Effect of Salinity on Growth of Twelve Cultivars of the United Arab Emirates Date Palm

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Effect of Salinity on Growth of Twelve Cultivars of the United Arab Emirates Date Palm

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²University of Arizona, Department of Soil, Water, and Environmental Science, Tucson, Arizona, USA

Abstract: To successfully use salt water for crop production and start a breeding program, more information is needed about the response of salt-tolerant plants to saline environments. The objective of this experiment was to test the growth of 12 cultivars of the United Arab Emirates date palm seeds at four sodium chloride (NaCl) levels. The experiment was a randomized complete block design with three replicates. Optimal growth was found at control and 3000 ppm of NaCl. Relative growth rate (RGR), biomass, and number of leaves (NL) decreased significantly by increasing salinity. Increased NaCl leads to significant decreases in potassium (K⁺), magnesium (Mg²⁺), and calcium (Ca²⁺) contents of plants. The Na/K ratios were lower in shoots than in roots. ‘Lulu,’ ‘Fard,’ ‘Khnaizi,’ ‘Nabtat Safi,’ and ‘Razez’ cultivars showed greater RGR and biomasses, whereas ‘Khnaizi,’ ‘Mesally,’ and ‘Safri’ had greater Na/K ratios than others in the control indicating greater Na⁺ discriminations from plant parts.

Keywords: Halophyte, seedling, sodium chloride
INTRODUCTION

Arid and semi-arid regions represent about one third of the world’s land (Archibold 1995). Lack of fresh water in these regions is one of the most critical problems facing agricultural development. Soil salinity is often associated with the lack of water in arid areas. Halophytic plants that have the ability to survive in these stressful conditions are needed.

Date palm (*Phoenix dactylifera*) accounts for more than 1500 cultivars around the world (FAO 2002). It has the ability to survive in harsh environments with long, dry summers and mild winters. Date palm is a halophytic plant; in fact, it is more salt tolerant than any other fruit crop (FAO 1982). Khudairi (1958) stated that the date palm around Baghdad survives in saline soils that have 6% total soluble salts and 0.32% chloride (Cl). Furr (1975) reported that date palm is more salt tolerant than barley and may be the most salt tolerant of all crop plants. Barley is usually grown in the cool season; in contrast, date palms grow faster in hot weather when salinity has the most adverse influence on plants.

The stages of germination and establishment are critical stages in the life cycle of halophytes (Irwin 1978). In a laboratory experiment using *Atriplex semibaccata*, Millington, Burvill, and Marsh (1951) found that *Atriplex s.* was more sensitive to salinity at the germination stage than at other stages of growth. Generally solutions with salinities of more than 1% sodium chloride (NaCl) cause reductions in germination of halophytes. Germination time is delayed (Chapman 1974), and germination percentages are decreased (Irwin 1978) with increasing salt concentrations.

Because only a few varieties of date palms have been used in research (Aljuburi 1992; Furr and Ream 1968; Hewitt 1963; Khudairi 1958; Ramoliya and Pandey 2003), little information is available about the growth of date palm seedlings in saline environments, and the variability in salt tolerance among cultivars is largely unknown. Khudairi (1958) was one of the early scientists to evaluate the behavior of date seeds in a saline environment. Khudairi (1958) used the ‘Zahedi’ cultivar to examine the seed germination in three concentrations of NaCl solutions (0.5, 1.0, and 2.0%). It was observed that NaCl suppressed the germinations during the early stages, and at 2% NaCl the germination was delayed for 25 days and the maximum germination did not exceed 50%. In the same experiment, Khudairi (1958) evaluated the effect of NaCl ranging between 0.1% (1000 ppm) to 2.5% (25,000 ppm) on germination of ‘Zahidi’ date palm seeds. It was concluded that seed germination was not affected by solution concentrations up to 0.8% (8000 ppm) and germination continued in solutions up to 2% (20,000 ppm). Ramoliya and Pandey (2003) studied the effect of chlorides and sulfate salts of
sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg) on the
growth of the ‘Rati’ cultivar of date palm using six different concentra-
tions of salts (4.3, 6.0, 8.2, 10.5, 12.8, and 14.6 dS m\(^{-1}\)). They found that
the ‘Rati’ cultivar is salt tolerant at the seed germination stage and that it
survived and grew up in soil salinity exceeding 12.8 dS m\(^{-1}\). Furr and
Ream (1968) conducted a field experiment to determine the effect of
salinity between 520 to 24,000 ppm of salt on growth and salt uptake of
‘Deglet Noor’ and ‘Medjool’ varieties of date palms. Their results
suggested that the accumulation of Na and chloride in the plants
increased as the salt concentration of the irrigation water increased, but
the concentration in the plants was not proportional to the concentration
of those ions in the water for each treatment. Furthermore, the average
growth rate of leaves was depressed as the salt concentration of the water
increased. They also found that the Na and chloride in the tops of ‘Deglet
Noor’ were slightly greater than in ‘Medjool,’ but in the roots the reverse
was true. They concluded that depression of growth was more related to
salinity of irrigation water than to salt content of the plants. Hewitt
(1963) tested the effect of various salts and salt concentrations on the
germination of ‘Deglet Noor’ seeds. He used various combinations of
NaCl, calcium chloride (CaCl\(_2\)), sodium sulfate (Na\(_2\)SO\(_4\)), NaCl + CaCl\(_2\),
and NaCl + Na\(_2\)SO\(_4\) with concentrations from 10,000 to more than
30,000 ppm of salts. The result of his study was that the growth decreased
slightly at 10,000 ppm, decreased drastically at 20,000 ppm, and was
prevented at 30,000 ppm except for three seedlings in NaCl + Na\(_2\)SO\(_4\)
34,000 ppm treatment. Moreover, it was found that chloride uptake by the
roots was not necessary associated with increased chloride concentration in
the tops. Other research done by Aljuburi (1992) evaluated the behavior of
four cultivars of date palms, ‘Lulu,’ ‘Khalas,’ ‘Boman,’ and ‘Barhee,’ using
four water salinity concentrations (0, 0.6, 1.2, and 1.8%). He indicated that
the cultivar ‘Lulu’ was highly susceptible to salinity compared to the other
cultivars. In addition, Furr and Armstrong (1962) studied the effect of
salinity on the growth of mature date palms. They tested the effect of
several soil salinities on 17-year-old ‘Halawy’ and ‘Medjool’ date palms
using electrical conductivity of the soil saturation extract (EC\(_e\)) ranges of
4–24 mmhos cm\(^{-1}\) (about 2,500–15,300 ppm). They found little or no effect
on growth rate of leaves, yield, size or quality of fruit, or on chloride
content of the leaf pinnae.

