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Medjool Date Palm Growth and Productivity in Relation to Spraying Some Nutrients and Antioxidants

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Abstract: In order to study the effect of potassium (K), iron (Fe), boron (B) and three antioxidants (ascorbic acid, citric acid and salicylic acid) on vegetative growth, photosynthesis pigments, mineral status and yield of Medjool date palm grown under sandy soil conditions, drip irrigation system was followed. located at Malawi district, El-Minia – Egypt. A field trial, designed in split plots, was achieved. The obtained results showed that, increasing K concentration from 0.25% to 0.75% was very effective in improving the vegetative growth, leaf chlorophyll, mineral status, and yield. However, sprayed the 'Medjool' date palm with the antioxidants showed a superior effect than spraying Fe of B. Furthermore, the palms treated with potassium at .75% combined with salicylic acid at 100 ppm presented the best results, during the two experimental seasons.

Key words: Medjool date palm, potassium, boron, antioxidants, growth, mineral status and yield.

1. Introduction

Date palm (*Phoenix dactylifera L.*) is an ancient crop of immense historical, cultural, and economic significance particularly in arid and semi-arid regions. Date palms have been cultivated in the Middle East and North Africa for more than 5,000 years **(Zaid and de Wet, 2002)**. Taxonomically, the date palm belongs to the family palmaceae, a large family includes numerous species adapted to desert climates. In Egypt, the date palm holds a special position not only as a source of nutrition but also as a cultural symbol associated with prosperity and resilience. Egypt leads the world in date production, contributing approximately 18% of global output **(FAO, 2022)**.

"Medjool" date palm is one of the famous semi-dry high quality international cultivars. Currently, Medjool considered as one of the main dates cultivars in Egypt (**Ibrahim et al., 2023**). Its fruit has a sweet, caramel taste and soft chewy texture. It has higher nutritional contents; reaches in

calories, protein, carbohydrates, vitamins and mineral nutrients. It also a good source of phytonutrients "plants compounds have many health benefits" (**Ibrahim *et al.*, 2023 and Mohamed, 2023**).

Potassium (K) plays a central role in osmoregulation, enzyme activation, photosynthesis efficiency, sugar translocation, and stomatal regulation. In date palms, potassium application especially through foliar spraying has shown significant effects on improving vegetative growth and enhancing fruit quality (**Marshner, 1995**). Micronutrients such as iron (Fe) and boron (B) are vital for proper plant development. Iron is crucial in chlorophyll synthesis and electron transport in photosynthesis, while boron is essential for cell wall formation, pollen tube growth, and fruit set. Foliar application of these micronutrients can significantly improve the growth and reproductive performance of date palms (**Marschner, 1995)**. The use of antioxidants such as ascorbic acid (vitamin C) and salicylic acid has gained attention in horticultural practices. These compounds act as bio-stimulants that enhance plant tolerance to environmental stresses and improve physiological and biochemical processes (**Al-Zubaidy & Al-Asad, 2025).**

The current study focused on the response of 'Medjool' date palm *cv.* to spraying potassium at different concentrations as well as spraying microelements (Fe at 200 ppm and B at 100 ppm) and three antioxidants (ascorbic, citric and salicylic acids) on the growth, productivity of 'Medjool' palms.

2. Materials and Methods

The present study was carried out during two successive seasons (2022 and 2023) on seventy-two derived offshoots 'Medjool' date palms. The chosen female palms were 10 years old, uniform in vigor, and free from insects and diseases. The palms were grown in private orchard located at Malawi district El-Minia Governorate - Egypt where the soil texture is sandy, well drained water. The chosen palms were planted at 9 X 9 meters apart and irrigated through underground well, with drip irrigation system. The old leaves were pruned so that the ratio of leaves to bunch was adjusted to eight leaves per each bunch. Then, the number of spathes per palm was adjusted to ten spathes, by removing the weak, young or earliest spathes. Pollination of the investigated palms was done by using one source of pollen grannies, using Ghanami *cv.* as pollinator. The female spathes were pollinated three times, with a four-day interval between them, by inserting five male strands into the female bunch (**Hussein et al., 1993 and Ibrahim 2023**). The 'Medjool' palms were subjected to recommended and regular horticulture practices that were applied in the orchard including fertilization, irrigation, hoeing and pest management.

2.1. Soil and irrigation water characters

The soil of experimental orchard, where the present experiment carried out, was sandy soil (table 2) at located at Malawi district Al-Minia Governorate. Composite samples of soil and irrigation water were collected and subjected to physicochemical analysis according to **Wilde *et al.* (1985**). Then, the obtained data are illustrated in Table (1).

2.2. Experimental work

In order to study the effects of K (in form of potassium sulphate 50% K_2O) and its suitable dose, as well as the role of some micronutrients (Fe and B) and some antioxidants (ascorbic, citric and salicylic acid) on 'Medjool' date palm, This study included two factors: the first one (A) is spraying potassium at four concentrations namely; a1- 0.0%, a2- 0.25%, a3- 0.50% and a4- 0.75%) and the second one included Fe (at 200 ppm in form of chelated ferrous sulphate), B (at 100 ppm in form of boric acid), ascorbic acid, citric acid, and salicylic acid (b1- 0.0 micronutrients and 0.0 antioxidants, b2- Fe at 200 ppm, b3- B at 100 ppm, b4- ascorbic acid at 100 ppm, b5- citric acid at 100 ppm, and b6- salicylic acid at 100 ppm), as well as the interaction between factors A and B. All the examined compounds were sprayed three times yearly (after winter pruning, 1 week after fruit setting, and the three weeks later (during Kamry stage). Each treatment was replicated three times, one palm per each.

