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Effects of salinity stress on vegetative growth of chrysanthemum [*Dendranthema glandiflora* Kitam.]

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ABSTRACT

Estimates show that about 10% of the world's arable land is affected by salinity. Since water is increasingly becoming a very limited resource in many parts of the world, there is need to explore the potential of using saline water in irrigated agriculture. A greenhouse experiment was carried out to determine the highest level of salinity, which chrysanthemum plants can tolerate in order to reduce use of fresh water in agriculture. The objective of the experiment was to determine the effects of different levels of sodium chloride [NaCl] on the vegetative growth of chrysanthemums. There were five treatments which consisted of irrigation water containing 0 [control], 2, 4, 8, and 16 dS/m NaCl. The treatments were laid out in a randomised complete block design [RCBD]. Results showed that the highest plant height [54.2 cm] was obtained from chrysanthemums irrigated with water containing 2 dS/m NaCl. The lowest plant height [35.6 cm], root length [21.2 cm], shoot fresh mass [203.5 g], shoot dry mass [48.0 g], and root dry mass [2.0 g] at 8 weeks after transplanting [WAT], were obtained from chrysanthemums irrigated with water at 16 dS/m NaCl. An increase in salt concentration above 4 dS/m resulted in a corresponding reduction in all parameters determined. There was more than four-fold reduction in root fresh mass between the control and plants irrigated with 16 dS/m NaCl. There was an almost 15 fold reduction in root dry mass between the control and plants irrigated using 16 dS/m solution. Irrigation water at 16 dS/m was highly detrimental to growth and development of chrysanthemums. Farmers interested in the production of chrysanthemums should use irrigation water at 4 dS/m or less to prevent reduction in plant growth and development.

INTRODUCTION

Chrysanthemum [*Dendranthema grandiflorum* Kitam.] is one of the leading cut flowers in the international market. It belongs to the Asteraceae Family. Modern chrysanthemum cultivars come in an astonishing variety of colours, colour combinations and petal styles [spoon, quill and flat]. They are in high demand during Easter and Mother's day holidays [Biondo and Noland, 2000; Dole and Wilkins, 2005]. They are short-day plants and need to be provided with light [long day] for vegetative growth and covered [short-day] to induce flowering.

Key words: Chrysanthemum, root length, root mass, shoot mass, sodium chloride

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By controlling light duration and temperature, chrysanthemums can be produced throughout the year. They are herbaceous perennial plants grown as cut flower, potted flowering plant, or bedding plant [Bhattachargee and De, 2003].

Salinity is one of the major abiotic stresses in crop production. This problem is especially serious in arid and semi-arid regions [Heyward and Bernstein, 1990]. Many areas which have water scarcity problems also have ground water which is saline [Yeo, 1983]. Such water contains significant amounts of dissolved salts which have detrimental effects on the growth of plants. In most drought prone arid and semi-arid areas, there is plenty of arable land that can be utilized for crop production but insufficient quantity and at times poor quality of water due to salinity, is a limiting factor to agricultural productivity. In these areas, the little fresh water available is reserved for human consumption whilst all other activities such as watering crops, use saline water. In this scenario, whereby the demand for fresh water increases with increasing population and rapid economic growth, saline water is considered an important substitute for fresh water in agriculture irrigation [Dagar, 2009; Robinson *et al*., 1983]. According to Dagar [2009], optimal irrigation with saline waters should entail irrigation schedules to eliminate excess build-up of salinity in soil and at the same time ensure adequate plant growth. The traditional approach for sustaining the use of saline waters is to irrigate the arable crops more frequently and provide adequate leaching requirements. Saline water can be used more successfully on a well-drained light soil than on a poorly-drained heavy soil, and also in areas where seasonal rainfall leaches salts accumulated in the soil. Trickle irrigation can reduce the effects of salinity by maintaining a continuously moist soil around the roots and providing steady leaching of salt to the edge of the wetted zone [Department of Agriculture and Food, 2005].

The response of crop plants to saline water depends on the salinity levels as well as the resistance of the plants to salt stress [Wahome, 2004]. These responses are highly due to osmotic effects, which lead to growth disruption occasioned by reduced water uptake as well as reduced water potential in the soil, which lead to physiological stress. In addition, salinity can lead to accumulation of toxic ions in plant tissues. On the other hand, it can antagonise uptake of essential nutrients, e.g. chloride ions cause reduction in nitrate uptake, while sodium ion causes reduction in potassium uptake, hence inducing deficiencies of ions already in adequate amounts in the soil [El-Wahab, 2006; Suarez and Grieve, 2011; Wahome, 2004].