Fresh water resources in most arid regions such as in the United
Arab Emirates (UAE) are limited. Biosaline agriculture systems could
decrease the demand for fresh water. Improved agricultural production
using salt water, which is more abundant than fresh water, will help to
decrease fresh water demands (Abdullah and Hasbini 2004). In the
fruiting stage, good water is more important because the quality and
quantity of fruits are affected by high salinity (Furr 1975). Thus, good
water can be saved for later stages of growth where the good water is more important.

Plants that tolerate high salinities are limited in number and economic importance (Karim and Dakheel 2006; Böer 2004). Little is known regarding the variability of salt tolerance among cultivars of date palms. Interspecies variability in salt tolerance is needed to start a breeding program to improve salt tolerance. Therefore, the main objective of this experiment was to test the growth ability of 12 cultivars of date palm seeds under four levels of saline water. More information regarding the response of salt-tolerant plants to saline environments will be useful for future studies and breeding programs using saline water.

**MATERIALS AND METHODS**

A greenhouse experiment was conducted using seeds of 12 cultivars of date palm: ‘Fard,’ ‘Khadrī,’ ‘Khalaṣ,’ ‘Khnaizi,’ ‘Lulu,’ ‘Mesally,’ ‘Nabtat Safi,’ ‘Razez,’ ‘Safri,’ ‘Sagaai,’ ‘Shishi,’ and ‘Mabrowm.’ These cultivars were selected based on their fruit quality and the fact that their occurrence is widespread in the UAE. Seeds were planted in 1-gallon plastic pots in a medium of washed sand and peat moss 2:1 (by volume). The seeds were planted in the summer when the average temperature in the greenhouse was 85 °F (29 °C). The pots were arranged in a randomized complete block design. The seeds were irrigated for 10 weeks with tap water containing 330 ppm salts. Thereafter, the plants were thinned to one plant per pot and irrigated with the designated salinity (NaCl) levels of 330 (control), 3,000, 6,000, and 12,000 ppm. Treatments were replicated three times, and the pots were irrigated every 3 days with sufficient water to allow drainage to flush out the extra salts. Soil salinities were monitored every 2 weeks by taking the average salinity of input and output water. Fertilizer [25 ppm nitrogen (N) and 0.125 g L⁻¹ of 20–20–20] was added after week 8 of treatments.

Plant height (PH), shoot growth rate (SGR), and number of leaves (NL) were recorded every 2 weeks. The SGR data were collected by measuring the length of the leaves in each pot. After 16 weeks of the treatment, plants were washed, shoots and roots were separated, and fresh and dry biomasses were measured. The samples were dried at 65 °C for 3 days, then ground and analyzed for cations and anions in shoot and root tissues using atomic absorption spectrophotometry. Shoot and root biomasses, relative growth rate (RGR), and cations were calculated based on total samples, because three replicates were analyzed as one sample to maintain a minimum sample weight requirement.

Relative growth rate was calculated using the dry biomass and following the method of Chiariello, Mooney, and Williams (1989); RGR...
\[ \text{final biomass} = \frac{\ln(\text{final biomass}) - \ln(\text{initial biomass})}{(\text{final time} - \text{initial time})}. \]

The results were analyzed with one- and two-way analysis of variance (ANOVA) (SPSS 13.0). Differences between means were determined using post hoc analyses by the Bonferroni procedure. In cases when data did not meet the requirements for normality (e.g., root/shoot), the Dunnett t-test was used at the 0.05 level (one-tail test) using a directional hypothesis. Based on the literature reviews (Aljuburi 1992; Husein et al. 1993), it has been reported that when salinity increases, the general plant health decreases. Therefore, we used a directional test assuming that increasing salinity leads to decreasing plant health.

RESULTS

Based on harvest data, the variables total plant height (TPH), average shoot growth rate (ASGR), number of leaves (NL), relative growth rate (RGR), shoot and root biomasses, root/shoot (R/S) ratio, and cation contents were determined and analyzed by one-way ANOVA tests.

Differences between TPH and salinity levels were not significant (Table 1). Significant differences between TPH and cultivars were noted at \( P < 0.01 \) (Table 2). Comparisons between cultivars in each treatment with those in the control were made to find differences in TPH among cultivars (data not shown). Most cultivars in 3,000 ppm and 6,000 ppm of the NaCl had greater TPH than the control. At 12,000 ppm, ‘Khnaizi,’ ‘Lulu,’ ‘Mesally,’ ‘Nabtat Safi,’ ‘Razez,’ ‘Safri,’ and ‘Shishi’ cultivars had TPH greater than the control. The interaction of salinity levels and cultivars on the TPH was not significant (Table 2).