Table (1). Physicochemical analysis of orchard soil and irrigation water

Soil analysis		Water analysis	
Constituents	**Values**	**Constituents**	**Values**
Sand %	80.1	**E.C (m.mhos/cm/25C)**	0.9
Silt %	12.0	**Hardness**	18.2
Clay %	7.9	**pH**	7.45
Texture	Sandy	**Ca (mg/L)**	34.4
EC (1:2.5Extract) mmhos/cm/ 25 ºC	1.6	**Mg (mg/L)**	20.3
Organic matter %	0.3	**K (mg/L)**	5.07
pH (1 : 2.5 extract)	8.2	**Na (mg/L)**	17.8
Active lime %	8.9	**Sum of Cations (mg/L)**	8.16
N (mg/kg)	0.3	**Alkalinity (mg/L)**	155
Phosphorus (ppm)	3.1	**Chlorides (mg/L)**	101
Available Ca (meq/100g)	0.61	**Nitrate (mg/L)**	9.2
C/N Ratio	17.7	**SAR**	1.87

2.3. Experimental design and statistical analysis

The treatments were arranged in complete randomized design in split plot, potassium treatments were occupied the main plots and micronutrients and antioxidants were occupied the sub plots. Then, the obtained data were tabulated and statistically analyzed by using statistical package MSTATC Program. The comparisons between the treatments were made by using New L.S.D at p= 0.05 (**Snedecore & Cochran, 1990** and **Gomez & Gomez, 1984).**

2.4. Different measurements and determinations

The following characters i.e. vegetative growth, plant pigments, leaf mineral content and yield were achieved during the two experimental seasons:

2.4.1. Leaf morphology parameters: Morphological measurements of leaves were achieved on eight full size leaves per palm (two leaves at each side). Morphological measurements included leaf length and width (m), number of leaflets per leaf, Leaflet area (cm^2), and leaf area (m^2).

2.4.2. Determination leaf pigments: Sample of sixteen mature and fresh leaflets were taken from the middle part of furor mature leaves (six month old leaves) one leaf per each side, the samples were collected at 1st week of August (according to **Ibrahim 2010**). The fresh leaflets were cut into small pieces and 0.5 g weight from each sample was taken, the rest will be used in mineral determinations of leaves. the weight of 0.5 g was homogenized and extracted by 85% acetone in the presence of little amounts of Na_2CO_3, then it filtered and washed several times with acetone until the filtrate became colorless. The extract was completed to a 20 ml with acetone 85%. A portion of this extract was taken for the determination of chlorophylls: a, b, and total chlorophyll as well as total carotenoids calorimetrically at the wave length = 662 and 664 nm to determine chlorophylls A and B, and 440 for total carotenoids respectively, by using the following equations (**Walsh and Beaton, 1986** and **Martin-Préval *et al.*, 1984)**.

Chl. a = (9.784 x E 662) – (0.99 x E 662) = mg / 100 g F.W.

Chl. b = (21.426 x E 644) – (4.65 x E 644) = mg /100 g F.W.

Where E = optical density at a given wavelength.

The Total chlorophyll was estimated by summation of chlorophyll a and chlorophyll b.

2.4.3. Determination of mineral elements (N, P, K): The leaflets samples rest from pigments determination were used to mineral determination**.** The samples were washed several times with tap water and rinsed with distilled water and air-dried. Then, oven dried overnight at 70 ℃. The samples were grounded, then 0.5 g weight was used to determine the three macro nutrients. Nitrogen was determined by using micro-Kjeldahl method as described by (**Walsh and Beaton, 1986**). Phosphorus was determined by using colorimetric method by measuring the optical density of phosphor-molibdo-vanadate complex using Spectro-photometer at wave length 430 nm (**Martin-Preval *et al.*, 1984)**. Potassium was determined by using flam-photometrically method outlined by **Martin-Préval *et al.*, (1984)**.

2.4.4. Bunch weight (kg) and Yield (kg/palm): Bunches of 'Medjool' date palms were picked at the optimum commercial harvesting time (**Ibrahim 2023**) under Meddle Egypt region conditions (at mid of September) in the two experimental seasons. The yield of each palm was recorded in terms of weight in kilograms per palm, by multiplying the average bunch weight (kg) by total number of bunches per palm (ten bunches).

