

## THE POTENTIAL USE OF $\text{Ca}(\text{NO}_3)_2$ TO IMPROVE SALINITY TOLERANCE IN DATE PALM (*Phoenix dactylifera* L.)

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### ABSTRACT

The study was conducted to investigate the impact of  $\text{Ca}(\text{NO}_3)_2$  on different levels of salt-stress in date palm. Three-years-old date palm plants were subjected to four NaCl levels: 50, 100, 150 and 200 mM. The saline solutions were supplemented with 0, 5, 10 and 20 mM  $\text{Ca}(\text{NO}_3)_2$ . The combined NaCl/ $\text{Ca}(\text{NO}_3)_2$  treatments were conducted over a period of 10 weeks. Control plants were only subjected to the four salinity levels with no Ca ( $\text{NO}_3$ )<sub>2</sub> addition. Results showed an inhibitory effect of salinity on almost all plants' parameters under investigation, mainly the accumulation of ions such as N, K, Ca, plant dry weight, chlorophyll and net photosynthesis rate. Addition of Ca ( $\text{NO}_3$ )<sub>2</sub> in the solution was more beneficial when added in a moderate concentration (10 mM) compared to lower (5 mM) and higher (20 mM) under all salinity levels. The addition of 10 mM Ca ( $\text{NO}_3$ )<sub>2</sub> noticeably enhanced chlorophyll content under 50 mM Na Cl (2.5 mg/100 cm<sup>2</sup>) and 150 mM NaCl (2 mg/100 cm<sup>2</sup>). In addition, 10 mM Ca ( $\text{NO}_3$ )<sub>2</sub> reduced the accumulation of Na and Cl in plant parts. For instance, in trees subjected to 10 mM Ca ( $\text{NO}_3$ )<sub>2</sub>, Cl content in leaves and stems under 50 mM Na Cl were 0.23% and 0.65%, respectively. On the other hand, Cl content under 100 mM Na Cl and 200 mM Na Cl were lower compared to their corresponding control treatments. It seems that the use of Ca ( $\text{NO}_3$ )<sub>2</sub> had ameliorative effects on salt-stressed date palm plants when used with moderate concentrations.

Keywords: Net Photosynthesis, Ion partitioning, Nutrient balance, Na Cl, Chlorophyll content

التركي

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صالح مبارك التركي

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المستخلص

تم تنفيذ الدراسة بهدف القضاء على الضوء ومعرفة تأثير نترات الكالسيوم ( $\text{Ca}(\text{NO}_3)_2$ ) على نمو نخيل التمر تحت إجهاد مستويات مختلفة من أملاح الصوديوم كلوريد (Na Cl)، وقد تم تعريض فسائل نخيل التمر بعمر 3 سنوات لأربعة تركيزات من أملاح الصوديوم كلوريد: 50، 100، 150 و 200 مليمولر (mM)، كما تم إضافة تركيزات مختلفة من نترات الكالسيوم (0، 5، 10 و 20 مليمولر) إلى محلول الأملاح. استمرت التجربة، إضافة المعاملات لمدة 20 أسبوع، وخلال هذه المدة تم إضافة تركيزات الأملاح فقط إلى معاملات الشاهد دون إضافة نترات الكالسيوم. أوضحت النتائج أن هناك تأثير سلبي لتركيزات الأملاح المضافة على معظم العوامل تحت الدراسة خاصة فيما يتعلق بمحتوى النيتروجين والبوتاسيوم والكالسيوم والكلوروفيل في أنسجة نباتات نخيل التمر إضافة إلى نسبة التمثيل الضوئي، وقد لوحظ أن إضافة نترات الكالسيوم إلى أوساط الأملاح المختلفة له تأثير إيجابي خاصة بتركيز 10 مليمولر مقارنة بتركيزات 5 و 10 مليمولر، وكان واضحاً أن إضافة 10 مليمولر من نترات الكالسيوم أدى إلى تحسين محتوى الكلوروفيل تحت إجهاد تركيز الأملاح 50 و 150 مليمولر، كما أن هذا التركيز من نترات الكالسيوم أدى إلى انخفاض تراكم عنصر الصوديوم والكلوريد في أنسجة النبات، وكمثال نجد أن الفسائل التي تعرضت إلى إضافة 10 مليمولر من نترات الكالسيوم، فإن محتوى الكلوريد في أنسجة الأوراق والساق تحت إجهاد أملاح 50 مليمولر صوديوم وكلوريد كان 0.23% و 0.65% على التوالي، كما أن مستوى الكلوريد تحت إجهاد الأملاح 100 و 200 مليمولر صوديوم كلوريد و 10 مليمولر نترات الكالسيوم في هذه الظروف له تأثير إيجابي ويحسن من قدرة أشجار النخيل في تحمل إجهاد الأملاح خاصة إذا تم الاستخدام بتركيزات متوسطة ومناسبة.

