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Influence of salinity levels on nutrient content in leaf, stem and root of major date palm (*Phoenix Dactylifera* L) cultivars

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Abstract

Date Palm (*Phoenix Dactylifera* L) is the most important fruit crop of the Kingdom of Saudi Arabia which produces nearly a million tons of dates annually. The Arabian Peninsula is characterized by high soil salinity impacting the growth and productivity of date palm. We studied the influence of salinity on nutrient (N, K^+, Na^+, K^+/Na^+, Ca^{2+}, $Mg^2$and Cl^-) content in major date palm cultivars *viz.* Khalas, Madjol and Barhy at the National Date Palm Research Centre, Al Hassa, Saudi Arabia. Results revealed that in young leaves, stem and roots of date palm, N, K^+, K^+/Na^+ ratio,Ca^{2+} and Mg^{2+} content decreased with increasing levels of salinity, while Na^+ content increased with the rise in salinity stress levels. As regards Cl^- content a reduction was seen at intermediate levels (50 and 100mM) which increased at higher salinity levels (200 and 400mM). In the cultivar Khalas N, K^+, K^+/Na^+, Ca^{2+} and Mg^{2+} were the highest and superior to the cultivars Madjol and Barhy. Further, $Na^+$and Cl^- content were the lowest in Khalas followed by Madjol and Barhy. It can be inferred that all the three date palm cultivars tested are strong salt excluders due to the increase in Na^+ and Cl^- ions even at 400mM NaCl salinization. The cultivar Khalas registered a significant drop in K/Na ratio indicating better salt tolerance compared to Madjol and Barhy.

Keywords: Date Palm - Salinity - Nutrient content - Leaf - Stem – Root.

INTRODUCTION

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 (Marie, 1971).

The date palm is the major crop fruit crop in the Kingdom of Saudi Arabia covering approximately 72% of the total area under permanent crops. The Kingdom produces nearly a million tons of dates annually and is among the top three date producing countries of the world. More than 400 different date palm cultivars are estimated to exist in Saudi Arabia (Anonymous, 2006). The date palm is a multipurpose tree closely linked to the life and heritage of the people in the Arabian peninsula. It provides food, shelter, timber products and all parts of the palm can be used in many different ways. The date fruit is very rich in food nutrients as compared to other fruits. Due to the high sugar content, dates are extremely high in calories, providing instant energy to the consumer. The major date producing countries in the world are situated in the Middle East and North Africa.

Soil salinity is a major abiotic environmental stress prevalent throughout the Arabian Peninsula. Date palm exhibits a high degree of tolerance to salinity (FAO,

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1982). Plant growth and productivity can be greatly reduced due to salinity (Erskine et al 2004). Seedlings are more sensitive to salinity that mature plants as salt tolerance in plants is generally age dependant. Salinity can directly affect nutrient uptake, such as Na^+ reducing K^+ uptake or by Cl^- reducing NO_3^- uptake. Salinity can also cause a combination of complex interactions that affect plant metabolism, susceptibility to injury or internal nutrient requirement. High concentrations of Na^+ and Cl^- in the soil may depress nutrient-ion activities. The impact of salinity on growth and development of plants is a combination of three major processes *viz.* reduced water availability from the soil caused by the low osmotic potential of the soil solution, specific toxic effects of salt ions on the metabolism of the plant and ion imbalances within the plant. High salt stress causes ion imbalance and hyperosmotic stress in plants which distrupts homeostatis in water potential and ion distribution that leads to molecular damage, growth inhibition and even death (Zhu,2001). Tunçtürk et al 2011 studied the effect of salinity stress on nutrient composition in different cultivars of canola, *Brassica napus* L. and found that under saline conditions Na^+ and Cl^- contents of the leaf shoot and root increased, while Ca^{2+}, K^+ content and K^+/Na^+ ratio contents decreased.

We studied the influence of salinity on nutrient (N, K^+, Na^+, K^+/Na^+, Ca^{2+}, $Mg^2$and Cl^-) content in major date palm cultivars *viz.* Khalas, Madjol and Barhy.

MATERIALS AND METHODS

The experiments were carried out at the experimental site of the National Date Palm Research Center at Al Hassa, Saudi Arabia (25^{O}19' 60"N latitude and 49 ^{O} 37' 60" E longititude).

Date palm cultivars

Three-year-old offshoots of major date palm cultivars viz. Khalas, Majdool and Barhy were used in the study. The test cultivars for this study were selected based on the local, regional and international importance. Khalas is the most popular date palm cultivar in the Eastern province of Saudi Arabia where Al-Hassa is located, the cultivar Barhy is preferred by farmers of the Gulf countries in the Middle East, while Majdool is an internationally acclaimed date cultivar of North Africa.