3. Results and Discussion

3.1. Leaf length (cm)

The obtained results showed that, spraying K at different concentrations (0.0%, 0.25%, 0.50% and 0.75 %) was combined with significant enhancement of leaf length (m). However, all K concentrations were capable to increase the leaf length significantly, during the two experimental seasons. This increment was gradual and parallel to increasing the concentration used of K. Spraying Medjool date palm with Fe at 200 ppm, B at 100 ppm, ascorbic acid at 100 ppm, citric at 100 ppm or salicylic at 100 ppm significantly enhanced adult leaf length (m). Spraying any one of the micronutrients (Fe and B) or any antioxidant (ascorbic, citric and salicylic acids) was capable to increase the leaf length compared to control treatment. These findings were true during the two experimental seasons. However, spraying the antioxidants caused a superior increase of leaf length rather than the micro-nutrients. However, spraying salicylic acid at 100 ppm produced highest leaf length compared to other anti-oxidants or micronutrients, in both experimental seasons respectively. Regarding the inter-actions between K concentrations as well as micro-nutrients and antioxidants, the data shows that the combined effect of K and micro-nutrients & antioxidants significantly increased with increasing the concentration of K from 0.25% to 0.75%. On the other side, the interaction between K and Salicylic acid at 100 ppm showed more pronounced than the other interactions. On the opposite side, untreated palms produced the lowest leaf length (m), during the two experimental seasons respectively.

Table (2). Effect of spraying potassium, iron, Boron, Ascorbic acid, Citric acid, and salicylic acid on the length of adult leaf (m) of 'Medjool' date palm, during 2022 and 2023 seasons

Treatments	Leaf length - First season					Leaf length - Second season				
	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B
b1 (0.0 Fe, B & antioxidant)	3.09	3.33	3.53	3.62	3.39	3.21	3.52	3.71	3.81	3.55
b2 (Fe at 200 ppm)	3.43	3.55	3.77	3.83	3.65	3.63	3.85	4.06	4.19	3.93
b3 (B at 100 ppm)	3.35	3.63	3.85	3.85	3.67	3.67	3.87	3.92	3.97	3.85
b4 (Ascorbic at 100 ppm)	3.43	3.77	3.79	3.97	3.74	3.77	3.98	4.19	4.27	4.05
b5 (Citric at 100 ppm)	3.31	3.68	3.85	3.97	3.70	3.85	3.87	4.05	4.19	3.99
b6 (Salicylic at 100 ppm)	3.67	3.97	4.09	4.15	3.97	3.80	4.15	4.29	4.38	4.16
Mean A	3.38	3.66	3.81	3.90		3.64	3.87	4.04	4.16	
New LSD at 5%	A = 0.23 ; B= 0. 26 ; AB= 0.38					A = 0. 28 ; B= 0.30 ; AB= 0.52				

3.2. Effect on adult leaves width

It is clearly showed that, increasing K concentration from 0.00% to 0.25% failed to increase the leaf width significantly, neither in the first season nor in the second season. Contrary increasing the potassium concentration used from 0.25% to 0.5% or 0.75% was capable to increase the width of leaf significantly. However, the highest K concentration (0.75%) produced the best adult leaf width. Spraying 'Medjool' date palm with Fe at 200 ppm or B at 100 ppm failed to improve the leaf width significantly, neither in the first season nor in the second season. Contrary, spraying any one of the antioxidant (ascorbic, citric and salicylic acids) was capable to improve the leaf width (m) significantly. However, the palms received salicylic acid at 100 ppm produced highest leaf width in both experimental seasons respectively. Regarding the inter-actions between the K concentrations and micro-nutrients & antioxidants it was significant in both seasons. However, the interaction between K concentrations and salicylic acid shows more effective on leaf width than the other interactions. Furthermore, the palms received K at 0.75% combined with salicylic acid at 100 ppm produced the highest leaf width. Contrary, untreated palms (control) produced the lowest leaf width.

Table (3). Effect of spraying potassium, iron, Boron, Ascorbic acid, Citric acid, and salicylic acid on the leaf width (m) of 'Medjool' date palm, during 2022 and 2023 seasons

Treatments	Leaf width - First season					Leaf width - Second season				
	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B
b1 (0.0 Fe, B & antioxidant)	0.39	0.42	0.46	0.48	0.44	0.40	0.44	0.47	0.48	0.45
b2 (Fe at 200 ppm)	0.44	0.46	0.50	0.51	0.48	0.46	0.48	0.49	0.51	0.49
b3 (B at 100 ppm)	0.45	0.47	0.50	0.52	0.49	0.44	0.46	0.48	0.50	0.47
b4 (Ascorbic at 100 ppm)	0.47	0.50	0.53	0.54	0.51	0.48	0.52	0.55	0.56	0.53
b5 (Citric at 100 ppm)	0.47	0.49	0.53	0.53	0.51	0.49	0.51	0.54	0.55	0.52
b6 (Salicylic at 100 ppm)	0.49	0.50	0.53	0.55	0.52	0.52	0.54	0.57	0.59	0.56
Mean A	0.45	0.47	0.51	0.52		0.47	0.49	0.52	0.53	
New LSD at 5%	A = 0.06 ; B= 0.07 ; AB= 0.10					A = 0.05 ; B= 0.07 ; AB= 0.11				

3.3. Effect on leaflet number per adult leaf

The obtained data showed that, all K treatments was capable to significantly increase the number of leaflets per leaf rather than the check treatment, in both experimental seasons, except the case of lowest potassium concentration (0.25%) in the first season. This stimulation was gradually and related to increase K concentration. It is worth to mention that, spraying any antioxidant (Ascorbic, citric or Salicylic acids) at 100 ppm was more effective on increasing the number of leaflet per leaf rather than spraying Fe at 200 ppm or B at 100 ppm. Regarding the interaction between K concentrations and micronutrients (Fe and B) and antioxidants (ascorbic, citric and salicylic acids) it was significant for the number of leaflets per leaf in both experimental seasons. The highest leaflet number per leaf was obtained when the trees received K at 0.75% combined with salicylic acid at 100 ppm. While, control treatment present the least leaflet number per leaf, during 2022 and 2023 seasons.

