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Effect of Mineral and Organic Fertilizers on the Chemical Characteristics and Quality of Date Fruits

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ABSTRACT

The study evaluated the effect of mineral and organic fertilizers with and without the supplementation of micronutrients on the chemical characteristics and quality of date fruits from two cultivars of date palm (*Phoenix dactylifera* L.) viz. Khalas and Khassab. Thirty date-palm trees from each of the cultivars, 6-7 years of age, were randomly selected and divided into 10 groups with 3 replicates in each group. The study was conducted in a completely randomized block design (RCBD) during the years 2002-2004 at Al-Fairoz Private Farms in Al-Batinah region, Sultanate of Oman. The fertilizers used were organic peat (80 L) either alone or with 1 kg of urea (divided into 4 & 5 equal N-doses) together with 500 g of triple super phosphate and 800 g of K_2SO_4 and with or without supplementation of micronutrients. The control did not include any fertilizers. The samples of date fruit were collected at *"Rutab"* stage (soft, ripe). Significant (P<0.05) differences were observed in the chemical characteristics and quality parameters of dates on different fertilizer applications as compared to control. The highest dry matter content was observed in both the date cultivars when mineral fertilizers (NPK, in 4-N doses) were supplemented with organic peat and micronutrients. The application of organic peat alone resulted in higher tannin and pectin contents but lower titeratable acidity (TA) in both the cultivars as compared to all other treatments. During the year 2004, both the cultivars showed lower pectin, tannin and moisture contents but higher pH values as compared to the years 2002 and 2003. Overall the application of organic peat over a period of 3 years in both cultivars increased the tannin contents, whereas the mineral fertilizers reduced it. The interactions between fertilizer application, year and stage of maturity were also significant (P<0.05) for DM, tannin and TA.

Key Words: Chemical characteristics; Date fruits; Mineral fertilizers; Organic peat; Urea

INTRODUCTION

Date palm (*Phoenix dactylifera L.*) is one of the oldest fruit crops grown in the arid regions of the Arabian Peninsula, North Africa and Middle East (Chao & Krueger, 2007). It is considered as the primary fruit crop in the Sultanate of Oman representing about 82% of all fruit trees in the country (Al-Yahyai, 2007). According to the Ministry of Agriculture and Fisheries, the estimated production of dates during the year 2007 was about 255,871 metric tons (MAF, 2007). Dates are considered as an almost ideal food that provides a wide range of essential nutrients with many potential health benefits (Barreveld, 1993; Al-Shahib *et al.*, 2003; Al-Farsi *et al.*, 2005; Elleuch *et al.*, 2008). The chemical composition of dates can vary depending on cultivar, soil conditions, agronomic practices as well as the ripening stage (Barreveld, 1993; Ahmed *et al.*, 1995; Al-Hooti, 1997; Myhara *et al.*, 1999; Al-Farsi *et al.*, 2005; Ismail *et al.*, 2006). The most important components of dates are the reducing sugars, which constitute about 70 to 78% (FAO, 1984). Dates also contain dietary fiber, pectin, tannins, some vitamins, minerals, low quantities of organic acids, with very little or no starch and a number of antioxidant anti-mutagenic compounds (Rouhani & Bassiri, 1976; Sawaya *et al.*, 1983; El-Shurafa, 1984; Ahmed *et al.*, 1995; Vayalil, 2002; Allaith, 2008; Biglari *et al.*, 2008; Khan *et al.*, 2008).

The chemical composition of date fruits keeps on changing during the various fruit development stages; internationally known with their Arabic names *"Kimri"*

