Journal of Medicinal Plants Research Vol. 5(14), pp. 3142-3145, 18 July, 2011
Available online at http://www.academicjournals.org/JMPR
ISSN 1996-0875 ©2011 Academic Journals

Full Length Research Paper

Changes in essential oil content of dill (*Anethum graveolens*) organs under salinity stress

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Accepted 8 March, 2011

Salinity is one of the most serious environmental factors limiting crop production of marginal agricultural soils in many arid and semi-arid parts of the world. Effects of four levels of salinity (0, 4, 8 and 12 dS/m NaCl) on yield and essential oil content of dill (*Anethum graveolens*) organs (leaves, flowers and seeds) were investigated in 2010. A factorial experiment based on randomized complete block design with four replications was carried out at the Greenhouse of the University of Tabriz, Iran. Results indicated that mean leaf dry weight per plant under non-saline condition was considerably lower than that under saline conditions. However, the effect of salinity on dry weights of flowers and seeds was not significant. Mean essential oil yield was increased with increasing salinity. This improvement directly related with enhancing total yield under saline condition, since essential oil percentage was not significantly affected by salinity stress. The highest and the lowest percentage and yield of essential oil were obtained from seeds and leaves, respectively. Seeds and flowers were the most beneficial organs of dill for essence production. It was concluded that the dill plant is highly salt tolerant and it can well perform under NaCl salinities up to 12 dS/m.

Key words: Dill, essential oil, organs, salinity stress, yield.

INTRODUCTION

Proper management of crop production is needed to achieve high quality plants (Tabatabaie and Nazari, 2007). In medicinal plants, the content of metabolite is economically more important than the yield of the plant part containing the metabolite, as it determines the cost of its extraction (Jaleel et al., 2007). The biosynthesis of secondary metabolites in medicinal and aromatic plants is strongly influenced by environmental factors (Tabatabaie and Nazari, 2007). Salinity in soil or water is one of the serious environmental problem causing drastic changes in the growth, physiology, metabolism and crop productivity (Çiçek and Çakirlar, 2002; Jaleel et al., 2008). The main deleterious effects of salinity on plant growth and yield attributed to osmotic effect, ion toxicity and nutritional imbalance leading to photosynthetic efficiency and stomatal closure (Munns, 2002; Ali et al., 2004; Luo et al., 2005; Muhammad and Hussain, 2010). This reduces CO_2 availability in the leaves and inhibits energy, which in turn could increase the generation of reactive oxygen species and other effects (Parida and Das, 2005; Parvaiz and Satyawati, 2008). For each condition and plant, water and soil management must be properly defined with the aim to reduce hazardous effects of salts (Chartzoulakis and Loupassaki, 1997). High salinity in soils results from naturally high salt levels or from local salt accumulation due to irrigation or the mistake and incorrect application of chemical fertilizers (Tripathi et al., 1998).

All plants tolerate salinity up to a certain threshold level without any yield reduction. Thereafter, an increasing in salinity rate significantly reduces yield (Ozturk et al., 2004). The response of plants to salinity may depend on their developmental stage (Adam, 1990). Dill (*Anethum graveolens*) is an annual aromatic and medicinal plant belonging to the Apiaceae (Umbilliferae) family. Constituents of dill include essential oils, fatty oil, moisture (8.39%), proteins (15.68%), carbohydrates (36%), fibre (14.80%), ash (9.8%) and mineral elements such as calcium, potassium, magnesium, phosphorous, sodium, vitamin A and niacin (Kaur and Arora, 2010). Most of the essential oil is produced in the fruits and flowers of dill, although leaves and stems also contain essential oil (Ghassemi-Golezani et al., 2008). Little information is

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Table 1. Mean dry weights of leaves, flowers, seeds and percentage and yield of essential oil of dill under different salinity treatments.

Salinity (dS/m)	Dry weight (g)			Essential oil (%)	Essential oil yield (mg/plant)
	Leaves	flowers	seeds		
0	0.195b	1.291	0.648	0.518	3.657b
4	0.278a	1.275	0.808	0.523	4.045ab
8	0.309a	1.405	0.900	0.440	4.323ab
12	0.298a	1.491	0.842	0.574	4.834a

Different letters in each column indicate significant difference at P≤0.05.

available regarding the relative salt tolerance of dill at different stages of development. Thus, the objective of this research is to investigate changes in essential oil of leaves, flowers and seeds of dill in response to salinity stress.