Table (4). Effect of spraying potassium, iron, Boron, Ascorbic acid, Citric acid, and salicylic acid on the number of leaflets per leaf of 'Medjool' date palm, during 2022 and 2023 seasons

Treatments	No. of leaflet - First season					No. of leaflet - Second season				
	0.0% K (a1)	0.25% K (a2)	0.5% K (a3)	0.75% K (a4)	Mean B	0.0% K (a1)	0.25% K (a2)	0.5% K (a3)	0.75% K (a4)	Mean B
b1 (0.0 Fe, B & antioxidant)	157.3	158.9	159.3	160.1	158.9	156.1	158.7	161.0	162.3	159.5
b2 (Fe at 200 ppm)	159.5	160.2	161.3	162.4	160.9	158.3	162.9	163.3	164.6	162.3
b3 (B at 100 ppm)	158.9	162.3	163.8	164.9	162.5	157.7	160.1	163.3	163.7	161.2
b4 (Ascorbic at 100 ppm)	160.5	163.3	165.5	166.7	164.0	158.4	161.1	165.1	166.2	162.7
b5 (Citric at 100 ppm)	162.4	163.4	165.5	165.7	164.3	159.1	163.9	167.1	167.7	164.5
b6 (Salicylic at 100 ppm)	163.9	165.9	166.7	167.2	165.9	161.2	166.2	167.7	169.7	166.2
Mean A	160.4	162.3	163.6	164.5		158.8	162.2	164.6	165.7	
New LSD at 5%	A= 3.1 ; B= 3.7 ; AB= 5.4					A= 3.7 ; B= 3.2 ; AB= 4.7				

3.5. Effect on leaflet area (cm^2)

It is clear from the obtained results that, only spraying the highest concentration of K (0.75%) was capable to increase the leaflet surface area (cm^2), while the other concentrations (0.25% and 0.50%) failed to do so. The treatments of factor B showed that, only spraying any one of the antioxidants (ascorbic, citric, and salicylic acids) was able to significantly improve the leaflet surface area (cm^2) compared to untreated palms. While, spraying Fe or B was unable to cause any significant increase in leaflet surface area (cm^2) in both experimental seasons. Concerning the effect interaction between K treatments and micronutrients or antioxidants, it is becomes clear to us that, the leaflet surface area which produced by spraying 'Medjool' date palm with K at high concentrations (0.5% or 0.75%) in combination with any micro nutrient or any antioxidant was significant, in compared to untreated palms. However, the highest leaflet surface area (cm^2) was obtained when the palms received K at 0.75% combined with salicylic acid at 100 ppm. In the contrary, control palms present the least leaflet surface area.

Table (5). Effect of spraying potassium, iron, Boron, Ascorbic acid, Citric acid, and salicylic acid on leaflet area (cm^2), during 2022 and 2023 seasons

Treatments	Leaflet area (cm^2) - First season					Leaflet area (cm^2) - Second season				
	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B
b1 (0.0 Fe, B & antioxidant)	128.5	133.3	137.5	137.7	134.3	131.3	135.5	137.9	139.3	136.0
b2 (Fe at 200 ppm)	135.3	136.3	139.7	139.5	137.7	135.8	138.9	140.3	142.5	139.3
b3 (B at 100 ppm)	133.5	135.5	137.9	137.3	136.1	138.7	140.3	140.7	141.1	140.2
b4 (Ascorbic at 100 ppm)	137.7	138.7	139.5	140.4	139.1	139.9	142.8	143.7	144.2	142.6
b5 (Citric at 100 ppm)	135.8	139.7	140.7	142.7	139.7	141.2	143.3	144.8	145.9	143.8
b6 (Salicylic at 100 ppm)	138.9	140.5	143.7	144.7	141.9	143.5	146.5	147.1	147.7	146.2
Mean A	134.9	137.3	139.8	140.4		138.4	141.2	142.4	143.5	
New LSD at 5%	A= 5.1 ; B= 5.0 ; AB= 7.3					A = 5.0 ; B= 6.1 ; AB= 8.9				

3.6. Leaf chlorophyll a, b and total chlorophyll contents

It is clear from the obtained data that increasing the concentration of potassium from 0.25% to 0.75% was combined with gradual and significant increment of chlorophyll a, b, and total chlorophyll in 'Medjool' date palm leaves. However, the palms received the highest potassium concentration (0.75%) produced the highest chlorophyll a, b and total chlorophyll contents in their leaves, followed by those received potassium at 0.5 in both experimental seasons (Table 6).

