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EFFECT OF DRIP IRRIGATION AND NITROGEN FERTILIZATION ON:
II- THE LEAF WATER STATUS, BIOCHEMICAL ASPECTS AND MINERAL CONTENTS OF "ANNA" APPLE TREES GROWN IN NEW RECLAIMED SOILS

Shahein, A.H.;M.B.El-Sabrout*,M.M.Yehia and W.M. Abd El-Messeih***

* Department of Pomology, Faculty of Agriculture, Alexandria University, Alexandria, Egypt.

** Horticulture Research Institute, ARC, Giza, Egypt.

ABSTRACT

The present investigation was carried out in 1997 , 1998 , 1999 seasons on 5-years old "Anna" apple trees budded on MM. 106 rootstock and grown in a loamy sand soil at Desert Development Center (DDC) of the American University in Cairo (AUC) Sadat Research Station (SRS), El-Menofeya Governorate . The goal of this work was to study the effect of four irrigation treatments and three nitrogen levels on the leaf water status, biochemical aspects and mineral contents. The amount of irrigation water applied to each tested tree based on soil-matrix-potential in the three irrigation treatments (I_1 , I_2 and I_3) , and the control treatment.

The main results can be summarized in the following points:

1- Relative water content (RWC) in the leaves significantly decreased with decreasing irrigation rate, whereas N level had no significant effect on RWC.
2- The total chlorophyll content of the leaves significantly increased with increasing irrigation rate and nitrogen fertilization level.
3- Decreasing the quantity of irrigation water applied to each tree caused a significant increase in free leaf proline content especially in I_3 . In addition, there is no significant effect of N levels on the free leaf proline content generally.
4- Increasing irrigation rate and N level increased leaf N, P, Ca and Fe but decreased leaf Mn and Zn in the three seasons of study.
5- Increasing irrigation rate also increased leaf K and decreased leaf Mn and Cu, whereas increasing N level increased leaf Cu but decreased leaf Mn and Zn in the three seasons.
6- Increasing water stress evidently depressed leaf Fe content but significantly raised the concentration of leaf Mn, Zn and Cu in all three seasons. Nitrogen level significantly affected leaf Fe and Cu contents positively but had a negative effect on leaf Mn and Zn contents.

INTRODUCTION

Apple is one of the most important fruit crops in Egypt. The area devoted for apple plantation rapidly increased through the last two decades from less than one thousand feddans in 1979 to more than 70 thousand feddans in 1997 producing 403 thousand tons of fruits (according to statistics of the Ministry of Agriculture and Land Reclaimation in 1979 and 1997). In other words, apple occupied the fifth rank of fruit crops in 1997. This rapid increase in the apple acreage is due to the introduction of "Anna" apple variety (a hybrid between "Red Hadassiya" and "Golden Delicious" apple varieties).

Most of the increase of the new established apple orchards concentrated in Nubaria region (new cultivated area), where the total area of apple orchards reached to 50400 feddan that representing 71.5% of the total apple acreage in Egypt. In these new cultivated regions, the drip irrigation is the main system used to irrigate apple orchards, since saving water is considered one of the main aims in these regions.

The mineral composition of apple leaves as well as the balance between the different nutrients cause an appreciable influence on the yield of apple trees and on the chemical composition of the fruits, consequently their quality characteristics. The apple growers in Egypt fertilize their orchards with different amounts of inorganic and organic fertilizers.

The present investigation was conducted on "Anna" apple trees budded on MM. 106 rootstock in order to study the effect of applying the trees with four irrigation treatments and three nitrogen levels on the leaf water content (RWC), total chlorophyll, proline and certain mineral contents.

MATERIALS AND METHODS

The present investigation was carried out during 1997, 1998 and 1999 growing seasons, on 5-year-old "Anna" apple trees (*Malus domestica,* Brokh*)* budded on MM. 106 rootstock, in order to study the effect of different drip irrigation treatments combined with three nitrogen fertilization levels on the water status, biochemical aspects and mineral contents of the leaves.

The experimental trees spaced at 3.5 × 3.5 meters apart and grown in the Desert Development Center (DDC), American University in Cairo (AUC), at Sadat Research Station (SRS), El-Menofeya Governorate. "Dorsette Golden" apple variety was planted as a pollinator. The physical and chemical analysis of the experimental orchard soil were conducted before starting these experiments in 1996. Four soil layers, reached to 150 cm depth, were distinguished and the percentages of sand, clay and silt were ranged from 84-86.2%, 8 .9-10.3% and 4.8 – 5.3%, respectively. In addition, chemical analysis of soil samples showed that its pH was 7.05 – 7.29, EC = 1.81 – 2.47 ds/m and $CaCo_3$ = 5.8 – 13.8%. Thus, the soil texture was classified as loamy sand with pH=7.2. The chemical analysis of irrigation water [according to Chapman and Pratt, 1961] cleared that pH was 7.4 , sodium absorption ratio (SAR) = 2.6 and EC = 0.94 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 1.65 – 1.72 , 0.71 – 0.73, 0.77 – 0.81, 2.88 – 2.94 and 1.28 – 1.32%, respectively, on the dry weight basis. The corresponding concentrations of Fe, Mn, Zn and Cu were ranged from 540 – 553, 29-34, 122-130 and 48 – 55 ppm, respectively. There was one line of drip irrigation for every row of the trees, with 2 emitters per tree (12 L/h for each) installed in a location opposite to tree trunk at distance of 35 cm of tree trunk. The trees received the same cultural practices as usually done in this orchard.