No differences were found between salinities and ASGR at various weeks (data not shown) nor between ASGR of all weeks and salinities (Table 1). Significant differences between ASGR and cultivars were noted at \( P < 0.05 \). Differences of ASGR between cultivars relative to control were made (data not shown). Many cultivars at the three salinity levels had faster ASGR than the control. No ASGR interaction of cultivars and salinities was observed (Table 2).

Differences between NL and salinity levels \( (P < 0.0001) \) were noted (Table 1). The result showed an inversely significant relationship between NL and salinities (Table 3). The control had the most NL, and this value decreased with increasing salinity. There were no differences between the control and 3,000 ppm, 3,000 and 6,000 ppm, or 6,000 and 12,000 ppm. No differences were found between NL and cultivars at any salinity level when they were compared with the control (data not shown). The interaction between the salinities and cultivars was not significant (Table 2).
**Table 1.** Total plant height (TPH), average shoot growth rates (ASGR; in cm per 2 weeks), number of leaves (NL), relative growth rate (RGR; in grams per grams per day), dry biomass weight (in mg), and root/shoot ratio (R:S) for all cultivars of date palm seedlings (means ± SD) grown at four concentrations of NaCl (in part per million) for 16 weeks.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TPH</th>
<th>ASGR</th>
<th>NL</th>
<th>RGR</th>
<th>Shoot biomass</th>
<th>Root biomass</th>
<th>R/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>19.02 ± 2.47a</td>
<td>0.31 ± 0.21a</td>
<td>3.58 ± 0.55a</td>
<td>0.026 ± 0.001a</td>
<td>0.0030 ± 0.001a</td>
<td>0.0054 ± 0.001a</td>
<td>1.85 ± 0.20a</td>
</tr>
<tr>
<td>3,000</td>
<td>19.71 ± 2.40a</td>
<td>0.36 ± 0.25a</td>
<td>3.28 ± 0.51ab</td>
<td>0.026 ± 0.001a</td>
<td>0.0030 ± 0.001a</td>
<td>0.0052 ± 0.001a</td>
<td>1.73 ± 0.23b</td>
</tr>
<tr>
<td>6,000</td>
<td>20.02 ± 3.00a</td>
<td>0.34 ± 0.24a</td>
<td>2.97 ± 0.45bc</td>
<td>0.026 ± 0.001b</td>
<td>0.0026 ± 0.000b</td>
<td>0.0045 ± 0.001b</td>
<td>1.74 ± 0.24b</td>
</tr>
<tr>
<td>12,000</td>
<td>19.40 ± 2.32a</td>
<td>0.38 ± 0.24a</td>
<td>2.72 ± 0.51c</td>
<td>0.023 ± 0.001c</td>
<td>0.0020 ± 0.000c</td>
<td>0.0036 ± 0.001c</td>
<td>1.78 ± 0.20a</td>
</tr>
</tbody>
</table>

**Statistic**

- **F**: 1.01
- **P**: 0.39

**Notes.** The F and P values from one-way ANOVA are given. Within columns, values followed by different letters are significantly different at $P \leq 0.05$ as separated by Bonferroni test. $N = 36$.

aThe Dunnett t-test was used (one-tail test). Based on the literature reviews, it appears that when salinity increases, the plant health decreases. Therefore, we used a directional hypothesis, assuming that increasing salinity leads to decreasing plant health.
After 16 weeks of treatment, the RGR was significantly \((P < 0.0001)\) greater in plants grown at control and 3,000 ppm of NaCl than in plants grown at greater salinities (Table 1). Some cultivars at 3,000 ppm and 6,000 ppm NaCl had greater RGR than the control. These cultivars are ‘Fard,’ ‘Khnaizi,’ ‘Nabtat Safi,’ ‘Razez,’ ‘Safri,’ and ‘Sagaai’ cultivars at 3,000 ppm and ‘Fard’ and ‘Lulu’ cultivars at 6,000 ppm.

A one-way ANOVA showed a significant effect of salinity on the shoot and root biomasses \((P < 0.0001)\). Plants grown under control and 3,000 ppm had greater shoot and root biomasses, and both were greater than plants grown under 6,000 and 12,000 ppm (Table 1). In addition, the shoot and root biomasses of plants grown under 6,000 and 12,000 ppm were different. Shoot and root biomasses of plants grown with 12,000 ppm were the least among the salinities. Many cultivars at 3,000 ppm had greater shoot biomasses than the control. At 6,000 ppm, ‘Fard,’ ‘Lulu,’ and ‘Shishi’ had greater or the same shoot biomasses than the control, whereas there were no cultivars at 12,000 ppm with greater shoot biomass than the control.

The R/S ratio was significantly \((P < 0.03)\) affected by salinities at 0.05 (one-tail test) using one-way ANOVA (Table 1). The R/S ratio differences were found between plants grown at control versus 3,000 ppm

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**Table 2.** Effect of NaCl and cultivars on total plant height (TPH), average shoot growth rates (ASGR; in cm per 2 weeks), and number of leaves (NL) for all date palm seedlings grown at four concentrations of NaCl (in part per million) for 16 weeks

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>NaCl</th>
<th>Cultivars</th>
<th>NaCl × Cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPH</td>
<td>1.11 NS</td>
<td>3.32 **</td>
<td>1.13 NS</td>
</tr>
<tr>
<td>ASGR</td>
<td>0.95 NS</td>
<td>2.74 *</td>
<td>0.99 NS</td>
</tr>
<tr>
<td>NL</td>
<td>22.76 ***</td>
<td>2.02 NS</td>
<td>0.88 NS</td>
</tr>
</tbody>
</table>

*Notes.* Numbers represent F values from two-way ANOVA. \(N = 36\).

