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Effect of salinity on leaf growth, leaf injury and biomass production in date palm (*Phoenix dactylifera* L.) cultivars

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Abstract

The date palm *Phoenix dactylifera* L. is the most important crop in the Kingdom of Saudi Arabia. The Kingdom produces nearly a million tons of dates annually from an estimated 21 million date palms. Trials conducted at the National Date Palm Research Centre, Al Hassa, Saudi Arabia to determine the effect of salinity on leaf growth, leaf injury and biomass production in date palm revealed that increasing soil salinity levels adversely impacted growth and biomass of date palm, besides causing leaf injury. However, Saudi Arabia's premier date cultivar (Khalas) was the most salt tolerant cultivar tested in this study as it recorded the best leaf growth, least leaf injury and significantly lowest reduction in biomass upon application of salt treatments.

Keywords: *Phoenix dactylifera* L., biomass, date palm, leaf growth, salinity

Introduction

The Kingdom of Saudi Arabia (KSA) covers an area of 2000,000 km^2, which is about 80% of the total Arabian Peninsula. The country lies between latitude 15.2° and 32.6° North and longitude 34.1° and 55.5° East. The climate is characterized as desert-like and arid, rainfall occurs mainly in winter but never exceeds 100 mm per year in most regions except for the southwestern mountains of Asir, where it rains more often during summer. The agricultural sector in the Kingdom has to face serious problems of drought and salinity, the latter affecting crop production in many areas.

The date palm (*Phoenix dactylifera* L.) belongs to the family *Palmaceae*. The origin of date palms is considered to be in Babel (Iraq). However, others believe that it originated in Dareen, Hofuf (KSA) or Harqan, an island in the Arab Gulf in Bahrain and was afterwards spread to Babel (Marei, 1971). Date palm is the major fruit crop of Saudi Arabia covering approximately 72% of the total area under permanent crops. With an estimated 23 million date palm trees is 162,000 ha, the Kingdom produces one million of tons annually. More than 400 different date palm cultivars are reported to exist in Saudi Arabia (Anonymous, 2006). The date palm is a multipurpose tree, providing food, shelter, timber products and all parts of the palm can be used in many different ways. The date fruit is a good source of food providing, fibre, carbohydrates, minerals and vitamins besides having anti-mutagenic and anti-carcinogenic properties (Mohamed, 2000; Vayalill, 2002; Al-Farsi *et al*., 2005; Ishurd & Kennedy, 2005; Baloch *et al*., 2006). Date palm is considered to have high salt tolerance as compared to other fruit crops (Anonymous, 2002).

This study is aimed at describing the effects of salinity on leaf growth, leaf injury and biomass production in date palm.

Materials and methods

The experiments were carried out at the experimental site of the National Date Palm Research Center at Al Hassa, Saudi Arabia. With an estimated three million date palms Al Hassa (25^{O}19' 60"N latitude and 49 ^{O} 37' 60" E longitude) is the largest date palm oasis of the Kingdom situated about 300 km South East of the capital Riyadh.

Date palm cultivars

Three-year-old offshoots of Khalas, Barhee, and Majdool date palm cultivars were used. The study pertains to the nonbearing stage of date palm cultivars (young offshoots), since adult trees are difficult to partition for detailed nutrient analysis and biomass production. Furthermore, many studies have shown the close relation of such studies between effects on nonbearing (offshoots/seedlings) and bearing stages (adult trees) of fruit crops (Sykes, 1992; Marschner, 1997).

Selection of the three cultivars for this study was based on the local, regional and international popularity of these cultivars. While Khalas is the most popular date palm cultivar in the Eastern province of Saudi Arabia where Al-Hassa is located, the cultivar Barhee has high regional preference among farmers of the Gulf countries in the Middle East, while Majdool is an internationally acclaimed date cultivar of North Africa.

Salinity treatments

During the course of the experiment, the growth medium was salinized with 0, 50, 100, 200 and 400 mM NaCl as the main source of salinity. These concentrations represent low, medium, high and excessive high salinity conditions and simulate the levels of NaCl in natural and sea irrigation water.