Seventy two trees, as uniform as possible, were selected at random for this study. The trees were planted in eight rows each of nine trees. Within

the row, the trees were divided into three groups, and each group received one of the three fertilization treatments. Such selected trees were under three irrigation treatments plus control one. The treatments were arranged in a randomized complete block design with six replicates for each treatment, using one tree as a single replicate (twelve treatment x six replicates = seventy two trees). The main factor was the irrigation treatments, and the submain factor was the fertilization treatments. The treatments were laid out as split in complete randomized design. The statistical analysis was done according to SAS (1989). The trial was repeated for three consecutive seasons on the same trees in 1997, 1998 and 1999.

Irrigation treatments

In order to calculate water requirements of trees, a retention curve of the soil was made by determining the soil moisture in samples taken at every 15 cm from the soil surface to 120 cm depth at bars from 0.0 to 0.8 bars according to Black (1965).

For every irrigation treatment (except the control) a mercury manometer was used to monitor the irrigation treatments. The manometer was located beside one of the two emitters and on 45 cm soil depth. When the mercury reached the detected soil matrix potential, the irrigation started and the manometer was readjusted after every irrigation. The irrigation treatments for the three years were as follows:

I_1 (Normal irrigation treatment): Each tree received 30, 40 and 60 litres of water in 1997, 1998 and 1999, respectively, when the soil matrix potential reached to 0.1 – 0.3 bars.

I_2 (Medium irrigation treatment): Each tree received 25, 34 and 53 litres of water in 1997, 1998 and 1999, respectively, when soil matrix potential reached to 0.3 – 0.5 bars.

I_3 (Deficit irrigation treatment): Each tree received 22, 29 and 46 litres of water in 1997, 1998 and 1999, respectively, when soil matrix potential reached to 0.5 – 0.7 bars.

I_4 (Control treatment): Each tree received 72, 72 and 84 litres of irrigation water in 1997, 1998 and 1999, respectively.

In addition, each tree was supplied with leaching requirements (6%) to the applied quantity of water/tree to every fourth irrigation (except for the control treatment).

Fertilization treatments

Each fertilizer was added to each tree during irrigation. There were three different nitrogen treatments for "Anna" apple trees in addition to supplying the trees with a constant dose of potassium sulphate (352 , 484 and 761 gm) and orthophosphoric acid (80 , 110 and 172.8 cm^3) in 1997, 1998 and 1999 seasons, respectively. Thus, the added doses differed in the three years of experiment according to the size of tree and the quantity of irrigation water supplied to it. In addition, tree growing season was divided into three periods each as follows: from mid February to end of March, from first April to end of June and from first July to end of September. In each period, the fertilizer was dissolved in one litre of water and applied in a circle

(70 cm in diameter) around the tree trunk. The doses of ammonium nitrate supplied was 325, 405.6 and 487.6 gm/tree in 1997, 442.0 , 552.5 and 663 gm/tree in 1998 and 702.0 , 877.5 and 1053 gm/tree in 1999 for the first, second and third nitrogen treatment, respectively. The total amount of manure, which added (in December) to each experimental tree was 10 kgs/tree in either 1997 or 1998 and increased to 15 kgs/tree in 1999. In addition, from the beginning of April, the trees were sprayed with a solution of chelated Fe, Mn and Zn at 0.75 , 0.33 and 0.17 gm per litre, respectively. The spray was repeated every month till the end of September.

A. Leaf relative water content (RWC)

Ten mature leaves were taken from the six experimental trees of every treatment on September 5th,1997,1998 and 1999 seasons, then equal leaf discs (of l cm^2) were cut, weighed to find the fresh weight (F.W). Flooted on water for 24 hours until they attained equilibrium, reweighed (turgidity weight) and finally dried in oven at 70°C for 24 hours till reached a constant weight. Relative water content, was determined according to Ritch, (1974).

B. Determination of leaf biochemical constituents

Total leaf chlorophyll content was determined by using MINOLTA CHLOROPHYLL METER SPAD-502 (Minolta camera co., LTD JAPAN). Ten reading were taken on ten leaves (the fourth leaf of the new shoot) of each experimental tree. The reading was taken on August10th , in 1998 and 1999 seasons. The reading was taken at the middle of leaves blade.

Leaf samples were taken on August 10th, in 1997 and 1999 seasons and free leaf proline content was determined according to Singh *et al.*, (1973). The proline concentration was determined from standard curve and calculated on dry weight basis.

C. Determination of leaf mineral contents

To study the effect of different irrigation and nitrogen fertilization treatments on the leaf mineral composition, samples consisted of 20 mature leaves each were collected at random, on August 10th, in 1997, 1998 and 1999 seasons. The leaves were washed several times with tap water, rinsed three times in distilled water, and then dried at 70 – 80° C in an electric air drying oven. The dried leaves of each sample were ground in porcelain motar to avoid contamination with any minerals, 0.3 gm from the ground dried material of each sample was digested with H_2O_2 and H_2SO_4 according to Evenhuis and DeWaard (1980). Suitable aliquots were then taken for mineral determinations. Total nitrogen and phosphorous were determined colorimetrically according to Evenhuis (1976), and Murphy and Riley (1962), respectively. Potassium was determined against a standard, using air propane flame photometer (Chapman and Pratt, 1961). Calcuim and magnesium were measured, using versenate method (Chang and Bray, 1951) and iron, manganese, zinc and copper by a Perkin-Elmer atomic absorption spectrophtometer Model 305-B. The concentrations of nitrogen, phosphours, potassium, magnesium and calcium were expressed as

percentage, while those of iron, manganese, zinc and copper were expressed as parts per million (ppm), on dry weight basis.