Table (6). Effect of spraying potassium, iron, Boron, Ascorbic acid, Citric acid, and salicylic acid on chlorophyll contents (mg/100g FW) of 'Medjool' date palm, during 2022 and 2023 seasons

Treatments	Chlorophyll a - First season					Chlorophyll a - Second season				
	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B
b1 (0.0 Fe, B & antioxidant)	3.6	3.8	4.1	4.1	3.9	3.5	3.9	4.2	4.4	4.0
b2 (Fe at 200 ppm)	4.1	4.3	4.4	4.6	4.4	4.1	4.4	4.7	4.9	4.5
b3 (B at 100 ppm)	3.8	3.9	4.2	4.4	4.1	4.0	4.2	4.4	4.6	4.2
b4 (Ascorbic at 100 ppm)	4.0	4.1	4.3	4.7	4.3	4.2	4.6	4.8	5.0	4.6
b5 (Citric at 100 ppm)	4.0	4.3	4.2	4.5	4.3	4.3	4.7	5.0	5.1	4.8
b6 (Salicylic at 100 ppm)	4.1	4.6	4.8	4.9	4.6	4.4	4.8	5.1	5.3	4.9
Mean A	3.9	4.2	4.4	4.5		4.1	4.4	4.7	4.9	
New LSD at 5%	A= 0.3 ; B= 0.4 ; AB= 0.6					A= 0.2 ; B= 0.3 ; AB= 0.5				
Treatments	Chlorophyll b - First season					Chlorophyll b - Second season				
	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B
b1 (0.0 Fe, B & antioxidant)	0.9	1.2	1.3	1.4	1.2	0.8	1.2	1.4	1.4	1.2
b2 (Fe at 200 ppm)	1.3	1.5	1.6	1.7	1.5	1.4	1.6	1.7	1.9	1.7
b3 (B at 100 ppm)	1.2	1.4	1.5	1.6	1.4	1.3	1.4	1.6	1.7	1.5
b4 (Ascorbic at 100 ppm)	1.3	1.5	1.6	1.7	1.5	1.4	1.5	1.7	1.9	1.6
b5 (Citric at 100 ppm)	1.3	1.5	1.7	1.6	1.5	1.4	1.6	1.7	1.8	1.6
b6 (Salicylic at 100 ppm)	1.2	1.6	1.7	1.8	1.6	1.4	1.5	1.7	1.9	1.6
Mean A	1.2	1.5	1.6	1.6		1.3	1.5	1.6	1.8	
New LSD at 5%	A= 0.2 ; B= 0.3 ; AB= 0.4					A= 0.3 ; B= 0.4 ; AB= 0.6				
Treatments	Total Chlorophyll - First season					Total Chlorophyll - Second season				
	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B	0.0% K (a1)	0.25 % K (a2)	0.5% K (a3)	0.75 % K (a4)	Mean B
b1 (0.0 Fe, B & antioxidant)	4.5	5.4	5.4	5.5	5.1	4.3	5.1	5.6	5.8	5.2
b2 (Fe at 200 ppm)	5.4	5.8	6.0	6.3	5.9	5.8	6.0	6.4	6.8	6.3
b3 (B at 100 ppm)	5.0	5.3	5.7	6.0	5.5	5.3	5.8	6.0	6.3	5.8
b4 (Ascorbic at 100 ppm)	5.3	5.6	5.9	6.4	5.8	5.3	6.1	6.5	6.9	6.2
b5 (Citric at 100 ppm)	5.4	5.8	5.9	6.1	5.8	5.7	6.3	6.7	6.9	6.4
b6 (Salicylic at 100 ppm)	5.3	6.2	6.5	6.5	6.1	5.8	6.3	6.8	7.2	6.5
Mean A	5.2	5.6	6.1	6.1		5.4	5.9	6.3	6.6	
New LSD at 5%	A= 0.4 ; B= 0.6 ; AB= 0.9					A= 0.4 ; B= 0.7 ; AB= 0.9				

Spraying Fe at 200 ppm or any antioxidant (ascorbic acid, citric acid, and salicylic acid) at 100 ppm was capable to enhancing leaf chlorophyll a, b and total chlorophyll contents, in both experimental seasons. Contrary, spraying the 'Medjool' date palm with boron at 100 ppm failed to increase the leaf chlorophylls contents a, b, and total chlorophyll), neither in the first season nor in the second season. However, the palms received salicylic acid at 100 ppm produced the best chlorophyll a contents in both seasons, in compared to those received Fe, B, Citric, and ascorbic.

Regarding the interactions between potassium concentrations and micro-nutrients or antioxidants presented in Table (6), shows that the combined effect of potassium concentrations and micro-nutrients or antioxidants on leaf chlorophylls contents significantly increased with increasing the concentration of potassium from 0.25% to 0.75%. However, the palms received potassium at 0.75% combined with salicylic acid at 100 ppm produced the highest chlorophyll a, b and total chlorophyll in their adult leaves, in both seasons respectively. On the opposite side, untreated palms (control) produced the lowest chlorophylls values, during the two experimental seasons respectively.

