American-Eurasian J. Agric. & Environ. Sci., 10 (5): 728-736, 2011
ISSN 1818-6769

Soil Fertilization Study on Zaghloul Date Palm Grown in Calcareous Soil and Irrigated with Drainage Water

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Abstract: The present study was conducted during 2008/2009 and 2009/2010 seasons on Zaghloul date palm grown in calcareous loamy sand soil and irrigated with drainage water. Palms were fertilized with 1000g/palm of actual nitrogen as ammonium sulphate (N1), ammonium nitrate (N2) or urea (N3) as well as two levels (500 and 1000g/palm) of potassium (K) and elemental sulfur (S) in order to study their effect on the nutritional status, yield and fruit quality. Data showed that the N1 increased yield compared to N2 and N3. Also, the N1 gave better results of fruit weight, length and color than the N3 one. In general, fruit chemical characteristic were improved by the N1 and N2 compared to N3. Fruit TSS, sugars, anthocyanin and dry matter content were increased while, fruit acidity and tannins were decreased by the N1. Furthermore, the K2 and S2 rates greatly enhanced the fruit physico-chemical characters. Leaf N, K, Ca, Fe and Zn content increased by N1, K2 and S2 applications. Fruit N, P, K, Fe and Zn content increased by N1 whereas, fruit Cd, Pb and NO_3 was the highest with N2 form. The high level of both K and S increased fruit N, Fe, Mn, Cd, Pb and NO_3.

Key words: Fertilization · Date palm · Nitrogen form · Potassium · Sulphur · Productively

INTRODUCTION

Date palm (*Phoenix dactylifera*) is the most common fruit trees grown under the hot, semiarid and arid- regions. In Egypt many farmers rely on date palm cultivation and according to FAO [1], Egypt is considered the first country of the top ten date producers (1130000 tones). Zaghloul date is the most economically important soft cultivar grown in Egypt which is usually harvested and consumed at the Khalal (Bisr) stage. It is mostly cultivated under little rain and high evapotranspiration conditions. Palms of the present study are growing in loamy calcareous soil and irrigated with drainage water. These conditions have a great influence on nutrient uptake validity. Tisdale and Nelson [2] stated that loamy and sandy loamy soils might with time become deficient in N, P, K, Mg and B". Therefore the adaptation of a proper fertilization program, in terms of adequate rates, appropriate sources, efficient methods of application and application timing are important strategies for better yield and fruit quality [3].

Nitrogen and potassium are the two most needed nutrients by palms for optimum growth, yield and fruit quality [4]. Nitrogen is one of the major nutrients that have many important roles in plant development and physiological process. Nitrogen levels and forms, cultivars and soil physical and chemical properties are being as factors related to its use by plants [5-7]. The form of the applied nitrogen can have a significant effect on plant growth and productivity [8, 9, 10]. Ammonium (NH_4^+) and nitrate (NO_3^-) as well as urea are the major forms of nitrogen applied and one source or another may be preferred according to plant species [11]. The response of a large number of fruit trees to the application of different nitrogen forms has been reported [12, 13, 14]. Potassium is also an important nutrient for date palm growth and productivity [15-18]. Potassium is necessary for basic physiological functions such as formation of sugars and starch, synthesis of proteins, cell division, growth and fruit formation and it enhanced fruit size, flavor and color [19, 20,]. Potassium has been shown to promote plant disease reduction and potassium stress can increase the degree of crop damage by bacterial and fungal diseases [21, 22]. Furthermore, in the last few years, there has been an increase concerns about using sulfur application to reduce alkalinity in calcareous soil [23] and it has become one of the most limiting nutrients in agricultural production [24].

In the present market economy, product quality has become increasingly important. Therefore, the present study was carried out in order to investigate the efficiency of using different nitrogen forms as well as potassium and

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sulfur fertilization rate on yield, leaf and fruit mineral content and fruit marketing and edible quality of Zaghloul dates grown in calcareous soil and irrigated with derange water.

MATERIALS AND METHODS

Plant Materials and Experimental Design: The present study was conducted during 2008/2009 and 2009/2010 seasons on 22 years old Zaghloul date palms grown in calcareous loamy sand soil at a private orchard located in Mariut region, near Alexandria, Egypt. Analysis of the experimental orchard soil and irrigation water is presented in Table 1. Palms were planted at 10 meters apart and irrigated with drainage water. In December of 2008 and 2009 years, cattle manure (~1.5% N) and calcium superphosphate (15.5% P_2O_5) was applied at the rate of 25-30 and 1.5 kg/palm, respectively. All the routine agro-technical operations were carried out according to the traditional schedule for date palm plantation. The leaf/bunch ratio was adjusted, in both years, by the end of the blooming season to meet the value of 10:1 for all experimental palms. Seven soil application treatments were arranged in a completely randomized design with three replicates (1 replicate = 1 palms) per treatment (i.e. 1×3×7 = 21 palm). The treatments were as follow: The unfertilized trees [(N0K0S0) control], 1,000g actual nitrogen from either ammonium sulphate [(21.5% N) N1], ammonium nitrate [(33.5% N) N2] or urea [(46 % N) N3], also two potassium (K_2O) levels (K1= 500 and K2 = 1000 g K_2O/palm) from potassium sulphate (48% K_2O) and elemental sulfur (S = 1000 gm/palm) were applied in order to study their influence on leaf mineral content, palm yield and fruit quality.