RESULTS AND DISCUSSION

A. Relative water content (RWC) in the leaves

Concerning the effect of the different irrigation treatments on the leaf RWC, irrespective the effect of the different N levels, the data of the three seasons inTable (1) indicated that the highest significant RWC in the leaves was found in the control and I_1 treatments followed by those of I_2 treatment while the lowest significant value was found in I_3 treatment. These findings agreed with those obtained by Hussein (1998), who found that the relative water content "turgidity" in the leaves of "Anna" apple trees was decreased significantly as irrigation rates were decreased.

As for the effect of the different N levels on the leaf RWC, irrespective the effect of the different irrigation treatments, the data of the three seasons in the same table showed no consistent trend among the three N levels.

Table (1) : Effect of irrigation and nitrogen fertilization treatments on the percentage of relative water content (RWC) in the leaves of "Anna" apple trees in 1997 , 1998 and 1999 seasons.

Fertilization levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1997				
N_1	68.13 ^{b}	64.58 ^{c}	60.83 ^{e}	68.72 ^{ab}	65.57 ^{b}
N_2	68.83 ^{ab}	63.85 ^{c}	62.43 ^{d}	69.08 ^{a}	66.05 ^{a}
N_3	68.93 ^{a}	63.95 ^{c}	62.73 ^{d}	69.17 ^{a}	66.21 ^{a}
Average	68.63 ^{a}	64.13 ^{b}	62.00 ^{c}	68.99 ^{a}	
L.S.D. (0.05)	Irrigation 0.640	Fertilization 0.392		Interaction 0.784	
	1998				
N_1	68.25 ^{b}	64.55 ^{c}	62.47 ^{d}	69.07 ^{ab}	66.08 ^{a}
N_2	69.10 ^{ab}	64.05 ^{c}	61.85 ^{de}	69.23 ^{a}	66.06 ^{a}
N_3	68.62 ^{ab}	63.45 ^{c}	61.32 ^{e}	69.27 ^{a}	65.66 ^{a}
Average	68.66 ^{a}	64.02 ^{b}	61.89 ^{c}	69.19 ^{a}	
L.S.D. (0.05)	Irrigation 0.699	Fertilization 0.566		Interaction 0.941	
	1999				
N_1	70.38 ^{a}	65.63 ^{bc}	65.07 ^{d}	70.04 ^{a}	67.78 ^{a}
N_2	70.11 ^{a}	65.98 ^{bc}	65.29 ^{cd}	70.21 ^{a}	67.91 ^{a}
N_3	70.46 ^{a}	65.31 ^{cd}	64.87 ^{d}	70.36 ^{a}	67.76 ^{a}
Average	70.32 ^{a}	65.64 ^{b}	65.07 ^{c}	70.21 ^{a}	
L.S.D. (0.05)	Irrigation 0.282	Fertilization 0.233		Interaction 0.467	

The values followed by the same letter do not differ at 5% level of significance.

B. Leaf biochemical aspects

1. Total leaf chlorophyll content

Concerning the effect of irrigation treatments on the total leaf chlorophyll content, irrespective the effect of different N levels, the data listed in Table (2) showed significant differences among those of the control and I_1 treatments, as compared with that of I_2 treatment, while the lowest significant value was found in the I_3 treatment.

Table (2): Effect of irrigation and nitrogen fertilization treatments on the total leaf chlorophyll content (mg / 100gm fresh weight) of "Anna" apple trees in 1998 and 1999 seasons.

Fertilization levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1998				
N_1	53.22 ^{bc}	50.68 ^{de}	46.20 ^{g}	53.72 ^{b}	50.95 ^{c}
N_2	54.60 ^{b}	51.53 ^{d}	49.10 ^{f}	54.62 ^{b}	52.46 ^{b}
N_3	56.23 ^{a}	51.80 ^{cd}	49.57 ^{ef}	56.62 ^{a}	53.55 ^{a}
Average	54.68 ^{a}	51.34 ^{b}	48.29 ^{c}	54.98 ^{a}	
L.S.D. (0.05)	Irrigation	Fertilization		Interaction	
	0.765	0.748		1.496	
	1999				
N_1	54.80 ^{b}	51.20 ^{cd}	46.40 ^{e}	54.40 ^{b}	51.70 ^{c}
N_2	55.70 ^{ab}	52.10 ^{c}	50.10 ^{d}	55.20 ^{b}	53.28 ^{b}
N_3	57.50 ^{a}	52.40 ^{c}	50.90 ^{cd}	57.10 ^{a}	54.48 ^{a}
Average	56.00 ^{a}	51.90 ^{b}	49.13 ^{c}	55.57 ^{a}	
L.S.D. (0.05)	Irrigation	Fertilization		Interaction	
	1.044	0.929		1.860	

The values followed by the same letter do not differ at 5% level of significance.