MATERIALS AND METHODS

A factorial experiment based on randomized complete block design with four replications was carried out to evaluate the essential oil content of leaves, flowers and seeds of dill under four levels of salinity (0, 4, 8 and 12 dS/m NaCl). Seeds of dill were obtained from Pakan Bazr Company, Esfahan, Iran. Plastic pots with a top diameter of 25 cm and a depth of 25 cm were filled with 900 g perlite. Then, pots were placed in the greenhouse of the Faculty of Agriculture, University of Tabriz, Iran. The lowest and the highest mean temperatures in the greenhouse were 17 and 30ºC, respectively. Tap water (EC = 0.6 dS/m) and saline solutions were added to the pots in accordance with the treatments to achieve 100% FC (field capacity). Ten seeds were sown at 1 cm depth in each pot on 16 February, 2010. After emergence, seedlings were thinned to four plants per pot. During plant growth and development, the pots were weighed and the losses were made up with Hoagland solution (EC = 2 dS/m). Perlite within the pots was washed every 20 days and non saline and salinity treatments were reapplied in order to prevent further increasing in electrical conductivity due to adding Hoagland solution. After harvesting leaves, flowers and seeds, each sample was dried in a room at about 25 to 26ºC for three days, reducing moisture content of plant organs to about 7.4, 3.8 and 4.2%, respectively. Then, harvested organs were separately weighed. Each sample was mixed with 300 ml of distilled water and the essential oil content was determined by hydro-distillation for 3 h, using a modified Clevenger apparatus. All obsevations and measurements were performed on four plants. Analysis of variance of the data was carried out using the MSTAT-C software. Means of each trait were compared by Duncan test at p≤0.05.

RESULTS

Leaf dry weight per plant significantly (P≤0.05) varied in response to salinity. However, flower and seed yields per plant were not significantly affected by salinity (P>0.05). Mean leaf dry weight per plant under non-saline condition was considerably lower than that under saline conditions. However, dry weight of leaves at 4, 8 and 12 dS/m NaCl salinity was statistically similar. Although, mean dry weights of flowers and seeds under salinity stress were also higher than those of control (no-salinity), but these differences were not significant (Table 1). Salinity had significant effect on essential oil yield (P≤0.05). Percentage and yield of essential oil were also significantly varied among plant organs (P≤0.01). However, interaction of salinity × plant organs on these traits was not significant (P>0.05). Mean essential oil percentage under severe salinity was slightly, but not significantly improved (Table 1). In contrast, mean essential oil yield of dill was linearly increased with increasing salinity (Figure 1). The highest mean essential oil percentage was obtained from seeds (0.804%), while the lowest amount was produced from leaves (0.335%). There was no significant difference in essential oil percentage of leaves and flowers (Figure 2). Essential oil yield in seeds and flowers was considerably higher than that in leaves. The highest essential oil yield produced from seeds, which was statistically similar with that of flowers (Figure 3).

DISCUSSION

Increasing leaf, flower and seed dry weights under salinity stress (Table 1) strongly suggests that the dill plant not only tolerate NaCl salinity up to 12 dS/m, but reaches optimal levels of growth under saline conditions. Growth stimulation by salinity has also been reported in *Salicornia europaea* L. (Keiffer et al., 1994), *Alhagi pseudoalhagi* (Kurban et al., 1999), *Atriplex* spp. (Khan et al., 2000), *Salicornia europaea* and *Suaeda maritina* (Moghaieb et al., 2004), *Cakile maritime* (Debez, et al., 2004), *Crithmum maritimum* (Ben-Amor et al., 2005) and *Tetragonia tetragonioides* (Yousif et al., 2010). It would appear that the growth response at moderate salinities may be largely the consequence of an increased uptake of solutes that are required to induce cell expansion, since this maintains the pressure potential in plant tissues (Khan et al., 2000). Salinity may decrease biomass production, because it causes a lowering of plant water potentials, specific ion toxicities, or ionic imbalances (Neumann, 1997). Plants protect themselves from NaCl toxicity by minimizing Na^+ uptake and transport to the shoot (Cramer et al., 1985). Osmotic adjustment under saline condition may be achieved by ion uptake, synthesis of osmotica or both (Cheeseman, 1988; Popp, 1995). Salt tolerant plants differ widely in the extent to which