In both experimental years; nitrogen fertilizer was divided into four equal doses added in March, April, May and July. Potassium fertilizer was divided into three equal doses added in March, May and August. Elemental sulfur was added as a single dose in December with the manure fertilizer. Twelve fertilization treatments representing all possible combinations of the three forms of nitrogen fertilizer, two levels of potassium and two levels of elemental sulfur fertilizer were used (3×2×2=12 treatments). Each treatment was added as a broadcast on the soil surface (~ 1.5 meter apart from the palm trunk) and palms were irrigated immediately after adding the fertilizer. The experiment was conducted as a split–split plot in randomized complete design with three replicates (1 replicate = one palm) for each treatment. The soil moisture content was kept at an appropriate field capacity for sandy soil (50–75%) as described by Klocke and Fischbach [25] and Miles and Broner [26].

Yield Determination: In both seasons, palms were harvested in mid-October when fruits reached the Khalal stage (full mature, crunchy and red in color) and the average fruit yield/date and bunch weight were recorded in kilograms. Additionally, fruit samples were randomly taken from four different bunches in order to determine fruit physical and chemical quality characteristics.

Fruit Physical Characters: In a fruit sample of 30 mature dates for each replicate; fruit weight (g), length (cm), width (cm) and shape (length/width) were determined. Also fruit color was measured by using a degree of color intensity as follows: (1) = 100% green, (2) = 25% red, (3) = 50% red, (4) = 75% red and (5) = 100% red.

Table 1: Analysis of the experimental orchard soil and irrigation water

	Orchard soil depth (cm)		
Properties	0-50	50-100	Irrigation water
EC (dS/m)	3.3	4.1	3.8
pH	8.2	7.9	7.2
HCO^-_3 (meq/L)	10.0	12	10.8
Ca^{++} (meq/L)	21.3	24.7	14.0
Mg^{++} (meq/L)	8.6	10.5	7.6
K^+ (meq/L)	2.4	1.3	1.1
Na^+ (meq/L)	12.6	18.2	17.5
Fe (ppm)	20.9	16.3	0.75
Mn (ppm)	32.8	15.5	0.21
Zn (ppm)	11.6	6.7	0.62
Cu (ppm)	14.8	11.8	0.6
Organic matter (%)	1.3	0.4	-
$CaCO_3$ (%)	32.1	35.4	-
Cl^-_2 (meq/L)	21	17.3	17.6

Fruit Chemical Characters: In a fruit sample of 40 mature dates for each replicate, fruit chemical characteristics were determined as follows: Fruits were peeled at evenly spaced location on the equatorial region of the fruits and cut into small pieces with a clean knife. Anthocyanin content in 1 g fruit peel tissue was determined according to Fuleki and Francis [27]. Five grams were taken from the whole fresh fruit (peel + pulp) to extract the reducing and non-reducing sugars by water at 85°C and the 3-5, dinitro salicylic acid according to the method of Barbin [28]. The non-reducing sugars percent was determined by hydrolysis with hydrochloric acid into reducing sugars. The percentage of reducing and total sugars power was determined according to AOAC [29]. Non-reducing sugars were calculated by the difference between total sugars and reducing sugars. Another 5 g was taken to determine the soluble tannins content (g/100 g fresh weight) as illustrated by Abou Sayed *et al.* [30]. In the fruit juice, the percentage of total soluble solids (TSS) was determined using hand refractometer and acidity as malic acid was determined according to AOAC [29].

Fruit Dry Matter and Nutritional Status: A sample of 40 mature fruits was taken to determine fruit dry matter and mineral content. Fruits were cut into pieces with a clean knife, then an amount of the fresh fruit was weighed (fresh weight) and dried to a constant weight (g) in air drying oven at 70°C, then weighed (dry weight) and fruit dry matter content was calculated as follows:

$$\text{Fruit dry matter (\%)} = [\text{average dry weight}/\text{average fresh weight}] \times 100$$

A leaf sample of three consecutive leaves located just below the fruiting zone (about two years old) was taken at random from each replicate in mid-October of both years. Leaf samples were washed with tap water, rinsed twice in distilled water and dried in air drying oven at 70 °C. Dried leaves and fruits were grounded and digested with H_2O_2 and H_2SO_4 according to Evanhuis and De Waard [31]. Suitable aliquots were taken for the determination of the mineral content. Nitrogen was determined by the Kjeldahl method [29]. Phosphorus was determined by ascorbic acid method according to Murphy and Riley [32]. Potassium and sodium were determined by flame photometer. Ca, Mg, Fe, Zn, Mn, Cu, Pb and Cd contents were measured using an atomic absorption spectrophotometer (Model 305B). The concentrations of N, P, K, Ca, Na and Mg were expressed as percentages, while Fe, Mn, Zn, Cu, Pb and Cd as parts per million (ppm) on dry weight basis. Fruit nitrate content was determined spectrophotometrically at 540 nm, then calculated as mg/kg dry weight as described by Singh [33].

Statistical Analysis: The obtained results were evaluated using one-way analysis of variance (ANOVA). Treatments means were separated and compared using LSD test at 0.05 significance level. Calculations were carried out using the software package Statistica™ for Windows version 6.1 [34], Oklahoma, USA.

RESULTS

Yield: Regarding the effect of nitrogen forms, the results obtained in Table (2), showed that, yield components were higher by the application of the ammonium sulphate (N1) and ammonium nitrate (N_2) forms than applying urea form (N3). Additionally, nitrogen as (N1) resulted in higher yield than (N2). Furthermore, the high level of both potassium and sulfur fertilization significantly increased palm yield in both seasons (Table 2).

