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Effect of Salinity and Drought Stresses on Growth Parameters and Essential Oil Content of *Matricaria chamomila*

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ABSTRACT

Chamomile (*Matricaria chamomila*) is an important essential oil bearing plant that has adaptability to a wide range of climates and soils. Two experiments were conducted to determine the effect of salinity and drought stresses on growth and oil content of chamomile. Irrigation water with five different salinity levels (0, 84, 168, 252 & 336 mmol L^{-1} NaCl) were applied at shooting stage in potted plants. In the second experiment, five irrigation regimes (irrigation after 2, 4, 6, 8 & 10 days) were used for three months from shooting stage to the end of flowering under field conditions. Results indicated that increased salinity caused reduction in the number of branches per plant, flowers per plant, peduncle length and head diameter. Increased salinity also significantly reduced the fresh and dry flower weight and essential oil content. Drought caused a significant reduction in plant height, the number of branches and flowers, peduncle length, head diameter, fresh and dry flower weight and essential oil content. The highest values of flower dry weight and essential oil content were observed under non-salinity stress (control) and 2 days interval irrigation. Chamomile did tolerate 84 mmol NaCl and 4 days interval irrigation without severe reduction in flower yield and oil content.

Key Words: Chamomile; Essential oil; Salinity; Drought; *Matricaria chamomile*; Growth; Irrigation; Dry weight

INTRODUCTION

Salinity and drought have considerable adverse impacts on productivity of agricultural plants. Soil salinity, resulting from natural processes or from crop irrigation with saline water, occurs in many arid and semi-arid regions of the world (Laüchli & Epstein, 1990). It adversely affects plant growth and development. According to Tanji (1990), 20% of cultivated lands are adversely affected by high salt concentration worldwide, which inhibits plant growth and yield. Removing salinity stress is a main issue in these regions to ensure agricultural sustainability. An excess of soluble salts in the soil leads to osmotic stress, specific ion toxicity and ionic imbalances (Munns, 2003) and the consequences of these can be plant death or yield losses in both crop species and medicinal plants (Rout & Shaw, 2001). Ashraf *et al.* (2004) found that increasing salt concentrations caused a significant reduction in the fresh and dry masses of both shoots and roots as well as seed yield of *Ammolei majus*, while reduced plant fresh and dry yield in *Hyoscyamus niger*.

Limited water supply is also another major environmental constraint in productivity of crop and medicinal plants. Moisture deficiency induces various physiological and metabolic responses like stomatal closure and decline in growth rate and photosynthesis (Flexas & Medrano, 2002). The results of Baher *et al.* (2002) showed that greater soil water stress decreased plant height and total fresh and dry weight of *Satureja hortensis*. Colom and Vazzana (2002) also showed that the number of stem per plant and plant dry weight was negatively related to water stress in *Eragrostis curvula*.

Chamomile (*Matricaria chamomila* L.) is an important essential oil bearing and medicinal plant in recent years. The production of essential oil not only depends upon the metabolic state of the source tissues, but also may be integrated with the stress factors (Sangwan *et al.*, 2001). Chamomile has adaptability to a wide range of climates and soil conditions and its cultivation may be an alternative option in areas with drought and salinity problems. However, the performance of this plant in drought and salinity stress environments, and the effect of these stresses on its oil production have not been studied well. The objective of this research was to evaluate the effect of drought and saline water on growth characteristics and essential oil content of chamomile.

MATERIALS AND METHODS

Salinity experiment. Plastic pots with a top diameter of 20 cm and a depth of 25 cm were filled with clay loam soil. Three seeds of chamomile (*Matricaria chamomila* L.) collected from natural rangelands of Iran were planted in each pot. Then water with five different salinity levels (0,

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84, 168, 252 & 336 mmol L^{-1}) was prepared. This experiment was conducted using a randomized complete block design with three replications under natural conditions in Isfahan, Iran. Irrigation with two liters of saline water was started at shooting stage in each pot and then irrigation with saline water was applied every day for two months. Plant height, peduncle length, the number of flowers per plant, head diameter, the number of branches per plant and fresh and dry weight of flowers were measured. A 20 g sample of dried and threshed flowers was mixed with 500 mL of tap water in flask and water was distilled for 7 h using a Clevenger-type apparatus. The essential oil content was measured. Data were analyzed using SAS statistical program (SAS Institute, 1989).