الكلمات المفتاحية: التمثيل الضوئي، توزيع الأيونات، التوازن الغذائي، صوديوم كلوريد، محتوى الكلوروفيل

## INTRODUCTION

Date palm (*Phoenix dactylifera* L.) is a member of the family *Palmace* (*Arecaceae*). It is native to almost all the Middle East countries concentrating in Arabic Peninsula and economically is the most known commercial crop with a large area covered by more than 62.0 million tree (11). It is one of the oldest trees from which man has derived benefit, and it has been cultivated since ancient times. It is the only indigenous wild desert plant definitely domesticated in its native harsh environments. The date palm is considered a symbol of life in the desert, because it tolerates high temperatures, drought and salinity more than many other fruit crop plant species (24). It needs a climate with plentiful sun, minimal rain, yet good access to water, which to a large extent is only provided by oases. They are very cold tolerant, salt tolerant; they can also take extreme heat, dry and wet conditions (22). Within the climatological limits of where the palms are now grown, the upper range of temperature tolerance is of little importance to the palm. Maximum temperatures of around 50C as they occur do not harm the palm (4). Date palm cultivation expanded very rapidly in Saudi Arabia during the last two decades where KSA ranks the second of the world after Egypt regarding the total production of date fruits (7). In 2011, KSA ranked top of the world based on the number of date palm trees. Total number of palms in KSA exceeds 25 million covering more than 170 thousand hectares (Al-Redhaimam, 2014). In fact, there are more than 400 date palm varieties in KSA, of which only about 40 varieties with an economic value. These varieties are spread in 7 Saudi regions characterized by suitable climate for their growth and fruiting (7). Sukkary, Saquee, khlass, Ajwa, Barhee, Anbara, Safawi, Rothana, Rashodya, and Khedry are the most economic well-known cultivars in KSA (7). Riyadh, Qassim Eastern Region and Medina are the most famous production areas in KSA. The total area of date palm increased from 55, 000 ha in 1990 to more than 170, 000 ha in 2011 (the increment exceeded 218.1%). In addition, the total production of date fruits increased from 530, 000 MT in 1990 to more than 1,122,822 MT in 2011 (the increment

exceeded 111.6 %) (3). Soil salinity in irrigated areas is becoming a serious problem for agriculture, especially in arid and semi-arid climates. Salinity commonly occurs in irrigated soil because of the accumulations of soluble salts introduced from the continuous use of irrigation waters containing medium or high quantities of dissolved salts. Several agricultural areas in KSA are deteriorating due to a serious salinity crisis. In fact, land degradation or salinization in KSA is due to a decline in quality and quantity of groundwater and drying up of many water wells. This was due to the lengthy rainless period, the decreased in filtration of water into soil due to the increase in runoff and floods and the decrease in water table levels in some areas. As a result, an increase in soil salinity and a loss of fertility appeared (12). Consequently, scarcity of water contributes vigorously to reducing date palm productivity and even to the death of the trees. In 2004, a Saudi hydrological expert claimed that date palm is water consuming and suggested to stop planting it (8). Several attempts were made to rehabilitate this sector while it was faced by many constraints such as high cost of production, insufficient replacement of low-quality varieties, weakness of marketing services and others. Very little scientific information is available regarding salt tolerance in the date palm. It was reported that date palm can tolerate a relatively high soil salinity level reaching 9 or 12.8 dS m<sup>-1</sup> and that this tolerance is depend on the variety (2 , 19). Plants can adapt to soil salinity through three major mechanisms: (i) osmotic tolerance, (ii) Na<sup>+</sup> or Cl<sup>-</sup> exclusion and secretion, and (iii) accumulation of Na<sup>+</sup> or Cl<sup>-</sup> in the tissues (15). Consequently, this study was conducted to find a solution regarding salinity. The main objective was to study the potential use of Ca (NO<sub>3</sub>)<sub>2</sub> as a method to alleviate different levels of salt-stress on date Palm. In addition, this study can illustrate the salinity level that date palms can tolerate.

## MATERIALS AND METHODS

**Study site;** The research was conducted in the Agricultural - Veterinarian Training and Research Station of King Faisal University (15 kilometers away from King Faisal University's main campus) Alahsa, Saudi Arabia. The

region is situated at 150 m above sea level, characterized by a desertic climate; with a relative humidity ranging between 30% (From May to August) and 60% (From November to February), a temperature of  $37\pm 8^{\circ}\text{C}$  from April till October and of  $24\pm 10^{\circ}\text{C}$  from November till February and rainfall of 200 mm per year. Date palm trees were selected from the orchard (Sandy soil).