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(unripe), *"Khalal"* (full size, crunchy), *"Rutab"* (ripe, soft) and *"Tamr"* (ripe, sun-dried). Reducing sugars tend to increase, whereas the sucrose decreases in soft dates. Titeratable acidity, tannins, pectins and moisture contents tend to decrease, whereas the dry matter increases with progressing maturation (Sawaya *et al.*, 1983; Buchaev *et al.*, 1987; Ahmed *et al*., 1995; EL Mardi *et al.*, 1998a, b). The stringent taste of fruit during the early stages of maturity is due to its higher tannins contents. The concentration of tannins however decreases during the ripening of fruit and is almost negligible at the *"Rutab"* stage (Makki *et al.*, 1998; Myhara *et al.,* 2000). Date growers in many parts of the world believe that the date palm remains productive as long as it keeps on receiving water and organic manure. The production of good quality dates however depends on adequate irrigation, fertilization, disease protection, pollination and harvesting as well as post-harvest handling techniques (Barreveld, 1993; Osman, 1995; Iqbal *et al.*, 2004; MAF, 2005). It has been reported that large amounts of macro and micronutrients are depleted annually from the soil as a result of heavy crop production/yields and pruning of leaves (Hass & Bliss, 1935; El-Shurafa, 1984). Such huge reductions in soil mineral contents must be compensated annually by adding fertilizers to maintain the high yield and good quality of dates. Only a few limited studies have reported the effect of fertilizer applications on the chemical characteristics of date fruits (Hussein & El-Zeid, 1977; Bacha & Abo-Hassan, 1983; Al-Juburi, 1995). However no systematic and controlled trials have been conducted to evaluate the effects of organic and mineral fertilizers on the chemical characteristics and quality of date fruits. The present study was therefore conducted to investigate the effects of mineral and organic fertilizers on the chemical characteristics of fruits of two date palm cultivars viz. Khalas and Khassab at early *"Rutab"* stage, grown in Sultanate of Oman.

MATERIALS AND METHODS

Thirty date-palms from each of Khalas and Khassab cultivars, 6-7 years of age, were randomly selected and divided into 10 groups with three replicates in each group. The study was conducted in a completely randomized block design (RCBD) during the years 2002-2004 at Al-Fairoz Private Farms in Al-Batinah region, Sultanate of Oman. The fertilizers used were organic peat (80 L) either alone or with 1 kg of urea (divided into 4 & 5 equal N-doses) together with 500 g of triple super phosphate and 800 g of K_2SO_4 and with or without supplementation of micronutrients. The control group did not receive any fertilizers. The macronutrients (Fetrilon–Combi 2) were supplemented at the rate of 20 g per palm. The details of treatment combinations are given in Table I. The experiment was conducted over a period of three years. Each treatment was replicated three times. The fruit samples (three strands from each replication) were collected weekly at the early *"Rutab"* stage (the time when the fruit ripens & gets a soft structure due to pectin precipitation with a dark-honey or dark-red colour). The samples were kept in ice filled chest at the time of harvest and brought to the laboratory for analysis. The chemical characteristics of fruits included moisture, dry matter, total nitrogen total pectin, tannins, titeratable acidity and pH. The analysis was carried out according to the methods of AOAC (2000). The sugar fractions (glucose, fructose & sucrose) were determined by high performance liquid chromatography (HPLC) according to the method as described by Myhara *et al.* (1999) with slight modifications. The instrument was calibrated with freshly prepared standard solutions of glucose, fructose and sucrose. The statistical analysis of the data was done using the general linear model (GLM) and one-way analysis of variance (ANOVA) technique. The means were separated by least significant difference (LSD) and were compared using the Duncan's Multiple Range Test (Duncan, 1955) as described by Snedecor and Cochran (1989). The statistical analysis was performed with the help of statistical software package (SPSS v. 14).

RESULTS AND DISCUSSION

Effects of fertilizers. The results on the effect of different fertilizers treatments on the various chemical characteristics of two cultivars of dates are presented in Table II and III, respectively. Significant (P<0.05) differences were observed in the chemical characteristics and quality parameters of both the date cultivars on different fertilizer applications as compared to control. However some variability was observed in some of the chemical characteristics and quality parameters between both the date cultivars (Khalas & Khasab) on different fertilizer treatments. The highest dry matter content was observed in both the date cultivars when mineral fertilizers (NPK, in 4-N doses) were supplemented with organic peat and micronutrients (T-10). The lowest dry matter contents were observed in both the date cultivars when organic peat (T-2) was applied alone as compared to all other fertilizer treatments. There was a gradual decrease in the moisture content associated with increasing dry matter content (Table II & III). The uptake of nutrients by plants and the overall crop yields have been shown to increase when the chemical fertilizers were applied together with the organic fertilizers/compost (Kanal & Kuldkepp, 1993; Mottaghian *et al.*, 2008). The type of fertilizers and the doses of nitrogen application can also affect the yield and yield components (Das & Ghosh, 1993; Tuncturk & Yildrim, 2004). Our results support some of the earlier findings, which indicated the importance of supplementing the organic matter with mineral fertilizers to improve the fruit growth and yields (Al-Bakr, 1982; Bacha & Abo-Hassen, 1983; El-Mardi *et al.*, 1998a).