Fruit Physical Characters: Data of both seasons presented in Table 2 indicated that fruit weight was higher by applying nitrogen in the ammonium sulphate form (N1) than urea. However, fruit weight was significantly higher in the first season only by applying nitrogen as ammonium nitrate (N2) than ammonium sulphate (N1) and urea (N3). Furthermore, higher fruit length was recorded in both seasons by the application of nitrogen as the sulphate form (N1) than N2 and N3. Fruit width was higher in the second season only by applying nitrogen as sulphate (N1) and nitrate (N2) than as urea (N3). However, no significant influence on fruit shape was obtained between the different nitrogen forms. Application of ammonium sulphate (N1) significantly increased fruit color compared to urea (N3) in both seasons. In the meanwhile, no significant difference in fruit color was obtained between N1 and N2. In addition, the data of both seasons presented in Table 2 showed that K2 and S2 fertilization rate significantly increased fruit weight, length, width and color, while, fruit shape was not affected.

Fruit Chemical Characters: Data presented in Table 3 indicated that fruit acidity decreased by the application of nitrogen as sulphate (N1) and ammonium (N2) forms compared to urea (N3) in the first season. A significant increase in fruit TSS content was obtained by applying

Table 2: Effect of nitrogen forms, potassium and sulfur on yield and fruit physical characters of Zaghloul date in 2008/2009 and 2009/2010 seasons.

	Yield						
Treatments	Kg/palm	Kg/bunch	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit shape	Fruit red color
				2008/2009			
N0K0S0	175^{d}	16^{d}	23.4^{e}	5.5^{d}	2.1^{c}	2.62^{a}	4.3^{c}
N1	209^{a}	20^{ab}	25.2^{c}	6.3^{a}	2.6^{a}	2.42^{a}	4.9^{a}
N2	195^{b}	20^{ab}	26.7^{b}	5.9^{bc}	2.7^{a}	2.19^{a}	4.8^{ab}
N3	188^{c}	18^{c}	24.1^{d}	6.0^{b}	2.6^{a}	2.31^{a}	4.6^{b}
K1	195^{b}	19^{bc}	24.2^{d}	5.8^{c}	2.4^{b}	2.42^{a}	4.6^{b}
K2	212^{a}	21^{a}	27.3^{b}	6.1^{ab}	2.7^{a}	2.26^{a}	4.9^{a}
S	198^{b}	18^{c}	24.1^{d}	5.9^{bc}	2.4^{b}	2.46^{a}	4.6^{b}
				2009/2010			
N0K0S0	163^{e}	15^{d}	24.8^{d}	5.6^{d}	2.3^{c}	2.43^{a}	4.1^{e}
N1	192^{b}	19^{ab}	26.3^{b}	6.8^{ab}	2.9^{a}	2.34^{a}	4.7^{bc}
N2	186^{c}	19^{ab}	26.1^{b}	6.3^{c}	2.9^{a}	2.17^{a}	4.8^{ab}
N3	184^{d}	17^{c}	25.4^{c}	6.2^{c}	2.6^{b}	2.38^{a}	4.4^{d}
K1	189^{bc}	18^{bc}	25.5^{c}	6.4^{bc}	2.6^{b}	2.46^{a}	4.7^{bc}
K2	204^{a}	20^{a}	26.8^{a}	6.9^{a}	2.9^{a}	2.38^{a}	4.9^{a}
S	179^{e}	18^{bc}	25.7^{c}	6.2^{c}	2.6^{b}	2.38^{a}	4.6^{b}

Values within a column with the same letter are not significantly different ($p<0.05$).

Table 3: Effect of nitrogen forms, potassium and sulfur on fruit chemical characters of Zaghloul date in 2008/2009 and 2009/2010 seasons.

Treatments	Acidity(%)	TSS(%)	Non- reducing	Reducing Sugars (%)	Total	Tannins(%)	Anthocyanin (mg/100 g)	Dry matter (%)
				2008/2009				
N0K0S0	0.30^{d}	23.8^{e}	4.0^{e}	17.2^{d}	21.3^{d}	0.30^{c}	20.1^{d}	24.2^{e}
N1	0.33^{cd}	28.4^{a}	6.2^{ab}	21.2^{a}	27.4^{a}	0.46^{b}	29.8^{a}	28.7^{c}
N2	0.32^{d}	27.3^{ab}	6.4^{a}	20.6^{ab}	27.0^{a}	0.47^{b}	29.7^{a}	25.9^{d}
N3	0.44^{a}	25.8^{cd}	4.5^{d}	18.7^{c}	23.2^{c}	0.62^{a}	23.4^{b}	26.7^{d}
K1	0.35^{c}	27.0^{bc}	5.9^{b}	20.6^{ab}	26.5^{ab}	0.35^{c}	23.1^{b}	31.0^{b}
K2	0.38^{b}	27.3^{ab}	6.5^{a}	21.2^{a}	27.7^{a}	0.20^{d}	24.4^{b}	32.4^{a}
S	0.31^{d}	25.5^{d}	5.4^{c}	19.9^{b}	25.3^{c}	0.19^{d}	22.2^{c}	27.8^{c}
				2009/2010				
N0K0S0	0.26^{c}	24.5^{c}	4.0^{d}	19.1^{f}	23.1^{c}	0.35^{c}	22.4^{c}	30.3^{c}
N1	0.33^{b}	29.9^{a}	5.8^{ab}	23.9^{a}	29.7^{a}	0.42^{b}	26.9^{a}	35.8^{a}
N2	0.34^{ab}	29.7^{a}	5.6^{b}	22.8^{bc}	28.4^{a}	0.44^{b}	26.3^{a}	32.3^{b}
N3	0.32^{b}	26.4^{b}	4.7^{c}	21.0^{d}	25.7^{b}	0.55^{a}	23.7^{b}	32.4^{b}
K1	0.34^{ab}	26.7^{b}	5.5^{b}	20.7^{e}	26.2^{b}	0.33^{c}	23.5^{b}	32.5^{b}
K2	0.37^{a}	29.8^{a}	6.3^{a}	23.4^{ab}	29.7^{a}	0.22^{d}	26.3^{a}	34.7^{a}
S	0.25^{c}	26.1^{b}	4.9^{c}	21.3^{de}	26.2^{b}	0.32^{c}	24.4^{b}	32.8b

