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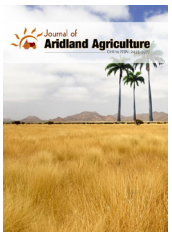
Research Article



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The improvement of antioxidant contents and fruit quality of Sukkary date cultivar using various Potassium levels and Irrigation interval

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ABSTRACT

Sukkary date palms (*Phoenix dactylifera* L.) were treated with three levels of potassium fertilizer combined with three irrigation intervals regime, five replicates were allocated per treatment, to enhance better date peel color; decrease loose crust, and subsequently, improve high market ability. Potassium sulfate (49% K_2O) was applied annually at a rate of 490 g (as common fertilization applied in the farm in which this experiment was carried out, therefore, it was considered as a control treatment), 735 g, or 980 g K_2O per palm tree, each level was divided into three equal doses. The first dose was added one month after pollination; the other two doses were added at two month interval, whereas the irrigation treatments were as follows: 24 hrs (as common irrigation application in the farm used for this study, and it was considered as a control treatment), 48 hrs, or 72 hrs. The results showed a great decrease in the loose crust dates at harvesting time. An inverse proportional relationship between irrigation intervals and loose crust of dates was observed. The High potassium fertilizer treatment accompanied with 72 hrs irrigation interval treatment produced a significantly higher date quality regarding with bright yellow color, less darkening, and loose crust. High potassium fertilizer treatments (735, or 980 g K_2O per palm) increased total yield, improved date weight, size, and color. Moreover, increasing potassium level affected significantly the date total antioxidant. This study showed that, a potential means to control peel darkening and loose date crust and improve quality of cv. Sukkary dates, which ultimately improves its market ability, through implementing appropriate potassium and irrigation regimes.

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KEYWORDS: Date palm, Date peel loos and color, Fruit marketing, Agricultural practices, Date chemical contents

INTRODUCTION

The date palm (*Phoenix dactylifera* L.) is an important fruit crop in arid and semi-arid regions of the world, especially, in the Middle East countries. Saudi Arabia is one of the largest date producers in the world. Its annual production exceeds 1.5 million tons (National Center for Palm & Dates, 2022; FAO, 2022). The vast majority of date palms in the Kingdom of Saudi Arabia are planted in sandy or sandy loam soils with high $CaCO_3$ levels (Abdalla *et al.*, 1987). These soils have an extremely low cation capacity and a tendency to leach or fix nutrient (Tisdale & Nelson, 1978). Potassium has an important physiological and biochemical functions in plants, and it is one of the most up taken and accumulated elements for plant growth and development, moreover, potassium increases enzyme activity (antioxidant enzymes) and neutralize negative effects of free radicals by antioxidant enzyme (Cakmak, 2002; Hu & Schmidhalter, 2005). Date palm fruit is rich in potassium as high as 0.9% in the flesh and 0.5% in seed (Awad, 2011), subsequently; date palm trees need large amounts of K mostly higher than N requirement (Klein & Zaid, 1999). 'Sukkary' cultivar is one of the most popular cultivars in Saudi Arabia and its economic value depends on the quality of dates which decreases sharply when dates either lose their bright yellow color and become dark brown and/or have a loose crust (Figure 1) it is considered as low quality dates and sold at lower prices. Studies have been carried out to overcome these problems and to improve date quality using different fertilization regimes (Behrooznam & Shirzadi, 2007; Desouky *et al.*, 2007; Khayyat *et al.*, 2007; Harhash & Abdel-Nasser, 2010). Shawky *et al.* (1999) recommended 1.5 kg of potassium sulfate/palm for the highest yield and quality of Seewy' date palm, whereas Bamiftah (2000) recommended 2-3 kg of potassium for sulfate/palm for 'Zaghloul' dates. However, responses to these treatments have been limited and could be due to the time of application and/or the amount applied in each dose.