Salinity culture system

The offshoots were grown in 30-litre pots filled with quartz sand (particle size 0.7-2.0 mm, field capacity 17.7

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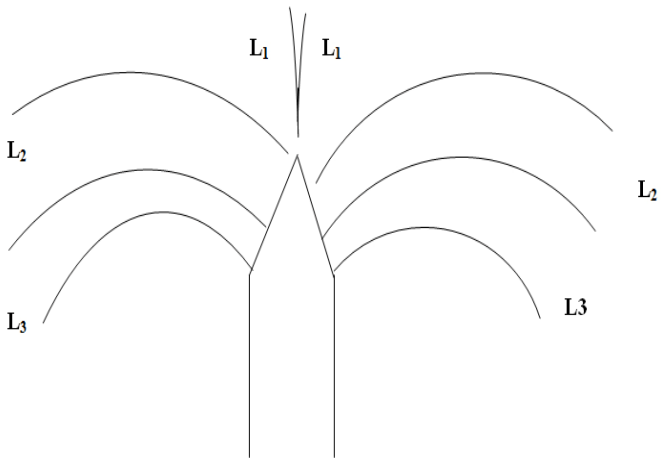
wt %). Natural soil of date palm stands was not used since it includes nutrients that will interfere with the treatments. However, defined amounts of nutrients applied as compound NPK (N18%- P18%- K5%) fertilizers were provided as 10 grams NPK to each offshoot twice a year during the course of the experiment.

Experimental procedures

Vegetative growth

Leaf dynamics: Leaves of the offshoots were categorized as: a). Expanding (the most upper leaf, L_1), b). Recently expanded (the middle leaf, L_2) and c). Fully expanded (the base leaf, L_3) as described in Fig.1. Leaf growth was evaluated by measuring the extension in leaf length of tagged most upper leaf (L_1) of the offshoots at the start of the experiment and in 8-weeks intervals throughout the experiment until its termination. Number of initiated and senescent leaves was determined from the start of the experiment in one-month intervals until the end of the trials.

Fig. 1. Date palm offshoot leaf categorization, where L_1 represents the upper most leaf; L_2 the middle leaf and L_3 the fully expanded leaf.



Salt injury symptoms in leaves: The position, time of occurrence and intensity of visible salt injury symptoms due to 400 mM NaCl application was monitored on the leaves during the course of the experiment. The intensity of leaf injury was estimated on leaflets of two tagged fully expanded leaves according to the following scale: 0 = no visible salt injury symptoms (healthy); 1 = less than 5% of the leaf area is affected (light damage); 2 = between 5 to 15% of the leaf area is affected (moderate damage); 3 = more than 15% of the leaf area is affected (severe damage).

*Biomass production and partitioning***:** At the end of the experiment, all offshoots were harvested and separated into their individual parts, namely leaf, trunk and root, and fresh weight was assessed. Dry weight was determined after drying the samples in a forced air oven at 75°C until constant weight.

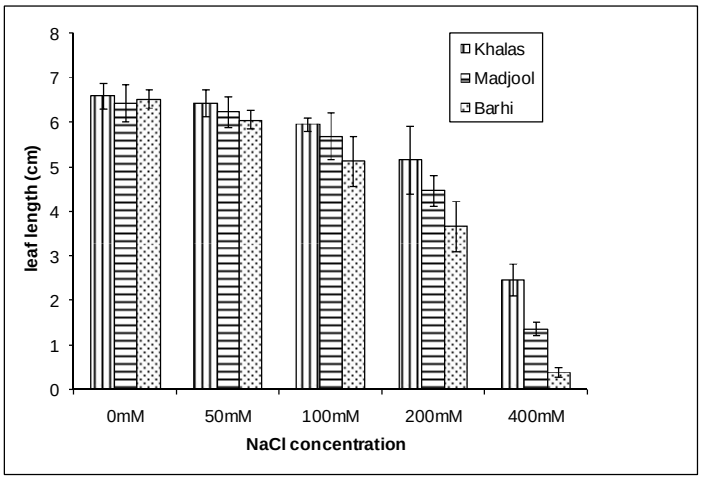
Statistical analysis

A fully randomized block design with factorial combinations of three date palm cultivars and five NaCl levels replicated three times were used to conduct the experiment. Experimental data on all variables was subjected to analysis of variance (ANOVA) procedures using the SAS program (SAS Institute, 1985). Mean separation was calculated by Duncan Multiple Range Test (Gomez & Gome, 1984). Experimental results are presented and discussed below. Throughout, p=0.05 was used to define statistical significance.