We used 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 (Marschner,1997; Syertsen et al., 1988; Sykes, 1992).

Salinity treatments

During the course of the experiment, the growth medium has been salinized with 0, 50, 100, 200 or 400 mM NaCl as the main source of salinity. These concentrations represent low, medium, high and excessively 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 wt %). Natural soil of date palm stands were not used since it includes nutrients that will interfere with the treatments. However, defined amounts of nutrients were applied as compound NPK fertilizers to each seedling during the course of the experiment.

Sampling procedures

Twenty mid-positions leaflet samples of young leaves were collected, oven-dried at 75° C and ground for chemical analysis.

Mid-rib of same leaflets and trunks (stem) in addition to the thoroughly cleaned roots of offshoots were oven dried at 75° C and ground for mineral analyses. Nutrient ion distribution was determined in each offshoot part separately.

Analytical procedures

Total nitrogen was determined using an automated semi-micro Kjeldahl apparatus. The procedure involves high temperature (330 to 350°C) digestion of plant tissue with concentrated sulphuric acid (H_2SO_4) in presence of a catalyst (K_2SO_4 and selenium) to convert organic nitrogen to NH_4^+. The amount of NH_4^+ generated was colorimetrically quantified following distillation of the sample after addition of alkali (NaOH).

The chemical procedures for determination of K^+, Na^+, Ca^{2+} and Mg^{2+} consisted of ashing 250 mg of the dried ground sample at 500° C in a muffle furnace and treating the sample with HCl to dehydrate silica and to solubilize the elements in question. The dissolved constituents were then filtered and adjusted to 50 ml volume. Ca^{2+} and Mg^{2+} were determined with Atomic Absorption Spectrophotometry (AA); while K^+ and Na^+ was estimated with flame emission according to A.O.A.C. (1989).

Chloride (Cl^-) in plant tissue extracts was determined by potentiometric titration (La Croix et al., 1970). The procedure involves extraction of Cl^- from dried, powdered plant material in hot deionized water. The concentrations were determined directly by silver ion titration using Eppendorf chloridometer (type 6610).

Table 1. Influence of salinity on nutrient content (mMol/g) in young leaves of date palm

	0mM	50mM	100mM	200mM	400mM
Cultivars	**Nitrogen (N)**				
Khalas	1.36	1.33	1.26	1.13	0.84
Madjol	1.28	1.23	1.16	0.98	0.64
Barhy	1.23	1.19	1.12	0.90	0.44
(CD:p=0.01)	0.10	0.03	0.07	0.04	0.04
	Potassium (K^+)				
Khalas	1.38	1.31	1.24	1.17	0.84
Madjol	1.26	1.24	1.14	0.99	0.63
Barhy	1.27	1.21	1.12	0.84	0.45
(CD:p=0.01)	0.01	0.03	0.01	0.19	0.04
	Calcium (Ca^{2+})				
Khalas	1.73	1.68	1.58	1.39	1.13
Madjol	1.44	1.34	1.25	1.12	0.74
Barhy	1.52	1.44	1.22	0.84	0.52
(CD:p=0.01)	0.25	0.03	0.01	0.05	0.10
	Magnesium (Mg^{2+})				
Khalas	0.56	0.55	0.46	0.38	0.17
Madjol	0.58	0.54	0.36	0.24	0.06
Barhy	0.59	0.50	0.32	0.18	0.04
(CD:p=0.05)	NS	0.01	0.01	0.04	0.01
	Sodium (Na^+)				
Khalas	0.27	0.28	0.31	0.41	0.63
Madjol	0.26	0.31	0.47	0.58	0.75
Barhy	0.26	0.32	0.51	0.60	0.80
(CD:p=0.01)	NS	0.02	0.02	0.15	0.06
	Potassium / Sodium (K^+/Na^+)				
Khalas	5.04	4.76	3.97	2.87	1.34
Madjol	4.82	3.95	2.43	1.70	0.84
Barhy	4.86	3.74	2.20	1.40	0.56
(CD:p=0.01)	0.12	0.06	0.06	0.04	0.12
	Chlorine (Cl^-)				
Khalas	0.08	0.04	0.03	0.06	0.09
Madjol	0.06	0.06	0.02	0.04	0.08
Barhy	0.06	0.06	0.05	0.05	0.1
(CD:p=0.01)	NS	0.01	0.01	0.002	NS