* \(P < 0.05\).

** \(P < 0.01\).

*** \(P < 0.0001\).

NS, nonsignificant.

---

**Table 3.** Correlation coefficients of NaCl with average shoot growth rates (ASGR), total plant height (TPH), and number of leaves (NL) \((N = 144)\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Significant</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASGR</td>
<td>0.28</td>
<td>0.09</td>
</tr>
<tr>
<td>TPH</td>
<td>0.65</td>
<td>0.04</td>
</tr>
<tr>
<td>NL</td>
<td>&lt;0.0001</td>
<td>−0.53</td>
</tr>
</tbody>
</table>
and control versus 6,000 ppm. Further, differences were found between
plants grown at 3,000 or 6,000 ppm versus 12,000 ppm (Table 1).
However, there was no difference between plants grown at the control
and 12,000 ppm, nor between plants grown at 3,000 and 6,000 ppm.
Cultivars ‘Khalas,’ ‘Mesally,’ and ‘Mabrowm’ at 3000 ppm of NaCl had
greater R/S ratios than the control. Cultivars ‘Khadri,’ ‘Mesally,’ and
‘Razez’ at 6,000 ppm had greater R/S ratios than the control plants. At
12,000 ppm, ‘Fard,’ ‘Khnaizi,’ ‘Mesally,’ ‘Nabtat Safi,’ ‘Razez,’ and
‘Shishi’ had greater R/S ratios than the control.

The Na⁺ content increased in both the shoot and the root with
increased salinity. However, the percentage in the root was almost four
times higher than that in the shoot. Further, all the cultivars at all
salinities had greater Na⁺ percentages than the control in both shoots and
roots (Table 4). ‘Sagaai’ cultivar at 12,000 ppm NaCl had Na⁺
concentrations 22 times more than the control in the shoots, followed
by ‘Mesally’ and ‘Shishi’ with 20 and 18 times, respectively, more than
the control (Table 5). On the other hand, the differences between cultivars
at different salinities relative to the control were less in the roots than
shoots (Table 6).

The K⁺ content in both the shoot and the root decreased with
increasing salinity (Table 4). The K⁺ content was more in the shoots than
in the roots. The results in both the shoot and the root showed that the
differences between the different salinity levels were significant at P <
0.0001, except that the control and the 3,000 ppm in the shoots were not
significant. Shoot K⁺ of cultivars at various salinities relative to the
control varied among cultivars (Tables 5 and 6). Many cultivars at
3,000 ppm had greater K⁺ than the control, whereas at 6000 ppm, only
‘Fard’ and ‘Safri’ cultivars had greater K⁺ concentrations. At
12,000 ppm, one cultivar, ‘Safri,’ had a K⁺ concentration similar to that
in the control. On the other hand, root K⁺ concentrations did not vary
much between cultivars at various salinity treatments relative to the
control.

The Na/K ratio was significant (P < 0.0001) between all salinity
levels (Table 4). The Na/K ratio increased with increasing salinity levels in
both shoots and roots. Large increases were noted in the roots. All
cultivars at 3,000 ppm behaved similarly and had Na/K ratios less than
the control (Tables 5 and 6). This was opposite to cultivars at 6,000 ppm
and 12,000 ppm. Many cultivars had Na/K ratios greater than the
control. Of these cultivars, ‘Mesally’ and then ‘Safri’ cultivars at
12,000 ppm had the greatest Na/K ratios in the shoots. ‘Khnaizi’ cultivar
at 3,000 ppm and 12,000 ppm as well as ‘Mabrowm’ at 6,000 ppm had the
greatest Na/K ratio in the roots.

The Mg²⁺ content in the root was twice as much as in the shoot. The
Mg²⁺ content in both shoots and roots decreased with increasing salinity
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Na</th>
<th>K</th>
<th>Mg</th>
<th>Ca</th>
<th>N</th>
<th>P</th>
<th>Total</th>
<th>Na/K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoot</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
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<td>NaCl</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.06 ± 0.02a</td>
<td>2.44 ± 0.25a</td>
<td>0.20 ± 0.03a</td>
<td>0.87 ± 0.07a</td>
<td>2.53 ± 0.19a</td>
<td>0.23 ± 0.03a</td>
<td>6.34 ± 0.36a</td>
<td>0.27 ± 0.01a</td>
</tr>
<tr>
<td>3,000</td>
<td>0.34 ± 0.03b</td>
<td>2.48 ± 0.16a</td>
<td>0.23 ± 0.03b</td>
<td>0.87 ± 0.10a</td>
<td>2.96 ± 0.24b</td>
<td>0.30 ± 0.03b</td>
<td>7.18 ± 0.36bc</td>
<td>0.14 ± 0.01b</td>
</tr>
<tr>
<td>6,000</td>
<td>0.50 ± 0.06c</td>
<td>2.27 ± 0.23b</td>
<td>0.22 ± 0.03b</td>
<td>0.80 ± 0.13b</td>
<td>3.13 ± 0.22c</td>
<td>0.30 ± 0.04b</td>
<td>7.23 ± 0.31b</td>
<td>0.22 ± 0.04c</td>
</tr>
<tr>
<td>12,000</td>
<td>0.88 ± 0.20d</td>
<td>2.04 ± 0.20c</td>
<td>0.18 ± 0.02c</td>
<td>0.62 ± 0.05c</td>
<td>3.01 ± 0.25bc</td>
<td>0.28 ± 0.03e</td>
<td>7.01 ± 0.32c</td>
<td>0.44 ± 0.10d</td>
</tr>
<tr>
<td>Root</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>NaCl</td>
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</tr>
<tr>
<td>Control</td>
<td>0.41 ± 0.05a</td>
<td>2.12 ± 0.36a</td>
<td>0.54 ± 0.11a</td>
<td>0.65 ± 0.09a</td>
<td>1.48 ± 0.16a</td>
<td>0.16 ± 0.03a</td>
<td>5.36 ± 0.54a</td>
<td>0.20 ± 0.03a</td>
</tr>
<tr>
<td>3,000</td>
<td>1.49 ± 0.10b</td>
<td>1.68 ± 0.12b</td>
<td>0.47 ± 0.05b</td>
<td>0.48 ± 0.06b</td>
<td>1.67 ± 0.17b</td>
<td>0.18 ± 0.02b</td>
<td>5.97 ± 0.30b</td>
<td>0.89 ± 0.10b</td>
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<tr>
<td>6,000</td>
<td>1.77 ± 0.17c</td>
<td>1.42 ± 0.13c</td>
<td>0.44 ± 0.06b</td>
<td>0.45 ± 0.05b</td>
<td>1.68 ± 0.13b</td>
<td>0.19 ± 0.03c</td>
<td>5.95 ± 0.37b</td>
<td>1.25 ± 0.13c</td>
</tr>
<tr>
<td>12,000</td>
<td>2.35 ± 0.16d</td>
<td>1.16 ± 0.10d</td>
<td>0.38 ± 0.04c</td>
<td>0.36 ± 0.03c</td>
<td>1.73 ± 0.15b</td>
<td>0.20 ± 0.02c</td>
<td>6.17 ± 0.24b</td>
<td>2.05 ± 0.28d</td>
</tr>
<tr>
<td>Statistic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>F</td>
<td>375.16</td>
<td>32.20</td>
<td>20.04</td>
<td>54.22</td>
<td>48.52</td>
<td>47.71</td>
<td>52.83</td>
<td>366.97</td>
</tr>
<tr>
<td>P</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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</tbody>
</table>