Results and discussion

Leaf growth

Fig. 2. Effect of NaCl concentrations (0, 50, 100, 200 and 400 mM) on leaf growth in date palm. Bars = LSD (5%)EffE- -



In the present experiment, NaCl salinity depressed plant growth of all date palm. Leaf length was significantly reduced in all cultivars cultivars (Fig.2). With increasing salt level, the effect was more sever in cv. Madjol and Barhi than Khalas (62, 78 & 93%), respectively. At 400mM NaCl, all cultivars exhibited reduced leaf length at (77%) compared with 50,100 and 200Mm NaCl (4, 13 and 31%, respectively). Reduction in vegetative growth due to salinity was also reported by Ramoliya & Pandey (2003) in date palm and Shalhevet *et al.* (1974) in citrus. Decrease in leaf length in (Fig.1) may be explained by (1) a reduced net assimilation rate, (2) a reduction of mesophyll cell size and/or (3) a decrease in palisade cell layer in the leaves (Chen *et al.,* 1997). Levitt 1980 proposed that the excessive accumulation of Na and /or Cl might depress plant growth, because high concentration of these ions in the cytoplasm result a loss of enzyme activity and inhibition of leaf photosynthesis. Increased water salinity (12.9 ds/m) reduced growth of date palm seedlings as expressed by length or fresh weight of the seedlings, besides increasing infection rate by the fungus *Thielaviopsis paradoxa* which causes black scorch in date palm (Al-Rokibah *et al.,* 1998). Plant growth measured as a rate of leaf births in *Puccinellia*

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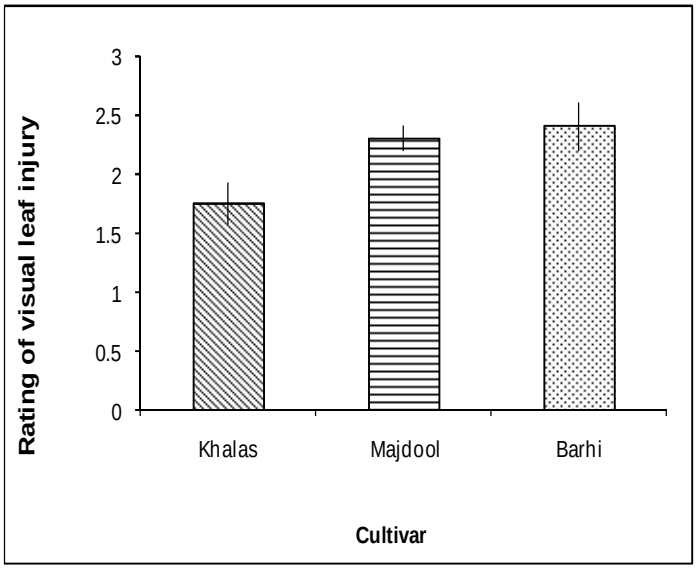
phyrganodes was reduced by high soil salinities (Srivastava & Jefferies, 1996).

Fig. 3. Effect of Nacl (400mM) on leaf injury in date palm. Three cultivars were tested "Khalas - Majdool & Barhi". Bars = LSD (5%).



Leaf injury

Ten days from the start of salt application (400 mM NaCl), fully expanding leaves (at lower ring of tree) of Madjol showed necrotic symptoms as result of the salt treatment. These necrotic symptoms started with leaflet tip burning, which advanced progressively along the leaflet margins but the mid rib of the leaf was green. In Khalas and Barhi the burning leaflet was observed at mid rib. The symptoms were sever in leaves from lower rings to upper rings (fully expanding, recently expanding and expanding leaves) treated with higher salt level (400 mM NaCl). The necrotic symptoms increased after 21 days for Madjol and Barhi, but after 40 days from start of treatment in Khalas Fig.3. The leaves of Khalas , Madjol and Barhi trees treated with salt (400 mM NaCl) showed necrotic symptoms (Rating of visual leaf injury 1.7, 2.3 and 2.4) respectively, Khalas was the lowest (1.7) damage of leaves compared with Madjol and Barhi . Findings on damaged leaf blade were in agreement with the observations by Maas (1993) who reported that in many herbaceous crop species, grapevine and several fruit trees, salinity resulted injury, in form of marginal chlorosis and necrosis on mature leaves. Greenway & Munns (1980) observed the accumulation of Cl and or Na ions in leaves of salt affected plants .The causes of leaf damage may differ among species and cultivars. Carter (1981) suggested that it could be due to the increase in EC (osmotic effect) in the soil while Ulrich *et al.* (1980) mentioned that it could be due to the accumulation of Na ion in the leaf, but Hoffman 1981 attributed leaf injury in salt affected crops due to specific action of Cl ion.