As for the effect of different N levels on the total leaf chlorophyll content, irrespective the effect of irrigation treatments, significant differences were found in the total leaf chlorophyll content in 1998 and 1999 among the three N levels (Table 2). These findings were in line with those obtained by Klein *et al.* (1989), who reported that leaf chlorophyll content of "Starking Delicious" apple trees was significantly lower in the lowest N treatment. Also, Neilsen *et al.*, (1995) mentioned that the leaf SPAD readings (Chlorophyll readings obtained with Minolta – 502 SPAD meter) of apple trees increased in response to N fertigation rate. Moreover, El- Morshedy (1997) found that "Anna" apple trees which treated with 800 g N had the highest content of total leaf chlorophyll.

2. Leaf proline content

Concerning the effect of irrigation treatments on the free leaf proline content, irrespective the effect of N levels, the data listed in Table (3) showed that trees grown at the deficit irrigation (I_3) had the higher free leaf proline

content than that of the trees grown at moderate irrigation (I_2), normal irrigation (I_1) and high irrigation (control). Moreover, the statistical analysis showed a significant differences between free leaf proline content of the trees in I_3 treatment, as compared with those of I_1 and control treatments. These results are in general agreement with previous investigators such as, Hussein (1998) working on "Anna" apples, and found that water stress treatments significantly raised the concentration of proline in leaves.

Table (3) : Effect of irrigation and nitrogen fertilization treatments on the free leaf proline content (mg / 100gm dry weight) of "Anna" apple trees in 1997 and 1999 seasons.

Fertilization Levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1997				
N_1	5.34 ^{c}	6.75 ^{bc}	7.96 ^{ab}	5.15 ^{c}	6.30 ^{a}
N_2	6.14 ^{bc}	6.92 ^{bc}	8.12 ^{ab}	5.17 ^{c}	6.59 ^{a}
N_3	6.32 ^{bc}	7.08 ^{bc}	9.57 ^{a}	6.26 ^{bc}	7.31 ^{a}
Average	5.93 ^{b}	6.92 ^{ab}	8.55 ^{a}	5.53 ^{b}	
L.S.D. (0.05)	Irrigation 2.429	Fertilization 1.056		Interaction 2.112	
	1999				
N_1	7.43 ^{c}	8.80 ^{bc}	10.40 ^{ab}	7.28 ^{c}	8.48 ^{a}
N_2	8.19 ^{c}	8.92 ^{bc}	10.50 ^{ab}	7.36 ^{c}	8.74 ^{a}
N_3	8.35 ^{c}	9.18 ^{bc}	12.01 ^{a}	8.28 ^{c}	9.46 ^{a}
Average	7.99 ^{b}	8.97 ^{ab}	10.94 ^{a}	7.64 ^{b}	
L.S.D. (0.05)	Irrigation 2.513	Fertilization 0.994		Interaction 1.989	

The values followed by the same letter do not differ at 5% level of significance.

As for the effect of the different nitrogen levels on the free leaf proline content, irrespective the effect of irrigation treatments, the data in Table (3) indicated that the differences among the different N levels were not significant. This mean that accumulative free leaf proline content was due to water stress (deficit irrigation). Accumulation of free proline in the plant leaves has been shown to be an adaptive mechanism for resistance to stress (Kathiresan, 1987).

C. Leaf mineral contents

1. Nitrogen

Concerning the effect of different irrigation treatments on the leaf N content, irrespective the effect of N levels, the data in Table (4) showed that it was significantly higher in the control and I_1 treatments, as compared with that in I_2 and I_3 treatments in the three seasons. These results were in line with those of Pacholak (1986 and 1991) , who found that the irrigation tended to increase total leaf N content of apple trees. Likewise, Buwalda and Lenz (1992) reported that water stress reduced the leaf N content of apple trees. Whereas, Vasileva and Doichev (1989) working on apple trees,

mentioned that the irrigation regimes had no significant effect on the leaf N content. On the contrary, Hipps (1997) noted that the irrigation reduced the leaf N content in apple trees.

As for the effect of the three N levels on the leaf N content, irrespective the effect of irrigation treatments, the data in Table (4) revealed that the highest values of leaf N content was found in the trees grown at N_3 level followed by those at N_2 level while trees grown at N_1 level had the lowest leaf nitrogen content and the differences among the three nitrogen levels were statistically significant during the three seasons. These results are in general agreement with previous investigators such as Cripps (1988), who mentioned that N application increased N content in apple leaves. Also, Klien *et al.*, (1989) found that leaf N content of apple trees was significantly lower in the lowest N treatment. Neilsen *et al.*, (1995) working on apple trees, found that leaf N content increased in response to N fertigation rate. In addition, Khattari and Shatat (1996) reported that the leaf N content of apple trees increased significantly with N application. Raese and Drake (1997) working on "Fuji" apple trees, found that the lower concentrations of leaf N content were related to the lower rates of N application.

Table (4): Effect of irrigation and nitrogen fertilization treatments on the percentage of leaf nitrogen content (on the dry weight basis) of "Anna" apple trees in 1997 , 1998 and 1999 seasons.