Variable results were observed in the glucose and fructose contents of Khalas and Khasab cultivars on

Table I. Summary of Fertilizers Treatment Combinations

Fertilizers Combinations	March	May	July	August	October	November	December	January-February
Control	-	-	-	-	-	-	-	-
Organic Peat (L)	-	-	-	-	-	40	-	40
Urea (g) (5-N)	200	200	-	200	200	-	200	-
TSP (g)	200	100	-	100	100	-	-	-
K_2SO_4 (g)	200	200	200	-	200	-	-	-
Urea (g) (5-N)	200	200	-	200	200	-	200	-
TSP (g)	200	100	-	100	100	-	-	-
K_2SO_4 (g)	200	200	200	-	200	-	-	-
Organic Peat (L)	-	-	-	-	-	40	-	40
Urea (g) (5-N)	200	200	-	200	200	-	200	-
TSP (g)	200	100	-	100	100	-	-	-
K_2SO_4 (g)	200	200	200	-	200	-	-	-
Micronutrients (g)	20	20	20	-	20	-	-	-
Urea (g) (5-N)	200	200	-	200	200	-	200	-
TSP (g)	200	100	-	100	100	-	-	-
K_2SO_4 (g)	200	200	200	-	200	-	-	-
Micronutrients (g)	20	20	20	20	20	-	-	-
Organic Peat (L)	-	-	-	-	-	40	-	40
Urea (g) (4-N)	250	250	250	-	250	-	-	-
TSP (g)	200	100	100	-	100	-	-	-
K_2SO_4 (g)	200	200	200	-	200	-	-	-
Urea (g) (4-N)	250	250	250	-	250	-	-	-
TSP (g)	200	100	100	-	100	-	-	-
K_2SO_4 (g)	200	200	200	-	200	-	-	-
Organic Peat (L)	-	-	-	-	-	40	-	40
Urea (g) (4-N)	250	250	250	-	250	-	-	-
TSP (g)	200	100	100	-	100	-	-	-
K_2SO_4 (g)	200	200	200	-	200	-	-	-
Micronutrients (g)	20	20	20	-	20	-	-	-
Urea (g) (4-N)	250	250	250	-	250	-	-	-
TSP (g)	200	100	100	-	100	-	-	-
K_2SO_4 (g)	200	200	200	-	200	-	-	-
Micronutrients (g)	20	20	20	-	20	-	-	-
Organic Peat (L)	-	-	-	-	-	40	-	40

different fertilizers applications. The highest values for glucose (27.6%) and fructose (28.7%) in Khalas cultivar were observed on T-4 (NPK 5-N doses + Organic peat), whereas the lowest values for glucose (20.1%) and fructose (19.9%) were observed in control group (T-1). The application of NPK in 5-N doses overall produced relatively 15.48% higher fructose and 12.2% glucose contents when compared with 4-N doses in Khalas cultivar. The levels of glucose and fructose in Khassab fruit however showed different responses on various fertilizer treatments as compared to Khalas (Table II & III). This may be attributed to cultivar characteristics. The ratio of sucrose to reducing sugars (glucose & fructose) is mainly controlled by cultivar characteristics. Most of the date cultivars in the Sultanate of Oman contain higher percentages of reducing sugars (glucose & fructose) at the final mature stage "Tamr" (ripe, sun-dried). This is attributed to the activities of invertase enzyme and it affects the firmness and storing ability of the date fruits (Cook & Furr, 1952; Myhara *et al.*, 1999; Al-Farsi *et al.*, 2005). The results of a taste panel evaluation indicated that there was an increase in sweetness of dates when 5-N NPK doses were applied. This may be attributed to the higher fructose contents of dates at 5-N doses as compared to 4-N doses. The sweetness of fructose is higher than that of sucrose and glucose.