Plants vary in their tolerance to irrigation with saline water. Irrigating plants with water of salinity higher than the plant can tolerate will result in yield loss and may decrease crop quality [Department of Agriculture and Food, 2004]. Soils with electrical conductivity [EC] in excess of 4 dS/m are considered as saline, while soils with EC less than 2 dS/m are considered non-saline [Anon., 2011; Dagar, 2009]. Chrysanthemums and carnations can tolerate salinity up to 6 dS/m [Zapryanova and Atanassova, 2009]. Concentrations of Cl^- in the external solution of more than 20 mM can lead to chloride toxicity in sensitive plant species [Mauromicale and Licandro, 2002]. In contrast, 20-30 g chloride per kg of leaf dry weight [60-90 mM Cl^- in the leaf water] does not have a harmful effect on tolerant species [Francois, 1980]. In tolerant species, the external concentration can be four to five times higher without reduction in growth. Differences in Cl^- toxicity levels are related mainly to the differences in the sensitivity of leaf tissue to excessive Cl^- levels [Francois, 1980].

In semi-arid and arid regions, particularly under irrigation, concentrations of 50 to 100 mM Na^+ [mostly as NaCl in the soil solution] are typical and have a rather detrimental effect on the growth of most crop plants [Tyerman and Skerret, 1999]. Growth responses of plants to Na^+ are merely reflections of a high salt requirement for osmotic adjustments.

High soil salt contents can cause a plant to become water stressed even though the soil moisture content appears to be adequate. This is due to the difference in salt content between the soil water and the water inside the plant. As soil salts become excessive, uptake of soil water becomes difficult for the plant. The resulting damage looks similar to damage caused from drought or root injury. Symptoms appear as marginal leaf burn, leaf yellowing, reduced root growth, stunted growth or premature leaf drop. As the damage progresses, twig or stem die-back occurs followed by plant death when salt levels exceed the plants maximum salt tolerance [Yeo, 1983]. Thus, plant damage is often easy to detect based on visual symptoms. For ornamental plants, size and appearance are the important criteria for determining salt tolerance. Saline soils contain ions that are high in concentration; the resulting plant damage may be due to specific ion toxicity. All of these mentioned symptoms of salinity effects on plant growth have an overall reduction in crop quality and yield. This study was conducted to determine the effect of using saline irrigation water on vegetative growth of chrysanthemums. It intended to determine the highest salinity level that can significantly reduce growth and development of chrysanthemums.

MATERIALS AND METHODS

Experimental site

The experiment was conducted between 12th January and 30th March 2010 in the greenhouse of the Horticulture Department, Faculty of Agriculture, Luyengo Campus, at the University of Swaziland. The geographical location of the experimental site is latitude 25^0 34' S and longitude 31^0 12' E at an average altitude of 730 m in the Middleveld agro-ecological zone of Swaziland.

Plant materials

Shoot-tip cuttings of chrysanthemum were obtained from the Horticulture Farm and rooted in cold frames for five weeks. Rooted cuttings were planted into black polyethylene bags [25 cm in diameter and 45 cm high]. The substrate used consisted of a mixture of garden soil, sand and cattle manure at the ratio of 1:1:1 [v/v]. The plants were placed in the greenhouse for a week and irrigated using tap water for the purpose of conditioning them before applying the treatments.

Experimental design

There were five treatments which consisted of irrigation water supplied with NaCl at the rate of 0 [control], 2, 4, 8, and 16 dS/m. The treatments were laid out in a Randomised Complete Block Design [RCBD]. Each treatment consisting of 10 pots was replicated four times. The plants were irrigated by applying 140 ml of the solutions per plant every morning using the drip irrigation system. The plants were applied with 2:3:2 [22] + zinc fertiliser at a rate of 2 g per plant.

Data collection and analysis

The data were collected at 2, 4, 6, and 8 weeks after transplanting [WAT]. The parameters measured were plant height [using tape measure], and at the end of the experiments, five plants from each replication were carefully uprooted and root length [using tape measure], shoot fresh and dry mass, root fresh and dry mass measured.

Data collected were subjected to analysis of variance [ANOVA] using MStat-C statistical package. Means that were significant at the 5% level were separated using the Duncan New Multiple Range Test [DNMRT] at P = 0.05.