Figure 1: Different quality parameters of Sukkary dates. a) High quality yellow dates and b) low quality darkened dates

Due to a lack of information regarding the effect of irrigation intervals on date quality, some date palm growers have a misconception that increasing irrigation water to palms could lead to higher yield and better fruit quality. Moreover, research studies related to the combined effect of potassium fertilization and irrigation on some physical and chemical properties of dates such as date antioxidant activity, loose crust, and dark dates color are limited.

High concern in phytochemical contents and antioxidant activity of fruits and vegetables has been observed in recent years (Yaldiz, 2017). In addition to the important functions of phytochemical contents in plant due to their role as defense mechanisms for disease infections and external stresses (Feucht *et al.*, 1992; Mayer *et al.*, 1996; Wang *et al.*, 2003;). Furthermore, they have an influence on fruit quality, color, taste and fruit juice and slice (Robards *et al.*, 1999; Bushway *et al.*, 2002; Van der Sluis *et al.*, 2002). Low concentration of phenolics may prevent food deterioration caused by oxidation. protect food from oxidative, while at high concentration, they (or their oxidation products) may involve in food discoloration (Robards *et al.*, 1999; Bushway *et al.*, 2002). The color of apple fruits, after oxidation, depends on the balance between the phenolics: hydroxyl cinnamic, and flavonols (Amiot *et al.*, 1992; Goupy *et al.*, 1995). Dates are considered one of the excellent source of phenolics and therefore have a high antioxidant activity (Saafi *et al.*, 2009). Dates have been reported to contain various phenolics, such as Protocatechuic, p. Hydroxy benzoic, Vanillic, Syringic, Caffeic, Coumaric, Ferulic, hydroxy benzoic, hydroxyl cinnamic (Al-Farsi *et al.*, 2005a; Al-Redhaiman, 2005), which contribute significantly to total antioxidant activity. Many studies have discussed the physical and chemical development of dates as they pass through these stages (Sawaya *et al.*, 1983, 1984; Mustafa *et al.*, 1986; Siddiqui & Gupta, 1994; El-Zoghbi, 1994; Ahmed *et al.*, 1995; Al-Hooti *et al.*, 1997; Myhara *et al.*, 1999; Al-Shahib & Marshall, 2003). Studies regarding the effect of potassium fertilization and irrigation on some physical and chemical properties of dates such as date antioxidant activity, loose crust, and dark dates color are also limited. Hence, the aim of this was to investigate the effects of different levels of potassium sulfate fertilizer and irrigation intervals on Sukkary dates quality.

MATERIALS AND METHODS

Mature date palm trees cv. Sukkary (*Phoenix dactylifera* L.) of the same age (around 15 years old), uniform in growth, good physical condition, free from insect damage and diseases, and subjected to the same horticultural management treatments were selected for this study. Selected date palm trees grown at a private palm orchard in the Qassim region, Kingdom of Saudi Arabia, received nine different treatments in a factorial experiment included three potassium fertilization levels and three irrigation intervals. Five replicates, each palm tree represented a replicate, were assigned per treatment. All chemicals and solvents were obtained from Sigma Aldrich Co. Ltd (St. Louis, France).

Potassium sulfate (49% K_2O), produced by Xuzhou Sushang Chemical Trading Co., Ltd. was applied annually at a rate of 490 g (as a common fertilization application in the farm in which this experiment was carried out, it was considered as a control treatment), 735 g, or 980 g K_2O per palm, divided into three equal doses. The addition of the first dose was after one month of pollination; the other two doses were added at two month interval. Each level of potassium fertilizer was subjected to three irrigation interval treatments; 24 hrs (as a common irrigation application in the farm in which this experiment was carried out, it was considered as a control treatment for irrigation treatments), 48 or 72 hrs).