Drought (irrigation regimes) experiment. Seeds were planted in rows using a randomized complete block design with three replications in the field. Plot size was 2×2 m with 8 rows, row distance was 20 cm and the distance between plans in each row was 10 cm. Plants were watered with five irrigation regimes (at day 2, 4, 6, 8, or 10) after reaching shooting stage during 2006 growth season. Treatments were continued for three months under natural conditions. Plant height, fresh and dry weight of flowers, peduncle length, the number of flowers, head diameter, the number of branches and essential oil content (based on percent flower dry weight) were measured after harvesting and data were statistically analyzed as described for salinity experiment.

RESULTS AND DISCUSSION

Salinity experiment. With increase in salinity from 0 to 336 mmol L^{-1} NaCl, plant height, flower fresh weight, flower dry weight, and peduncle length were reduced from 39 to 20 cm, 4.02 to 1.23 g, 3.78 to 0.81 g and 11.7 to 6.3 cm, respectively (Table I). Salinity also caused reduction in the number of flowers, the number of branches and head diameter (Table II). The main reason for this reduction may be attributed to suppression of growth under salinity stress during the early developmental stages (shooting stage) of the plants. Greatest reduction was observed in oil content (71%) and flower dry weight (78.6%) at 336 mmol L^{-1} NaCl level, but at 84 mmol NaCl level, reduction was as low as 25 and 29.3%, respectively. Also the reduction in the number of flowers (61.36%) was more drastic than other parameters. Reduction in flower dry weight due to salinity may be a cumulative effect of decline in the number of flowers.

Salinity stress significantly decreased essential oil content from 1% in control treatment to 0.29% at 336 mmol salinity level (Table II). Ashraf *et al.* (2004) also showed that oil content in the seed of medicinal plant, bishop's weed (*Ammolei majus*), was decreased consistently with increase in external salt levels. In crop species, salinity also caused reduction in oil content, achene and oil yield (Khatoon *et al.*, 2000; Qasim *et al.*, 2004). Reduced flower weight may have resulted in oil content reduction of chamomile under salinity stress environment. As stated by Munns (2003), suppression of plant growth under saline conditions may either be due to decreased availability of water or to the toxicity of sodium chloride. Also the reduction in dry weight under salinity stress may be attributed to inhibition of hydrolysis of reserved foods and their translocation to the growing shoots. Salinity stress imposes additional energy requirements on plant cells and less carbon is available for growth and flower primordial initiation and then less essential oil may be synthesized (Cheesman, 1988). Kumar and Gill (1995) showed that increasing salinity stresses caused a reduction, both in shoot and root yield of C*itronella*, lemongrass and vetiver. Ansari *et al.* (1998) also compared the performance of three *Cymbopogon* grasses, *C. winterianus, C. flexuosus* and *C. martinii* at different levels of NaCl salinity. They concluded that salinity resulted in the suppression of plant growth and a decline in essential oil concentration and yield in all species.

The ability to limit Na^+ transport into the shoots, and to reduce the Na^+ accumulation in the rapidly growing shoot tissues, is critically important for maintenance of high growth rates and protection of the metabolic process in elongating cells from the toxic effects of Na^+. However, this characteristic was not considered in this study.