The average pectin content of Khalas and Khasab was higher on 5-N doses as compared to 4-N doses (Table II & III). The pectin content is a strong indicator of fruit cell wall strength and the lower levels of pectin have been related to softness of fruits (Hassegawa *et al.*, 1972; El-Mardi *et al.*, 1998b). These results indicated that adaptability of Khassab in Al-Batinah region may not be only because of its dry matter contents but rather, because of its higher pectin and tannins contents. The pectin in dates accumulates during the period of fast growth of fruit to reach a maximum at the beginning of sugar accumulation and then drops with the further growth of fruit. The soluble pectins however keep on accumulating regularly until the date fruit reaches the Rutab stage. Although the activities of various degradative enzymes increase during the ripening process, they did not affect the degree of esterification of pectin suggesting that the pectin esterase enzyme is of minor importance in softening of these fruits (Mustafa *et al.*, 1986).

The application of organic peat alone (T-2) resulted in higher tannin contents in both the Khalas and Khassab cultivars as compared to all other treatments. A reduction was found in tannins with the application of NPK with or without micronutrients and organic peat as compared to organic peat and control. The supplementation of micronutrients showed relatively higher tannins with 5-N

Table II. Effect of Fertilizer on the Chemical Characteristics of Khalas Fruits

Fertilizers Combinations	Moisture (%)	DM (%)	Glucose (%)	Fructose (%)	Pectin (%)	Tannin (%)	TA (%)	pH
Control	68.99^{b}	31.01^{f}	20.1^{d}	19.9^{e}	5.80^{c}	0.039^{b}	1.29^{d}	5.55^{bc}
Organic Peat	71.13^{a}	28.87^{g}	23.0^{c}	22.0^{d}	8.55^{a}	0.052^{a}	1.13^{e}	6.36^{a}
NPK (5-N)	66.07^{c}	33.93^{e}	23.1^{c}	23.0^{d}	6.95^{b}	0.028^{c}	1.28^{d}	6.54^{a}
NPK (5-N)+Org	69.26^{b}	30.74^{f}	27.6^{a}	28.7^{a}	3.50^{d}	0.028^{c}	1.52^{c}	6.52^{a}
NPK (5-N)+Mic	69.70^{ab}	30.29^{f}	24.7^{b}	24.8^{c}	7.90^{ab}	0.013^{e}	1.36^{cd}	6.54^{a}
NPK (5-N)+Org +Mic	62.57^{d}	37.43^{d}	25.2^{b}	26.4^{b}	2.60^{e}	0.018^{de}	1.54^{c}	6.60^{a}
NPK (4-N)	56.32^{e}	43.68^{c}	24.2^{bc}	22.6^{d}	4.30^{d}	0.022^{cd}	1.41^{cd}	6.46^{a}
NPK (4-N)+Org	56.49^{e}	43.51^{c}	24.2^{bc}	22.6^{d}	3.75^{d}	0.026^{cd}	1.82^{a}	5.60^{b}
NPK (4-N)+Mic	49.33^{f}	50.67^{b}	20.9^{d}	22.2^{d}	3.15^{de}	0.020^{cd}	1.54^{c}	5.12^{c}
NPK (4-N)+Org +Mic	44.32^{g}	55.68^{a}	20.3^{d}	21.7^{de}	3.75^{d}	0.015^{e}	1.69^{ab}	5.88^{b}

a, b, c, d, e, f, g = Different superscripts in the same column means significantly different at 5%
NPK= Urea + Triple Super phosphate + Potassium sulphate
(4-N) and (5-N) = 4 and 5 Nitrogen doses
Mic = Micronutrients
Org. = Organic peat