Chemical Analysis

Harvested fruits were subjected to the following analysis: Antioxidant contents, SSC% (measured with a temperature compensated RFM 110 Bellingham + Stanley LTD refractometer (Lawrenceville, GA, USA), fruit contents of reduced and total sugars which were determined calorimetrically according to Dubios (1956) using Perkin Elmer Ez301 spectro-photometer (Shelton, CT, USA), fruit physical and chemical properties, and fruit peel color (was measured by using Lovibond Tintometer GmbH).

Antioxidants Extraction Method

Date extracts for total phenolic and antioxidant activity were measured in methanol extract analysis. The extracts were prepared using the method of Al-Farsi *et al.* (2005b). Two hundred milligrams of the sample were extracted with 2 mL of 50% methanol at room temperature on an orbital shaker set at 200 rpm for 2 h. The extracts were centrifuged at 1000 g for 15 min, and the supernatants were decanted into 4 mL vials. Supernatants were combined and used for total Antioxidants. The sample extract of 150 µL sample was placed into a 3 mL fluorescence cell, then into 150 µL of 0.12 150 µM Fluorescein sodium solution, and 2055 mL 75 mM phosphate buffer was used as a blank, and Trolox (a water-soluble α tocopherol analogue) at 2.5, 5, and 10 µM was used as a standard. The cell was incubated at 37 °C for 15 min in a water path. The measurement of initial fluorescence ($f0$) was at the excitation wavelength of 515 nm using an RF-540 Shimadzu spectrofluorometers (Shimadzu, Kyoto, Japan). After $f0$ had been recorded, 150 µL 320 mM AAPH reagent, as a free radical generator, was added into a cell and mixed well using a glass rod, fluorescence was measured and recorded every 5 min ($f5$, $f10$, $f15$, and $f20$) until the

fluorescence of the last reading declined by > 95% from the first reading (~60 min). The relative Oxygen Radical Absorbance Capacity (ORAC) values were calculated according to the method of Wang *et al.* 2003. Values are expressed as micromoles of Trolox equivalents (TE) per gram of fresh weight.

Statistical Analysis

Data were analyzed using a two way factorial design with five replicates per treatment, using the Student-Newman-Keul's Test. The least significant differences were used to compare means at $P \leq 0.05$ according to the procedure outlined by Snedecor and Cochran (1980). The experiment was carried out for two successive seasons.

RESULTS AND DISCUSSION

Antioxidant Content

Significant increases in total antioxidant values were observed among Sukkary date fruits harvested from palms that received higher potassium fertilization doses (735 g, or 980 g K_2O per palm per year) and longer time between irrigations (72 hrs irrigation interval treatment) (Figure 2). No significant difference was observed between these treatments. In general, there was a proportional relationship between the amount of added potassium and total antioxidant values in dates, the higher the potassium dose, the higher the total antioxidant values in 'Sukkary' dates.

On the contrary, there was an inverse proportional relationship between the irrigation interval and total antioxidant values in date palms subjected to a long period between irrigations (72 hrs irrigation interval treatment) produced dates higher in total antioxidant values.

Reduced and Total Sugar Contents

Reduced and total sugar contents in Sukkary date fruits were significantly affected by potassium application (Figures 3 & 4).

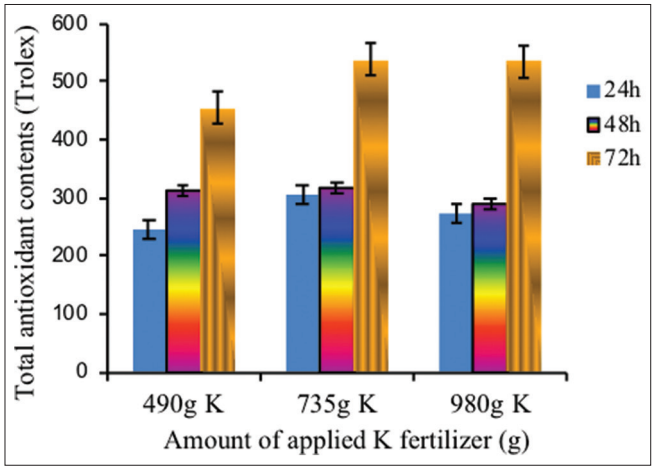

Figure 2: Total antioxidant contents (Trolex) in Sukkary dates as affected by different potassium fertilization levels and irrigation intervals