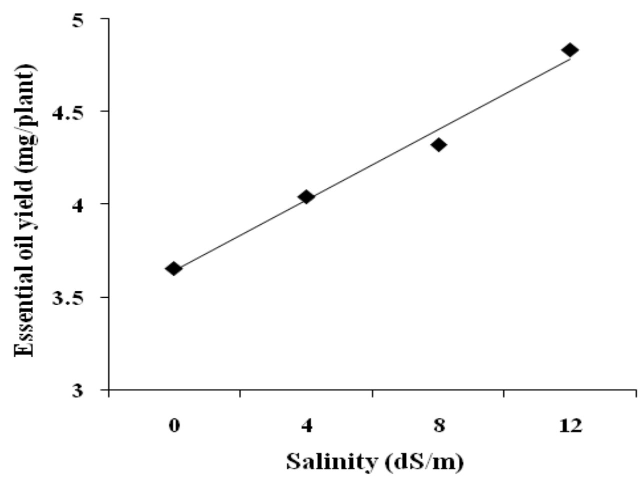

Figure 1. Changes in essential oil percentage of dill under saline and non-saline conditions.

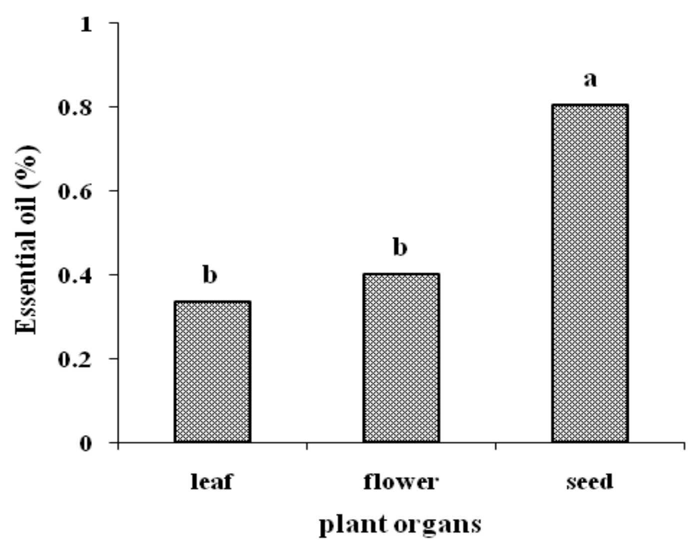

Figure 2. Mean essential oil percentage at different organs of dill.

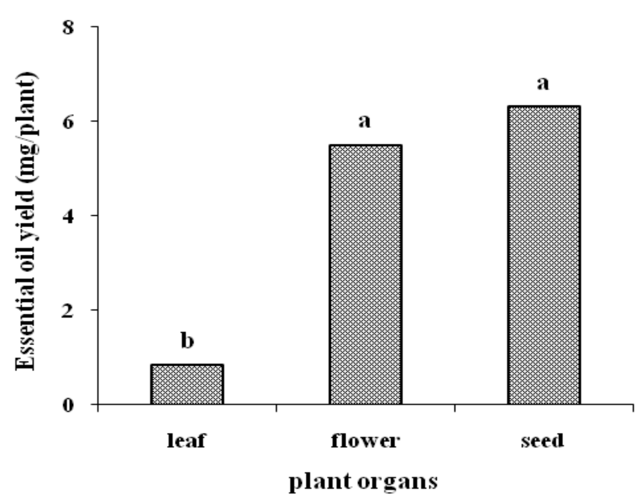

Figure 3. Mean essential oil yield at different organs of dill.

they accumulate ions and overall degree of salt tolerance (Glenn et al., 1996).

Ghassemi-Golezani et al. (2008) reported that the essential oil percentage of dill significantly improved, when plants were subjected to water stress during reproductive stages. This may be attributed to the function of seconddary metabolites as self-defense components against stress conditions. In other words, the stress conditions accelerated the biosynthesis of essential oils (Ezz et al., 2009).No significant effect of salinity stress on essential oil percentage of dill organs (Table 1) clearly indicates that dill plants are well avoided from osmotic stress under saline conditions. Therefore, increasing essential oil yield of dill with enhancing NaCl salinity (Figure 1) can be attributed to the improvements in leaf, flower and seed yields under salinity stress (Table 1).

Essential oil content of seeds was much higher than that of leaves and flowers (Figure 2), suggesting that most of the secondary metabolites of dill were accumulated in seeds. However, essential oil yield of seeds and flowers was statistically similar, but much higher than that of leaves (Figure 3). This was resulted from comparatively higher yield of flowers (Table 1). Seeds and flowers of dill also produced more essential oil in comparison with leaves under drought stress, as previously reported by Ghassemi-Golezani et al. (2008). Thus, seeds and flowers are the most beneficial organs of dill, regarding essential oil production. Nevertheless, dill is largely used as a vegetable because of its medicinal and aromatic characteristics.

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