Drought (irrigation regimes) experiment. Drought induced by irrigation regimes caused reduction in all growth parameters (Table III & IV). As irrigation regimes increased from 2 to 10 days, plant height, flower fresh weight, flower dry weight, peduncle length and the number of branches were reduced from 43.08 cm to 32.33 cm, 462.4 gm^{-2} to 171.2 gm^{-2}, 188.8 gm^{-2} to 67.2 gm^{-2}, 9.71 cm to 6.52 cm and 464.0 m^{-2} to 388.0 m^{-2}, respectively. Colom and Vazzana (2002) reported that drought, severely reduced average plant height and flower dry weight in three cultivars of *Eragrostis curvula*. The greatest reduction was observed in oil content (69.54%) and flower dry weight (64.4%) under 10 days interval irrigation but under 4 days interval irrigation the reduction was as low as 25.86% and 23.94%, respectively.

The essential oil content decreased from 1.74% in 2 days irrigation regime to 0.53% in 10 days irrigation regime (Table IV). Similar results were observed for *C. flexuosus* under drought by Sangwan *et al.* (1993). The reduction in essential oil content may be due to disturbance in photosynthesis and carbohydrate production under stress condition and suppression of the plant growth (Flexas & Medrano, 2002). Reduction in oil content and compositional alterations in the essential oils as a consequence of drought has also been described in mints (Charles *et al.*, 1990) and sweet basil (Simon *et al.,* 1992). In *Artemisia annua*, Chalchat *et al.* (1994) observed that water stress strongly depressed oil yield and plentiful irrigation raised it. Putievsky *et al.* (1990) also reported that water stress had a negative impact on green yield and essential oil yield of geranium. However, Holtzer *et al.* (1988) believed that depending upon the plant species and plant genotype, drought stress can increase, decrease or have no effect on

Table I. Effect of salinity levels on some growth parameters of chamomile

Salinity (mm)	Height (cm)	Flower fresh weight (g pot^{-1})	Flower dry weight (g pot^{-1})	Peduncle length (cm)
0	39.3±2.25^{a}* (0)	4.02±0.24^{a} (0)	3.78±0.5^{a} (0)	11.7±1.01^{a}* (0)
84	36.0±1.22^{ab} (8.4%)	3.60±0.22^{b} (10.4)	2.67±0.35^{b} (29.3%)	9.3±0.42^{b} (20.5%)
168	33.0±1.03^{bc} (16%)	2.94±0.41^{b} (26.9%)	2.61±0.21^{b} (30.9%)	8.8±0.35^{c} (24.78%)
252	28.3±2.1^{c} (27.9%)	2.79±0.30^{b} (30.6%)	2.04±0.14^{b} (46.03%)	8.2±0.65^{c} (29.91%)
336	20.0±1.54^{d} (49.1%)	1.23±0.12^{c} (69.4%)	0.81±0.06^{c} (78.6%)	6.3±0.83^{d} (46.15%)

*means (±SE) with different letters in each column have significant difference based on Duncan's significant range test, P<0.05. Data in parenthesis are percent reduction in the trait over control treatment in each salinity level.

Table II. Effect of salinity levels on some growth parameters of chamomile

Salinity (mm)	Number of flower per plant	Head diameter (cm)	Number of branch per plant	Essential oil content (%)
0	194.1±14.21^{a} (0)	2.19±0.14^{a}* (0)	24.09±1.04^{a} (0)	1.0±0.007^{a} (0)
84	163.5±10.46^{ab} (15.76%)	2.08±0.09^{a} (5%)	21.09±1.01^{b} (12.45%)	0.75±0.006^{b} (25%)
168	129.9±8.56^{bc} (33.07%)	1.84±0.08^{b} (15.98%)	19.08±1.1^{b} (20.79%)	0.40±0.001^{c} (60%)
252	123.9±6.42^{c} (36.16%)	1.83±0.06^{b} (16.43%)	15.18±1.04^{c} (36.98%)	0.33±0.004^{d} (67%)
336	75.0±7.62^{d} (61.36%)	1.70±0.08^{b} (22.37%)	13.5±1.12^{c} (43.96%)	0.29±0.001^{e} (71%)

*means (±SE) with different letters in each column have significant difference based on Duncan's significant range test, P<0.05. Data in parenthesis are percent reduction in the trait over control treatment in each salinity level.

