I. Effect of Fertigation With Nitrogen and Potassium on Vegetative Growth, Yield and Leaf Mineral Content of "Washington" Navel Orange Trees Grown in Sandy Soils

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ABSTRACT

The present investigation was carried out during 2000 and 2001 seasons, in order to study the effect of fertigation with nitrogen and potassium on vegetative growth, fruit set, fruit drop, yield and leaf mineral content of "Washington" Navel orange trees grown in sandy soils.

The main results can be summarized in the following points:

1. Average shoot length, leaf chlorophyll content, fruit set percentage, yield per tree, leaf N, K, Fe, Zn and Mn contents significantly increased with increasing drip irrigation, nitrogen and potassium fertilization rates, in both seasons.
2. Fruit drop percentage significantly decreased with increasing drip irrigation, nitrogen and potassium fertilization rates, in both seasons.
3. Increasing drip irrigation rate significantly increased leaf P, Ca and Mg contents, whereas increasing potassium fertilization rate significantly decreased leaf Ca and Mg contents. On the other hand, increasing nitrogen fertilization rate significantly decreased leaf P content, in both seasons.

INTRODUCTION

Citrus is considered the first economic fruit crop in Egypt. The total *Citrus* cultivated area in ARE reached 355518 feddans producing 2465813 tons of fruits annually according to the statistics of the Ministry of Agriculture and Land Reclamation, Cairo, 1999.

Oranges are considered the most important *Citrus* crop. "Washington" Navel orange is one of the leading varieties, for local market and especially export.

The newly reclaimed sandy soils have been recently considered as the main area for *Citrus* plantation extensions out of the Nile Valley such as mandarins, limes and oranges. Such sandy soils have low water-holding capacity and low native fertility levels, thus trees respond well to frequent irrigation and fertigation (Smajstrla, 1993).

Nitrogen has been the primary nutrient element recommended for growth and yield of *Citrus* trees. Potassium is one of the essential elements in nutrition of *Citrus* trees that needs to be added regularly in the fertilizer.

Nitrogen and potassium are quantitatively the most common fertilizers applied in Egypt, especially in new reclaimed soil.

Addition of soluble fertilizers to irrigation water (fertigation) has attracted increasing research attention in major fruit growing in lack water source. Fertigation management can minimize nitrate leaching (Hartz, 1994).

Moreover, the informations about the effect of drip irrigation and nitrogen, potassium fertilization on vegetative growth and productivity of "Washington" Navel orange trees are lacking.

Therefore, the objective of this work was to determine the suitable rates of added nitrogen and potassium fertilizers and annual amount of irrigation water required by fruiting "Washington" Navel orange trees through drip irrigation and grown in sandy soil to assess their effect on vegetative growth, yield and leaf mineral contents.

MATERIALS AND METHODS

The present investigation was carried out during 2000 and 2001 growing seasons on 12 years old trees of "Washington" Navel orange (*Citrus sinensis*, Osbeck) budded on sour orange rootstock (*Citrus aurantium L.*) and spaced at 5 x 5 meters apart (168 trees/feddan). Trees were selected (at random) to be as uniform as possible in growth and productivity. They were grown in a sandy soil, in a private orchard at El-Nubaria region, Beheira Governorate, in order to study the effect of three drip irrigation treatments combined with three nitrogen and three potassium fertilization rates on the vegetative growth, fruit set, fruit drop, yield and leaf mineral content. Soil and irrigation water were analyzed according to the method of Chapman and Pratt (1961). The physical and chemical analysis of the soil of experimental orchard were determined before starting these experiments.

The percentages of sand, clay and silt were 87.3%, 9.1% and 3.6%, respectively. The chemical analysis of the top 40 cm. of soils sampled from under the trees was as follows: pH = 7.8 , EC = 2.6 (ds/m), lime = 8.6% and HCO_3 = 0.7 (meq./1). The chemical analysis of irrigation water indicated that pH was 7.6 and EC = 1.4 (ds/m). The organic manure samples were taken yearly in November, dried and chemically analyzed. The average N, P, K, Ca and Mg content of manure was 1.66 – 1.70, 0.70 – 0.72 , 0.76 – 0.78, 2.86 – 2.90 and 1.24 - 1.28% , respectively, on the dry weight basis through 2000 and 2001 years. The corresponding values of Fe, Mn, Zn and Cu ranged from 540 – 548 , 28 – 32 , 120 – 126 and 46 – 50 ppm, respectively. Annually, all trees received organic manure fertilization at the rate of 20 m^3 per feddan in December. Two foliar sprays of chelated Fe, Mn and Zn were applied in April and September in each season. The experimental trees received the same horticultural practiecs as usually done in this orchard.