Fertilization levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1997				
N_1	2.23 ^{d}	2.09 ^{f}	1.96 ^{h}	2.24 ^{d}	2.13 ^{c}
N_2	2.29 ^{c}	2.16 ^{e}	2.05 ^{g}	2.30 ^{bc}	2.20 ^{b}
N_3	2.33 ^{ab}	2.21 ^{d}	2.07 ^{fg}	2.35 ^{a}	2.24 ^{a}
Average	2.28 ^{a}	2.15 ^{b}	2.03 ^{c}	2.31 ^{a}	
L.S.D. (0.05)	Irrigation 0.022	Fertilization 0.018		Interaction 0.037	
	1998				
N_1	2.19 ^{cd}	2.07 ^{e}	1.99 ^{f}	2.17 ^{de}	2.10 ^{c}
N_2	2.28 ^{ab}	2.15 ^{de}	2.00 ^{f}	2.25 ^{bc}	2.17 ^{b}
N_3	2.33 ^{a}	2.20 ^{cd}	2.10 ^{e}	2.31 ^{ab}	2.24 ^{a}
Average	2.27 ^{a}	2.14 ^{b}	2.03 ^{c}	2.24 ^{a}	
L.S.D. (0.05)	Irrigation 0.059	Fertilization 0.037		Interaction 0.074	
	1999				
N_1	2.12 ^{bcd}	2.02 ^{ef}	1.80 ^{h}	2.13 ^{bc}	2.02 ^{c}
N_2	2.16 ^{ab}	2.06 ^{de}	1.93 ^{g}	2.18 ^{ab}	2.08 ^{b}
N_3	2.22 ^{a}	2.09 ^{cd}	1.96 ^{fg}	2.31 ^{a}	2.12 ^{a}
Average	2.17 ^{a}	2.06 ^{b}	1.89 ^{c}	2.18 ^{a}	
L.S.D. (0.05)	Irrigation 0.040	Fertilization 0.032		Interaction 0.064	

The values followed by the same letter do not differ at 5% level of significance.

2. Phosphorus

pIn view of the effect of different irrigation treatments on the leaf P content, irrespective the effect of N levels, the data in Table (5) indicated that the highest significant leaf P content was found in the control and I_1 treatments, as compared with I_2 or I_3 through the three seasons. These findings are in line with those obtained by Pacholak (1986 and 1991), who stated that irrigation tended to increase total leaf P content of apple trees. Buwalda and Lenz (1992) reported that water stress reduced the leaf P content of apple trees. Moreover, Hussein (1998) found that the leaf P content of "Anna" apple trees significantly decreased as irrigation quantity decreased from optimum to moderate to low rate.

Table (5) : Effect of irrigation and nitrogen fertilization treatments on the percentage of leaf phosphorus content (on the dry weight basis) of "Anna" apple trees in 1997 , 1998 and 1999 seasons.

Fertilization levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1997				
N_1	0.31 ^{bc}	0.24 ^{d}	0.20 ^{d}	0.32 ^{abc}	0.27 ^{b}
N_2	0.32 ^{abc}	0.27 ^{cd}	0.22 ^{d}	0.34 ^{ab}	0.29 ^{b}
N_3	0.37 ^{a}	0.26 ^{d}	0.26 ^{d}	0.37 ^{a}	0.31 ^{a}
Average	0.33 ^{a}	0.26 ^{b}	0.23 ^{b}	0.34 ^{a}	
L.S.D. (0.05)	Irrigation 0.039	Fertilization 0.026		Interaction 0.052	
	1998				
N_1	0.21 ^{c}	0.17 ^{f}	0.15 ^{h}	0.21 ^{c}	0.18 ^{b}
N_2	0.20 ^{d}	0.18 ^{e}	0.15 ^{h}	0.21 ^{c}	0.18 ^{b}
N_3	0.22 ^{b}	0.18 ^{e}	0.16 ^{g}	0.23 ^{a}	0.21 ^{a}
Average	0.20 ^{b}	0.18 ^{c}	0.15 ^{d}	0.21 ^{a}	
L.S.D. (0.05)	Irrigation 0. 007	Fertilization 0. 006		Interaction 0. 012	
	1999				
N_1	0.26 ^{ab}	0.20 ^{c}	0.15 ^{e}	0.25 ^{b}	0.22 ^{b}
N_2	0.29 ^{a}	0.21 ^{c}	0.16 ^{e}	0.27 ^{ab}	0.23 ^{ab}
N_3	0.29 ^{a}	0.22 ^{c}	0.16 ^{e}	0.27 ^{ab}	0.24 ^{a}
Average	0.28 ^{a}	0.21 ^{b}	0.16 ^{c}	0.26 ^{a}	
L.S.D. (0.05)	Irrigation 0.022	Fertilization 0.018		Interaction 0.037	

The values followed by the same letter do not differ at 5% level of significance.

Concerning the effect of the three N levels on the leaf P content, irrespective the effect of irrigation treatments, the data in Table (5) cleared that the increase of the N quantity applied to tree proportionally increased leaf P content. These findings were in line with those of Forshey (1963), who mentioned that both urea foliar sprays and soil N fertilization increased the concentration of P in the leaves of "McInstosh" apple trees.

3. Potassium

Regarding the effect of the different irrigation treatments on the leaf K content, irrespective the effect of different N levels, the data in Table (6) indicated that it was significantly higher in the control and I_1 treatments than that in the other irrigation treatments through the three seasons. These findings were in line with those reported by Pacholak (1986), who mentioned that irrigation tended to increase the total leaf K content in apple trees. Likewise, Buwalda and Lenz (1992) reported that water stress reduced the leaf K content of the apple trees.

In view of the effect of different N levels on the leaf K content, irrespective the effect of the different irrigation treatments, the data in the same table indicated that the decrease of the leaf K content with N application through the three seasons. These results were in line with those obtained by Schembecker and Ludders (1990), who found that the high N nutrition caused a diminish in leaf K concentration on apple trees. In addition, Fallahi *et al.*, (1997) reported that the leaf K content was at the lowest percentage as a results of urea soil application in apple trees.