3.7. Effect on leaf mineral contents

Data in Table (7) shows the effect of spraying potassium at 0.25%, 0.50% and 0.75% as well as Fe at 200 ppm, B at 100 ppm, ascorbic acid at 100 ppm, citric acid at 100 ppm, and salicylic acid at 100 ppm on N, P, and K percentages of 'Medjool' date palm adult leaves, during 2022 and 2023 seasons. It is clear from this Table that spraying potassium at lowest concentration (0.25%) failed to enhance the leaf N and P contents, neither in the first season nor in the second season. On the other hand spraying the 'Medjool' date palm with potassium at 0.5% and 0.75% was capable to improve N and P contents in adult leaves of 'Medjool' date palm. These findings were true during the two experimental seasons. However, all K treatments were capable to increase leaf K contents in both seasons. However, the palms received potassium at 0.75% present the highest percentage of N, P and K in their adult leaves. Contrary, untreated palms produced the lowest N, P, K %, during 2022 and 2023 seasons.

Data in Table (7) also shows that, during the first season, all treatments (Fe, B, ascorbic acid, citric acid and salicylic acid were failed to varying the adult leaf N%. On the opposite side, during the second season, all Fe and anti-oxidants (ascorbic, citric and salicylic acids) treatments significantly improved adult leaf N%. While, spraying boron at 100 ppm hasn't any significantly an effect on leaf N% in both experimental seasons (2022 and 2023). The seam table shows that spraying any antioxidant (ascorbic, citric or salicylic acid each one at 100 ppm significantly increase the leaf P%. While, spraying Fe at 200 ppm or B at 100 ppm failed to do this. Concerning leaf K%, during the first season all micro-nutrients and antioxidants treatments were capable to increase leaf K%, except spraying the B which failed to do this. While, during the second season spraying Fe at 200 ppm, ascorbic at 100 ppm or salicylic at 100 ppm significant improved leaf K%, contrary non-significant effect was observed whine spraying B at 100 ppm or citric acid at 100 ppm. The obtained data shows that the interaction between treating 'Medjool' date palm with potassium (at different concentrations) and Fe, B, ascorbic, citric and salicylic acid was significant in both experimental seasons (2022 and 2023). However, treated 'Medjool' date palm with 0.75% potassium combined with salicylic acid 100 ppm produced the best leaf N. P and K contents. Contrary, untreated palms (control) present the lowest values.

3.8. Effect on bunch weight (kg) and yield (kg/palm)

It is clear from the obtained data that spraying K at different concentration as well as Fe, B, ascorbic acid, citric acid and salicylic acid and their interactions was very effective in enhancing bunch weight (kg) and yield (kg/palm) of 'Medjool' date palm grown in sandy soil under Al-Minia conditions, during 2022 and 2023 seasons. Table (8) shows that spraying potassium at 0.5% or 0.75% was capable to significantly increase the bunch weight (kg) and yield / palm (kg) of 'Medjool' date palm. On the other hand spraying K at lowest concentration (0.25%) failed to enhance the weight of bunch and yield / palm significantly. These findings were true during the two seasons. Consequently, sprayed 'Medjool' date palm with higher concentration of K (0.75%) presented the highest weight of bunch and yield/palm followed by those received 0.50% K. Contrary the palm received 0.0% K present the lowest values during the two experimental seasons. Data presented in Table (8) shows that, all micronutrients and anti-oxidants treatments were very effective on enhancing bunch weight (kg) and yield (kg/palm). Except,

the case of spraying Fe at 200 ppm, during the first season. Moreover, spraying any one of the three anti-oxidants showed more effective in enhancing bunch weight and yield / palm (kg) rather than spraying the micro-nutrients. The palms sprayed with salicylic acid at 100 ppm presented the highest bunch weight and yield / palm (kg), during 2022 and 2023 seasons. On the opposite side, the palms untreated palms presented the lowest bunch weight and yield / palm, these findings were true during 2022 and 2023 seasons.

Table (7). Effect of spraying potassium, iron, Boron, Ascorbic acid, Citric acid, and salicylic acid on leaf N, P and K percentages of 'Medjool' date palm, during 2022 and 2023 seasons