The drip irrigation treatments involved three application rates using 3000 (I_1), 4500 (I_2) and 6000 (I_3) m^3 of water /feddan/year. Application methods included drip irrigation with 2,3 and 4 drippers (each of 4 L/h discharge) per tree according to the irrigation rate. Irrigation uniformity was achieved by fixing the daily period of irrigation for all the tested rates. Moreover, number of irrigation days/month ranged from 20 in spring, autumn and winter to 25 in summer.

Fertigation treatments were yearly imposed from March till September. Three rates of nitrogen fertilizer (ammonium sulphate, 20.6% N), i.e. 75.6 (N_1), 151.2 (N_2) and 226.8 (N_3) Kgs N/fed./yr., were injected through 2, 3 and 4 drippers (with the same N solution concentration), respectively. Also, three rates of potassium fertilizer (potassium sulphate, 48% K_2O), i.e. 0.0 (K_1), 58.8 (K_2) and 117.6 (K_3) Kgs K/fed./yr., were injected through 2,3 and 4 drippers (with the same K solution concentration), respectively. Each considered nitrogen or potassium fertilizer rate was divided into fourteen equal applications at two weeks intervals.

Shoot length was used as index to the vegetative growth. In the spring of both seasons, 20 non-fruiting shoots were tagged around each tree and their lengths were measured in November. For the determination of leaf chlorophyll and mineral contents, leaf samples were taken at random from the medium part of the tagged non-fruiting shoots and at all directions of each tree. Each leaf sample consisted of 30 leaves. Leaf samples were taken on the first of October in both seasons according to Chapman (1960). Each leaf sample was washed with tap water, rinsed with distilled water.

A proportion of each leaf sample was saved fresh, whereas the rest was weighed, dried at 65 °C in oven till a constant weight and then ground.

In the fresh leaf material of each sample, chlorophyll content was determined according to the method of Torrecillas *et al.*, (1984).

The dried leaf samples were digested with sulfuric acid and hydrogen peroxide, as outlined by Evanhuis and De Waard (1980). Suitable aliquots were then taken for the determination of mineral elements. Nitrogen and phosphorus were determined colorimetrically according to Evanhuis (1976) and, Murphy and Riley (1962), respectively. Potassium was determined by Flame photometer, calcium, magnesium, iron, manganese and zinc by Perkin Elmer atomic absorption spectrophotometer.

To determine fruit set, four limbs were tagged on each experimental tree; the total numbers of flowers on each limb were counted at full bloom. The numbers of set fruitlets were counted on the same limbs by the end of flowering period. Fruit set percentage was calculated as follows:

$$\text{Fruit set percentage} = \frac{\text{Number of set fruitlets}}{\text{Total number of flowers}} \times 100$$

For fruit drop determination, the number of fruits retained on the tagged limbs till harvest time were counted and consequently numbers of dropped fruits were calculated as follows:

$$\text{Fruit drop percentage} = \frac{\text{Number of dropped fruits}}{\text{Number of set fruitlets}} \times 100$$

At harvest time, mid December of 2000 and 2001, the fruit yield of each tree was recorded as Kgs fruits per tree.

Twenty-seven treatments, representing all the possible combinations of the three rates of irrigation water (3I), three levels of nitrogen fertilizer (3N), and three levels of potassium fertilizer (3K), were used in this investigation (3 I x 3 N x 3 K = 27 treatments). The main factor was the irrigation rates, submain factor was nitrogen fertilization levels and sub-submain factor was potassium fertilization levels.

The experiment was arranged in split-split plot in a randomized complete block design with 5 replicates for each treatment, using one tree as a single replicate (27 treatments x 5 replicates = 135 trees). All data were subjected to statistical analysis according to Steel and Torrie (1980). The trial was repeated for two consecutive seasons (2000 and 2001) using the same selected trees.

RESULTS AND DISCUSSION

1. Shoot length

Concerning the effect of drip irrigation rates on the average shoot length, regardless of nitrogen and potassium fertilization, the results indicated that the average shoot length showed a tendency for positive responses to irrigation rates, in both seasons. The differences among the three irrigation rates were not big enough to be significant (Table 1). In accordance with these results, are those reported by Marler and Davies (1990), who found that the shoot length of "Hamlin" orange trees significantly increased with increasing irrigation levels. However, Ghaly *et al.*, (1994) reported that the vegetative growth of five *Citrus* rootstocks increased with increasing irrigation rates. Similarly, Nakhlla *et al.*, (1998) found a positive relation between irrigation water and the vegetative growth of "Washington" Navel orange trees. In addition, El-Wazzan *et al.*, (2000) reported that shoot length responded positively and significantly to the amount of irrigation water applied to "Valencia" orange trees.

