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Influence of Alternate Bearing on Leaf and Fruit Mineral Composition at Different Developmental Stages of Date Palm Fruits

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تأثير ظاهرة المعاومة على محتوى سعف وثمار نخلة التمر من المعادن خلال
مراحل تطور الثمار

عثمان المرضي

الخلاصة: تم أخذ عينات السعف والثمار من نخلات الفرض تراوح عمرها بين 15 و 16 عاماً أثناء مراحل تطور الثمار المختلفة وكانت النخلات إما ذات حمل خفيف (6عذوق) أو ثقيل (8عذوق). جففت العينات ومن ثم رمدت وهضمت. تم تحديد تركيز(K, Ca, Mg, Na, Fe, Zn, Cu and Mn) باستخدام (ICP – AES) وتركيز النيتروجين بطريقة Kjeldhal. وجدت تغيرات بفروقات معنوية في تركيزات المعادن في السعف والثمار بين مرحلة الكمري (ثمار خضراء) والبسر (أحمر مصفر) تناقص تركيز (Mg) و (K) في السعف والثمار. كما تناقص (Ca) و (Na) في الثمار وازداد في السعف. لم تظهر فروقات معنوية في تركيز(Fe و Zn و Mn) بين مرحلتي تطور الثمار. بينما ازداد (Fe) قليلاً في السعف والثمار بين الكمري والبسر ونقص بين البسر والرطب (بداية ليونة الثمار). وقد وجد أن تركيز (Mg و Fe و Mn) كان أعلى في السعف عن الثمار بينما كانت تركيز (K و Zn و Cu) أعلى في الثمار. تزامنت أعلى تركيزات (Mg , Ca) في السعف عن الثمار مع أعلى تركيز (K) في الثمار عن السعف و ظهرت فروقات معنوية في تركيز (Fe, Mn, Ca) في الثمار و(K, Mg) في السعف بين النخيل ذات الحمل الخفيف وتلك ذات الحمل الثقيل أثناء مراحل تطور الثمار. ولكن النمط العام أثناء مرحلة الرطب (حيث تغير اللون إلى العســـلي مع ليونة الأنسجة) يدل على أن الخوص النخيل ذات الحمـــل الخفيف تحتوي على تركيزات أعـــــلى من (Mn, Cu, Zn, Fe, Mg, Ca, N) عن سعف النخيل ذات الحمل الثقيل. بينما كانت محتويات خوص النخيل ذات الحمل الثقيل أعلى في (Na, K) عن سعف النخيل ذات الحمل الخفيف. ولكن في مرحلة الرطب كانت تركيزات (Zn, Fe, Mg, Ca) مماثلة لتركيزاتها في سعف النخيل خفيفة الحمل. بينما كان تركيز (Na, K) أعلى في ثمار النخيل ذات الحمل الخفيف عن الخوص، بينما كان (Mn, Cu) أعلى في ثمار النخلات ذات الحمل الثقيل عن الخوص. تدل النتائج على الحاجة الى أستمرارية مثل هذا البحث.

ABSTRACT: Samples of leaflets and fruits at different stages were collected from 6 “on-palms” and 6 “off-palms” (15-16 years) of the Fard Cultivar. Samples were dried, ashed and digested. Macro and micronutrient concentrations of K, Ca, Mg, Na, Fe, Zn, Cu and Mg were determined by ICP-AES and N was measured by Kjeldhal method. Significant changes in the elemental concentrations of leaf and fruit occurred between *Kimri* (green color) and *Bisir* (yellowish-red color) development stages. Potassium and Mg concentration was reduced in leaf and fruit. Calcium and Na were reduced in the fruit and increased in the leaf. Iron, Zn and Mn were not significantly different between *Bisir* and *Kimi*. However, Fe in the fruit and leaf increased between *Kimri* and *Bisir* and decreased from *Bisir* to *Rutab* stages. The concentration of Ca, Mg, Fe and Mn was higher in the leaf than fruit. In contrast K, Zn and Cu were higher in the fruit. Higher Ca and Mg in leaves through the developmental stages were associated with higher concentration of K in the fruit than the leaf. These variations in the leaf and fruit elemental concentration were associated with physiological and biochemical changes during fruit development. Significant differences in the fruit elemental concentrations between the “on” (high yield producing) and “off” (low yield producing) palms during the developmental stages were in Ca, K, Mn and Fe and in the leaf in Mg and K. However, the general trend during *Rutab* (honey color, soft tissue) indicates that “off-palm” leaves have higher N, Ca, Mg, Fe, Zn, Cu and Mn than “on-palm” leaves. Potassium and Na were higher in the “on-palm” leaves than “off-palm” leaves. But in the fruit*, Rutab* Ca, Mg, Fe, and Zn content followed similar trends as in the “off-palm” leaves; in contrast to leaves, K and Na were higher in “off-palms” fruits and Cu and Mn higher in “on-palm” fruits. The results indicate the need for further research.