Table III. Effect of Fertilizers on the Chemical of Characteristics of Khassab

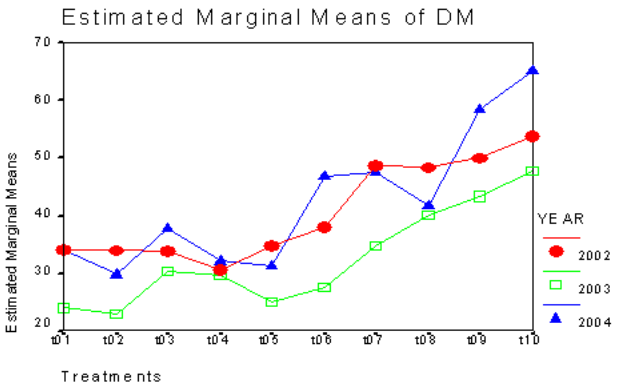
Fertilizers Combinations	Moisture (%)	DM (%)	Glucose (%)	Fructose (%)	Pectin (%)	Tannin (%)	TA (%)	pHz
Control	65.38^{a}	34.62^{f}	18.3^{c}	18.6^{d}	5.74^{b}	0.075^{ab}	0.15^{d}	7.36
Organic peat	62.27^{b}	37.73^{ef}	24.5^{b}	23.5^{b}	6.06^{ab}	0.076^{ab}	0.20^{cd}	7.45
NPK (5-N)	58.64^{c}	41.36^{de}	17.5^{d}	19.5^{d}	5.97^{ab}	0.061^{c}	0.20^{cd}	7.26
NPK (5-N)+Org	56.01^{cd}	43.53^{cd}	18.8^{cd}	20.4^{cd}	6.30^{a}	0.080^{a}	0.24^{c}	7.46
NPK (5-N)+Mic	59.06^{c}	40.94^{de}	20.0^{c}	21.6^{c}	5.79^{b}	0.069^{b}	0.26^{c}	7.53
NPK (5-N)+Org +Mic	57.03^{cd}	42.97^{cde}	18.2^{cd}	20.5^{cd}	5.64^{bc}	0.060^{c}	0.33^{b}	7.39
NPK (4-N)	54.19^{de}	45.81^{cd}	29.9^{a}	24.8^{b}	5.47^{c}	0.050^{d}	0.36^{b}	7.37
NPK (4-N)+Org	52.33^{e}	47.67^{bc}	25.4^{b}	26.9^{a}	5.92^{ab}	0.070^{b}	0.44^{a}	7.46
NPK (4-N)+Mic	50.06^{ef}	49.94^{ab}	17.1^{d}	18.3^{d}	5.93^{ab}	0.071^{b}	0.45^{a}	7.39
NPK (4-N)+Org +Mic	48.21^{f}	51.79^{a}	19.6^{c}	20.3^{cd}	5.81^{ab}	0.076^{a}	0.45^{a}	7.35

a, b, c, d, e = Different superscripts in the same column means significantly different at 5%
NPK= Urea + Triple superphosphate + Potassium sulphate
(4-N) and (5-N) = 4 and 5 Nitrogen doses
Mic = Micronutrients
Org. = Organic peat

doses as compared to 4-N doses. The tannin contents of Khassab were higher as compared to Khalas (Table II & III). During the early stages of maturity the concentration of tannins in dates is high but decreases with the progressive ripening of fruit. Myhara *et al.* (2000) reported that the tannin contents of Omani date cultivars (Khalas & Khasab) were the lowest at Rutab stage (ripe, soft). Our results are in line with these findings. The solubility characteristics of tannins change during the fruit development stages as a result of their association with certain proteins. The protein content of dates plays a role in the non-oxidative browning (Maillard Reactions) of dates and help in the precipitation of tannins during the ripening process (Barreveld, 1993). Tannins are therefore responsible for the dark colour of dates in the post-harvest period (Makki *et al.*, 1998). The balance between the soluble and insoluble tannins largely determines the edible stage of the fruit. Higher concentrations of tannins may render the date fruit inedible (Sawaya & Mashadi, 1983; Al-Redhaiman, 2004).

Mineral fertilizers application with or without the organic peat increased the levels of titeratable acidity (TA). The application of organic peat alone (T-2) resulted in the lower titerable acidity in both the cultivars as compared to all other fertilizer treatment combinations. Treatment combinations of NPK in 4-N doses with organic peat and

Fig. 1. Interaction Effects of Fertilizer x Year on dry matter content of Khalas



micronutrients produced significantly higher titerable acidity values as compared to NPK in 5-N doses with similar combinations. The pH values in Khalas differed significantly on various treatment combinations. However, the results for the pH values in Khassab on various fertilizer applications were non-significant (Table II & III). When the overall averages of various parameters on 4-N and 5 N doses were compared, the general trend indicated that 5-N doses produced lower dry matter and TA but higher

Fig. 2. Interaction Effects of Fertilizer x Year on dry matter content of Khassab