Biomass

The effect of salinity on plants has always been determined not in terms of plant survival , but in its effect on plant growth (Flowers & Yeo, 1989) .Moreover, plants are normally categorized on the basis of their growth response to salt (Greenway & Munns, 1980). This clearly indicates that plant growth is a key parameter in determining effects of salt stress. Al-Rokibah *et al.* (1998) reported that increased salinity levels adversely affected growth of date palm.

Our study revealed significant biomass reduction with increasing salinity level in all the three cultivars Khalas, Madjol and Barhi at root, stem, young leaf and mature leaf (Fig.4). Highest reduction was recorded in young leaf as compared to stem, root and mature leaf (74.6, 70.5, 69.3 and 60.9 %, respectively). Lowest reduction of biomass was recorded in Khalas as compared with Madjol and Barhi cv at 400 mM NaCl at (Root: 55.0, 77.9 and 75.1%), (Stem: 53.7, 75.6 and 82.1%), (Young leaf: 60.4, 79.6, and 83.8%), (Mature leaf 47.2, 64.9 and 60.9%), respectively. In Australia, recent reports suggest that the date palm can be successfully cultivated in an extremely salty root zone environment (Anonymous, 2007). Our results are in agreement with the studies pertaining to salinity of an Arctic salt-marsh which revealed that soil salinity was inversely related to above-ground biomass and shoot density of the graminioid, *Puccinellia phyrganodes* (Srivastava & Jefferies, 1996).

Conclusion

Studies on the effect of salinity on three date palm cultivars revealed that, salinity depressed plant growth of all date palm cultivars tested. Leaf length was significantly reduced in all cultivars with increasing salt level, the effect was more sever in cv. Madjol and Barhi than Khalas (62, 78 and 93%, respectively). At 400mM NaCl all cultivars registered 77% leaf length reduction as compared with 50,100 and 200Mm NaCl (4, 13 and 31%).

With regard to leaf injury, after 10 days from the start of salt application, fully expanding leaves (at lower ring of tree) of Madjol showed necrotic symptoms as result of the salt treatments. These necrotic symptoms started with leaflet tip burning, which advanced progressively along the leaflet margins. However, the mid rib of the leaf was green. In Khalas and Barhi the burning leaflets with mid rib. The symptoms were sever in leaves started from lower rings to upper rings (fully expanding, recently expanding and expanding leaves) treated with higher salt level (400 mM NaCl). The necrotic symptoms increased after 21 days for Madjol and Barhi. However, leaf injury symptoms in Khalas were seen after 40 days from the start of salt application. The leaves of Khalas, Madjol and Barhi trees treated with salt (400 mM NaCl) showed necrotic symptoms (Rating of visual leaf injury 1.7, 2.3 and 2.4) respectively .Khalas recorded the lowest (1.7) damage of leaves compared with Madjol and Barhi.