Keywords: Off-palm, on-palm, alternate bearing, physio-biochemical changes, Sultanate of Oman.

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Introduction

There is a growing concern about the bearing habit of some date cultivars which show fluctuations in yield, a phenomenon identified as alternate bearing. High yields of date palm in general are associated with low quality fruits, i.e. small fruit, high acidity and tannin and low sugars (Nixon and Crawford, 1942; Al Juburi, 1993; El Mardi *et al.,* 1995; Mekki *et al.,* 1998). How this phenomenon works is still not well understood, although in many cases it has been associated with depletion of carbohydrates and mineral nutrient reserves following a heavy cropping in the "on" year. Alternate bearing is also influenced by several factors, including the genetic make-up of the cultivar, biotic and abiotic stresses, and improper culture techniques during the "on" year (that is a year of high yield) (Jonkers, 1979; Batjar and Westwood, 1958).

Several attempts were made to minimize the effect of alternate bearing on the date palm through horticultural practices. Possible regulation of alternate bearing of date cultivar through maintaining balance between vegetative and reproductive growth have been reported by many researchers (Nixon, 1935 and 1936; Nixon, 1940; Swingle, 1925; Mathes and Bliss, 1942; Al Khateeb *et al*., 1993). Much of such work involved nutrition, especially nitrogen fertilizers, thinning of fruits and girdling. All these relate to the balance between vegetative and reproductive growth of the tree.

Understanding and control of alternate bearing seems more difficult in monocotyledonous plants than dicots. In dicots some branches could be "on" while others are "off" (Patrick, 1988 and 1991; Goren and Monselise, 1971). The alternate bearing phenomenon is controlled by growth regulators. It has been indicated that too high gibberellins in the flower bud inhibit its development. Thinning by daminozide and ethephon (auxin effect) can be used to help overcome biennial bearing (Faust, 1989).

Alternate bearing in the Fard cultivar is not in regular annual cycles, the interval between "off" and "on" status could be 1, 2 or 3 years (Nixon and Crawford; 1942, El Mardi *et al*., 1998). During these cycles there will always be competition between leaves and fruit for nutrients and carbohydrates. Loading and mobilization of these materials is expected to be regulated by the fruit and leaf developmental stages (Nixon and Wedding, 1956; Hassan *et al*., 1984; Mustafa, 1993; El Mardi *et al.,* 2002).

This research was intended to investigate the changes in mineral nutrients during fruit developmental stages in relation to alternate bearing in the Fard date cultivar.

Materials and Methods

Twelve date palms of the Fard cultivar, 15-16 years old were selected randomly from those grown at Sultan Qaboos University Campus for this study: six "on-year palms" and six "off-year palms" ("on-palm" has ≥ 8 bunches of fruits and "off-palm" has ≤ 6 bunches). Leaflet samples were collected from the same position (leaflet number 8 from top leaflet) along the rachis of leaves in the axil of which the bunches were born. Fruits were collected at three developmental stages: *Kimri* (green), *Bisir* (at cultivar characteristic color, yellowish-red), and Rutab (honey color and softening). All samples were washed with distilled water, dried and stored at –18 °°C pending analysis. Each treatment was replicated 6 times.

Leaf and fruit samples were digested by a dry ashing procedure (Jones *et al.,* 1991). After drying in the oven (105 °C), 1g sample was ashed in a muffle furnace (Gallenkamp, size 2) at 550 °C. The ash was moistened with few drops of de-ionized water, immersed in 3 ml conc. HCl and evaporated to dryness. The residue was dissolved in 5 ml of 2 M HNO_3, filtered through Whatman filter paper #41 into a 25 ml volumetric flask and diluted to volume with Millipore water. Similarly, a blank sample was prepared excluding the plant specimen. Concentrations of K, Ca, Mg, Na, Fe, Zn, Cu, and Mn were determined using inductively coupled plasma – atomic emission spectroscopy (ICP-AES) calibrated with spectrosol atomic absorption reference standards. Nitrogen was determined using the Kjeldhal method. Data were statistically analyzed using SPSS. Spearman's rank correlation coefficients were determined and means were separated using Duncan's Multiple Range test (Duncan, 1955).