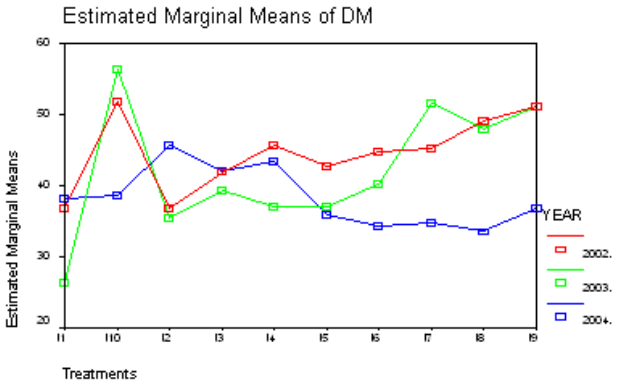


Fig. 3. Interaction Effect of Fertilizer x Year on Tannin contents of Khalas

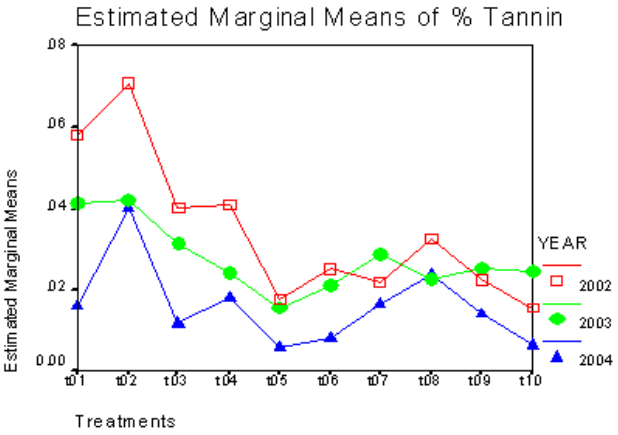
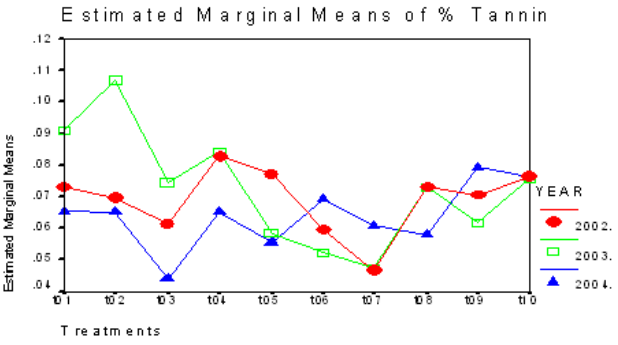


Fig. 4. Interaction Effect of Fertilizer x Year on Tannin contents of Khassab



glucose, fructose and tannin contents. These results suggest that the sugars and tannins received their carbonyl group from the available carbohydrates resulting in higher sugar contents in the fruit. Under such circumstances lower amounts were used for respiration, which may lead to accumulation of higher quantities of dry matter and organic acids (Faust, 1989). The date-fruits contain malic acid, which is produced during the Krebs cycle and its reduction

Fig. 5. Interaction Effect of Fertilizer x Year on Titeratable Acidity of Khalas

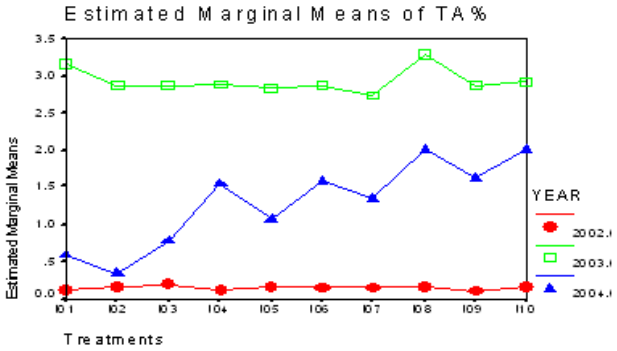
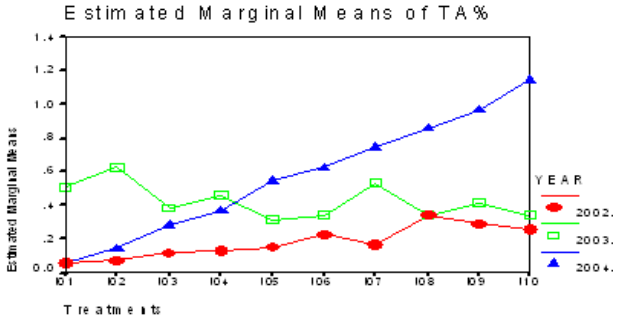