Table (6) : Effect of irrigation and nitrogen fertilization treatments on the percentage of leaf potassium content (on the dry weight basis) of "Anna" apple trees in 1997 , 1998 and 1999 seasons.

Fertilization Levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1997				
N_1	1.97^{ab}	1.65^{cde}	1.33^{f}	2.08^{a}	1.76^{a}
N_2	1.90^{abc}	1.62^{de}	1.42^{ef}	2.00^{ab}	1.73^{a}
N_3	1.68^{cde}	1.52^{def}	1.62^{de}	1.73^{bcd}	1.64^{a}
Average	1.85^{a}	1.59^{b}	1.46^{c}	1.94^{a}	
L.S.D. (0.05)	Irrigation 0.108	Fertilization 0.183		Interaction 0.274	
	1998				
N_1	1.53^{a}	1.33^{c}	1.15^{e}	1.55^{a}	1.39^{a}
N_2	1.48^{ab}	1.27^{cd}	1.20^{de}	1.53^{a}	1.37^{a}
N_3	1.40^{bc}	1.23^{cde}	1.25^{cde}	1.45^{ab}	1.33^{a}
Average	1.47^{a}	1.28^{b}	1.20^{c}	1.51^{a}	
L.S.D. (0.05)	lirrigation 0.071	Fertilization 0.085		Interaction 0.117	
	1999				
N_1	1.77^{a}	1.36^{d}	1.20^{f}	1.72^{ab}	1.51^{a}
N_2	1.62^{bc}	1.33^{de}	1.23^{ef}	1.58^{c}	1.44^{b}
N_3	1.52^{c}	1.29^{def}	1.25^{ef}	1.52^{c}	1.39^{b}
Average	1.63^{a}	1.33^{b}	1.23^{b}	1.61^{a}	
L.S.D. (0.05)	Irrigation 0.119	Fertilization 0.052		Interaction 0.104	

The values followed by the same letter do not differ at 5% level of significance.

4. Calcium

The data of the effect of different irrigation treatments on the leaf Ca content, irrespective the effect of different N levels, cleared that it was significantly higher in the control and I_1 treatments, as compared with that of I_2 and I_3 treatments in the three seasons (Table 7). The above mentioned results were in line with those obtained by Williamson and Coston (1990), who found that the deficit of irrigation decreased leaf Ca content in peach trees.

Table (7) : Effect of irrigation and nitrogen fertilization treatments on the percentage of leaf calcium content (on the dry weight basis) of "Anna" apple trees in 1997, 1998 and 1999 seasons.

Fertilization Levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1997				
N_1	2.05 ^{d}	1.92 ^{f}	1.80 ^{h}	2.08 ^{cd}	1.96 ^{c}
N_2	2.10 ^{bc}	2.00 ^{e}	1.88 ^{g}	2.16 ^{a}	2.04 ^{b}
N_3	2.12 ^{b}	2.01 ^{e}	1.92 ^{f}	2.17 ^{a}	2.06 ^{a}
Average	2.09 ^{b}	1.98 ^{c}	1.87 ^{d}	2.14 ^{a}	
L.S.D. (0.05)	Irrigation 0.022	Fertilization 0.018		Interaction 0.037	
	1998				
N_1	2.07 ^{cd}	1.99 ^{f}	1.90 ^{h}	2.10 ^{c}	2.02 ^{c}
N_2	2.15 ^{b}	2.03 ^{e}	1.94 ^{g}	2.17 ^{ab}	2.07 ^{b}
N_3	2.18 ^{ab}	2.06 ^{de}	1.97 ^{fg}	2.19 ^{a}	2.10 ^{a}
Average	2.13 ^{b}	2.03 ^{c}	1.94 ^{d}	2.15 ^{a}	
L.S.D. (0.05)	Irrigation 0.015	Fertilization 0.019		Interaction 0.037	
	1999				
N_1	2.11 ^{cd}	2.03 ^{efg}	2.00 ^{g}	2.10 ^{cd}	2.06 ^{c}
N_2	2.18 ^{ab}	2.07 ^{def}	2.01 ^{fg}	2.14 ^{bc}	2.10 ^{b}
N_3	2.22 ^{a}	2.09 ^{cde}	2.02 ^{fg}	2.20 ^{ab}	2.13 ^{a}
Average	2.17 ^{a}	2.06 ^{b}	2.01 ^{c}	2.15 ^{a}	
L.S.D. (0.05)	Irrigation 0.050	Fertilization 0.032		Interaction 0.064	

The values followed by the same letter do not differ at 5% level of significance.

As for the effect of the different N levels on the leaf Ca content, irrespective the effect of irrigation treatments, the data for the three seasons of study, proved a positive relation between N level and leaf Ca content in apple trees and the differences in leaf Ca content among the different N levels were significant as shown in Table (7). These results agreed with those obtained by Forshey (1963), who mentioned that N fertilization increased the concentration of Ca in the leaves of "McIntosh" apple trees. Similarly, Ferree and Cahoon (1987) found that urea foliar sprays increased leaf Ca content of apple trees.