Results and Discussion

Data in Table 1 shows the significant correlation coefficient for pairs of macro and micronutrients in the fruits by development stage. In *Bisir* stage Ca showed positive correlation with K (they increase or decrease together). A similar correlation was found between Na and K, but Fe and Mn were negatively correlated (one increases the other decreases). Likewise, K and Na

Table 1. Spearman's rank correlation coefficients that are statistically significant for pairs of macro and micro nutrient elements in date fruits and leaves by stages of fruit development.

	Stages of Development								
	Bisir			**Kimri**			**Rutab**		
	Element pairs	**Corr. Coefficient (rho)**	**P-value**	**Element pairs**	**Corr. Coefficient (rho)**	**P-value**	**Element pairs**	**Corr. Coefficient (rho)**	**P-value**
Fruit	Ca- K	0.811	< 0.01	K – Na	-0.580	<0.05	Mg – K	0.825	< 0.01
	Na – K	0.783	< 0.01				Mg – Na	0.637	< 0.05
	Fe – Mn	-0.651	< 0.01				Mg – Zn	0.609	< 0.05
							Mg – Mn	0.608	< 0.05
							K – Mn	0.832	< 0.01
Leaf	Mg – K	0.783	< 0.01	K – Mn	0.690	< 0.05	K – Mg	0.797	< 0.01
	Mg – Fe	0.615	< 0.05	Cu – Zn	0.793	< 0.01	K – Na	0.625	< 0.05
	Na – Zn	0.660	< 0.05	Mn – Fe	-0.634	< 0.05	K – Mn	0.937	< 0.01
							Mn – Mg	0.720	0.01 >

were negatively correlated *in Ki*mri st*a*ge. *In Ru*tab Mg was positively correlated with K, Na, Zn, Mn and K was positively correlated with Mn.

All the detected correlations were positive in the leaves during the three developmental stages, except for Mn and Fe which were negatively correlated. Positively correlated pairs include K and Mg during *Bisir* and *Rutab*, K and Mn during *Kimri* and *Rutab* stages. Magnesium, Fe, Na and Zn during *Bisir;* Cu, Zn, Mn and Fe during *Kimri*; and K, Na, Mn and Mg during *Rutab* stage.

The general trend of mineral concentration indicates that, of the macronutrients, only Mg and K, and Ca and K were correlated positively in the fruit during the *Rutab* and *Kimri* stages, respectively. Whereas Mg in leaf correlates to Fe during *Bisir* and to Mn during *Rutab*, K correlates with Mn in *Kimri* and *Rutab* stages. In addition, K and Mg were the main macronutrients which influenced the concentration of Ca and Na. Potassium and Mg are known to be highly soluble and move freely in the plant body (El Mardi *et al.,* 1995b) and this could be the explanation for the high correlation to other minerals within the plant body.

Effect of fruit developmental stages on the macro and micronutrients concentrations of the fruit and leaf

Table 2 shows the levels of the concentrations of the macro and micronutrient elements in the fruit and leaf, for the three fruit developmental stages (*Kimri, Bisir* and *Rutab*). The concentrations of Ca, Mg, K and Na showed a significant reduction from the *Kimri* to the *Bisir* fruit stages (Table 2). These results are in partial agreement with Sawaya *et al.* (1982), Clark and Smith (1990), Bacha *et al.* (1993) and Al Juburi, (1995). In contrast, the present results showed a slight but not significant increase in the concentration of Mg and Na and a significant increase in Ca and K from *Bisir* to *Rutab* stages, whereas Sawaya *et al.* (1982) and Al Juburi *et al*. (1994), showed a continuous reduction in these elements from *Bisir* to *Rutab* stages.