Values within a column with the same letter are not significantly different ($p<0.05$).

Table 4: Effect nitrogen forms, potassium and sulfur on leaf and fruit macronutrients content (%) of Zaghloul date in 2008/2009 and 2009/2010 seasons.

	N		P		K		Ca		Mg		Na	
Treatments	leaf	Fruit	leaf	fruit	leaf	Fruit	leaf	Fruit	Leaf	Fruit	leaf	Fruit
						2008/2009						
Control	2.13^{d}	1.09^{f}	0.23^{c}	0.15^{d}	1.60^{d}	0.70^{d}	1.11^{d}	0.48^{c}	0.30^{d}	0.21^{c}	0.30^{a}	0.15^{a}
N1	2.40^{a}	1.58^{a}	0.34^{a}	0.19^{b}	1.90^{ab}	0.91^{b}	1.36^{a}	0.66^{b}	0.42^{c}	0.30^{b}	0.32^{a}	0.14^{a}
N2	2.35^{ab}	1.32^{cd}	0.31^{a}	0.20^{ab}	1.80^{bc}	0.92^{b}	1.32^{ab}	0.62^{b}	0.55^{a}	0.44^{a}	0.30^{a}	0.11^{a}
N3	2.24^{c}	1.37^{d}	0.23^{c}	0.19^{ab}	1.75^{c}	0.82^{c}	1.25^{b}	0.60^{b}	0.41^{c}	0.33^{b}	0.32^{a}	0.15^{a}
K1	2.20^{cd}	1.30^{d}	0.23^{c}	0.17^{c}	1.87^{ab}	0.87^{bc}	1.31^{ab}	0.47^{c}	0.52^{ab}	0.32^{b}	0.33^{a}	0.17^{a}
K2	2.41^{a}	1.47^{d}	0.31^{a}	0.15^{d}	1.94^{a}	1.12^{a}	1.40^{a}	0.60^{b}	0.47^{bc}	0.43^{a}	0.35^{a}	0.16^{a}
S	2.25^{bc}	1.19^{e}	0.27^{b}	0.19^{b}	1.72^{c}	0.87^{bc}	1.41^{a}	0.77^{b}	0.44^{c}	0.33^{b}	0.22^{b}	0.15^{a}
						2009/2010						
Control	2.18^{d}	1.11^{e}	0.22^{d}	0.17^{d}	1.64^{d}	0.72^{e}	1.07^{d}	0.55^{e}	0.22^{d}	0.21^{c}	0.29^{a}	0.17^{a}
N1	2.42^{a}	1.61^{a}	0.33^{a}	0.21^{b}	1.86^{b}	0.94^{bc}	1.44^{a}	0.60^{d}	0.37^{b}	0.30^{b}	0.31^{a}	0.18^{a}
N2	2.37^{b}	1.35^{c}	0.29^{ab}	0.25^{a}	1.75^{c}	0.90^{bc}	1.30^{bc}	0.72^{b}	0.52^{a}	0.43^{a}	0.28^{a}	0.21^{a}
N3	2.28^{c}	1.29^{cd}	0.27^{bc}	0.20^{bc}	1.73^{c}	0.80^{d}	1.26^{bc}	0.61^{c}	0.35^{b}	0.32^{b}	0.31^{a}	0.20^{a}
K1	2.25^{c}	1.32^{c}	0.24^{cd}	0.18^{cd}	1.86^{b}	0.99^{b}	1.32^{bc}	0.67^{c}	0.44^{a}	0.32^{b}	0.30^{a}	0.19^{a}
K2	2.44^{a}	1.49^{b}	0.30^{ab}	0.20^{bc}	1.98^{a}	1.21^{a}	1.40^{ab}	0.70^{bc}	0.40^{b}	0.43^{a}	0.26^{a}	0.20^{a}
S	2.28^{c}	1.22^{d}	0.28^{bc}	0.20^{bc}	1.82^{b}	0.87^{cd}	1.36^{c}	0.77^{a}	0.41^{b}	0.31^{b}	0.24^{b}	0.20^{a}

Values within a column with the same letter are not significantly different ($p<0.05$).

Table 5: Effect nitrogen forms, potassium and sulfur on leaf and fruit micronutrients, fruit heavy metals and nitrate contents (ppm) of Zaghloul date in 2008/2009 and 2009/2010 seasons.