5. Magnesium

Regarding the effect of the different irrigation treatments on the leaf Mg content, irrespective the effect of the N levels, the data in Table (8) indicated that the highest significant leaf Mg content was found in the trees grown in I_3 treatment while the lowest one was found in the control treatment during the three seasons of study. The above mentioned results disagreed with those obtained by Pacholak (1986 and 1991), who found that irrigation increased leaf Mg content of apple trees.

Table (8) : Effect of irrigation and nitrogen fertilization treatments on the percentage of leaf magnesium content (on the dry weight basis) of "Anna" apple trees in 1997 , 1998 and 1999 seasons.

Fertilization levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1997				
N_1	0.39 ^{cde}	0.38 ^{de}	0.54 ^{a}	0.35 ^{e}	0.41 ^{a}
N_2	0.40 ^{cde}	0.39 ^{cde}	0.49 ^{ab}	0.40 ^{cde}	0.42 ^{a}
N_3	0.45 ^{bc}	0.44 ^{bcd}	0.43 ^{bcd}	0.42 ^{bcde}	0.44 ^{a}
Average	0.41 ^{b}	0.40 ^{b}	0.49 ^{a}	0.39 ^{c}	
L.S.D. (0.05)	Irrigation 0.045	Fertilization 0.032		Interaction 0.074	
	1998				
N_1	0.31 ^{ef}	0.35 ^{cde}	0.45 ^{a}	0.29 ^{f}	0.35 ^{a}
N_2	0.33 ^{def}	0.36 ^{bcde}	0.41 ^{ab}	0.32 ^{def}	0.36 ^{a}
N_3	0.33 ^{def}	0.37 ^{bcd}	0.39 ^{bc}	0.34 ^{cdef}	0.36 ^{a}
Average	0.32 ^{c}	0.36 ^{b}	0.42 ^{a}	0.32 ^{c}	
L.S.D. (0.05)	Irrigation 0.022	Fertilization 0.020		Interaction 0.052	
	1999				
N_1	0.25 ^{f}	0.30 ^{c}	0.35 ^{a}	0.25 ^{c}	0.29 ^{b}
N_2	0.27 ^{de}	0.32 ^{b}	0.34 ^{b}	0.26 ^{ef}	0.31 ^{a}
N_3	0.28 ^{d}	0.31 ^{bc}	0.32 ^{b}	0.27 ^{de}	0.31 ^{a}
Average	0.27 ^{c}	0.31 ^{b}	0.34 ^{a}	0.26 ^{c}	
L.S.D. (0.05)	Irrigation 0.016	Fertilization 0.009		Interaction 0.018	

The values followed by the same letter do not differ at 5% level of significance.

Concerning the effect of the different N levels on the leaf Mg content, irrespective the effect of the irrigation treatments, the data of the three seasons in Table (8), revealed that the leaf Mg content did not differ significantly among the three N levels in 1997 and 1998, while in 1999, it was significantly higher in the trees which fertilized with N_3 and N_2 , as compared with those under N_1 level. These results agreed with those obtained by Forshey (1963), who found that N fertilization increased the concentration of Mg in the leaves of "McIntosh" apple trees. Moreover, Kassem *et al.*, (1994) found that N fertilizer increased the concentration of leaf Mg in "Anna" apple trees.

6. Iron

As for the effect of irrigation treatments on the leaf Fe content, irrespective the effect of N levels, the data of the first and second seasons indicated that it was significantly higher in the control treatment than all other irrigation treatments. The same trend was found in 1999 but the leaf Fe content in I_1 was significantly higher than that in the control treatment (Table 9). The above mentioned findings are in line with those obtained by Hussein (1998), who mentioned that leaf Fe content of "Anna" apple trees markedly decreased under low irrigation rate.

Table (9) : Effect of irrigation and nitrogen fertilization treatments on the leaf iron content (in ppm on the dry weight basis) of "Anna" apple trees in 1997 ,1998 and 1999 seasons.

Fertilization levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1997				
N_1	110.00 ^{fg}	106.00 ^{gh}	98.00 ^{i}	112.00 ^{ef}	106.50 ^{c}
N_2	116.00 ^{cde}	114.00 ^{def}	102.00 ^{hi}	118.00 ^{cd}	112.50 ^{b}
N_3	125.00 ^{b}	120.00 ^{c}	104.00 ^{h}	130.00 ^{a}	119.75 ^{a}
Average	117.00 ^{b}	113.33 ^{c}	101.33 ^{d}	120.00 ^{a}	
L.S.D. (0.05)	Irrigation 2.322	Fertilization 2.224		Interaction 4.448	
	1998				
N_1	107.33 ^{cd}	105.67 ^{d}	88.00 ^{f}	110.33 ^{bc}	102.83 ^{c}
N_2	110.00 ^{bc}	110.33 ^{bc}	89.67 ^{f}	112.33 ^{ab}	105.58 ^{b}
N_3	113.67 ^{ab}	111.33 ^{bc}	94.33 ^{e}	116.00 ^{a}	108.83 ^{a}
Average	110.33 ^{bc}	109.11 ^{c}	90.67 ^{d}	112.89 ^{a}	
L.S.D. (0.05)	Irrigation 2.190	Fertilization 2.147		Interaction 4.294	
	1999				
N_1	150.00 ^{d}	133.17 ^{ef}	113.17 ^{h}	147.17 ^{d}	135.88 ^{c}
N_2	157.83 ^{c}	137.17 ^{e}	119.00 ^{g}	153.00 ^{c}	141.75 ^{b}
N_3	175.00 ^{a}	151.00 ^{d}	130.83 ^{f}	165.17 ^{b}	155.50 ^{a}
Average	160.94 ^{a}	140.44 ^{c}	121.00 ^{d}	155.11 ^{b}	
L.S.D. (0.05)	Irrigation 3.484	Fertilization 2.579		Interaction 5.154	

The values followed by the same letter do not differ at 5% level of significance.