Notes. The $F$ and $P$ values from two-way ANOVA are given. Within columns, values followed by different letters are significantly different at $P \leq 0.05$ as separated by the Bonferroni test. $N = 36$. 

Table 5. Cations content (in %; mean ± SD) of shoots for 12 cultivars of date palm seedlings grown at four concentrations of NaCl (in part per million) for 16 weeks

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Shoot</th>
<th>Na</th>
<th>K</th>
<th>Mg</th>
<th>Ca</th>
<th>N</th>
<th>P</th>
<th>Total</th>
<th>Na/K</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Fard’</td>
<td>0.50</td>
<td>2.40</td>
<td>0.20</td>
<td>0.78</td>
<td>2.90</td>
<td>0.27</td>
<td>7.05</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>‘Khadri’</td>
<td>0.41</td>
<td>2.50</td>
<td>0.19</td>
<td>0.71</td>
<td>2.55</td>
<td>0.25</td>
<td>6.60</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>‘Khalas’</td>
<td>0.44</td>
<td>2.25</td>
<td>0.22</td>
<td>0.78</td>
<td>2.98</td>
<td>0.29</td>
<td>6.96</td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>‘Khnaizi’</td>
<td>0.46</td>
<td>2.18</td>
<td>0.24</td>
<td>0.83</td>
<td>2.85</td>
<td>0.28</td>
<td>6.84</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>‘Lulu’</td>
<td>0.41</td>
<td>2.45</td>
<td>0.22</td>
<td>0.85</td>
<td>2.97</td>
<td>0.28</td>
<td>7.18</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>‘Mesally’</td>
<td>0.60</td>
<td>2.68</td>
<td>0.20</td>
<td>0.74</td>
<td>2.98</td>
<td>0.29</td>
<td>7.47</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>‘Nabtat Safi’</td>
<td>0.43</td>
<td>2.08</td>
<td>0.20</td>
<td>0.75</td>
<td>3.08</td>
<td>0.29</td>
<td>6.82</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>‘Razez’</td>
<td>0.40</td>
<td>2.28</td>
<td>0.19</td>
<td>0.81</td>
<td>2.93</td>
<td>0.30</td>
<td>6.89</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>‘Safri’</td>
<td>0.41</td>
<td>2.28</td>
<td>0.19</td>
<td>0.85</td>
<td>2.73</td>
<td>0.24</td>
<td>6.69</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>‘Sagaai’</td>
<td>0.42</td>
<td>2.05</td>
<td>0.24</td>
<td>0.88</td>
<td>3.03</td>
<td>0.33</td>
<td>6.95</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>‘Shishi’</td>
<td>0.50</td>
<td>2.30</td>
<td>0.21</td>
<td>0.79</td>
<td>2.98</td>
<td>0.30</td>
<td>7.07</td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td>‘Mabrowm’</td>
<td>0.39</td>
<td>2.30</td>
<td>0.18</td>
<td>0.73</td>
<td>2.95</td>
<td>0.23</td>
<td>6.78</td>
<td>0.18</td>
<td></td>
</tr>
</tbody>
</table>

| Statistic | F     | 0.41   | 7.63   | 5.61   | 1.95   | 2.80   | 7.27   | 3.23    | 0.37    |
|           | P     | 0.95   | <0.0001 | <0.0001 | 0.38   | 0.003  | <0.0001 | <0.001  | 0.97    |

Notes. The F and P values from two-way ANOVA are given. N = 12.
Table 6. Cations content (in %; mean ± SD) of roots for 12 cultivars of date palm seedlings grown at four concentrations of NaCl (in part per million) for 16 weeks