	Fe		Zn		Mn		Cu		Cd	Pb	NO_3
Treatments	leaf	Fruit	leaf	fruit	leaf	Fruit	leaf	Fruit	Fruit	Fruit	Fruit
					2008/2009						
20K0S0	107^{c}	45^{bc}	27^{c}	28^{cd}	35^{c}	31^{c}	30^{a}	17^{a}	0.009^{d}	0.65^{c}	34^{d}
N1	130^{a}	50^{b}	42^{a}	34^{bc}	37^{bc}	31^{bc}	29^{a}	18^{a}	0.019^{bc}	0.94^{b}	50^{bc}
N2	122^{bc}	42^{c}	34^{b}	24^{d}	46^{a}	36^{b}	30^{a}	21^{a}	0.030^{a}	1.22^{a}	65^{a}
N3	119^{bc}	43^{c}	31^{b}	23^{d}	34^{c}	30^{c}	37^{a}	17^{a}	0.015^{bc}	1.19^{a}	54^{b}
K1	121^{c}	46^{bc}	34^{b}	25^{d}	36^{c}	35^{b}	36^{a}	20^{a}	0.011^{cd}	0.86^{b}	42^{cd}
K2	130^{a}	70^{a}	32^{b}	30^{cd}	42^{ab}	40^{a}	32^{a}	21^{a}	0.021^{ab}	0.97^{b}	47^{bc}
S	132^{a}	75^{a}	40^{b}	38^{a}	44^{a}	36^{b}	24^{b}	19^{a}	0.023^{ab}	0.92^{b}	24^{e}
					2008/2010						
N0K0S0	103^{f}	44^{cd}	24^{d}	22^{b}	30^{d}	30^{b}	39^{a}	20^{a}	0.007^{c}	0.82^{c}	41^{c}
N1	134^{a}	48^{c}	40^{b}	36^{a}	34^{cd}	30^{b}	35^{ab}	19^{a}	0.019^{bc}	1.02^{b}	60^{b}
N2	120^{de}	40^{b}	30^{c}	25^{b}	50^{a}	36^{b}	34^{ab}	20^{a}	0.030^{a}	1.29^{a}	73^{a}
N3	126^{bc}	39^{b}	31^{c}	25^{b}	31^{d}	28^{b}	34^{ab}	20^{a}	0.017^{bc}	1.22^{a}	56^{b}
K1	122^{cd}	43^{cd}	32^{c}	32^{a}	32^{d}	33^{ab}	35^{ab}	19^{a}	0.017^{bc}	0.90^{bc}	51^{bc}
K2	115^{e}	63^{b}	44^{a}	23^{b}	40^{bc}	38^{a}	39^{a}	18^{a}	0.022^{ab}	1.22^{a}	54^{b}
S	128^{b}	76^{a}	46^{a}	33^{a}	43^{ab}	37^{a}	31^{b}	21^{a}	0.019^{bc}	1.24^{a}	30^{d}

Values within a column with the same letter are not significantly different ($p<0.05$).

ammonium sulphate compared to ammonium nitrate in the second season and urea in both seasons. Furthermore, data of the second season showed that fruit non-reducing sugars content was higher by N1 and N2 than N3 application. Also, N1 and N2 increased fruit reducing and total sugars content comparing with N3 in both seasons. The application of ammonium sulphate (N1) lowered fruit tannins compared to urea application (N3) in both seasons. However, the lowest value of tannins content was obtained in the second season by applying ammonium nitrate (N2). Anthocyanin content was higher by applying N1 and N2 than N3 in both seasons. Applying ammonium sulphate resulted in higher fruit dry matter content as compared with ammonium nitrate and urea.

In addition, data presented in Table 3 showed a significant increase in fruit acidity by K2 rate, whereas, acidity was not influenced by S2 level. Moreover, fruit TSS, anthocyanin, dry matter, reducing and total sugars content were increased significantly by K2 and S2 application rate. Fruit non reducing sugars content increased by K2 fertilization, whereas, it was not affected by S2 application. An obvious decrease in fruit tannins was observed by K2 fertilization in both seasons, while S2 lowered fruit tannins content in the first season only.

Leaf Mineral Content: Regarding the influence of nitrogen forms on leaf mineral content, data presented in Tables 4 and 5 showed that leaf nitrogen was increased by the application of N1 and N2 compared to N3. Ammonium sulphate (N1) resulted in higher leaf P, K, Ca, Fe and Zn content than urea (N3). However, ammonium nitrate (N2) gave the highest leaf Mg and Mn content in comparison with N1 and N3. Sodium concentration in the leaves was not affected by any N form. Furthermore, the data presented in Tables 4 and 5 showed that leaf N, P, K, Fe and Mn content increased significantly by K2 and S2. However, Ca and Mg content were decreased by K2 application, while Ca was not affected by applying S2. In the same time, leaf Na and Cu content decreased by S2 application and was not affected by K2.

Fruit Mineral and Nitrate Content: The obtained results in Tables 4 and 5 showed that nitrogen added as ammonium sulphate (N1) increased fruit N, Fe and Zn content in comparison with ammonium nitrate (N2) and urea (N3). Fruit P and Ca content was higher by applying N2 than N3 in the second season. In addition, fruit potassium content was increased significantly by the application of N1 and N2 as compared to N3. On the other hand, fruit Mg, Mn, Cd and NO_3 content was lower by the N1 and N3 forms than N2. Fruit Pb content decreased by the application of the sulphate form (N1) in comparison with N2 and N3. However, nitrogen fertilizer form had no influence on fruit Na and Cu content. With regard to potassium fertilization, data presented in Tables 4 and 5 indicated that fruit N, K, Fe, Mn, Cd, Pb and NO_3 content was increased while, Ca and Mg content decreased by the application of K2 fertilizer. On the other hand, fruit P, Na, Zn and Cu content was not affected by K2 fertilization. In addition, the application of elemental sulfur (S2) significantly increased fruit N, Fe, Zn, Mn, Cd and Pb while, decreased Cu and NO_3 contents. On the contrary, fruit P, K, Ca, Mg and Na content was not influenced by S2 application.