CD= Critical Difference. NS=Non Significant

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 were subjected to analysis of variance (ANOVA) procedures using the SAS program SAS Institute, Inc, 1985. Mean separation (p=0.05/0.01) was calculated by Duncan Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Results presented in Tables 1, 2 and 3 reveal that that in young leaves, stem and roots of date palm, N, K^+, K^+/Na^+ ratio,Ca^{2+} and Mg^{2+} content decreased with increasing levels of salinity, while Na^+ content increased with the rise in salinity stress levels. As regards Cl^- content a reduction was seen at intermediate levels (50 and 100mM) which increased at higher salinity levels (200 and 400mM). In the cultivar Khalas N, K^+, K^+/Na^+, Ca^{2+} and Mg^{2+} were the highest and superior to the cultivars Madjol and Barhy. Further, $Na^+$and Cl^- content were the lowest in Khalas followed by Madjol and Barhy. Al-Abdoulhadi et al 2011a reported decrease in biomass production in leaves, stem and roots of date palm with increasing salinity levels where the cultivar Khalas exhibited the least leaf injury as compared to the cultivars Madjol and Barhy with the rise in salinity stress. Our findings are in agreement to the

Table 2. Influence of salinity on nutrient content (mMol/g) in stem of date palm

	0mM	50mM	100mM	200mM	400mM
Cultivars	**Nitrogen (N)**				
Khalas	1.19	1.16	1.08	0.90	0.74
Madjol	1.17	1.15	0.99	0.79	0.63
Barhy	1.17	1.11	0.94	0.69	0.41
(CD:p=0.01)	0.01	NS	0.03	NS	0.01
	Potassium (K^+)				
Khalas	1.19	1.15	1.12	0.96	0.83
Madjol	1.17	1.15	1.01	0.87	0.56
Barhy	1.17	1.11	0.96	0.63	0.40
(CD:p=0.01)	NS	0.02	NS	NS	0.05
	Calcium (Ca^{2+})				
Khalas	1.39	1.34	1.22	0.99	0.78
Madjol	1.37	1.30	1.17	0.93	0.56
Barhy	1.37	1.25	1.10	0.82	0.41
(CD:p=0.05)	0.02	0.03	0.01	0.03	0.03
	Magnesium (Mg^{2+})				
Khalas	0.59	0.56	0.50	0.41	0.22
Madjol	0.54	0.54	0.40	0.29	0.15
Barhy	0.55	0.53	0.38	0.21	0.06
(CD:p=0.01)	NS	NS	NS	0.01	0.01
	Sodium (Na^+)				
Khalas	0.66	0.67	0.72	0.81	0.90
Madjol	0.64	0.67	0.78	0.86	1.00
Barhy	0.60	0.65	0.85	0.97	1.06
(CD:p=0.01)	0.01	0.01	0.01	0.01	0.01
	Potassium / Sodium (K^+/Na^+)				
Khalas	1.80	1.71	1.56	1.19	0.92
Madjol	1.82	1.71	1.29	1.02	0.56
Barhy	1.94	1.70	1.13	0.65	0.38
(CD:p=0.05)	0.02	0.03	0.04	0.09	0.05
	Chlorine (Cl^-)				
Khalas	0.06	0.05	0.05	0.08	0.08
Madjol	0.08	0.03	0.05	0.04	0.09
Barhy	0.06	0.04	0.06	0.07	0.09
(CD:p=0.01)	NS	0.01	NS	NS	0.01

CD= Critical Difference. NS=Non Significant

report by Tunçtürk et al 2011 who found that K+, Ca2+ and K+/Na+ contents in canola decreased by salt stress, but Na+ and Cl- content in the roots, shoots and leaves of all the canola cultivars tested significantly increased. Salinity has been shown to severely affect the uptake and transport of Ca resulting in plant shoots showing Ca deficiency (Cramer et al 1989, Rengel, 1992). In the present study it is seen that increase in salinity resulted in the decrease of Ca in young leaves, stem and root of date palm. Ca is strongly competitive with Mg^{2+} and the binding sites on the root plasma membrane appear to have less affinity for the highly hydrated Mg^{2+} than for Ca^{2+} (Marschner, 1995). High concentration of Ca^{2+} often results in increased leaf-Ca along with a marked reduction in leaf-Mg (Bernstein and Hayward, 1958) which is in accordance to our findings.

The root system was the most affected part particularly at higher salinity levels resulting in significant shift in K/Na ratio (Figure 1).