Fig. 6. Interaction Effect of Fertilizer x Year on Titeratable Acidity of Khassab



in the fruit indicates an increase in sugar contents. The observed differences between the various fertilizer treatments might have occurred due to variability in nitrogen and phosphorous at the 4-N and 5-N NPK doses. These results are in line with those reported by Gahgah *et al.* (1993). Hussein and El-Zeid (1977) however reported a reduction in the dry matter content with an increase in nitrogen fertilizer application. These results reflect the changes, which might have occurred in tree growth towards the vegetative growth rather than the reproductive growth, especially when they did not use N, P and K, which have a direct impact on photosynthesis and might increase the dry matter and total soluble solids (TSS). Such differences might also be due to cultivar and environmental differences. Fertilizer applications, between March and August, are considered important for the date fruit growth and development. During this period, the cells have a greater requirement of energy (adenosine triphosphate, ATP) to carry out the various metabolic processes viz. cell division and elongation (Al-Bakr, 1982; Jarrah, 1983).

Interaction effects of fertilizers and year on the dry matter of Khalas and Khassab. The interaction effects of fertilizers and year on the dry matter contents of both the Khalas and Khassab cultivars were highly significant (P<0.001) and are shown in Fig. 1 and 2, respectively. However, some variability did exist in the dry matter contents between both the cultivars during the three years

(2002-2004). The Khalas date fruits produced during the year 2003 showed lower dry matter contents as compared to 2002 and 2004, whereas the Khassab fruit showed higher dry matter contents in the year 2002 and 2003 compared to 2004. This may be attributed to improper pollination due to a number of factors such as non-compatibility of male pollens, or high temperatures, or high wind velocities, during these years, which might have caused low fruit set. In addition to this the Khalas palms entered into the cycle of alternate bearing (off–year). The general trend indicated that the application of 4-N doses of NPK, with or without the supplementation of micronutrients and organic peat, produced higher dry matter on the average over the three years period. The overall highest dry matter contents during the three years period were produced by application of 4-N doses of NPK when supplemented with micronutrients and organic peat (T-10).

Interaction effects of fertilizers and year on tannins of Khalas and Khassab. The interaction effects of fertilizers and year on the tannin contents of both the Khalas and Khassab cultivars were significant (P<0.05) and are shown in Fig. 3 and 4, respectively. However, some variability did exist in the tannin contents between both the cultivars during the three years (2002-2004) on various fertilizer applications. The tannin contents in Khalas fruit were lower during the year 2004 as compared to 2002 and 2003, whereas the Khassab fruit showed higher tannin contents during the year 2003 as compared to 2002 and 2004. Overall, the application of organic peat over a period of three years in both the cultivars increased the tannin contents, whereas the mineral fertilizers reduced it.

Interaction effects of fertilizers and year on the titeratable acidity of Khalas and Khassab cultivars. The interaction effects of fertilizers and year on the titeratable acidity contents of both the Khalas and Khassab cultivars were significant (P<0.05) and are shown in Fig. 5 and 6, respectively. However, some variability did exist in the titeratable acidity contents between both the cultivars during the three years (2002-2004) on various fertilizer applications. Consistently higher TA values were observed in Khalas fruit during the year 2003 as compared to the values in 2002 and 2004. However the trend in Khassab was different as compared to Khalas during the year 2004, which sowed a gradual increase in titeratable acidity. The high tannin content during year 2002 (Fig. 1) might have masked the effect of organic peat on TA values. Overall, the application of organic peat alone over a period of three years in both the cultivars showed the lowest titeratable acidity values, whereas supplementation with mineral fertilizers in 4-N doses produced higher TA values.

CONCLUSION

Overall the results of this study indicated that the application of organic peat alone resulted in higher tannin and pectin contents but lower titeratable acidity (TA) values in both the cultivars as compared to all other treatments. During the year 2004, both the cultivars showed lower pectin, tannin but higher dry matter and pH values as compared to the years 2002 and 2003. The interactions for the fertilizer application, year and stage of maturity were significant (P<0.05) for dry matter, tannins and titeratable acidity.

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Dedication. Dedicated to Late Dr. Mehdi Osman El-Mardi, who initiated this study. May Allah (SWT) bless his soul and rest him in piece.

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