### Treatments

Three-year-old date palm plants were irrigated with deionized water supplemented with 50, 100, 150 or 200 mM NaCl. The saline solutions were further enriched with either 0, 5, 10 and 20 mM  $\text{Ca}(\text{NO}_3)_2$ . The combined NaCl /  $\text{Ca}(\text{NO}_3)_2$  treatments were conducted over a period of 20 weeks. Treatments were as follows:

Treatment (T)	Na Cl (mM)	$\text{Ca}(\text{NO}_3)_2$ (mM)
T1	50	0
T2	50	5
T3	50	10
T4	50	20
T5	100	0
T6	100	5
T7	100	10
T8	100	20
T9	150	0
T10	150	5
T11	150	10
T12	150	20
T13	200	0
T14	200	5
T15	200	10
T16	200	20

### Measurement of dry weight of plant parts

At the end of the 36 weeks period, destructive sampling took place and plant parts were separated into young leaves (grown during salinity), old leaves (grown before the onset of the salt treatments), stems, shoots and roots. Dry weight of these parts was determined after oven drying the samples at  $80^{\circ}\text{C}$  to a constant weight.

**Nutrient determination:** K, Ca and Na concentrations were determined from dry powdered plant tissue after extraction in HCl, using an atomic absorption spectrophotometer (905AA, GBC, Australia) (6). Cl was assessed according to LaCroix et al. (13) with a chloride meter 6610, Eppendorf, Germany) by silver ion titration. Total N was determined

using an automated semi-macro Kjeldahl apparatus (430/322, BuÈchi, Switzerland).

### Chlorophyll measurement

For the chlorophyll analysis,  $1\text{ cm}^2$  of leaf discs were frozen in liquid nitrogen and ground. Chlorophyll was extracted in acetone. The pigment density was measured in petrol ether with a spectrophotometer (SP8-300, Pye Unicam, UK) at 642.4 nm (Chl b) and 660 nm (Chl a).

### Net photosynthesis determination

Net photosynthesis rate (PN) was measured at the end of the experiment with a portable photosynthesis meter (CI-301PS, CID, USA) and a rectangular leaf chamber with an  $11\text{ cm}^2$  window. During the measurements, a high-pressure mercury lamp provided a constant photon flux density of  $1000\text{ }\mu\text{mol m}^{-2}\text{ s}^{-1}$  (6).

### Statistical analysis

The experiment was designed as a completely randomized block with 16 treatments. Results were expressed as means of four replicates. Kruskal Wallis statistical test was adopted to compare the means of K independent groups.  $P_{\text{value}} > 5\%$  was adopted.

## RESULTS AND DISCUSSION

### Nitrogen and potassium

In control plants, salinity caused a reduction in nitrogen and potassium contents in all plant parts mainly when comparing between the lowest and highest level of salt-stress (Table 1). At 50 mM NaCl, N and K contents in leaves were 2.85% and 1.73%, respectively. In the stem both mineral contents were 0.45% and 2.8%). These values were comparatively higher than those in leaves and stem under 200mM NaCl (1.6% for N and 0.68% for K in leaves and 0.18% for N and 2.13% for K in stems). The addition of  $\text{Ca}(\text{NO}_3)_2$  in the solution was the more beneficial when added in a moderate concentration (10 mM) compared to lower (5mM) and higher (20mM) ones. In specific, it seems that the use of 20 mM of  $\text{Ca}(\text{NO}_3)_2$  had inhibitory effects in some cases. This observation was valid at all levels of salinity. For instance, At 200 mM NaCl, in T15, N and K contents in leaves, stems and roots were higher than T13 (control) as illustrated by 0.53% and 0.6% (leaves), 0.15% and 0.35% (stems), 0.4% and 0.27% (roots).

**Table 1. Nitrogen and potassium (% of dry matter) contents in plant parts as affected by NaCl and Ca(NO<sub>3</sub>)<sub>2</sub>**