Fresh and dry masses of shoot and root systems

The roots were washed-off soil particles and inert material. They were then cut-off from the shoots and fresh mass determined. The fresh mass of the separated shoots was also determined. The plant materials were placed in an oven at $65^{o}C$ for three days after which the dry mass of both roots and shoots were determined.

RESULTS AND DISCUSSION

Plant height

There was a significant [$P < 0.05$] difference in plant height in all the treatments throughout the experimental period [2, 4, 6, and 8 WAT]. The highest plant height [54.2 cm] was obtained from chrysanthemums irrigated with 2 dS/m NaCl, while the lowest [35.6 cm] was obtained from plants irrigated with 16 dS/m at 8 WAT [Table 1]. Increasing NaCl concentration in the irrigation water from 2 to 16 dS/m resulted in a 34% reduction in plant height. Every increase in NaCl concentration in the irrigation water above 2 dS/m resulted in a significant [$P < 0.05$] reduction in plant height of chrysanthemums [Table 1].

Table 1. Effects of different NaCl levels on plant height of chrysanthemum plants.

NaCl concentration [dS/m]	Time of determination [weeks]/plant height [cm]			
	2	4	6	8 WAT
0	31.9c	36.7b	41.1 b	48.6b
2	33.7a	38.2a	41.9a	54.2a
4	30.4d	34.6c	38.8c	45.9c
8	32.4b	32.1d	36.0d	41.5d
16	29.3e	30.3e	32.7e	35.6e

Means followed by same letter along columns not significantly different. Mean separation by DNMRT at P = 0.05.

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Chrysanthemums grown *in vitro* under 0, 20, 40, 60, 80, 100, 150, and 300 mM NaCl showed significant reduction in plant height with increasing salinity [Shatnawi *et al*., 2011]. Farooq *et al*. [2010] observed a reduction in shoot length of acacia [*Acacia nilotica* L.] with increased salinity in the irrigation water. El-Wahab [2006] argued that, reduction in plant height in fennel with increased salinity could be attributed to decreased cell division and inhibition of differentiation of cells. Similarly, the reduction in plant height in chrysanthemum with increased NaCl concentration in irrigation water in this investigation could also be attributed to reduced growth caused by reduction in cell division.

Excess salts in the root zone hinder plant roots from absorbing water from surrounding soil [Montana State University, 2011]. The presence of salt in water causes plants to exert more energy extracting water from the soil. The reduction in plant height in this investigation as a result of increased NaCl levels in the irrigation water could also be attributed to reduction in water absorption and waste of energy in water extraction from soil, energy, which could have been used to support vegetative growth.

Highest plant height in Sedum [*Sedum album L.*] was obtained under non-saline conditions [Al-Busaidi *et al*., 2007]. In contrast, in this investigation, the highest plant height was obtained from chrysanthemums irrigated with water containing 2 dS/m NaCl at all times of determination. However, further increase in NaCl levels in the irrigation water resulted in significant reduction in plant height.

Root length

There was a significant [P < 0.05] difference in the root length of chrysanthemum plants in all the treatments. Chrysanthemums irrigated with 4 dS/m solution had the highest root length of 27.7 cm [Table 2]. The lowest root length [21.2 cm] was obtained from plants irrigated with 16 dS/m solution. Increase in salt concentration above 4 dS/m resulted in a corresponding significant [P < 0.05] reduction in root length of the plants [Table 2].

Table 2. Effects of different NaCl levels on vegetative growth of chrysanthemums at 8 weeks after transplanting.

NaCl concentration [dS/m]	Root length [cm]	Shoot fresh mass [g]	Shoot dry mass [g]	Root fresh mass [g]	Root dry mass [g]
0	24.6c	363.0c	79.0c	94.0a	29.5a
2	25.3b	384.5b	81.0b	68.5b	21.5b
4	27.7a	392.0a	85.5a	47.5c	17.0c
8	23.2d	267.0d	55.5d	25.0d	6.0d

16	21.2e	203.5e	48.0e	21.2e	2.0e

Means followed by same letter along columns not significantly different. Mean separation by DNMRT at P = 0.05.

A reduction in root length with increased salinity in the irrigation water was observed in acacia [Farooq *et al*., 2010] and eucalyptus seedlings [El-Juhany and Ahmed, 2008]. The reduction in root length in chrysanthemums in this study could probably have been caused by reduction in nutrient uptake, physiological drought and ion toxicity as a result of increased sodium and chloride ions in the soil solution.