Treatments	N% - First season					N% - Second season				
	0.0% K (a1)	0.25% K (a2)	0.5% K (a3)	0.75% K (a4)	Mean B	0.0% K (a1)	0.25% K (a2)	0.5% K (a3)	0.75% K (a4)	Mean B
b1 (0.0 Fe, B & antioxidant)	1.3	1.4	1.6	1.5	1.5	1.3	1.4	1.5	1.6	1.4
b2 (Fe at 200 ppm)	1.4	1.5	1.6	1.7	1.6	1.4	1.6	1.6	1.8	1.6
b3 (B at 100 ppm)	1.3	1.5	1.5	1.6	1.5	1.3	1.4	1.4	1.6	1.4
b4 (Ascorbic at 100 ppm)	1.4	1.6	1.6	1.7	1.6	1.5	1.6	1.7	1.7	1.6
b5 (Citric at 100 ppm)	1.5	1.5	1.7	1.7	1.6	1.5	1.5	1.6	1.6	1.6
b6 (Salicylic at 100 ppm)	1.5	1.5	1.7	1.7	1.6	1.6	1.7	1.8	1.8	1.7
Mean A	1.4	1.5	1.6	1.6		1.4	1.5	1.6	1.7	
New LSD at 5%	A= 0.2 ; B= NS ; AB= 0.3					A= 0.2 ; B= 0.2 ; AB= 0.3				
Treatments	**P% - First season**					**P% - Second season**				
	0.0% K (a1)	0.25% K (a2)	0.5% K (a3)	0.75% K (a4)	Mean B	0.0% K (a1)	0.25% K (a2)	0.5% K (a3)	0.75% K (a4)	Mean B
b1 (0.0 Fe, B & antioxidant)	0.15	0.17	0.18	0.20	0.18	0.16	0.19	0.22	0.22	0.20
b2 (Fe at 200 ppm)	0.18	0.19	0.20	0.22	0.20	0.19	0.22	0.23	0.25	0.22
b3 (B at 100 ppm)	0.17	0.19	0.19	0.20	0.19	0.17	0.20	0.22	0.24	0.21
b4 (Ascorbic at 100 ppm)	0.18	0.21	0.22	0.23	0.21	0.19	0.22	0.23	0.25	0.23
b5 (Citric at 100 ppm)	0.18	0.21	0.22	0.22	0.21	0.20	0.23	0.25	0.24	0.23
b6 (Salicylic at 100 ppm)	0.20	0.21	0.23	0.24	0.22	0.23	0.24	0.27	0.28	0.26
Mean A	0.18	0.20	0.21	0.22		0.19	0.21	0.23	0.25	
New LSD at 5%	**A= 0.03 ; B= 0.03 ; AB= 0.4**					**A= 0.03 ; B= 0.03 ; AB= 0.04**				
Treatments	**K% - First season**					**K% - Second season**				
	0.0% K (a1)	0.25% K (a2)	0.5% K (a3)	0.75% K (a4)	Mean B	0.0% K (a1)	0.25% K (a2)	0.5% K (a3)	0.75% K (a4)	Mean B
b1 (0.0 Fe, B & antioxidant)	1.2	1.3	1.4	1.5	1.3	1.3	1.5	1.6	1.6	1.5
b2 (Fe at 200 ppm)	1.4	1.5	1.6	1.7	1.6	1.5	1.6	1.7	1.8	1.7
b3 (B at 100 ppm)	1.3	1.5	1.5	1.6	1.5	1.3	1.5	1.6	1.7	1.5
b4 (Ascorbic at 100 ppm)	1.4	1.6	1.5	1.8	1.6	1.5	1.5	1.7	1.9	1.7
b5 (Citric at 100 ppm)	1.3	1.4	1.4	1.6	1.4	1.4	1.5	1.6	1.6	1.5
b6 (Salicylic at 100 ppm)	1.4	1.5	1.6	1.7	1.6	1.6	1.7	1.9	1.9	1.8
Mean A	1.3	1.5	1.5	1.7		1.4	1.6	1.7	1.8	
New LSD at 5%	A= 0.2 ; B= 0.3 ; AB= 0.4					A= 0.2 ; B= 0.3 ; AB= 0.4				

The obtained data showed that the interaction between spraying 'Medjool' date palm with K at different concentrations as well as micro-nutrients (Fe & B) or anti-oxidants (ascorbic, citric and salicylic acids) had a significant effect on bunch weight and yield / palm (kg). However, spraying the 'Medjool' palms with 0.75% K and 100 ppm salicylic acid gave the maximum bunch weight and yield (kg), followed by those sprayed with K at 0.5% combined with salicylic acid at 100 ppm. Contrary, the minimum bunch weights and yield / palm were recorded by untreated palms (control). These data were true during the two experimental seasons respectively.

Table (8). Effect of spraying potassium, iron, Boron, Ascorbic acid, Citric acid, and salicylic acid on bunch weight (kg) of 'Medjool' date palm, during 2022 and 2023 seasons

Treatments	Bunch weight(kg) - First season					Bunch weight (kg) - Second season				
	0.0 % K (a1)	**0.25 % K (a2)**	**0.5 % K (a3)**	**0.75% K (a4)**	**Mean B**	**0.0% K (a1)**	**0.25 % K (a2)**	**0.5 % K (a3)**	**0.75 % K (a4)**	**Mean B**
b1 (0.0 ppm)	5.7	6.0	6.1	6.2	6.0	5.2	6.0	6.2	6.2	5.9
b2 (Fe at 200 ppm)	6.0	6.3	6.4	6.4	6.3	6.2	6.3	6.5	6.6	6.4
b3 (B at 100 ppm)	6.3	6.6	6.9	7.0	6.7	6.4	6.7	6.9	7.2	6.8
b4 (Ascorbic at 100 ppm)	6.7	7.0	7.2	7.2	7.0	6.8	7.0	7.1	7.2	7.0
b5 (Citric at 100 ppm)	6.8	6.9	7.1	7.2	7.0	6.8	6.9	7.1	7.3	7.0
b6 (Salicylic at 100 ppm)	7.0	7.2	7.3	7.4	7.2	7.2	7.2	7.5	7.6	7.4
Mean A	6.4	6.7	6.8	6.9		6.4	6.7	6.9	7.0	
New LSD at 5%	A= 0.4 ; B= 0.5 ; AB= 0.7					A= 0.4 ; B= 0.4 ; AB= 6				
Treatments	Yield (kg/palm) - First season					Yield (kg/palm) - Second season				
	0.0% K (a1)	**0.25 % K (a2)**	**0.5% K (a3)**	**0.75 % K (a4)**	**Mean B**	**0.0% K (a1)**	**0.25 % K (a2)**	**0.5 % K (a3)**	**0.75 % K (a4)**	**Mean B**
b1 (0.0 ppm)	57	60	61	62	60	52	60	62	62	59
b2 (Fe at 200 ppm)	60	63	64	64	63	62	63	65	66	64
b3 (B at 100 ppm)	63	66	69	70	67	64	67	69	72	68
b4 (Ascorbic at 100 ppm)	67	70	72	73	70	68	70	71	72	70
b5 (Citric at 100 ppm)	68	69	71	72	70	68	69	71	73	70
b6 (Salicylic at 100 ppm)	70	72	73	74	72	72	72	75	76	74
Mean A	64	67	68	69		64	67	69	70	
New LSD at 5%	A= 4 ; B= 3 ; AB= 4					A= 4 ; B= 4 ; AB= 6				