Regarding the effect of nitrogen fertilization on the average shoot length, regardless of drip irrigation rates and potassium fertilization, the average shoot length showed a tendency for positive responses to nitrogen fertilization. The significant difference was found between N_3 or N_2 and N_1, in both seasons (Table 1). These findings agreed with those obtained by Dasberg and Erner (1997), who stated that fertigation of nitrogen positively affected vegetative growth characters of Mineola Tangelo trees. Similarly,Nakhlla *et al.*, (1998) found a positive correlation between N application and the vegetative growth of "Washington" Navel orange trees. However, Ezz and El—Kobbia (1999) found that shoot length of Balady mandarin trees significantly increased with increasing applied N rate. In addition, Kouka *et al.*, (2000) reported that the high rate of N fertilization increased the vegetative growth of Balady orange trees. On the other hand, Swietlik (1992) found that vegetative growth of grapefruit trees was not affected by nitrogen fertilization.

As for the effect of potassium fertilization on the average shoot length, regardless of drip irrigation rates and nitrogen fertilization, the data represented in Table (1) indicated that the differences among the three rates of potassium fertilization were not big enough to be significant, in the first season. While, K_3 significantly increased the average shoot length, as compared with K_2 and K_1 rates, in the second season. These results were in accordance with those found by Ibrahim (1993), who stated that fertigation of K was effective in improving vegetative growth characters of "Valencia" orange trees. In addition, Kouka *et al.*, (2000) reported that the high rate of potassium fertilization increased the vegetative growth of Balady orange trees.

2. Leaf chlorophyll content

Concerning the effect of drip irrigation rates on the leaf chlorophyll content, regardless of nitrogen and potassium fertilization, the results indicated that I_3 significantly increased the leaf chlorophyll content, as compared with the other irrigation rates, in both seasons (Table 1). These results are in agreement with those reported by Abd El-Messeih (2000), who found that leaf chlorophyll content of "Anna" apple trees significantly increased with increasing irrigation rate.

Regarding the effect of nitrogen fertilization on the leaf chlorophyll content, irrespective of the effect of drip irrigation rates and potassium fertilization, the results represented in Table (1) indicated that N_3 had the significantly higher leaf chlorophyll content, followed by N_2, as compared with N_1 rate, in both seasons. These results were in accordance with those found by Ezz and El-Kobbia (1999), who reported that leaf chlorophyll content markedly increased with increasing applied N rate to Balady mandarin trees.

As for the effect of potassium fertilization on the leaf chlorophyll content, regardless of drip irrigation rates and nitrogen fertilization, the results represented in Table (1) indicated that leaf chlorophyll content showed a tendency for positive responses to potassium fertilization. The significant difference was found between K_3 and K_2 or K_1, in the first season, and between K_3 or K_2 and K_1, in the second season.

3. Fruit set percentage

The data in Table (1) representing the effect of drip irrigation rates on the fruit set percentage, regardless of nitrogen and potassium fertilization, indicated that fruit set percentage showed a tendency for positive responses to irrigation rates. The significant differences were found between I_3 and I_2 or I_1, in the first season, and between I_3 or I_2 and I_1, in the second season. These results were in accordance with those reported by Nakhlla *et al.*, (1998), who found a positive correlation between irrigation water and fruit set in "Washington" Navel orange trees.

As for the effect of nitrogen fertilization on the fruit set percentage, irrespective of the effect of drip irrigation rates and potassium fertilization, the data presented in Table (1) showed that there was a significant increase in the fruit set percentage between N_3 and N_2 or N_1, during both seasons. These findings agreed with those obtained by Nakhlla *et al.*, (1998), who found a positive relation between N application and fruit set in "Washington" Navel orange trees. In addition, Kouka *et al.*, (2000) reported that the high rate of N fertilization increased fruit set of Balady orange trees.

Concerning the effect of potassium fertilization on the fruit set percentage, regardless of drip irrigation rates and nitrogen fertilization, the results indicated that, potassium fertilization increased the fruit set percentage. K_3 or K_2 rate significantly increased the fruit set percentage, as compared with K_1 rate, in both seasons (Table 1). Similar results were reported by Kouka *et al.*, (2000), who found that the high rate of potassium fertilization increased fruit set of Balady orange trees.

4. Fruit drop percentage

The data in Table (1) showing the effect of drip irrigation rates on the fruit drop percentage, regardless of nitrogen and potassium fertilization, indicated that fruit drop percentage showed a tendency for negative responses to irrigation rates. There was a significant increase in the fruit drop percentage for I_1 rate, comparing with the other irrigation rates, in both seasons.