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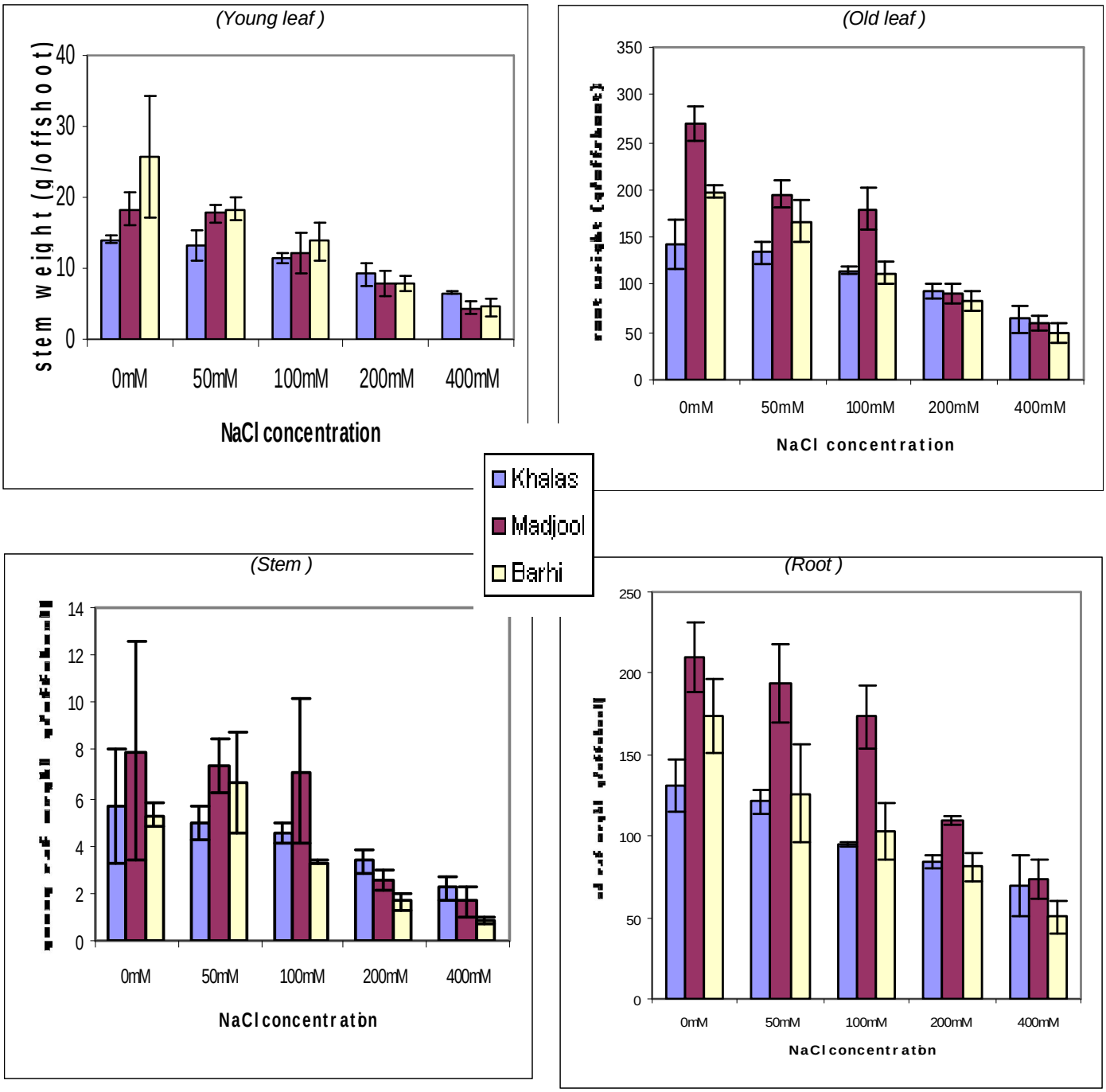
Fig. 4. Effect of Nacl concentrations (0, 50, 100, 200 and 400 mM) on biomass of date palm (Leaf, stem and root). Bars = LSD (5%).



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Experimental results revealed that biomass significantly reduced with increasing salinity levels for all cultivars tested (Khalas, Madjol and Barhi) at root, stem, young leaf and mature leaf. Highest reduction was seen in young leaf compared with stem, root and mature leaf (74.6, 70.5, 69.3 and 60.9 %, respectively). Cultivar wise the lowest reduction of biomass was recorded in Khalas cv as compared with Madjol and Barhi cv at 400 mM NaCl (root: 55,77.9 and 75.1%), (stem: 53.7, 75.6 and 82.1%), (young leaf: 60.4,79.6 and 83.8%),(mature leaf: 47.2, 64.9 and 60.9%), respectively .

In general our study reveals that increasing soil salinity levels adversely impact growth and biomass of date palm, besides causing leaf injury. However, Saudi Arabia's premier date cultivar (Khalas) recorded better leaf growth, least leaf injury and significantly lowest reduction in biomass due to application of salt treatments. Tolerance to soil salinity is probably one of the main reasons that Khalas is popular among the date farmers in Al Hassa oasis in Saudi Arabia.

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