Treatments	Treatments		Leaves		Stems		Roots	
	NaCl	Ca (NO <sub>3</sub> ) <sub>2</sub>	Nitrogen	Potassium	Nitrogen	Potassium	Nitrogen	Potassium
T1	50	0	2.85 ±0.21	1.73 ±0.13	0.45±0.13	2.80±0.14	0.38±0.10	1.10±0.14
T2	50	5	2.85 ±0.21	1.88 ±0.17	0.70±0.08	3.18±0.10	0.63±0.10	1.18±0.15
T3	50	10	3.35 ±0.31	2.45 ±0.13	1.10±0.14	3.43±0.17	0.85±0.06	1.40±0.08
T4	50	20	2.70 ±0.22	2.18 ±0.30	0.85±0.17	3.05±0.13	0.88±0.05	1.25±0.13
T5	100	0	2.70 ±0.08	1.50 ±0.18	0.28±0.10	2.53±0.10	0.45±0.13	0.70±0.08
T6	100	5	2.95 ±0.13	1.80 ±0.22	0.48±0.10	2.70±0.08	0.65±0.10	1.03±0.13
T7	100	10	3.05 ±0.13	2.78 ±0.10	0.88±0.05	3.33±0.17	0.78±0.10	1.30±0.08
T8	100	20	2.65 ±0.21	2.03 ±0.25	0.63±0.13	2.93±0.13	0.70±0.14	1.10±0.08
T9	150	0	2.18 ±0.10	1.30 ±0.18	0.23±0.05	2.40±0.08	0.38±0.10	0.80±0.08
T10	150	5	2.20 ±0.18	1.28 ±0.10	0.48±0.05	2.68±0.15	0.50±0.18	1.20±0.08
T11	150	10	2.65 ±0.13	1.60 ±0.14	0.73±0.05	2.95±0.13	0.70±0.14	1.18±0.15
T12	150	20	2.23 ±0.10	1.28 ±0.13	0.43±0.05	2.75±0.13	0.80±0.08	1.15±0.13
T13	200	0	1.60 ±0.18	0.68 ±0.17	0.18±0.10	2.13±0.13	0.43±0.15	0.68±0.05
T14	200	5	1.83 ±0.10	0.83 ±0.13	0.28±0.10	2.25±0.13	0.58±0.13	0.80±0.08
T15	200	10	2.13 ±0.17	1.28 ±0.13	0.33±0.10	2.48±0.10	0.83±0.10	0.95±0.13
T16	200	20	1.38 ±0.13	0.90 ±0.22	0.20±0.12	2.18±0.10	0.80±0.12	0.83±0.13

**Calcium**

The use of Ca(NO<sub>3</sub>)<sub>2</sub> decreased the salinity-induced reductions in Ca content in all plant parts (Table 2). In fact, all levels of Ca(NO<sub>3</sub>)<sub>2</sub> had ameliorative effects on this parameter with the best effect observed following the addition of 10 mM Ca(NO<sub>3</sub>)<sub>2</sub>. For instance, Ca content in leaves, stems and roots increased from

respectively 3.05%, 1.13% and 0.53% in T5 to reach a maximum of respectively 4.43%, 2.63% and 0.95% in T9. Under the remaining NaCl levels, similar findings were obtained. However, at 200 mM NaCl, the use of Ca(NO<sub>3</sub>)<sub>2</sub> with high dose (20 mM) did not had any effect mainly on Ca content in leaves and stems.

**Table 2. Calcium (% of dry matter) content in plant parts as affected by NaCl and Ca(NO<sub>3</sub>)<sub>2</sub>**

Treatments	Treatments		Leaves	Stems	Roots
	NaCl	Ca(NO <sub>3</sub> ) <sub>2</sub>			
T1	5	0	3.08 ±0.17	2.70±0.14	0.70±0.08
T2	50	5	4.28 ±0.34	2.90±0.14	0.83±0.22
T3	50	10	4.43 ±0.36	3.43±0.17	1.03±0.17
T4	50	20	3.65 ±0.19	3.10±0.08	0.90±0.14
T5	100	0	3.05 ±0.37	1.13±0.10	0.53±0.10
T6	100	5	3.18 ±0.24	1.38±0.05	0.75±0.10
T7	100	10	4.43 ±0.41	2.63±0.17	0.95±0.06
T8	100	20	3.43 ±0.36	2.28±0.10	0.75±0.13
T9	150	0	2.08 ±0.28	0.98±0.15	0.75±0.13
T10	150	5	1.98 ±0.34	1.13±0.05	0.93±0.17
T11	150	10	2.70 ±0.18	1.43±0.10	1.23±0.10
T12	150	20	2.13 ±0.31	1.20±0.08	0.90±0.32
T13	200	0	1.68 ±0.15	0.68±0.13	0.63±0.10
T14	200	5	1.85 ±0.30	0.83±0.88	0.85±0.06
T15	200	10	2.35 ±0.19	0.98±0.15	1.10±0.14
T16	200	20	1.60 ±0.39	0.63±0.10	0.88±0.24

**Chloride**

The accumulation of chloride was limited following the use of Ca(NO<sub>3</sub>)<sub>2</sub>. Compared to control at each salinity level, plants treated with Ca(NO<sub>3</sub>)<sub>2</sub> had lower Cl content except in roots (Table 3). For instance, Cl content in leaves and stems in T3 were 0.23% and 0.65% respectively, in T7 were 0.23% and 0.68%,

respectively and in T15 were 0.45% and 0.73%, respectively) were lower compared to their corresponding control treatments T1 (0.5% and 0.7% respectively, in T5 were 0.6% and 0.78%, respectively and in T13 were 0.78% and 0.88%, respectively. On the contrary, at root level, Cl content was higher in trees treated with Ca(NO<sub>3</sub>)<sub>2</sub> compared to

control at each salinity level. Similar patterns were observed for Na accumulation in all plant parts. The presence of this ion was inhibited in

leaves and stems and it was elevated in roots following  $\text{Ca}(\text{NO}_3)_2$  application.