As for the effect of nitrogen fertilization on the fruit drop percentage, irrespective of the effect of drip irrigation rates and potassium fertilization, the results revealed that N_1 significantly increased the fruit drop percentage, as compared with the other N rates, in both seasons (Table 1). These results were in accordance with those reported by Kouka *et al.*, (2000), who found that the high rate of N fertilization decreased fruit drop in Balady orange trees.

Concerning the effect of potassium fertilization on the fruit drop percentage, regardless of drip irrigation rates and nitrogen fertilization, the data listed in Table (1) indicated that the fruit drop percentage showed a tendency for negative responses to potassium fertilization. In the first season, there was a significant increase in the fruit drop percentage for K_1 rate, comparing with the other K rates, while in the second season, no significant differences were found between the three rates of potassium fertilization. These results are in general agreement with those obtained by Kouka *et al.*, (2000), who found that the high rate of K fertilization decreased fruit drop in Balady orange trees.

5. Yield

As for the effect of drip irrigation rates on the yield per tree, irrespective of the effect of nitrogen and potassium fertilization, the results indicated that the yield per tree increased, as the rate of irrigation water increased, in both seasons. There was a significant increase in the yield per tree between I_3 or I_2 and I_1, during the two seasons (Table 1). The same findings, also, were reported by Nakhlla *et al.*, (1998), who found a positive relation between irrigation water and yield of "Washington" Navel orange trees. In addition, El-Wazzan *et al.*, (2000) found that the yield of "Valencia" orange trees increased gradually as the amount of irrigation water increased.

Concerning the effect of nitrogen fertilization on the yield per tree, regardless of drip irrigation rates and potassium fertilization, the results indicated that the N_3 rate significantly increased the yield per tree, as compared with the other N rates, in the both seasons (Table 1). These results are agreement with those obtained by Alva and Paramasivam (1998), who found that the yield of "Hamlin" orange trees increased with increasing N levels. In the meantime, Nakhlla *et al.*, (1998) found a positive correlation between N application and yield of "Washington" Navel orange trees. However, Ezz and El-Kobblia (1999) found that increasing N rate markedly increased fruit yield of Balady mandarin trees. In addition, Kouka *et al.*, (2000) reported that the high rate of N fertilization increased the yield of Balady orange trees.

The data in Table (1) representing the effect of potassium fertilization on the yield per tree, regardless of drip irrigation rates and nitrogen fertilization, indicated that potassium fertilization tended to increase the yield per tree. K_3 or K_2 rate significantly increased the yield per tree, as compared with K_1 rate, in both seasons. Similarly, Abd El-Migeed (1996) found that yield of "Washington" Navel orange trees was gradually increased as the rate of K fertilization increased. However, Kouka *et al.*, (2000) found that the high rate of K fertilization increased the yield of Balady orange trees. In addition, El-Shobaky and Mohamed (2000) found that potassium fertilization is important to increase the yield of "Washington" Navel orange trees.

Table 1. The effect of drip irrigation, nitrogen and potassium fertilization treatments on the shoot length, leaf chlorophyll content, fruit set and fruit drop percentages, and yield of "Washington" Navel orange trees in 2000 and 2001 seasons.

Treatment	Average shoot length (cm)	Leaf chlorophyll content(mg/100g)	Fruit set (%)	Fruit drop (%)	Yield (Kg/tree)
		First experimental season (2000)			
I_1	11.78 bc	293 c	48 c	94.64 a	58 b
I_2	12.62 ab	340 b	63 b	89.79 b	73 a
I_3	15.84 a	363 a	78 a	84.58 c	78 a
L. S. $D_{0.05}$	**1.42**	**21**	**9**	**3.5**	**8**
N_1	11.32 b	296 c	56 b	92.32 a	62 c
N_2	13.86 a	329 b	60 b	89.49 b	70 b
N_3	15.06 a	371 a	73 a	87.19 c	77 a
L. S. $D_{0.05}$	**2.01**	**31**	**7**	**1.8**	**6**
K_1	11.93 bc	317 b	54 b	91.66 a	59 b
K_2	13.82 ab	322 b	68 a	88.79 b	73 a
K_3	14.50 a	357 a	67 a	88.54 b	77 a
L. S. $D_{0.05}$	**2.15**	**26**	**12**	**2.2**	**10**
L. S. $D_{0.05}$ I ×N	*	*	*	*	*
I × K	*	*	*	*	*
N × K	*	*	*	*	*
I ×N×K	*	*	*	*	*
		Second experimental season (2001)			
I_1	12.08 bc	321 b	59 b	95.17 a	51 b
I_2	13.87 ab	332 b	71 a	92.64 b	70 a
I_3	16.51 a	351 a	79 a	89.17 c	73 a
L. S. $D_{0.05}$	**1.92**	**18**	**10**	**1.82**	**10**
N_1	12.46 b	306 c	67 b	94.58 a	57 b
N_2	14.32 a	338 b	69 b	92.38 b	63 b
N_3	15.68 a	360 a	73 a	90.03 c	74 a
L. S. $D_{0.05}$	**1.73**	**18**	**4**	**2.0**	**7**
K_1	12.27 c	329 b	61 b	93.29 a	54 b
K_2	14.23 b	336 a	71 a	91.68 a	68 a
K_3	15.96 a	339 a	77 a	92.01 a	72 a
L. S. $D_{0.05}$	**1.36**	**7**	**9**	**NS**	**12**
L. S. $D_{0.05}$ I ×N	*	*	*	*	*
I × K	*	*	*	*	*
N × K	*	NS	*	NS	*
I×N× K	*	*	*	*	*