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Root</th>
<th>Na</th>
<th>K</th>
<th>Mg</th>
<th>Ca</th>
<th>N</th>
<th>P</th>
<th>Total</th>
<th>Na/K</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Fard’</td>
<td></td>
<td>1.52 ± 0.78</td>
<td>1.48 ± 0.26</td>
<td>0.48 ± 0.05</td>
<td>0.51 ± 0.08</td>
<td>1.70 ± 0.13</td>
<td>0.18 ± 0.02</td>
<td>5.87 ± 0.64</td>
<td>1.15 ± 0.75</td>
</tr>
<tr>
<td>Khadri</td>
<td></td>
<td>1.44 ± 0.71</td>
<td>1.78 ± 0.38</td>
<td>0.40 ± 0.06</td>
<td>0.45 ± 0.07</td>
<td>1.55 ± 0.12</td>
<td>0.20 ± 0.04</td>
<td>5.80 ± 0.45</td>
<td>0.93 ± 0.63</td>
</tr>
<tr>
<td>‘Khalas’</td>
<td></td>
<td>1.52 ± 0.79</td>
<td>1.55 ± 0.30</td>
<td>0.44 ± 0.05</td>
<td>0.51 ± 0.12</td>
<td>1.70 ± 0.15</td>
<td>0.17 ± 0.01</td>
<td>5.89 ± 0.46</td>
<td>1.11 ± 0.78</td>
</tr>
<tr>
<td>‘Khnaizi’</td>
<td></td>
<td>1.56 ± 0.80</td>
<td>1.40 ± 0.30</td>
<td>0.41 ± 0.05</td>
<td>0.45 ± 0.08</td>
<td>1.65 ± 0.23</td>
<td>0.18 ± 0.04</td>
<td>5.65 ± 0.64</td>
<td>1.28 ± 0.89</td>
</tr>
<tr>
<td>‘Lulu’</td>
<td></td>
<td>1.48 ± 0.74</td>
<td>1.53 ± 0.34</td>
<td>0.45 ± 0.06</td>
<td>0.46 ± 0.09</td>
<td>1.65 ± 0.12</td>
<td>0.17 ± 0.04</td>
<td>5.74 ± 0.39</td>
<td>1.12 ± 0.74</td>
</tr>
<tr>
<td>‘Mesally’</td>
<td></td>
<td>1.55 ± 0.71</td>
<td>1.73 ± 0.73</td>
<td>0.53 ± 0.14</td>
<td>0.46 ± 0.20</td>
<td>1.58 ± 0.11</td>
<td>0.20 ± 0.02</td>
<td>6.03 ± 0.36</td>
<td>1.15 ± 0.72</td>
</tr>
<tr>
<td>‘Nabtat Safi’</td>
<td>1.63 ± 0.77</td>
<td>1.58 ± 0.48</td>
<td>0.53 ± 0.09</td>
<td>0.54 ± 0.16</td>
<td>1.70 ± 0.07</td>
<td>0.18 ± 0.01</td>
<td>6.17 ± 0.29</td>
<td>1.24 ± 0.80</td>
<td></td>
</tr>
<tr>
<td>‘Razez’</td>
<td></td>
<td>1.40 ± 0.68</td>
<td>1.40 ± 0.22</td>
<td>0.43 ± 0.12</td>
<td>0.49 ± 0.16</td>
<td>1.65 ± 0.09</td>
<td>0.17 ± 0.02</td>
<td>5.53 ± 0.33</td>
<td>1.09 ± 0.66</td>
</tr>
<tr>
<td>‘Safri’</td>
<td></td>
<td>1.42 ± 0.66</td>
<td>1.65 ± 0.34</td>
<td>0.43 ± 0.06</td>
<td>0.48 ± 0.11</td>
<td>1.60 ± 0.20</td>
<td>0.17 ± 0.02</td>
<td>5.74 ± 0.45</td>
<td>0.96 ± 0.55</td>
</tr>
<tr>
<td>‘Sagaai’</td>
<td></td>
<td>1.52 ± 0.73</td>
<td>1.75 ± 0.49</td>
<td>0.52 ± 0.11</td>
<td>0.52 ± 0.18</td>
<td>1.65 ± 0.26</td>
<td>0.21 ± 0.01</td>
<td>6.17 ± 0.18</td>
<td>1.03 ± 0.62</td>
</tr>
<tr>
<td>‘Shishi’</td>
<td></td>
<td>1.60 ± 0.83</td>
<td>1.65 ± 0.38</td>
<td>0.47 ± 0.07</td>
<td>0.51 ± 0.10</td>
<td>1.83 ± 0.15</td>
<td>0.20 ± 0.03</td>
<td>6.25 ± 0.52</td>
<td>1.12 ± 0.72</td>
</tr>
<tr>
<td>‘Mabrowm’</td>
<td></td>
<td>1.45 ± 0.67</td>
<td>1.70 ± 0.45</td>
<td>0.39 ± 0.03</td>
<td>0.44 ± 0.08</td>
<td>1.40 ± 0.13</td>
<td>0.15 ± 0.03</td>
<td>5.53 ± 0.29</td>
<td>0.99 ± 0.59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Statistic</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>F</em></td>
<td>0.11</td>
<td>1.22</td>
<td>4.72</td>
<td>0.90</td>
<td>5.27</td>
<td>4.79</td>
<td>3.80</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td><em>P</em></td>
<td>1.00</td>
<td>0.28</td>
<td>&lt;0.0001</td>
<td>0.54</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.99</td>
<td></td>
</tr>
</tbody>
</table>

**Notes.** The *F* and *P* values from two-way ANOVA are given. *N* = 12.
levels. Differences between the control and the three salinity levels and between the 12,000 ppm and low salt levels were significant at $P < 0.0001$ in both the shoot and the root (Table 4). However, no significant differences were found between the 3,000 and 6,000 ppm treatments. There were no shoot or root Mg$^{2+}$ concentrations differences noted between cultivars at various salinities when they were compared with the control. Cultivars in the control had the greatest Mg$^{2+}$ contents.