Similar trends for Mg, and K levels were found in fruits and leaves (Table 2); they were significantly higher in *Kimri* stage than in *Bisir* and *Rutab* stages in both samples. However, Na concentration was not significantly different between these stages in the leaf, but it was significantly higher in the *Bisir* stage of fruit. On the other hand, Ca showed a significant increase from *Kimri* to *Bisir* stages followed by a reduction in *Rutab* stage (Table 2). These results are partially compatible with those from Bacha *et al.* (1993) and Al Juburi (1995).

Magnesium is a component of chlorophyll, thus its concentration is expected to decrease as the fruit changes in color from the *Kimri* stage, which is dark-green, to the reddish-yellow *Bisir* stage. Its

Table 2. Mean concentrations of macro and micro nutrient elements and sodium in the date fruit and leaf during its developmental stages (mg/kg).

Concentration	Stages of Development					
	Kimri		Bisir		Rutab	
	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf
Ca	1005.0a	2012.0b	548.0c	3425.0a	717.0b	2534.0b
Mg	1501.0a	2123.0a	805.0b	1254.0c	941.0b	1574.0b
K	6723.0a	3557.0a	4365.0c	1875.0c	5458.0b	2490.0b
Na	173.0a	121.0a	39.0b	135.0a	70.0b	127.0a
Fe	6.1c	70.7b	154.8a	143.7a	92.4b	32.9c
Zn	2.3a	1.5a	5.4a	4.4a	3.7a	1.4a
Cu	2.9a	1.6a	1.6a	1.6a	2.7a	1.1a
Mn	4.9a	9.1a	5.2a	8.8a	2.9a	7.4a

Means followed by the same letter are not significantly different at .05 level, based on Duncan's Multiple Comparison Test.

concentration in the Kimri fruit was about twice that in *Bisir* (Table 2). The pH of the date fruit is known to increase as the fruit develops from the *Kimri* stage, which has higher acidity than either the *Bisir* or *Rutab* stage (Rygg, 1946; Rouhani and Bassiri, 1976; El Shurafa *et al.,* 1982: El Mardi *et al.,* 1995). Such an increase in *Rutab* pH could have an inhibitory effect on K and Na; thus, they are at lower levels in the *Rutab* stage than in *Kimri (*Table 2). The high K in *Kimri* fruits relative to Fe (1120 times) could be attributed to the higher acidity in these fruits compared to that in the later stages. Titratable acidity in this cultivar is 1.25, 0.74 and 0.64 % during *Kimri, Bisir* and *Rutab*, respectively (El Mardi *et al.,* 1995). Such a relationship between K and Fe has also been found in apples (Faust, 1989).

Except for Fe in the fruit and leaf (Table 2), none of the micronutrient elements was significantly different between stages. In fruits iron was significantly higher in *Bisir* than in *Rutab* and *Kimri*. A similar trend was observed in the leaf. But Fe in the fruit during *Rutab* was significantly higher than during *Kimri,* whereas in the leaf it was higher in the *Kimri* than *Rutab* stage. Copper in fruit was not significantly different between stages, but it was higher in *Kimri* and *Rutab* than *Bisir*. Copper is an important element in the synthesis of anthocyanin, and so it is expected to be utilized for that purpose during the color development of *Bisir* (Ibrahim and Khileif, 1993).

Insignificant differences between the concentrations of these micronutrients during the three developmental stages in leaves and fruits of date palms indicate that their ratios to macronutrients and to each other could be of more significance than their individual quantities, as indicated above by the relationship between K and Fe, and K and Cu.

Table 2 shows that during the *Kimri* stage Ca, Mg, Fe and Mn in the leaf were higher than in the fruit, while K was higher in the fruit in the 3 stages and Cu was higher in the fruit than in the leaf during the *Kimri* and *Rutab* stages. These results support the opinion of sink power of fruit to K to be the same as to carbohydrates, thus it accumulates in greater quantities in the fruit throughout its developmental stages (Hansen, 1980). During *Bisir* and *Rutab,* Ca, Mg, K, Zn, Cu and Mn have similar trends as during Kimri (leaf > fruit). However, Na and Fe fluctuated in the different stages. Sodium was slightly higher in the fruit during *Kimri*, but in *Bisir* and *Rutab* it was much higher in the leaf. This is more likely related to the increase in sugar concentration during these stages causing an increase in the fruit osmotic pressure. This will cause Na to concentrate more in the leaf or move from the fruit back to the leaf. Iron was much higher in the leaf during *Kimri*, but slightly lower during *Bisir* and *Rutab*. There was mobility of Fe from the leaf to the fruit at the later stages of development, as indicated by its reduced concentration in the leaf and increased concentration in the fruit. Results of changes in fruit Na and Fe concentration found here are in agreement with those obtained by Sawaya *et al.* (1983) and Ibrahim and Khileif (1993). However, the concentration of Fe and Na during *Kimri* was lower in the present study, which could be considered an indication of Fe deficiency.