**Table 3. Chloride and sodium (% of dry matter) contents in plant parts as affected by NaCl and  $\text{Ca}(\text{NO}_3)_2$**

Treatments			Leaves		Stems		Roots	
	NaCl	$\text{Ca}(\text{NO}_3)_2$	Chloride	Sodium	Chloride	Sodium	Chloride	Sodium
T1	50	0	0.50 ±0.08	0.48 ±0.10	0.70±0.08	0.50±0.08	1.23±0.15	0.40±0.08
T2	50	5	0.45 ±0.06	0.33 ±0.10	0.68±0.10	0.48±0.05	1.35±0.13	0.50±0.08
T3	50	10	0.23 ±0.05	0.20 ±0.08	0.65±0.06	0.28±0.10	1.58±0.05	0.58±0.05
T4	50	20	0.28 ±0.10	0.28 ±0.05	0.80±0.08	0.33±0.05	1.53±0.10	0.63±0.10
T5	100	0	0.60 ±0.08	0.50 ±0.08	0.78±0.13	0.83±0.10	1.38±0.10	0.40±0.08
T6	100	5	0.48 ±0.10	0.43 ±0.10	0.75±0.06	0.73±0.05	1.48±0.05	0.53±0.10
T7	100	10	0.23 ±0.05	0.20 ±0.08	0.68±0.15	0.58±0.05	1.68±0.10	0.63±0.10
T8	100	20	0.35 ±0.13	0.25 ±0.06	0.90±0.16	0.63±0.10	1.48±0.05	0.48±0.10
T9	150	0	0.63 ±0.10	0.55 ±0.13	0.80±0.14	0.98±0.10	1.40±0.18	0.50±0.08
T10	150	5	0.53 ±0.05	0.48 ±0.13	0.83±0.10	0.88±0.05	1.50±0.14	0.63±0.05
T11	150	10	0.30 ±0.08	0.23 ±0.10	0.88±0.17	0.48±0.05	1.63±0.10	0.68±0.13
T12	150	20	0.33 ±0.10	0.30 ±0.08	0.93±0.13	0.53±0.10	1.48±0.10	0.53±0.10
T13	200	0	0.78 ±0.05	0.70 ±0.08	0.88±0.17	1.05±0.10	1.48±0.10	0.63±0.05
T14	200	5	0.60 ±0.08	0.58 ±0.15	0.88±0.21	0.88±0.05	1.60±0.12	0.80±0.08
T15	200	10	0.45 ±0.06	0.40 ±0.08	0.73±0.05	0.58±0.10	1.70±0.08	0.78±0.10
T16	200	20	0.53 ±0.10	0.50 ±0.14	1.00±0.18	0.63±0.10	1.53±0.10	0.53±0.10

#### Dry weight of plant parts

Increasing in salt-stress caused a slight gradual decrease in dry weight of leaves (LDW) (Table 4) with the highest values observed at 50 mM NaCl and the lowest obtained at 200 mM NaCl. However, the application of 10 mM of  $\text{Ca}(\text{NO}_3)_2$  was ameliorative mainly under moderate salt-stress (100 mM and 150 mM NaCl) compared to their control; T7 and T11 (respectively 338.33g and 336.83g) had higher values than T5 and T9 (respectively 336.73g and 335.53g). Salinity also decreased stem dry weight (SDW). T13 (200/0) was significantly different than T1 (50/0), T5 (100/0) and T9 (150/0) with respectively 90.95, 95.52, 95.70 and 94.28 g/plant. At 50 mM NaCl, the only

significant difference was observed between T3 (50/10) and T4 (50/20) while those treatments were not significant with other treatments at this level. At 100 mM NaCl, T8 (100/20) was significantly different than T6 (100/05) and T7 (100/10) only where SDW was the lowest in T8. Under 200 mM NaCl, SDW was the most enhanced by the application of 10 mM  $\text{Ca}(\text{NO}_3)_2$  compared to control. Root dry weight (RDW) decreased from 170.53 g/plant under 50 mM NaCl to 163.50 g/plant under 200mM NaCl in control plants. Similarly to LDW and SDW, the application of 10 mM  $\text{Ca}(\text{NO}_3)_2$  had ameliorative effects while its application with 20mM had inhibitory effects