DISCUSSION

Similar increase in the yield of date palms grown under Egyptian environment by fertilization is previously recorded by El-Hammady *et al.* [15], Kassem *et al.* [16], Hussein and Hussein [35] and Marzouk and Kassem [36]. Palms fertilization has been found to increase shoot and leaf growth [35, 37].which might have direct influence in improving palm productivity and fruit quality. Applying nitrogen as a sulphate form indicated the highest yield, fruit weight and fruit dry matter content. Guelser [38] stated that ammonium sulphate (NH_4) SO_4 as N-form decreases soil pH, which might favor elements availability and uptake by plants in slightly alkaline soils. Also, ammonium assimilation into plant metabolites requires less energy than nitrate assimilation, as it does not need to be reduced. Plants may save energy by taking up reduced nitrogen and energy saved may be used for increase production of secondary metabolites [39]. Additionally, the application of nitrogen as the sulphate and nitrate forms resulted in higher fruit quality characteristics than application of urea. This may be due to that urea is not suitable for fertilization under the conditions of the present study. Nitrogen validity and uptake efficiency depends on the applied form [10]. Urea-based fertilizers are susceptible to volatilization losses of nitrogen especially under the conditions of warm climate, light texture soil with pH levels greater than 7[40], which are similar to that of the Zaghloul palms of the present investigation.

Recently, the possible human health effect due to high nitrate content in vegetables and fruits is concerned. About 5-10% of the ingested nitrate is converted into the more toxic nitrite by salivary or gastrointestinal reduction [41]. Fertilization with ammonium sulfate and urea has been showed to lower the nitrate content in the edible part of plants compared to ammonium nitrate [42]. Similar findings are obtained in the present study as nitrate content in the fruits was decreased by applying ammonium sulphate and urea compared to ammonium nitrate. The nitrate accumulation in plants is very low when nitrogen is applied in the $(NH_4)_2$ SO_4 form because it is slowly nitrified [43].

Regarding to the effectiveness of sulfur in increasing the yield and fruit quality, it is well reported that plants assimilate inorganic sulphate into cysteine, which is converted into methionine [44]. This amino acid and others (tryptophan or phenylalanine) are precursors for glucosinolate production, a group of health-promoting compounds [45]. N and S interact to exert a strong effect on various growth parameters such as biomass and yield [46]. Sulfur is an essential constituent of enzymes involved in N metabolism [47, 48] and its availability could lead to an increase in N assimilation. Also, fruit Cd and Pb content was increased when N was applied in the nitrate form, as well as it increased by K and S fertilization. The influences of different nitrogen sources on Cd accumulation in plants are reported [49, 50]. Also, many studies confirmed the positive effect of K when applied in the sulphate form on Cd uptake by plants [51, 52]. Additionally, the sulfur anion weather applied as solo application or accompanied with K was also found to increase Cd accumulation in plants [53, 54]. However, McLaughlin *et al*. [55] showed no significant increasing effect of sulfur on Cd uptake and suggested that sulfur would not have the same effect as the chloride on Cd uptake. The strong relationship between soil salinity (chloride concentration) and Cd accumulation is reported by Norvell *et al.* [56]. Thus, studying the effect of K and S fertilization and soil conditions on plant Cd and Pb accumulation is very important to minimize their concentration in agricultural produce.

CONCLUSION

Hence, to produce higher yield and overall product quality of Zaghloul dates, in particular lower nitrate content, the application of nitrogen fertilizer as ammonium sulphate is advisable. Special considerations must be taken when fertilizing date palms with high level of potassium and sulfur as; their applied rate, form and salinity might affect the uptake of heavy metals, thus producing dates with quality and no human health risks.

REFERENCES

1. FAO, 2010. Food and Agriculture Organization of the United Nations.
2. Tisdale, S.L. and W.L. Nelson, 1978. Soil Fertility and Fertilizers. Macmillan Publishing Co. Inc., New York, USA., pp: 67-70.
3. Fageria, N.K. and V.C. Baligar, 2005. Enhancing nitrogen use efficiency in crop plants. Adv. Agron., 88: 97-185.
4. Tung, P.G.A., M.K. Yusoff, N.M. Majid, G.K. Joo and G.H. Huang, 2009. Effect of N and K fertilizers on nutrient leaching and groundwater quality under mature oil palm in Sabah during the monsoon period. American J. Appl. Sci., 6(12): 2006- 2009.