There is accumulating evidence that higher Ca and Mg in leaves throughout the developmental stages of different kinds of fruits is consistent with lack of Ca mobility in plants relative to K (Batjar and Westwood, 1958; Pichioni *et al.,* 1997; Van Goor and Van Lune, 1980; El Shurafa, 1984). Several studies have shown that K decreases in leaf during cropping while Ca and Mg are increasing (Pichioni *et al.,* 1997; Bould,1966; Diver *et al.,* 1984; Weinbaum *et al.,* 1994). Results in Table 2 confirm these results.

In deciduous fruit trees, such as apple and peach, leaves are annual (Batjar and Westwood, 1958). However, in date palms the leaf remains physiologically active for more than three years, then dries out and is pruned. Evidently this difference contributes to the variable trend of the nutrient element during fruit and leaf development. When the leaves in deciduous fruit trees reach full maturity, some of the nutrient elements, especially K, Mg and Ca, will be transferred to the branches before the leaf fall. But in the date palm the inflorescence first appears in the axil of the mature leaf (one-year old), which is still active in nutrient uptake. Thus, Ca, Mg, Na and Mn are always higher in the leaf than in the fruit. On the other hand, K, Zn and Cu were relatively higher in the fruit throughout its developmental stages.

Accumulation of Ca, Mg and K in the leaves amounted to 2.0X, 1.4X and 0.53X, respectively its concentration in the fruit during the *Kimri* stage of the date palm (Table 2). These ratios in pistachio during spring flush, which represent the *Kimri* stage in dates, were: 9.5X, 5.3X and 0.80X, respectively (Piechioni *et al.,* 1997). The trend of elemental distribution is similar, i.e. Ca > Mg > K, but the amount accumulated in leaves of pistachio was much higher than in date palm leaves. During seed fall (representing fruit maturation) of pistachio fruit, the ratios of leaf to fruit content of these elements were: 7.7X, 3.7X and 0.62X, respectively, whereas for the *Bisir* (representing date fruit maturation) they were: 6.3X, 1.5X and 0.43X, respectively. Thus, the previous trend was maintained. However, the ratios of the three elements in pistachio were lower than during the spring flush period. By contrast Ca and Mg ratios were higher and the K was lower in the date palm during *Bisir* than in *Kimr*i stage.

These results indicate that during maturation (seed fall) there was a reduction in leaf/fruit elemental concentrations in pistachio, which had been attributed to a seasonal increase in leaf mass (Marini and Marini, 1983) rather than reduction in concentration. By contrast, an increase in leaf/fruit elemental concentration for Ca and Mg and a reduction for K were observed in the date palm.

The date palm does not enter dormancy and the leaves used in this study were mature, being at least one-year old. These leaves accumulated more Ca and Mg with an increase in age. Calcium is known to be less mobile from one organ to another relative to K, which migrates from leaf to fruit as it matures (Batjar and Westwood, 1958; Piechioni *et al.,* 1997).

The date palm leaves tend to lose 65% of their photosynthetic efficiency after the second year (Nixon and Wedding, 1956); during the three stages of fruit development they tend to accumulate Mg and high chlorophyll concentrations. Moreover, many of the enzymes involved in carbohydrate metabolism require magnesium as an activator.

Effect of alternate bearing phenomenon on the mineral content of leaves and fruits

The effect of alternate bearing on fruit and leaf minerals concentrations during the three stages is shown in Table 3.