A slight increase was observed in fruit total sugar content in palms that received higher potassium applications (735 g and 980 g K_2O per palm). No significant effect was observed in all irrigation treatments under study on both reduced and total sugar contents in Sukkary date fruits. Highest fruit content of total sugar increment occurred at 980 g K_2O, while, the lowest fruit content of total sugar increment at 490 g K_2O. A clear relationship was observed between the level of potassium application and total sugar content. The more potassium rate applied, the higher the sugar content. These findings are similar to those reported earlier by other workers on various date cultivars (Shawky *et al.*, 1999; Bamiftah, 2000; Behrooznam & Shirzadi, 2007; Desouky *et al.*, 2007; Khayyat *et al.*, 2007; Harhash & Abdel-Nasser, 2010). Potassium has been considered to be functional in the transport of carbohydrates and translocation of sugar. This process may be enhanced by the formation of borate-sugar complexes (Gauch & Dugger, 1954; Price *et al.*, 1972; Marcus-Wyner & Rains, 1982; Katyal & Randhawa, 1983). The effect of K treatments on fruit chemical characteristics is presented in Figures 3 to 5. Potassium significantly increased fruit contents of TSS, reducing, non-reducing and total sugars compared with the control treatment. Similar findings were

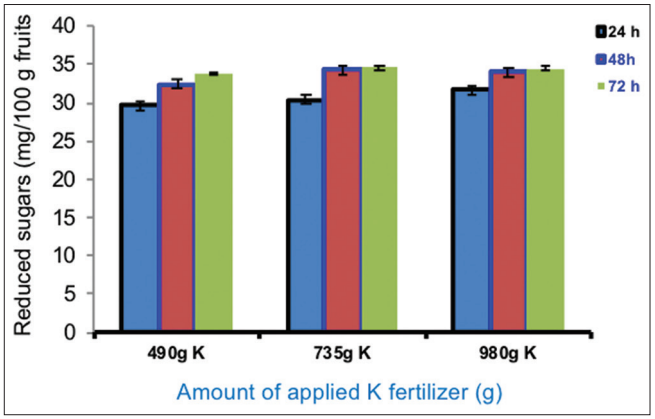

Figure 3: Effect of different potassium fertilization levels and irrigation intervals on fruit reduced sugar contents

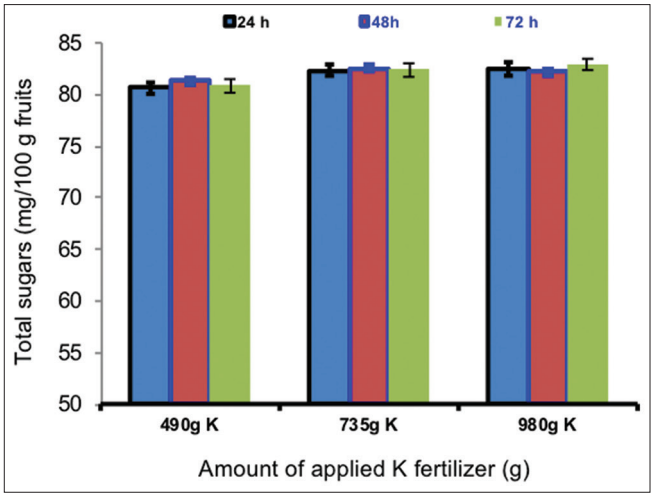

Figure 4: Effect of different potassium fertilization levels and irrigation intervals on fruit total sugar contents