5. Abd El- Khalek, A.M., 1992. Physiolgical studies on grapes. M. Sc. Thesis, Fac. of Agric., Mansoura Univ., Egypt.
6. Kage, H., C. Alt and H. Stutzel, 2003. Aspects of nitrogen use efficiency of cauliflower II. Productivity and nitrogen partitioning as influenced by N supply. J. Agric. Sci., 41: 17-29.
7. Li, H., R. Gordon, R. Lada, S. Asiedu and N. Goodyear, 2007. Development of high plant population seeding technology: Double-row direct seeding for *Brassica* vegetables. Abstract of Atlantic Agricultural Science and Communication Workshop. Truro, NS., pp: 18.
8. Owusu, E.O., G.O. Nkansah and E.A. Dennis, 2000. Effect of sources of nitrogen on growth and yield of hot pepper (*Capsicum frutescence*). Tropical Science, 40: 58-62.
9. Houdusse, F., M. Garnica and J.M. García-Mina, 2007. Nitrogen fertilizer source effects on the growth and mineral nutrition of pepper (*Capsicum annuum* L.) and wheat (*Triticum sativum* L.). J. Sci. Food and Agric., 87(11): 2099-2105.
10. Sady, W., S. Rozek, I. Domagala-Swiatkiewicz, R. Wojciechowska and A. Kolton, 2008. Effect of nitrogen fertilization on yield, NH_4^+ and NO_3^- content of white cabbage. Acta Scientarium. Polonorum, Hortorum Cultus, 7: 41-51.
11. Marschner, H., 1995. Mineral Nutrition of Higher Plants. Academic Press, London, pp: 262-264.
12. Kassem, A.A., A.H. Kassem, H.M. Kamal and M.M. Shalaby, 1995. The influence of nitrogen fertilizer and/or sulfur application on guava trees grown in alkaline sandy soil. 1. The effect on soil pH values and leaf mineral contents. Menofiya J. Agric. Res., 20(3): 1203-1222.
13. Saleh, M.M.S., M.S. Abou-Rayya and N.E. Kassim, 2000. A comparative study on the effect of fast and slow-release nitrogen fertilizers on nutritional status, yield and fruit quality of Le- Conte pear trees under Rafah conditions. J. Agric. Sci. Mansoura Univ., 25(4): 2189-2196.
14. Kassem, H.A. and H.A. Marzouk, 2002. Effect of organic and/or mineral nitrogen fertilization on the nutritional status, yield and fruit quality of flame seedless grapevines grown in calcareous soil. J. Adv. Agric. Res., 7(1): 117-126.
15. El-Hammady, A.M., A.S. Khalifa and A.S. Montasser, 1994. Effect of potash fertilization on "Seewy" date palms. II. Effect on yield and fruit quality. Egypt. J. Hort., 18 (2): 199-210.
16. Kassem, H.A., M.B. El-Sabrout and M.M. Attia, 1997. Effect of nitrogen and potassium fertilization on yield, fruit quality and leaf mineral content in some Egyptian soft varieties. Alex. J. Agric. Res., 42(1): 137-157.
17. Bamiftah, M.A.O., 2000. Effect of potassium fertilization and bunch thinning on yield and fruit quality of Zaghloul date palm. M.Sc. Thesis, Fac. Agric. Sci., Saba Basha, Alex. Univ.
18. Al-Kharusi, L.M., M.O. Elmardi, A. Ali, F. Al-Julanda, L. Al-Said, K. Abdelbasit and S. Al-Rawahy, 2009. Effect of mineral and organic fertilizers on the chemical characteristics and quality of date fruit. Int. J. Agric. Biol., pp: 1560-8530.
19. Obreza, T.A., 2003. Importance of Potassium in a Florida Citrus Nutrition Program. Better Crops, 87: 19-22.
20. Abbas, F. and A. Fares, 2008. Best management practices in citrus production. Tree For. Sci. Biotech., 3: 1-11.
21. Kettlewell, P.S., J.W. Cook and D.W. Parry, 2000. Evidence for an osmotic mechanism in the control of powdery mildew disease of wheat by foliar-applied potassium chloride. European J. Plant Pathol., 106: 297-300.
22. Holzmueller, E.J., S. Jose and M.A. Jenkins, 2007. Influence of calcium, potassium and magnesium on *Cornus florida* L. density and resistance to dogwood anthracnose. Plant and Soil, 290: 189-199.
23. Abbey, L., D.C. Jouce, J. Aked and B. Smith, 2002. Genotype sulfur nutrition and soil type effects on growth and dry matter production of spring onion. J. Hort. Sci. Biotechnol., 77: 340-345.
24. Eriksen, J., K. Thorup-Kristensen and M. Askegard, 2004. Plant availability of catch crop sulfur following spring incorporation. J. Plant Nut. Soil. Sci., 167: 609-615.
25. Klocke, N.L. and P.E. Fischbach, 1984. Estimating soil moisture by appearance and feel. Univ. of Nebraska-Lincoln Extension G84-690. http://digitalcommons. unl.edu/extensionhist/1201.
26. Miles, D.L. and I. Broner, 1998. Irrigation, estimating soil moisture. Colorado State Univ. Extension Crop Series. No. 4.700. www.ext.colostate.edu.pubs/ crops/04700.pdf.
27. Fuleki, T. and F.J. Francis, 1968. Quantitative methods for anthocyanins. 1. Extraction and determination of total anthocyanin in cranberries. J. Food Sci., 33: 72-77.