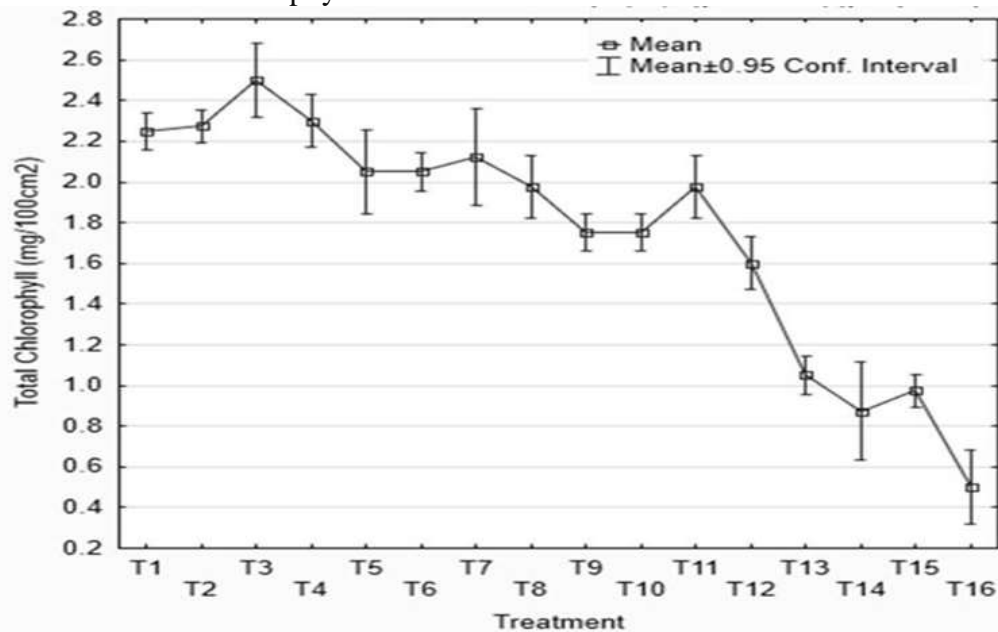
**Table 4. Effect of different concentration  $\text{Ca}(\text{NO}_3)_2$  on dry weight of leaf, stem and root of date palm at different salinity level**

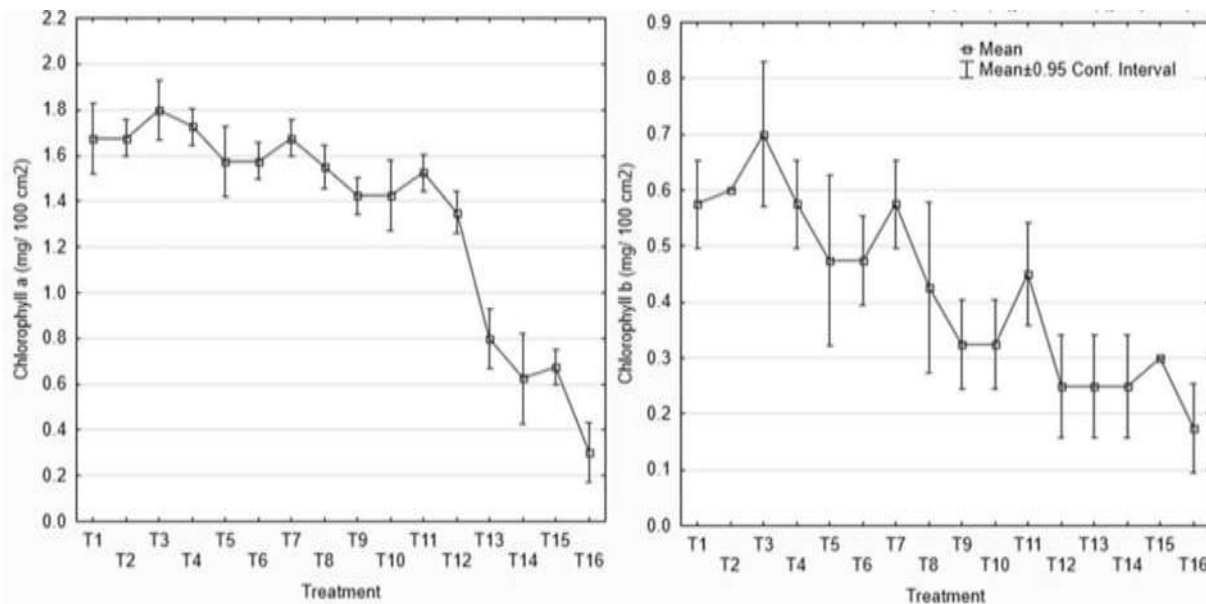
Treatment	Salinity (mM)	Dry weight (g/plant)		
		Leaf	Stem	Root
T1	50/00	336.75±0.48	95.52±1.03	170.53±0.62
T2	50/05	336.73±1.14	95.73±0.50	170.73±0.17
T3	50/10	336.20±0.65	96.40±0.37	171.68±0.22
T4	50/20	336.68±0.91	94.73±0.39	169.48±0.67
T5	100/00	336.73±1.01	95.70±0.51	170.30±0.18
T6	100/05	336.95±0.31	95.85±0.37	170.23±0.26
T7	100/10	338.33±0.40	95.98±0.88	171.15±0.37
T8	100/20	335.35±0.26	94.43±0.40	168.85±1.09
T9	150/00	335.53±0.35	94.28±0.21	167.58±0.35
T10	150/05	335.75±0.50	94.35±0.21	168.20±0.65
T11	150/10	336.83±0.56	94.85±0.17	168.53±0.61
T12	150/20	334.68±0.36	93.8±0.22	166.63±0.40
T13	200/00	334.48±0.26	90.95±1.10	163.50±0.32
T14	200/05	334.60±0.18	91.15±0.91	163.95±0.56
T15	200/10	334.80±0.14	92.18±0.68	164.73±0.17
T16	200/20	334.18±0.61	89.33±0.63	163.08±0.10