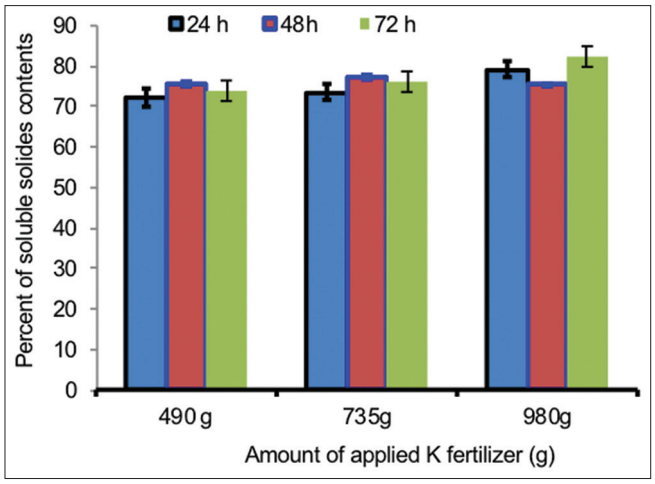

Figure 5: Effect of different potassium fertilization levels and irrigation intervals on the percentage of date fruits soluble solid content

reported by Desouky *et al.* (2007), Harhash and Abdel-Nasser (2007), Khayyat *et al.* (2007) and Shahin (2007).

Percentage of Soluble Solid Content

The percentage of soluble solids content in Sukkary date fruits increased significantly by potassium application (Figure 6). This increase could be due to the role of potassium in translocation and accumulation of sugar in fruits, which affect directly the SSC% (Gauch & Dugger, 1954; Price *et al.*, 1972; Marcus-Wyner & Rains, 1982; Katyal & Randhawa, 1983). Fruits from palms received irrigation water every 72 hrs intervals showed a slight increase in SSC% compared with the fruits from the other two irrigation treatments, perhaps this increment occurred as a result of lower water supply and then the water loss from the fruits at the ripening stage during hot summer and, accordingly, lower moisture contents could affect SSC% positively.

Loose Crust Fruits

Data revealed a great improvement in the loose crust of harvested fruits (Figure 6), both extending the periods between irrigations and increasing the potassium fertilization doses decreased effectively the percentage of loose crust of 'Sukkary' date fruits. There was an inversely proportional relationship between the irrigation intervals and the percentage of loose crust fruits. Whenever the irrigation interval was extended, the percentage of loose crust fruits decreased. The highest amount of K_2O (980 g/palm) resulted in the lowest percentage of loose crust fruits; whereas the highest percentage of loose crust was at 450 g K_2O/palm. Due to the different rates of growth of both fruit pulp (mesocarp) and fruit crust (exocarp) at the time of fruit ripening (as fruit crust increases in size at a rate exceeds that of fruit pulp), fruit crust becomes loose as irrigation rates increase (Zaid & Arias-Jimenez, 2002).

Fruit Weight and Total Yield

A slight improvement occurred in both fruit weight and total yield (Figures 7 & 8). Palms received the highest concentrations

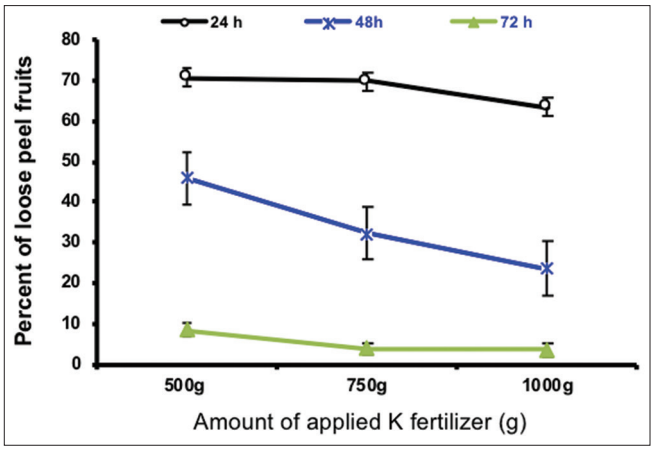

Figure 6: Effect of different potassium fertilization levels and irrigation intervals on percentage of loose peel fruits