Shoot fresh and dry masses

There was a significant [$P < 0.05$] difference in shoot fresh mass of chrysanthemums in all the treatments. The highest shoot fresh [392.0 g] and dry mass [85.5] were obtained from plants irrigated with 4 dS/m and the lowest fresh [203.5 g] and dry mass [48.0 g] from those irrigated with 16 dS/m solution [Table 2]. Any further increase in NaCl concentration above 4 dS/m resulted in a corresponding significant [$P < 0.05$] reduction in both shoot fresh and dry masses [Table 2].

A reduction in shoot fresh and dry mass with increased salinity in the irrigation water was observed in acacia [Farooq *et al*., 2010], eucalyptus seedlings [El-Juhany and Ahmed, 2008] and spinach [Yousif *et al*., 2010]. Lee and Van Iersel [2008] observed that the combination of a small reduction in dry mass and a large decrease in transpiration resulted in increased water use efficiency when chrysanthemum plants received 1 g/l NaCl. Concentrations of 3 g/l NaCl or higher resulted in poor quality plants either as a result of wilting of leaves [3 g/l NaCl] or severely stunted plants [6 and 9 g/l NaCl]. They concluded that chrysanthemums could be grown successfully with 1 g/l NaCl in the irrigation water without any negative impacts on plant quality. Similarly, in this investigation, increasing NaCl concentration in irrigation water from 0 to 4 dS/m resulted in significant increase in shoot fresh and dry mass indicating that growth was not impaired at these salinity levels. According to Mazher *et al*. [2007], salinity may stimulate or cause no change in physiological processes in halophytes. However, salinity reduces vegetative and reproductive growth in non-halophytes. In some plants, salinity decreases carbohydrates or growth hormones, thereby inhibiting growth.

Root fresh and dry masses

Each increase in salt concentration resulted in significant reduction in root fresh mass of chrysanthemums [Table 2]. The highest root fresh [94.0 g] and dry mass [29.5 g] were obtained from the control plants, while the lowest fresh [21.2 g] and dry mass [2.0 g] were from plants irrigated with 16 dS/m NaCl. Increasing NaCl concentration in irrigation water from 0 dS/m [control] to 16 dS/m NaCl resulted in a more than four times reduction in root fresh mass. There was an almost 15-fold reduction in root dry mass between the control and plants irrigated using 16 dS/m solution. Increasing NaCl concentration in irrigation water from 0 to 2 dS/m resulted in almost 30% reduction in root dry mass of chrysanthemums.

In this investigation, the highest root fresh and dry mass was obtained from chrysanthemum grown using non-saline water. Similar observations were reported in lettuce [Al-Maskri *et al.,* 2010]. Small changes in salt concentration are sufficient to suppress vegetative growth and plant development

[Zapryanova and Atanassova, 2009]. Farooq *et al*. [2010] observed a reduction in root fresh and dry mass of acacia with increase salinity in the irrigation water. Similarly, in this study, every increase in NaCl concentration in the irrigation water resulted in a significant [$P < 0.05$] reduction in root fresh and dry mass. Teerarak *et al*. [2009] postulated that, increasing levels of NaCl in irrigation water caused a reduction in root growth and had inhibitory effects on mitosis in root tips. This could have also been the case in this study.

Neumann [1995] indicated that salinity can rapidly inhibit root growth and hence capacity of water uptake and essential mineral nutrition from soil. Inhibition of plant growth by salinity may be due to the inhibitory effect of ions. The reduction in root and shoot development may be due to toxic effects of the NaCl used, unbalanced nutrient uptake by the plants as well as the ability of the root system to control entry of ions to the shoots which is of crucial importance to the plant's survival in the presence of NaCl. High salinity levels may inhibit root and shoot elongation due to the slow-down of water uptake by the plant. The chrysanthemum plant showed reduction in root fresh and dry masses and this could be attributed to osmotic effects [Volkmar *et al.*, 1998]. Similarly, in this study the reduction in root fresh and dry masses with increasing NaCl concentration in irrigation water could be attributed to both osmotic effects and specific ion toxicity.

CONCLUSION

Salinity levels above 4 dS/m resulted in reduction of all vegetative growth parameters determined. Irrigation water at 16 dS/m was highly detrimental to growth and development of chrysanthemums. Farmers interested in the production of chrysanthemums should use irrigation water at 4 dS/m or less to prevent reduction in plant growth and development.

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