Table III. Effect of drought (irrigation regimes) levels on some growth parameters of chamomile

Irrigation regime(day)	Height (cm)	Flower fresh weight (gm^{-2})	Flower dry weight (gm^{-2})	Peduncle length(cm)
2	43.08±3.1^{a}* (0)	462.4±21.2^{a}* (0)	188.8±7.25^{a}* (0)	9.71±1.2^{a}* (0)
4	40.20±3.04^{ab} (6.68%)	345.2±12.3^{b} (25.34%)	143.6±8.21^{b} (23.94%)	9.15±1.35^{a} (5.76%)
6	36.96±1.28^{bc} (14.2%)	294.4±11.4^{c} (36.33%)	108.4±2.2^{c} (42.58%)	7.39±0.42^{b} (23.89%)
8	35.33±1.2^{bc} (17.98%)	232.0±8.96^{d} (49.82%)	104.8±2.3^{d} (44.49%)	6.97±0.58^{bc} (28.22%)
10	32.33±1.08^{c} (24.95%)	171.2±8.4^{e} (62.97%)	67.2±1.23^{e} (64.4%)	6.52±0.81^{c} (32.85%)

*means (±SE) with different letters in each column have significant difference based on Duncan's significant range test, P<0.05. Data in parenthesis are percent reduction in the trait in each irrigation regime over 2 day irrigation

Table IV. Effect of drought (irrigation regimes) levels on some growth parameters of chamomile

Irrigation regime(day)	Number of flower (per m^2)	Head diameter (cm)	Number of branch (per m^2)	Essential oil (%)
2	7510.0±186.9^{a}* (0)	2.02±0.05^{a}* (0)	464.0±18.2^{a}* (0)	1.74±0.008^{a}* (0)
4	6204.0±156.8^{b} (17.39%)	1.75±0.02^{b} (13.36%)	456.4±12.1^{a} (1.6%)	1.29±0.002^{b} (25.86%)
6	5162.4±145.5^{c} (31.26%)	1.58±0.01^{c} (21.78%)	450.4±7.45^{ab} (2.93%)	0.73±0.006^{c} (58.04%)
8	4659.2±85.2^{d} (37.96%)	1.53±0.03^{cd} (24.26%)	419.2±8.9^{ab} (9.6%)	0.62±0.009^{d} (64.37%)
10	4097.2±59.4^{e} (45.4%)	1.43±0.01^{d} (29.2%)	388.0±5.8^{b} (16.4%)	0.53±0.001^{e} (69.54%)

*means (±SE) with different letters in each column have significant difference based on Duncan's significant range test, P<0.05. Data in parenthesis are percent reduction in the trait in each irrigation regime over 2-day irrigation

the levels of metabolites. Shabih *et al.* (1999) reported that when moisture deficiency does not limit plant growth and survival, the production of secondary metabolites such as essential oil is even stimulated by limited stressful environments. In this experiment, one accession was used but based on growth retardation under drought stress conditions it seems that irrigation at optimum condition may promote greater essential oil biosynthesis in chamomile.

In this study, NaCl had more inhibitory effect on oil production and all growth parameters except head diameter of chamomile than drought condition based on percent reduction in each trait. Na^+ and Cl^- may readily cross the cell membrane into the cytoplasm, and they are able to accumulate or decreased availability of some essential nutrients (Levitt, 1972). Specific ion toxicity of the Na^+ and Cl^- ions to cell membrane, cytoplasm or nucleus of the cells may partly be related to the fact that NaCl was greatly inhibitory to the growth than drought.

CONCLUSION

Chamomile was moderately tolerant to salinity and water stress, because salinity and water deficiencies inhibited various growth parameters of this plant to various degrees. The oil content indicated a greater reduction due to increased salinity and water stress than other traits. Chamomile can be grown successfully on most agricultural soils, as long as NaCl does not exceed the critical values (84 mmol in this study). Also 4 days irrigation regime may not severely affect flower yield and oil content of chamomile. Thus, chamomile can be grown in soils where enough irrigation water is not available.

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