6. Leaf mineral contents

6.1. Nitrogen

The data concerning the effect of drip irrigation rates on the leaf nitrogen content, regardless of nitrogen and potassium fertilization, presented in Table (2), revealed that the leaf N content significantly increased with increasing the rate of irrigation, in both seasons. These results were in accordance with those of Nakhlla *et al.*, (1998), who reported that there was a positive correlation between irrigation water and leaf N content in "Washington" Navel orange trees. On the contrary, Ghaly *et al.*, (1994) found that leaf N content of five *Citrus* rootstocks decreased with increasing the irrigation level.

Regarding the effect of nitrogen fertilization on the leaf nitrogen content, irrespective of the effect of drip irrigation rates and potassium fertilization, the results indicated that the leaf N content showed a tendency for positive responses to nitrogen fertilization. The differences were significant, in both seasons (Table 2). These results are in line with those obtained by Swietlik (1992), who found that leaf N content was increased by using N fertigation to "Ray Ruby" grapefruit trees. In the meantime, Swellem (1996) stated that increasing N applied through fertigation increased leaf N content of "Valencia" orange trees. Similarly, Nakhlla *et al.*, (1998) reported that there was a positive correlation between N application and leaf N content in "Washington" Navel orange trees. In addition, Ezz and El-Kobbia (1999) found that leaf N content in Balady mandarin trees markedly increased with increasing N rate.

Concerning the effect of potassium fertilization on the leaf nitrogen content, regardless of drip irrigation rates and nitrogen fertilization, the results indicated that K_2 or K_3 significantly increased the leaf nitrogen content, as compared with K_1 rate, in the first season. While, K_3 significantly increased the leaf N content, as compared with K_2 or K_1 rate, in the second season (Table 2). These results are in general agreement with those reported by Ibrahim (1993), who stated that fertigation of K was affected in improving leaf N content of "Valencia" orange trees. In addition, El-Shobaky and Mohamed (2000) found that K application gave a significant increase leaf N content in "Washington" Navel orange trees.

6.2. Phosphorus

Concerning the effect of drip irrigation rates on the leaf phosphorus content, regardless of nitrogen and potassium fertilization, the results of the two seasons, indicated that I_3 had significantly higher leaf P content, followed by I_2, as compared with I_1 rate (Table 2). These results are in agreement with those reported by Abd El-Messeih (2000), who found that increasing irrigation rate increased leaf P content of "Anna" apple trees.

As for the effect of nitrogen fertilization on the leaf P content, regardless of drip irrigation rates and potassium fertilization, the results indicated that leaf P content decreased with high nitrogen rates, in both seasons. N_1 or N_2 rate significantly increased the leaf P content, as compared with N_3 rate, in the first season. While, N_1 rate significantly increased the leaf P content, as compared with N_2 and N_3 rates, in the second season (Table 2). These results are supported by those of Swellem (1996), who stated that increasing nitrogen applied through fertigation was followed by a reduction in leaf P content of "Valencia" orange trees .

Regarding the effect of potassium fertilization on the leaf P content, irrespective of the effect of drip irrigation rates and nitrogen fertilization, the results indicated that the leaf P content did not differ significantly among the three K rates, in both seasons (Table 2). El-Shobaky and Mohamed (2000) found that K application resulted in a significant decrease of leaf P content in "Washington" Navel orange trees.

6.3. Potassium

Concerning the effect of drip irrigation rates on the leaf potassium content, regardless of nitrogen and potassium fertilization, the results indicated that I_3 rate significantly increased the leaf K content, as compared with the other irrigation rates, in the first season. While, I_3 or I_2 rate significantly increased the leaf K content, as compared with the I_1 rate, in the second season (Table 2). Similar results, also, were reported by Ghaly *et al.*, (1994), who reported that leaf K content of five *Citrus* rootstocks increased with increasing the irrigation water. In addition, Nakhlla *et al.*, (1998) found a positive correlation between irrigation water and leaf K content in "Washington" Navel orange trees.