4. Discussion

The positive role of potassium in improving leaves chlorophyll contents which observed in the present study are in harmony with the results obtained by: **Xinxiang *et al.*, (2020) on** 'Medjool' date palm; **Al-Hajaj *et al.* (2020)** on 'Medjool' offshoots and **Khodair *et al.*, (2021)** on Hayany date palm. It is well known that K is the most abundant inorganic cation, and it is important for ensuring optimal plant growth (**White and Karley, 2010; Xinxiang *et al.*, 2020 and Ibrahim *et al.*, 2019)**. It is well known that K is one of the essential macro-nutrients for plant growth and production. It is referred as the quality element for fruit trees growth and production (**Mengel and Kirkby, 1987 and Kumar *et al.*, 2006)**. The vital role of K comes from its role in promoting synthesis of plant photo-synthesis and transport the metabolic products of other plant organs (**Mengel & Kirkby, 1987** and **Kumar *et al.*, 2006**). With shortage of K many metabolic processes are affected, such as the rate of photosynthesis, the rate of translocation and activity of several enzymes (**Marschner, 1995** and **Kumar *et al.*, 2006**). K

is very essential for the production of high-energy molecules (ATP), which are produced both in photosynthesis and transpiration processes (**Willingford, 1980**). K maintains the balance of electric charges in chloroplasts, which is required for ATP formation (**Kumar *et al.*, 2006).** K is activator of more than 60 enzymes, and plays important roles in activation of synthetases, oxidoreductases, dehydrogenases, transferases and kinases. These enzymes are necessary for essential plant processes such energy utilization, starch synthesis, N metabolism and respiration (**Wallingford, 1980** and **Mengel & Krikby, 1987**).

Spraying micronutrients such as Fe and B are vital for proper plant development. Fe is crucial in chlorophyll synthesis and electron transport in photosynthesis, while B is essential for cell wall formation (**Mengel, 2001**). Foliar application of these micronutrients can significantly improve the growth, leaf chlorophyll, and leaf mineral contents of date palms. Spraying F and B on date palms improved vegetative growth and increasing leaves chlorophyll contents (**Mahmoud *et al.*, 2020)**. These improvements are attributed to the enhancement of photosynthetic efficiency and reproductive processes supported by these two micronutrients (**Mahmoud *et al.*, 2018)**.

Salicylic acid has been established as an important regulator of photosynthesis, water relations and metabolic aspects of plants, depending on its analogues, concentrations, mode of application and plant type (**Hayat *et al.*, 2005**). Salicylic acid is known to affect leaf and chloroplast structure (**Uzunova & Popova, 2000 and Hayat & Ahmed, 2007**), chlorophyll and carotenoid contents (**Fariduddin *et al.*, 2003 and Yazdanpanah *et al.*, 2011)**, and the activity of photosynthesis enzymes such as Rubisco (ribulose-1,5-bisphosphate carboxylase/oxygenase) and carbonic anhydrase (**Ghai *et al.*, 2002; Sarangthem & Singh 2003**; **Hayat *et al.*, 2013 and Yuoesef *et al.*, 2017).** The results of these previous studies, which were mentioned in previous lines, may be explained the positive effect of salicylic acid on leaf pigments which was found in present study. Salicylic acid (SA) play a vital role in plant physiological processes, including the modulating of hormonal balance, improving nutrient uptake, and enhancing photosynthesis pigments. Its influence on 'Medjool' date palms has been increasingly studied in recent years, particularly under environmental stress (**Mohammed & Hassan 2022)**. Improving vegetative growth, Chlorophylls contents and mineral nutrients was accompanied with increased the concentration of salicylic acid may be explained by enhanced hormones (gibberellins and cytokinins). It is well known that salicylic acid increase the ability of plant absorption of mineral nutrients, such as nitrogen and magnesium, these elements are present in a form acceptable to plants. In addition, salicylic acid known to effect leaf and chloroplast structure (**Uzunova and Popova, 2000**), stomatal closure (**Melotto *et al.*, 2006**), chlorophylls and carotenoid contents (**Fariduddin *et al.*, 2003**).

5. Conclusion

It is strongly recommended by spray 'Medjool' date palm grown in sandy soil under Al-Minia Governorate conditions, and resembling conditions, with potassium at 0.75% combined with salicylic acid three times yearly, in order to improve the nutritional status, yield and physical properties of fruits, or combined with boron at 100 ppm for improving chemical properties of 'Medjool' fruits.

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