From our findings it can be inferred that increase in $Na^+$and Cl^- content contributed to decrease in the biomass of young date palm leaves as reported previously by Abdoulhadi et al 2011a with the cultivar Khalas withstanding this effect to a great extent due to

Table 3. Influence of salinity on nutrient content (mMol/g) in roots of date palm

	0mM	**50mM**	**100mM**	**200mM**	**400mM**
Cultivars	**Nitrogen (N)**				
Khalas	0.80	0.78	0.70	0.52	0.41
Madjol	0.81	0.76	0.61	0.50	0.36
Barhy	0.79	0.73	0.53	0.39	0.26
(CD:p=0.05)	NS	NS	0.05	0.10	0.04
	Potassium (K^+)				
Khalas	0.72	0.69	0.65	0.52	0.42
Madjol	0.71	0.67	0.57	0.47	0.29
Barhy	0.70	0.64	0.53	0.40	0.18
(CD:p=0.05)	0.05	NS	0.03	0.05	0.06
	Calcium (Ca^{2+})				
Khalas	1.13	1.08	1.02	0.97	0.65
Madjol	1.12	1.08	1.01	0.86	0.54
Barhy	1.12	1.05	0.98	0.73	0.42
(CD:p=0.05)	NS	NS	NS	0.03	NS
	Magnesium (Mg^{2+})				
Khalas	0.43	0.37	0.31	0.25	0.12
Madjol	0.43	0.40	0.24	0.15	0.07
Barhy	0.42	0.37	0.19	0.11	0.03
(CD:p=0.05)	0.04	0.02	0.01	0.02	0.03
	Sodium (Na^+)				
Khalas	0.43	0.55	0.63	0.69	0.72
Madjol	0.37	0.48	0.59	0.68	0.69
Barhy	0.24	0.41	0.55	0.63	0.70
0.05	0.03	0.03	0.07	0.09	0.05
	Potassium / Sodium (K^+/Na^+)				
Khalas	1.66	1.26	1.04	0.75	0.59
Madjol	1.91	1.41	0.97	0.68	0.43
Barhy	2.90	1.56	0.96	0.63	0.25
(CD:p=0.01)	0.06	0.09	0.03	0.07	0.06
	Chlorine (Cl^-)				
Khalas	0.06	0.08	0.08	0.09	0.10
Madjol	0.10	0.04	0.06	0.09	0.12
Barhy	0.06	0.07	0.08	0.10	0.10
(CD:p=0.05)	NS	NS	NS	0.02	0.02

CD= Critical Difference. NS=Non Significant

the comparatively lower content of $Na^+$and Cl^- . It can be inferred that all the three date palm cultivars tested are strong salt excluders due to the increase in Na^+ and Cl^- ions even at 400mM NaCl salinization. The cultivar Khalas registered the most significant drop in K/Na ratio better compared to Madjol and Barhy.

Greenway and Munns 1980 recorded the accumulation of Cl and or Na ions in leaves of salt affected plants. Excessive accumulation of Na and /or Cl might depress plant growth, because high concentration of these ions in the cytoplasm results in the loss of enzyme activity and inhibition of leaf photosynthesis (Levitt , 1980).

Maintaining an adequate supply of Ca^{2+} in saline soil solutions is an important factor in controlling the severity of specific ion toxicities, particularly in crops which are susceptible to sodium and chloride injury (Mass, 1993). Thus, the adverse effects of $Na^+$and Cl^- in saline soils where date palm is cultivated could be mitigated by application of Ca^{2+}.

Report from Pakistan indicate that Na and Cl content of plants increased with an increase in salinity, while

Ca, Mg and K content decreased in a perennial grass *Halopyrum mucronatum* found on the coastal dunes of Karachi, Pakistan (Khan et al 1999). Recent reports from Australia suggest that the date palm can be successfully cultivated in an extremely salty root zone environment (Anonymous 2007).

A study quantifying the role of the interactive effects of salinity and soil drying on nutrient uptake in *Spartina alterniflora* in a simulated tidal system revealed that survival, shoot and root dry matter production, and concentrations of Al, Ca, Fe, Mg, N, P, K, Na, and S the interactive effects of salinity and soil drying were not additive on plant nutrient uptake or biomass. However, both salinity and soil drying significantly impacted root, shoot dry weights resulting in decrease of K and Ca as well as increase in shoot Na content. (Brown et al 2006). These findings are in agreement to our results. It can be inferred that among the cultivars tested Khalas is comparatively salt tolerant. It is for this reason (salt tolerance) and preferred quality traits (Al-Abdoulhadi et al 2011b) that the date palm cultivar Khalas is becoming increasingly popular in the Arabian Peninsula.

CONCLUSION

On the basis of our findings it can be concluded that increased salinity stress in date palm resulted in substantial decrease of N, K^+, K^+/Na^+ ratio,Ca^{2+} and Mg^{2+} in all palm parts. Na^+ levels increased in young leaves, stem and roots of date palm. As regards Cl^- content, a reduction was seen at intermediate levels (50 and 100mM) which increased at higher salinity levels (200 and 400mM). The root system was the most affected part particularly at higher salinity levels resulting in significant shift in K/Na ratio. It can be inferred that all the three date palm cultivars tested are strong salt excluders due to the increase in Na^+ and Cl^- ions even at 400mM NaCl salinization. The cultivar Khalas registered a significant drop in K/Na ratio indicating better salt tolerance compared to Madjol and Barhy.

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