The data in Table (2) showing the effect of nitrogen fertilization on the leaf K content, regardless of drip irrigation rates and potassium fertilization, indicated that the highest significant leaf K content was observed in the N_3 rate, as compared with N_2 and N_1 rates, in the first season. While, the N_3 or N_2 rate significantly increased the leaf K content, as compared with the N_1 rate, in the second season. These results are in agreement with those found by Nakhlla *et al.*, (1998), who reported that there was a positive correlation between N application and leaf K content in "Washington" Navel orange trees. On the contrary, Swellem (1996) found that increasing N applied through fertigation was followed by a reduction in leaf K content of "Valencia" orange trees.

Regarding the effect of potassium fertilization on the leaf K content, irrespective of the effect of drip irrigation rates and nitrogen fertilization, the data listed in Table (2) indicated that K_3 rate significantly increased the leaf K content, as compared with the K_2 or K_1 rate, in the first season. While, the differences among the three rates of potassium fertilization were significant, in the second season. These results agreed with those reported by Ibrahim (1993), who stated that fertigation of K was effective in improving leaf K content of "Valencia" orange trees. On the contrary, El-Shobaky and Mohamed (2000) found that K application resulted in a significant decrease of leaf K content in "Washington" Navel orange trees.

6.4. Calcium

As for the effect of drip irrigation rates on the leaf calcium content, regardless of nitrogen and potassium fertilization, the results indicated that I_3 rate significantly increased the leaf Ca content, as compared with the I_2 or I_1 rate, in the first season. While, the differences among the three rates of irrigation were significant, in the second season (Table 2). These findings agreed with those obtained by Abd El-Messeih (2000), who found that increasing irrigation rate increased leaf Ca content of "Anna" apple trees.

The data in Table (2) showing the effect of nitrogen fertilization on the leaf Ca content, regardless of drip irrigation rates and potassium fertilization, indicated that there was no consistent trend in the three N rates. The differences among the three N fertilization rates were not significant, in both seasons. Swellem (1996) found that increasing N applied through fertigation increased leaf Ca content of "Valencia" orange trees.

Concerning the effect of potassium fertilization on the leaf Ca content, regardless of drip irrigation rates and nitrogen fertilization, the results indicated that K_1 significantly increased the leaf Ca content, as compared with the other rates of potassium fertilization, in both seasons (Table 2). These findings agreed with those obtained by Abd El-Migeed (1996), who reported that K fertilization tended to decrease leaf Ca content in "Washington" Navel orange trees. In addition, El-Shobaky and Mohamed (2000) found that K application resulted a significant decrease leaf Ca content in "Washington" Navel orange trees.

6.5. Magnesium

Regarding the effect of drip irrigation rates on the leaf magnesium content, irrespective of the effect of nitrogen and potassium fertilization, the results indicated that I_3 or I_2 rate significantly increased the leaf Mg content, as compared with I_1 rate, in both seasons (Table 2).

As for the effect of nitrogen fertilization on the leaf Mg content, regardless of drip irrigation rates and potassium fertilization, the results revealed that N_3 rate increased the leaf Mg content, as compared with N_2 or N_1 rate, in the first season. While, there was no consistent trend in the three N rates, in the second season (Table 2). These results disagreed with those reported by Swellem (1996), who found that increasing N applied through fertigation was followed by a reduction in leaf Mg content of "Valencia" orange trees.

Concerning the effect of potassium fertilization on the leaf Mg content, regardless of drip irrigation rates and nitrogen fertilization, the results indicated that leaf Mg content showed a tendency for negative responses to potassium fertilization, in both seasons. There was a significant increase in the leaf Mg content for K_1 rate, comparing with the K_2 or K_3 rate (Table 2).These results are in line with those obtained by Abd El-Migeed (1996), who found that K fertilization tended to decrease leaf Mg content in "Washington" Navel orange trees.

6.6. Iron

Concerning the effect of drip irrigation rates on the leaf iron content, regardless of nitrogen and potassium fertilization, the results of the two seasons, indicated that I_3 rate significantly increased the leaf Fe content, as compared with I_1 or I_2 rate (Table 2). These findings agreed with those obtained by Ghaly *et al.*, (1994), who reported that leaf Fe content of five *Citrus* rootstocks increased with increasing the irrigation water. In addition, Nakhlla *et al.*, (1998) found a positive correlation between irrigation water and leaf Fe content in "Washington" Navel orange trees.