### Chlorophyll content

Chlorophyll a and b and consequently total chlorophyll content (Fig 1 and 2) were affected negatively by salinity. In T1 (50/0), chlorophyll a and b decreased between T1 (1.68 and 0.58 mg/100 cm<sup>2</sup>) T9 (1.43 and 0.33 mg/100 cm<sup>2</sup> respectively) and T13 (0.80 and 0.25 mg/100 cm<sup>2</sup>) (Figure 2).  $\text{Ca}(\text{NO}_3)_2$  application did not affect chlorophyll a and b

at all salinity levels. For total chlorophyll content, the addition of  $\text{Ca}(\text{NO}_3)_2$  to the solution was only beneficial under 50 and 150 mM NaCl mainly with the concentration of 10 mM. Compared to control, total chlorophyll content in T3 (2.5 mg/100 cm<sup>2</sup>) and T11 (2 mg/100 cm<sup>2</sup>) was higher than in T1 (2.23 mg/100 cm<sup>2</sup>) and T9 (1.75 mg/100 cm<sup>2</sup>).

**Figure 1. Total chlorophyll content (mg/100 cm<sup>2</sup>) grouped by treatment**

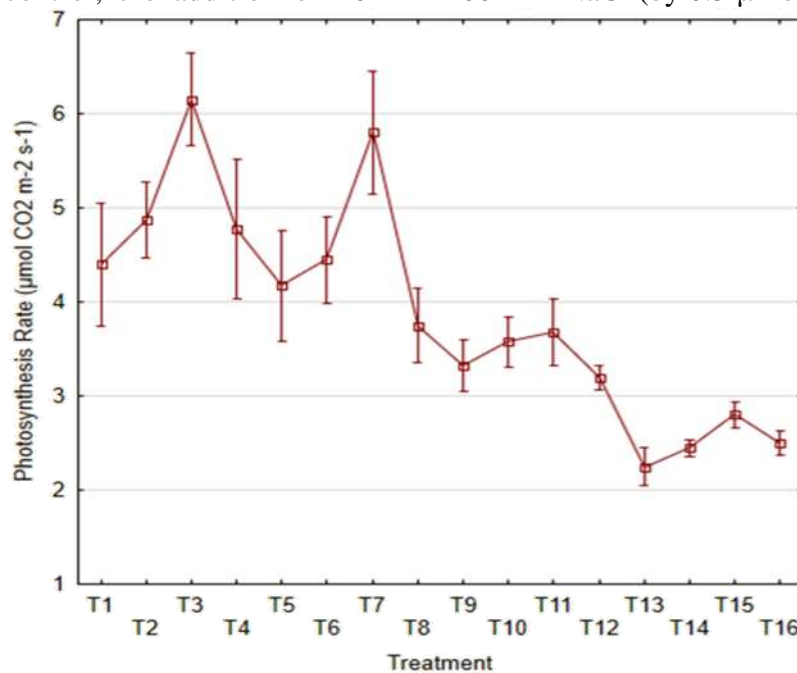


**Figure 2. Mean plot of Chlorophyll a and b (mg/100 cm<sup>2</sup>) grouped by treatment**

**Photosynthesis rate**

A descendant pattern in photosynthetic rate with increasing salt-stress was observed (Fig. 3). Compared to control, the addition of 10

mM Ca(NO<sub>3</sub>)<sub>2</sub> improved this parameter mainly under 50 mM NaCl (by 1.7 μmol CO<sub>2</sub>/m<sup>2</sup>/s<sup>1</sup>), 100mM NaCl (by 1.6 μmol CO<sub>2</sub>/m<sup>2</sup>/s<sup>1</sup>) and 200 mM NaCl (by 0.5 μmol CO<sub>2</sub>/m<sup>2</sup>/s<sup>1</sup>).