The Ca$^{2+}$ content was twice as much in the shoot than in the root. The Ca$^{2+}$ content decreased with greater salinities. The post hoc analyses showed that differences between various salinity levels were significant at $P < 0.0001$ with the exception of differences in the control and 3,000 ppm in the shoot and 3,000 and 6,000 ppm in the root (Table 4). No differences were found between Ca$^{2+}$ content of shoots among cultivars when they were compared with the control. Root Ca$^{2+}$ contents in the control were least in all cultivars. ‘Shishi’ cultivar at all salinity treatments had greater Ca$^{2+}$ content than the control. It was greatest at 6000 ppm, which was 27 times more than the control. ‘Sagaai’ and ‘Lulu’ also had high Ca$^{2+}$ at 12,000 ppm relative to the control.

Salinity had an effect ($P < 0.0001$) on N and P contents in both shoots and roots (Table 4). The N was greatest with 6000 ppm of NaCl in shoots (3.13%) and least in the control (2.50%). In roots, N increased with increasing NaCl concentrations from 1.48% in the control to 1.73% at 12,000 ppm. Phosphorus followed the same pattern as N in both shoots and roots. In shoots, it was greatest at 3000 and 6000 ppm (0.30%) and least in the control (0.23%). In roots, P content increased with increasing salinity, from 0.16% at control to 0.20% at 12000 ppm. All cultivars at all treatments had more N content than the control. When cultivars at different salinities were compared with the control, ‘Mabrowm’ at 3,000 ppm and 6,000 ppm and ‘Nabtat Safi’ at 12,000 ppm had the greatest N values in shoots. In roots, ‘Khnaizi’ at 3,000 ppm and 6,000 ppm and ‘Safri’ at 12,000 ppm had the greatest N values in shoots. In roots, ‘Khadri’ at 3,000 ppm, ‘Khnaizi’ at 6,000 ppm, and ‘Mabrowm’ at 12,000 ppm had greater values than the control. In roots, ‘Khadri’ at 3,000 ppm, ‘Khnaizi’ at 6,000 ppm, and ‘Lulu’ at 12,000 ppm had greater P values than the control.

The cation content for both the roots and shoots are shown in Table 4. All the cation contents were affected by salt level ($P < 0.0001$). In general, the total cation concentrations in the shoots were greater than in the roots. The differences in means between the control and various salinities (3,000, 6,000, and 12,000 ppm) were significant at $P < 0.0001$ for both the shoot and the root with the exception of the total cations between the control and the 12,000 ppm in the shoot. The cultivars were also found to differ from one another in total cation contents at different
salinities relative to control. In shoots, ‘Sagaai’ at 3,000 ppm and 12,000 ppm and ‘Shishi’ at 6,000 ppm had the greatest total cation content compared to the control. In roots, ‘Shishi’ cultivar at all salinities levels had the greatest total cation contents.

DISCUSSION

The overall results of this work demonstrated that the date palms are a salt-tolerant species during the first stage of growth, the most critical stages in the life cycle of halophytes. Data collected for TPH, ASGR, NL, and biomass showed that date palms grew best with 3,000 ppm or less of NaCl and were most inhibited at 12,000 ppm. Plants were able to survive at 12,000 ppm of NaCl regardless of their growth performance, and some plants did not show signs of nutrient imbalances. The growth response was similar to that found with date palm cultivars in Egypt (Husein et al. 1993); cultivars showed differences in growth parameters with increasing salinity. In general, salinity can reduce plant growth through osmotic effects, toxicity of ions, nutrient uptake imbalance, or a combination of these factors (Karim and Dakheel 2006; Maathuis 2006).

Total plant height (TPH) was not affected by salinities. However, variations between cultivars showed differences. ‘Razez’ and ‘Lulu’ cultivars showed the highest TPH in 12,000 ppm NaCl in comparison with the control.

The effect of salinity on the ASGR was very low, and no differences were observed at any NaCl levels, even though there was an increase in ASGR with increasing salinity (Table 1). Furthermore, the ASGR varied between weeks and did not have any constant trend. ‘Razez’ and ‘Safri’ cultivars had the greatest ASGR in 12,000 ppm NaCl in comparison with the control.

Numbers of leaves were highly affected by salinities. There was an inverse relationship between NL and salinity; as salt concentration increased, NL decreased (Table 1). The same results were observed by Aljuburi (1992). The control had the greatest NL but was not different than plants grown at 3,000 ppm. Moreover, the differences between NL at 3,000 and 6,000 ppm NaCl were not significant, nor were differences between 6,000 and 12,000 ppm. Plants grown at low NaCl levels were able to produce more leaves. On the other hand, variations in NL of cultivars were not significant at any NaCl levels (Table 2). All cultivars behaved similarly under each treatment. Moreover, there was no NL interaction between any NaCl levels and the cultivars (Table 2).

Low NaCl concentration (3,000 ppm) had no significant effect on the RGR of any date palm cultivars. At greater NaCl concentrations (6,000 and 12,000 ppm), salt reduced RGR compared to the control and
3,000 ppm. The greatest effect was at 12,000 ppm of NaCl. Among the cultivars, ‘Fard,’ ‘Khnaizi,’ ‘Lulu,’ ‘Nabtat Safi,’ and ‘Razez’ had the greatest RGR relative to control when 12,000 ppm NaCl was applied.