Redarding the effect of nitrogen fertilization on the leaf Fe content, irrespective of the effect of drip irrigation rates and potassium fertilization, the results presented in Table (2) indicated that N_3 or N_2 rate significantly increased the leaf Fe content, as compared with N_1 rate, in the first season. While, the differences among the three rates of nitrogen fertilization were significant, in the second season. In accordance with these results those reported by Swellem

(1996), who stated that increasing N applied through fertigation increased leaf Fe content of "Valencia" orange trees. In addition, Nakhlla *et al.*, (1998) found a positive correlation between N application and leaf Fe content of "Washington" Navel orange trees.

As for the effect of potassium fertilization on the leaf Fe content, regardless of drip irrigation rates and nitrogen fertilization, the results indicated that K_3 or K_2 rate significantly increased the leaf Fe content, as compared with K_1 rate, in both seasons (Table 2).

6.7. Zinc

The data in Table (2) showing the effect of drip irrigation rates on the leaf zinc content, regardless of nitrogen and potassium fertilization, indicated that I_3 significantly increased the leaf Zn content, as compared with the I_2 or I_1 rate, in the first season. While, significant differences were found between the I_3 or I_2 and I_1 rate of irrigation, in the second season. In accordance with these results, are those reported by Ghaly *et al.*, (1994), who found that leaf Zn content of five *Citrus* rootstocks increased with increasing the irrigation water. In addition, Nakhlla *et al.*, (1998) found a positive correlation between irrigation water and leaf Zn content in "Washington" Navel orange trees.

Concerning the effect of nitrogen fertilization on the leaf Zn content, regardless of drip irrigation rates and potassium fertilization, the results indicated that N_3 or N_2 rate significantly increased the leaf Zn content, as compared with the N_1 rate, in both seasons (Table 2). These findings agreed with those obtained by Nakhlla *et al.*, (1998), who found a positive correlation between N application and leaf Zn content in "Washington" Navel orange trees.

Regarding the effect of potassium fertilization on the leaf Zn content, irrespective of the effect of drip irrigation rates and nitrogen fertilization, the data listed in Table (2) indicated that K_3 rate significantly increased the leaf Zn content, as compared with the other rates of potassium fertilization, in the first season. While, K_3 or K_2 rate significantly increased the leaf Zn content, as compared with the K_1 rate, in the second season.

6.8. Manganese

As for the effect of drip irrigation rates on the leaf manganese content, regardless of nitrogen and potassium fertilization, the results indicated that leaf Mn content showed a tendency for positive responses to irrigation rates. Significant differences were found between the three irrigation rates, in the first season. While, the significant difference was found between I_3 or I_2 and I_1 rate, in the second season (Table 2). In accordance with these results, are those reported by Nakhlla *et al.*, (1998), who found a positive correlation between irrigation water and leaf Mn content in "Washington" Navel orange trees.

Concerning the effect of nitrogen fertilization on the leaf Mn content, regardless of drip irrigation rates and potassium fertilization, the results indicated that the N_3 significantly increased the leaf Mn content, as compared with the other rates of nitrogen fertilization, in both seasons (Table 2). These findings agreed with those obtained by Nakhlla *et al.*, (1998), who found a positive correlation between N application and leaf Mn content in "Washington" Navel orange trees.

The data in Table (2) representing the effect of potassium fertilization on the leaf Mn content, regardless of drip irrigation rates and nitrogen fertilization, indicated that potassium fertilization tended to increase the leaf Mn content, in both seasons. The differences among the three K rates were significant, in the first season. While, K_3 rate significantly increased the leaf Mn content, as compared with K_2 or K_1 rate, in the second season.

Table 2. The effect of drip irrigation, nitrogen and potassium fertilization treatments on the leaf mineral contents (on dry weight basis) of "Washington" Navel orange trees in 2000 and 2001 seasons.