**Figure 3. Mean plot of photosynthesis rate (μmol CO<sub>2</sub> m<sup>-2</sup> s<sup>-1</sup>) grouped by treatment**

In the current study, it was observed that mainly high levels of salinity caused severe reductions in ion partitioning and accumulation in all plant parts. On the contrary, it helps in the accumulation of Na and Cl which are considered toxic at certain levels in certain plant parts. Alrasbi et al. (2) found that some date palm varieties can tolerate up to 9 dS m<sup>-1</sup> soil salinity which almost confirm the result of this study where the major parameter was not affected by weak salt-stress. The studied parameters were

affected negatively by the salinity level 150 mM while the severe effect was detected at 200 mM NaCl. This latter concentration caused a substantial reduction by almost 50% in various plant parts. The 50% reduction is considered the minimal economic value acceptable in salt tolerance (2). The mechanisms of this negative effect may be due to osmotic effects that restrict water and nutrient uptake, specific ion effect of Na and Cl ions, nutritional imbalance and inhibition of physiological processes like photosynthesis,

transpiration, energy reactions, metabolism of nutrients and use of extra energy in osmoregulation. However, the salt tolerance is dependent on the texture and drainage of soil, climate and the genetic potential of the variety (2). In fact, soil salinity causes ionic toxicity and osmotic stress in salt-susceptible plants, a situation that reduces the growth rate and may lead to plant death (23). Some plants even check toxic ions entry into the root cortex and thus exercise ion selectivity. Date palm has very strict checking to the ion Cl absorption from soil solution which confers the ability to tolerate salt-stress. Al-Bahrany and Al-Khayri (1) found that the growth of cells was negatively affected by salt treatment and the cellular Na<sup>+</sup> content initially increased which confirm current results where salinity increased Na content in root, stem and leaves. Furr and Ream (9) also found that the average growth rate of leaves was depressed as the salinity increased. Sodium could accumulate in cell walls of leaves or increase intercellular concentrations, leading to specific ion toxicity. High Na in leaf cells could easily cause loss of turgor (10). Moreover, Accumulation of salts in the root zone affects plant performance due to water deficit and disruption of ion homeostasis (15). As mentioned in the results, 10 mM Ca(NO<sub>3</sub>)<sub>2</sub> was the most efficient concentration at all salinity levels. In contrary, 20 mM Ca(NO<sub>3</sub>)<sub>2</sub> affect negatively almost all parameters and at all salinity levels. In fact, calcium is required for cell elongation and cell division. According to Bush (5), Ca is involved in numerous cellular functions such as ionic imbalances, gene expression and carbohydrates metabolism. It mainly translocated in the xylem sap and less in the phloem. It was reported that Ca can mitigate the negative effects of salinity on shoot growth of plants (17). It minimizes the leakage of cytosolic potassium which maintains also a balanced K content in cells (14). In addition, calcium functions appeared as a cross-linkage of the middle lamella, which binds cells together. It is also needed in enzymatic reactions provides the balance of anions and cations in the plant and plays an important role in the stabilization of cell membranes (20). According to Marschner (16), the presence of Ca improves the accumulation of K element

rather than Na in the membrane. This fact was also reported in the current study. In addition, the presence of nitrate reduced the uptake of Cl<sup>-</sup> in the plants. This was translated by a lower translocation of chloride from roots and stems to the leaves. Ca(NO<sub>3</sub>)<sub>2</sub> also improved chlorophyll content and photosynthesis rate in stressed plants. Again, as mentioned by Shadad et al. (1988), chlorophyll content was promoted by nitrate, which induced the synthesis of chlorophyll.=

### CONCLUSIONS

The use of calcium nitrate had ameliorative effects on date palm. The limiting factor was related to the concentration of application. Ca(NO<sub>3</sub>)<sub>2</sub> had the ability to re-establish ion balance in plant parts and to reduce Na and Cl accumulation to a certain extent. Future works should be done to determine the effect of Ca(NO<sub>3</sub>)<sub>2</sub> on yielding capacity of stressed date palm trees.

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