Data in Table 3 were collected during the three development stages. *Rutab* is considered the harvestable stage of this cultivar in the study area. Therefore, the concentration of minerals in these stages is more likely to influence their concentration in the next season, and they were also being influenced by their concentration in the previous season. In the fruit, Ca was significantly higher in the “on-palm” than the “off-palm” during *Kimri,* whereas, K, Fe and Mn during *Bisir,* and Fe during *Rutab* were significantly higher in the “off-palm”. On the other hand, Mg in the leaf was higher in the “off-palm” during *Rutab* and K was higher in the “off-palm” during *Kimri.* These results indicate that during the experimental season major changes occurred in minerals involved in fruit pigmentation and taste (Rouhani and Bassiri, 1976; Rygg, 1946). However, the general trend indicates that

Table 3. Mean concentrations of minerals in the fruit and the leaf during the three stages of development for alternate bearing years of the Fard date cultivar (mg/kg).

	Stages of Development											
	Kimri				Bisir				Rutab			
	Fruit		Leaf		Fruit		Leaf		Fruit		Leaf	
	Bearing Year		Bearing Year		Bearing Year		Bearing Year		Bearing Year		Bearing Year	
	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off
Ca	1041.3a	969.2b	2075.4a	1948.8a	537.1a	558.8a	3509.6a	3341.3a	709.2a	724.6a	2491.3a	2575.8a
Mg	1515.4a	1487.5a	2155.8a	2088.3a	765.0a	844.2a	1209.2a	1297.9a	906.3a	976.3a	1433.3b	1714.6a
K	6666.7a	6779,2a	3446.7b	3666.7a	3704.2b	5025.0a	2172.1a	1576.3b	5325.0a	5591.8a	2556.7a	2424.2a
Na	180.5a	165.3a	116.1a	126.6a	43.4a	35.5a	136.4a	133.9a	66.4a	74.0a	132.2a	121.9a
Fe	6.8a	5.3a	74.1a	67.3a	6.6b	302.9a	7.5a	1.3a	8.5b	176.4a	27.9a	37.9a
Zn	1.7a	2.8a	1.1a	1.9a	6.0a	4.5a	7.5a	1.3a	1.2a	6.2a	0.6a	2.2a
Cu	2.8a	3.1a	1.5a	1.7a	2.0a	1.3a	2.0a	1.2a	3.4a	1.9a	0.4a	1.8a
Mn	5.2a	4.6a	9.3a	8.9a	2.2b	8.2a	9.6a	7.9a	3.7a	3.1a	7.2a	7.7a

Means in the same column for each stage with the same letter are not significantly different at the 0.05 level, based on Duncan's .Multiple Comparison test

the concentration of N is 13.3 % higher in leaves of the "off-palm" than "on-palm" indicating that the growth pattern in the "off-palms" was to a greater extent of a vegetative nature (data not shown in the tables). Ca, Fe, K and Mn were slightly higher in the leaves of "on-palms" during *Kimri* and *Bisir*. But during *Rutab* Ca, Mg, Fe, Zn, Cu and Mn were higher in the off-year leaves than on-year. On the other hand, in the fruit Ca, Mg, K, Na, Fe and Zn during *Rutab* were higher in the "off-year palm" than "on-year palms", whereas, Cu and Mn were higher in the "on-year palm" fruits. Note that "on-year palms" carried an average 8 bunches (8.0 kg/bunch) and the "off-year palms" carried 6 bunches (7.4 kg / bunch).

These results are comparable to those obtained in pecan (Sparks, 1977); pistachio (Pichioni, 1997), citrus (Monselise *et al.*, 1983) and 'French' prune (Weinbaum *et al.,* 1994). The lower K concentrations in the leaves of "off-palms" in spite of their lower yield, indicate that these palms were probably deficient in this element.

The concentrations of K, Mn, Na and Cu in the fruit during *Rutabs* showed an opposite trend than in the leaves of the same stage: K and Na were higher and Cu and Mn were lower in the fruits of "off-palm" than those of the "on-palm".

These results indicate that alternate bearing can influence the concentration of N, K, Mg, Cu, Fe and Zn in date palms. Regular fertilization with these minerals could be an effective practice to minimize the effect of alternate bearing on the date palm. But one season may not be sufficient to show the influence of alternate bearing on the mineral concentration in leaves and fruits. In this respect further study is needed for an extended period.

Conclusion

Alternate bearing showed significant effects on the concentration of Ca, K, Mn Fe in the fruit during one or more development stages; and in the leaf only in Mg and K. The results showed inconsistent variations in the minerals concentration in the fruit and leaf from "on-year" and "off-year" date palms. This indicates the need for experimentation over more than one season to verify the influence of alternate bearing on the mineral composition of the three developmental stages of the date fruit.

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