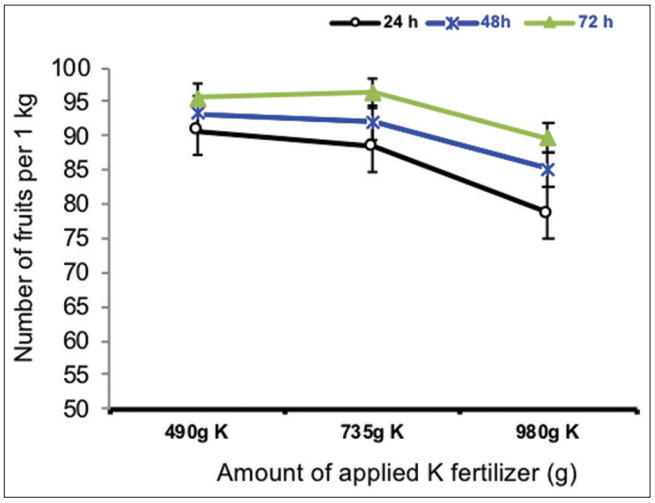

Figure 7: Effect of different potassium fertilization levels and irrigation intervals on the number of fruits per 1 kg

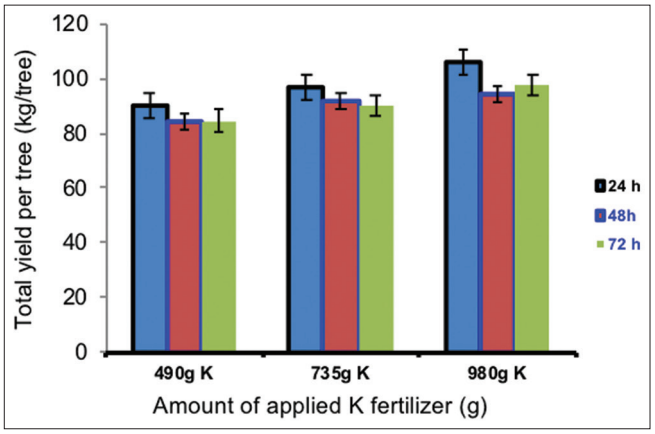

Figure 8: Effect of different potassium fertilization levels and irrigation intervals on fruit total sugar contents

of K_2O (980 g K_2O per palm) showed significant differences in both fruit weight and total yield compared with those received the lowest K_2O application (490 g K_2O per palm). No significant differences were observed in all irrigation treatments.

Table 1: Fruit skin color analysis of Sukkary date as affected by potassiumfertilization and irrigation intervals

Potassium K_2O (g)	Color characteristics[zx]														
	24 h irrigation intervals					48 h irrigation intervals					72 h irrigation intervals				
	L*	a*	b*	C*	h°	L*	a*	b*	C*	h°	L*	a*	b*	C*	h°
490	33.1a	11.8a	20.5a	75.5b	1.0b	30.1a	8.3a	20.2b	29.6b	0.6b	24.4a	7.4a	15.6a	27.2b	0.5b
735	28.2b	7.1b	19.2a	91.4a	1.5a	28.2b	6.3c	18.8b	52.a9	0.8a	21.7a	6.5a	15.5b	21.3c	0.5b
980	26.5c	6.8b	17.9c	63.3c	1.0b	25.6c	5.3b	15.8a	13.6c	0.4c	20.0a	3.6b	13.8c	56.4a	1a

[z]Each value in the table is the mean of three replicates, and three measurements were conducted for each replicate.
[x]Least significant difference (LSD) for means in the same column ($P < 0.05$)