Cultivars’ dry biomass in the control and at 3,000 ppm did not show any differences in shoot and root biomasses. Reductions were noted at greater levels of NaCl (6,000 and 12,000 ppm) for both shoot and root biomasses. The greatest reductions in the biomasses were observed with 12,000 ppm of NaCl. The reductions in shoot biomasses were comparable to these of roots, indicating that shoot and root were equally sensitive to salinity. In all treatments, root biomasses (i.e., growth) were less affected than shoots, thus root/shoot (R/S) ratios increased. The R/S ratios were similar between the control and 12,000 ppm as well as between 3,000 and 6,000 ppm of NaCl. Controls and plants grown in 12,000 ppm NaCl had greater R/S ratios than other treatments. Aljuburi (1992) reported similar results for ‘Lulu,’ ‘Boman,’ ‘Barhee,’ and ‘Khalas’ date palm cultivars treated with 0, 6,000, 12,000, and 18,000 ppm of NaCl for 21 weeks. This result could be due to an attempt of plants to decrease water transpiration and/or increase water uptake. Date palm cultivars were observed to change the pattern of dry biomass distribution, favoring root parts, as salt level was increased (Table 1). Shu, Zhang, and Lan (1997) reported that plants increased their R/S ratios when exposed to harsh environments. Between various cultivars, ‘Lulu’ showed the greatest shoot biomass and ‘Fard’ had the greatest root biomass and R/S ratio at 12,000 ppm salinity.

In saline environments, cations at strong concentrations in the soil solution (e.g., Na\textsuperscript{+}) are taken up at faster rates, which may result in large accumulations of these cations in the plants’ tissues and thus may inhibit biochemical processes (Greenway and Munns 1980) and protein synthesis in the cytoplasm (Gibson, Speirs, and Brady 1984). In response to salinity, halophytic plants usually do not accumulate Na\textsuperscript{+}. In the current study, date palms seemed to adjust cation uptake and retention; hence Na\textsuperscript{+} is selectively secreted from leaves and retained in roots, whereas K\textsuperscript{+} is taken up and retained in the leaves. Such response occurs with these two cations to adjust the osmotic potential. Therefore, the plants may avoid toxicity and buildup of Na\textsuperscript{+} in the leaves, whereas other cations such as K\textsuperscript{+}, Mg\textsuperscript{2+}, and Ca\textsuperscript{2+} could be available for the plant (Maathuis 2006; Khan, Ungar, and Showalter 2000; Epstein 1972). The total content of cations in the tissue increased with increasing NaCl, probably to maintain the osmotic potential and continue water uptake into the plant. The concentration of Na\textsuperscript{+} in shoots increased significantly from 0.06% in the control to 0.88% in the 12,000 ppm treatment. The same pattern was found in roots (0.41% in the control to 2.35% at 12,000 ppm). In general, roots had greater Na\textsuperscript{+} contents than shoots (Table 4). At 12,000 ppm, ‘Sagaai’ cultivar had the greatest shoot Na\textsuperscript{+} content, whereas
'Khalas' had the greatest Na⁺ content in root. On the other hand, K⁺ content was different from the Na⁺ content. In shoots, it was significantly more than in roots. In both shoots and roots, the K⁺ content significantly decreased with increasing salinity. The decline in shoots was from 2.44% in the control to 2.04 with 12,000 ppm NaCl; corresponding values for roots were from 2.12% to 1.16%. The Na/K ratios were greater in roots than in shoots. In shoots, it was 0.03 in the control and increased to 0.44 at 12,000 ppm, whereas in roots it was 0.2 in the control and increased with increasing salinity to 2.05 at 12,000 ppm of NaCl. These observations suggest that Na⁺ was transported from shoots and retained in roots and that K⁺ was transported from roots and retained in shoots. These results agreed with results found for other halophytes (Greenway 1968). ‘Mesally’ and ‘Safri’ cultivars had the greatest shoot Na/K ratios whereas ‘Khnaizi’ cultivar had greatest root Na/K ratio.

The Ca²⁺ was greater in shoots than in roots. This was opposite to the behavior of Mg²⁺; however, both cations decreased with increasing salinity. Mer et al. (2000) reported that a reduction in internal cation concentrations (e.g., Ca²⁺) in shoots may be because the activity of the ion in the external solutions was reduced and there was disturbance of the translocation of the ion by the main saline cations (Na⁺ and K⁺). The fact that Ca²⁺ and Mg²⁺ contents were decreased in shoots of date palms grown at high NaCl agrees with results obtained with other halophytes (Glenn and O’Leary 1984; Ayala and O’Leary 1995). The accumulation of N and P in shoots was not clearly in response to salinity. However, the results showed that their content in roots increased with increasing salinity level. In general, the concentrations of both cations were greater in roots than in shoots.

CONCLUSION

The results found that date palm seedlings grew best in the control and with 3000 ppm of NaCl and were most inhibited at 12,000 ppm. Plants were able to survive at 12,000 ppm of NaCl regardless of their growth performance, and some plants did not show signs of nutrient imbalances.

The current study indicates that there are differences in salt tolerance between date palm cultivars, which appear to be related to the salt exclusion mechanisms by the root parts (Greenway and Munns 1980), resulting in reduced Na⁺ translocation to the shoots (Karim and Dakheel 2006). ‘Khnaizi,’ ‘Lulu,’ ‘Nabtat Safi,’ and ‘Razez’ cultivars showed greatest growth parameters and Na/K ratios, which indicated greater sodium discriminations from plant parts than other cultivars. This could make them good candidates for a breeding program. Other cultivars,
such as ‘Mesally,’ ‘Safri,’ and ‘Shishi,’ may have potential for salt tolerance.

REFERENCES