28. Barbin, P., 2006. Contrôle et Elements De Maitrise De La Contamination Par La Levure Brettanomyces Au Cours Du Procedéde Vinification En Rouge: 257. Thèse de doctorat de l'institut national polytechnique de toulouse, France.
29. AOAC, 1995. Association of Official Agricultural Chemists, Official Methods of Analysis, 15th ed. A.O.A.C., Washington, DC.
30. Abou Sayed, T.A., E.A. Abd El-Bary and R.A. Al-Ashkar, 1997. Effect of different sources of irrigation water on soil and prickly pear fruit properties. In: Proc. First Sci. Conf. of Agric. Sci., Fac. Agric., Assiut Univ., Egypt.
31. Evanhuis, B. And P.W. De Waard, 1980. Principles and practices in plant analysis. FAO Soils Bull., 38: 152-163.
32. Murphy, J. and J.P. Riley, 1962. A modified single solution method for the determination of phosphorus in natural water. Anal. Chin. Acta, 27: 31-36.
33. Singh, J.P., 1988. A rapid method for determination of nitrate in soil and plant extracts. Plant Soil, 110: 137-139.
34. Statsoft, Inc., 2001. Statistics for Windows (Software-system for Data analysis) version 6.www. Statsoft.com.
35. Hussein, F. and M.A. Hussein, 1983. Effect of nitrogen fertilization on growth, yield and fruit quality of Sakkoti dates grown at Aswan. Proceeding of the first symposium on the date palm in Saudi Arabia, March 23-25, King Faisal Univ., pp: 182-188.
36. Marzouk, H.A. and H.A. Kassem, 2011. Improving fruit quality, nutritional value and yield of Zaghloul dates by the application of organic and/or mineral fertilizers. Scientia Hortic., 127: 249-254.
37. Al-Ghamidi, A.A., A.A. Helal and H.M. Al-Whaibi, 1999. Nitrogen source and the growth of date palm seedlings. Pakistan J. Biol. Sci., 2(4): 1207-1219.
38. Guelser, F., 2005. Effects of ammonium sulfate and urea on NO_3 and NO_2 accumulation, nutrient contents and yield criteria in spinach. Sci. Hort., 106: 330-340.
39. Elwan, M.W.M and K.E. Abd El-Hamed, 2011. Influence of nitrogen form, growing season and sulfur fertilization on yield and the content of nitrate and vitamin C of broccoli. Scientia Horticulturae, 127(3): 181-187.
40. Nielsen, R.L., 2006. N loss mechanisms and nitrogen use efficiency. Purdue nitrogen management workshops, Purdue University.
41. Boink, A. and G. Speijers, 2001. Health effects of nitrates and nitrites. A review, Acta Hort., 563: 29-36.
42. Sady, W., R. Wojciechowska and S. Rozek, 2001. The effect of form and placement of N on yield and nitrate content of white cabbage, Acta Hort., 563: 123-128.
43. Goh, K.M. and P. Vityakan, 1986. Effects of fertilizers on vegetable production.2. Effects of nitrogen fertilizers. N.Z. J. Agric. Res., 29: 485-494.
44. Nicoforova, V., J. Freitag, S. Kempa, M. Adamik, H. Hesse and R. Hoefgen, 2003. Transcriptome analysis of sulfur depletion in Arabidopsis thaliana: interacting of biosynthetic pathways provides response specificity. Plant J., 33: 633- 650.
45. Schonhof, I., D. Blankenburg, S. Mueller and A. Krumbein, 2007. Sulfur and nitrogen supply influence growth, product appearance and glucosinolate concentration of broccoli. J. Plant Nut. Soil. Sci., 170: 1-8.
46. Salvagiotti, F. and D.J. Miralles, 2008. Radiation interception, biomass production and grain yield as affected by the interaction of nitrogen and sulfur fertilization in wheat. Eur. J. Agron., 28: 282-290.
47. Campbell, W.H., 1999. Nitrate reductase structure, function and regulation: bridging the gap between biochemistry and physiology. Ann. Rev. Plant Physiol. Plant Mol. Biol., 50: 277-303.
48. Swamy, U., M. Wang, J.N. Tripathy, S.K. Kim, M. Hirasawa, D.B. Knaff and J.P. Allen, 2005. Structure of spinach nitrite reductase: implications for multi-electron reactions by the iron-sulfur: siroheme cofactor. Biochemistry, 44: 16054-16063.
49. Basta, N.T., W.R. Raun and F. Gav, 1998. Wheat grain cadmium under long-term fertilization and continuous winter wheat production. Better Crops, 82(19): 14-19.
50. Mair, N.A., M.J. McLaughlin, M. Heap, M. Butt and M.K. Smart, 2002. Effect of nitrogen source and calcium lime on soil pH and potato yield, leaf chemical composition and tuber cadmium concentrations. J. Plant Nut., 25(3): 523-544.
51. Zhu, Y.G., G. Shaw, A.F. Nisbet and B.T. Wilkins, 2002. Effect of potassium supply and plant age on the uptake of radiocaesium (^{137}Cs) by broad bean (*Vicia faba*): interpretation of results from a large-scale hydroponic study. Environ. Exp. Bot., 47: 173-187.
52. Zhao, Z., Y. Zhuet, H.L. Sally, E. Smith and F.A. Smith, 2003. Effects of forms and rates of potassium fertilizers on cadmium uptake by two cultivars of spring wheat (*Triticum aestivum*, L.). Environ. Intl., 29: 973-978.

53. Bingham, F.T., S. Garrison and J.E. Strong, 1986. The effect of sulfate on the availability of cadmium. Soil Sci., 141:172-177.
54. Grant, C.A., L.D. Baily and M.J. McLaughlin, 1999. Management factors which influence cadmium concentration in crops. In: M.J. McLaughlin, B.R. editors. Cadmium in soils and plants. Dordrecht, The Netherlands: Kluwer Academic Publishing, pp: 151-198.
55. McLaughlin, M.J., R.M. Lambrechs, E. Smolders and M.K. Smart, 1998. Effects of sulfate on cadmium uptake by Swiss chard: II. Effects due to sulfate addition to soil. Plant Soil, 202: 217-222.
56. Norvell, W.A., J. Wu, D.G. Hopkins and R.M. Welch, 2000. Association of cadmium in drum wheat grain with soil chloride and chelate-extractable soil cadmium. Soil Sci. Soc. Am. J., 64: 2162-2168.