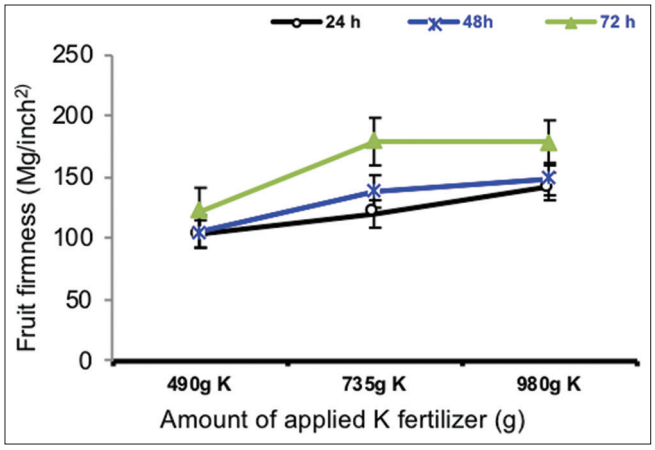

Figure 9: Effect of different potassium fertilization levels and irrigation intervals on fruit firmness

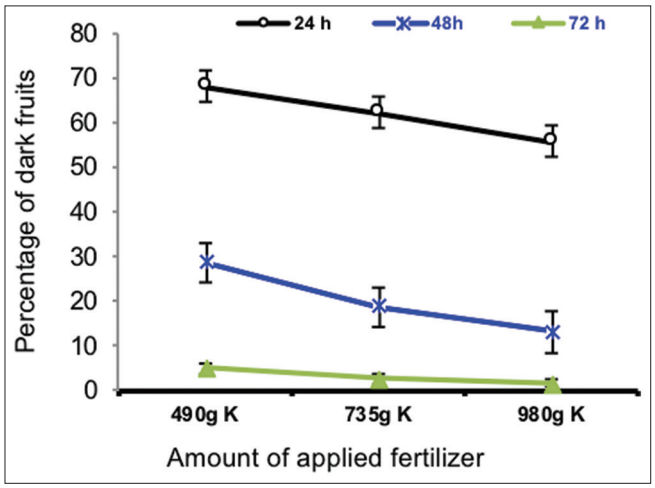

Figure 10: Effect of different potassium fertilization levels and irrigation intervals on the percentage of dark fruits

Fruit Firmness

Extending the periods between irrigations and increasing potassium fertilization doses increased slightly fruit firmness with a proportional relationship between both the irrigation intervals and potassium fertilization level and fruit firmness (Figure 9). Whenever the irrigation interval was longer, the higher fruit firmness. Also, the effect of K_2O on fruit firmness was clear, the higher the amount of K_2O, the higher the fruit firmness.

Fruit Peel Color Analysis

Date peel color analysis indicated that both irrigation regime and potassium treatments influenced significantly fruit peel lightness-darkness (L* values), the locus relative to purplish-red-bluish-green (a* values), the locus relative to yellow-blue (b* values), the index analogous to color intensity (c* values), and hue angle (h* values) (Table 1). A clear relationship was observed between different irrigation intervals and the fruit peel color analysis parameters. Fruit peel L*, a*, b*, c*, and h* values showed inverse proportion values to irrigation intervals and application of different potassium concentrations. High potassium treatments and 72 hrs irrigation interval produced fruits with near values to yellow color b* compared with all other treatments. In Sukkary dates, a decrease in fruit peel L* values is associated with longer irrigation intervals and higher potassium application. Subsequently, the effect of both longer irrigation interval application and higher potassium treatments on decreasing the darkening peel phenomena resulted in maintaining the fruit peel lightness (low L* values) and yellow color (low b* values) (Figure 10).

CONCLUSION

A significant improvement in Sukkary date quality occurred when higher potassium fertilization levels and longer irrigation intervals were applied. The potassium sulfate application had positive effects on the chemical and biological activities of the extracts. Increasing levels of potassium sulfate significantly improved date weight, size, crust color and total antioxidant. Increasing potassium sulfate to 970 g/palm, a significant reduction occurred in loose crust dates. A positive proportional relationship between irrigation intervals and fruit quality had occurred, especially regarding decreasing the loose crust dates.

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