of cell wall modifications. However, no significant effects of salinities up to 8 dS/m NaCl on these traits (Table 1) clearly indicate that dill plants are well avoided from osmotic stress under mild and moderate salinities. The most common anatomical response to salinity is related to cell wall modifications. In plants, an accelerated deposition of suberin in cells of the casparian strip was observed and by suberinization of cell wall, cell expansion were limited (Wilson and Peterson, 1983). On other hand, elevated osmotic stress, ion toxicity (due to over accumulation of Na^+), imbalance nutrition and salinity-induced oxidative damage are the principal causes to hamper plant growth under salinity (Munns *et al.,* 2006). Higher tissue Na^+ contents may damage the membranes and organelles leading to growth diminution and unusual development prior to plant mortality (Saqib *et al.,* 2012). No significant effects of salinity on root/shoot ratio of dill plant (table 1) indicated that the restriction of root growth by salinity was similar to that of shoot growth. Plant growth and development are adversely affected by salinity stress as a result of a low osmotic potential, specific effects, nutritional imbalances or combination of these factors (Marsher, 1995). High salinity can also injure cells in transpiring leaves, which leads to growth inhibition (Munns *et al.,* 2006).

Improving plant height, root and shoot weights and root/shoot ratio in response to GA_3 treatment of seeds (Table 1) could be the result of decreasing stomata resistance, increasing water use efficiency and enhancing plant growth rate (Maggio *et al.,* 2010). Increasing root and shoot weights by SA treatment (Table 1) is associated with limitation of ethylene synthesis (Leslie and romani, 1986), enhancing activity of nitrate reductase (Fariduddin *et al.,* 2003) and induction of antioxidant activity (Eraslan *et al.,* 2007). Decreasing the growth of plants from polymer coated seeds (Table 1) may be related to holding more Na^+ ions around the seeds, leading to higher absorption of this ion into leaves and roots.

Loss of grain yield under severe salinity is largely related with reduction in plant growth (Table 1), umbrella number (Fig. 1), grains per plant, 1000 grain weight, plant biomass and harvest index (Table 2). According to Munns (2002), salt stress decreases growth in most plants and these plants are not able to produce their maximum biomass. Reduction of plant growth can potentially reduce photosynthesis and consequently grain yield of dill plants. Decreasing harvest index under severe salinity indicates that reduction in grain yield due to salinity was greater than loss of plant biomass.

Seed polymer coating limited plant growth and reduced yield components and grain yield of dill plants (Tables 1 and 2).

In contrast, priming seeds by GA_3 and SA increased ion absorption and adjusted plants hormonal balance (Iqbal and Ashraf, 2013), leading to increase plant growth parameters (Table 1), yield components and grain yield of dill (Table 2). Increasing root growth with GA_3 and SA priming (Table 1) improved water and nutrient uptake and consequently plant biomass and yield. Less number of grains in plants from SA treated seeds were compensated by more photosynthate mobilization to grains, leading to the production of larger grains (Table 2). Improving plant performance by SA treatment under salt stress could be attributed to reducing damages of stress via increasing the activities of anti-oxidant enzymes (Shi *et al.,* 2006), limiting the synthesis of ethylene (Leslie and romani, 1986), and increasing photosynthetic parameters (Ghassemi-Golezani and Hosseinzadeh-Mahootchi, 2015). Pretreatment of dill seeds by SA had the greatest positive impact on grain yield rather than on plant biomass, leading to the highest harvest index (Table 2).

Conclusion

Means of all growth and yield parameters were not affected by salinities up to 8 dS/m, but significantly reduced under 12 dS/m salinity. This is a clear indication that dill plants can well tolerate low and moderate salinities. Seed polymer coating reduced growth parameters, yield components and grain yield of dill, due to holding more Na^+ ions around the seeds and plants. In contrast, pretreatment of seeds by GA_3 and SA considerably improved growth and yield parameters of dill plants under a non-saline and saline conditions.

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