Treatment	%					ppm		
	N	P	K	Ca	Mg	Fe	Zn	Mn
First experimental season (2000)								
I_1	2.21 c	0.16 c	1.15 c	2.58 b	0.38 b	140 b	34 b	33 c
I_2	2.52 b	0.18 b	1.36 b	2.68 b	0.50 a	151 b	33 b	40 b
I_3	2.81 a	0.20 a	1.52 a	3.02 a	0.51 a	169 a	38 a	49 a
L. S. D. 0.05	**0.12**	**0.01**	**0.13**	**0.16**	**0.07**	**12**	**2**	**6**
N_1	2.42 c	0.21 a	1.23 c	2.70 a	0.46 a	136 b	25 b	30 c
N_2	2.51 b	0.19 a	1.36 b	2.82 a	0.43 a	159 a	39 a	42 b
N_3	2.62 a	0.14 b	1.44 a	2.76 a	0.50 a	165 a	40 a	50 a
L. S. D. 0.05	**0. 10**	**0.03**	**0.06**	**NS**	**NS**	**7**	**5**	**9**
K_1	2.36 b	0.19 a	1.20 b	2.96 a	0.57 a	129 b	31 c	36 c
K_2	2.60 a	0.18 a	1.32 b	2.75 b	0.43 b	162 a	35 b	40 b
K_3	2.58 a	0.17 a	1.52 a	2.57 c	0.39 b	169 a	38 a	47 a
L. S. D. 0.05	**0.18**	**NS**	**0.18**	**0.17**	**0.12**	**18**	**2**	**3**
L.S. D.0.05 I × N	*	*	*	*	*	*	*	*
I × K	*	*	*	*	*	*	*	*
N × K	*	NS	*	NS	*	*	*	*
I × N × K	*	*	*	*	*	*	*	*
Second experimental season (2001)								
I_1	2.30 c	0.15 c	1.19 b	2.63 c	0.40 b	148 b	32 b	42 b
I_2	2.56 b	0.17 b	1.40 a	2.85 b	0.46 a	150 b	40 a	51 a
I_3	2.70 a	0.20 a	1.59 a	3.03 a	0.50 a	160 a	46 a	53 a
L. S. D. 0.05	**0.12**	**0. 01**	**0.20**	**0.16**	**0.03**	**8**	**7**	**5**
N_1	2.36 c	0.20 a	1.30 b	2.78 a	0.40 c	126 c	27 b	38 c
N_2	2.46 b	0.17 b	1.42 a	2.90 a	0.50 a	156 b	43 a	50 b
N_3	2.74 a	0.15 b	1.46 a	2.83 a	0.46 b	176 a	48 a	58 a
L. S. D. 0.05	**0. 10**	**0.03**	**0.08**	**NS**	**0.02**	**13**	**6**	**6**
K_1	2.43 b	0.17 a	1.21 c	3.02 a	0.53 a	138 b	34 b	46 b
K_2	2.48 b	0.18 a	1.34 b	2.83 b	0.43 b	160 a	41 a	48 b
K_3	2.65 a	0.17 a	1.63 a	2.66 c	0.40 b	160 a	44 a	53 a
L. S. D. 0.05	**0.08**	**NS**	**0.11**	**0.11**	**0.05**	**17**	**4**	**3**
L. S. D.0.05 I × N	*	*	*	*	*	*	*	*
I × K	*	*	*	*	*	*	*	*
N × K	*	NS	*	NS	*	*	*	*
I × N × K	*	*	*	*	*	*	*	*

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الملخص العربى

١- تأثير الرسمدة بالنيتروجين والبوتاسيوم على النمو الخضرى والمحصول والمحتوى المعدنى للأوراق فى أشجار البرتقال أبو سرة النامية فى الأراضى الرملية .

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أجرى هذا البحث خلال عامى ٢٠٠٠ ، ٢٠٠١ لدراسة تأثير الرى بـــالتنقيط والتســميد النيــتروجينى والبوتاسى (الرسمدة بالنيتروجين والبوتاسيوم) على النمو الخضرى ونسبة عقد الثمار ونسبة تســاقط الثمــار والمحصول والمحتوى المعدنى للأوراق فى أشجار البرتقال أبو سرة النامية فى الأراضى الرملية .

ويمكن تلخيص النتائج الرئيسية لهذه الدراسة فى النقاط التالية :-

١- إزداد معنويا كل من متوسط طول الفرخ ومحتوى الأوراق من الكلوروفيل والنسبة المئوية لعقد الثمــار وكمية المحصول للشجرة ومحتوى الأوراق من النيتروجين والبوتاسيوم والحديد والزنك والمنجنيز بزيادة معدلات الرى بالتنقيط والتسميد النيتروجينى والبوتاسى وذلك فى كلا الموسمين .

٢- انخفضت النسبة المئوية لتساقط الثمار معنويا بزيادة معدلات الــرى بــالتنقيط والتســميد النيــتروجينى والبوتاسى وذلك خلال الموسمين .

٣- أدت زيادة معدل الرى بالتنقيط إلى زيادة محتوى الأوراق من الفوسفور والكالسيوم والماغنسيوم فى حين أن زيادة معدل التسميد البوتاسى أدت إلى انخفاض معنوى فى محتوى الأوراق من الكالسيوم والماغنسيوم . ومن ناحية أخرى فإن زيادة معدل التسميد النيتروجينى أدت إلى انخفاض معنوى فى محتــوى الأوراق من الفوسفور وذلك خلال موسمى الدراسة .