As for the effect of the three N levels, on the leaf Fe content, irrespective the effect of irrigation treatments, the data of the three seasons cleared that leaf Fe content proportionally increased with increasing the rate of N fertilization, and the differences among the different N levels were significant (Table 9). These findings are in harmony with those obtained by Ferree and Cahoon (1987), who found that urea foliar sprays increased leaf Fe content of apple trees.

7. Manganese

Regarding the effect of the different irrigation treatments on the leaf Mn content , irrespective the effect of N levels , the data in Table (10) showed that the highest leaf Mn content was in leaves of I_3 trees, while the lowest one was in leaves of the control and I_1 trees during the three seasons. In accordance, Hussein (1998) found that the amount of Mn slightly increased in "Anna" apple trees which grown under water stress than well watered trees although, the data were not significant.

Table (10) : Effect of irrigation and nitrogen fertilization treatments on the leaf manganese content (in ppm on the dry weight basis) of "Anna" apple trees in 1997 , 1998 and 1999 seasons.

Fertilization levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1997				
N_1	80.83 ef	85.67 d	115.33 a	79.33 fg	90.29 a
N_2	79.67 fg	83.50 de	106.50 b	77.83 fg	86.88 b
N_3	77.50 fg	81.00 ef	98.67 c	76.67 g	83.46 c
Average	79.33 c	83.39 b	106.83 a	77.94 c	
L.S.D. (0.05)	Irrigation 2.180	Fertilization 1.785		Interaction 3.570	
	1998				
N_1	74.83 cde	76.67 cd	90.67 a	73.50 def	78.92 a
N_2	71.67 efg	74.50 cde	83.83 b	69.83 fg	74.96 b
N_3	70.33 efg	72.50 defg	79.00 c	68.83 g	72.67 c
Average	72.28 bc	74.56 b	84.50 a	70.72 c	
L.S.D. (0.05)	Irrigation 2.535	Fertilization 2.258		Interaction 4.515	
	1999				
N_1	76.33 efg	79.67 cd	107.67 a	77.33 def	85.25 a
N_2	74.67 fgh	78.67 de	94.50 b	76.17 efg	81.00 b
N_3	71.67 i	74.50 gh	87.83 c	73.17 hi	76.79 c
Average	74.22 c	77.61 b	96.67 a	75.56 c	
L.S.D. (0.05)	Irrigation 1.888	Fertilization 1.378		Interaction 2.755	

The values followed by the same letter do not differ at 5% level of significance.

Concerning the effect of the different nitrogen levels on the leaf Mn content during the three seasons, irrespective the effect of irrigation treatments, it was cleared that trees grown at lower nitrogen level (N_1) had higher leaf Mn content than those grown at moderate nitrogen (N_2) and higher nitrogen level (N_3) . The results were statistically significant among all N levels through the three seasons (Table 10). These findings were supported by those of Kassem *et al.*, (1994), who found that fertilized "Anna" apple trees with N alone decreased the leaf Mn content.

8. Zinc

As for the effect of different irrigation treatments on the leaf Zn content, irrespective the effect of N levels, the data in Table (11) showed that it was significantly higher in I_3, as compared with all other treatments during the three seasons of study. These findings were in line with those obtained by Williamson and Coston (1990), who reported that deficit irrigation increased leaf Zn in peach trees.

Table (11) : Effect of irrigation and nitrogen fertilization treatments on the leaf zinc content (in ppm on the dry weight basis) of "Anna" apple trees in 1997 ,1998 and 1999 seasons.

Fertilization levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1997				
N_1	40.67 ^{bcd}	45.83 ^{abc}	58.33 ^{a}	39.00 ^{bcd}	45.96 ^{a}
N_2	37.83 ^{bcd}	40.83 ^{bcd}	50.83 ^{ab}	34.50 ^{cd}	41.00 ^{b}
N_3	31.83 ^{d}	37.67 ^{bcd}	47.50 ^{abc}	31.67 ^{d}	37.17 ^{c}
Average	36.78 ^{b}	41.44 ^{b}	52.22 ^{a}	35.06 ^{b}	
L.S.D. (0.05)	Irrigation 7.690	Fertilization 6.750		Interaction 13.500	
	1998				
N_1	30.83 ^{bcd}	33.67 ^{ab}	36.67 ^{a}	29.67 ^{bcd}	32.71 ^{a}
N_2	27.50 ^{cde}	31.50 ^{abc}	32.50 ^{abc}	25.50 ^{de}	29.25 ^{b}
N_3	25.50 ^{de}	28.50 ^{bcde}	25.17 ^{de}	23.50 ^{e}	25.67 ^{c}
Average	27.94 ^{b}	31.22 ^{a}	31.44 ^{a}	26.22 ^{b}	
L.S.D. (0.05)	Irrigation 2.477	Fertilization 2.851		Interaction 5.702	
	1999				
N_1	39.67 ^{e}	46.67 ^{c}	54.00 ^{a}	41.50 ^{e}	45.46 ^{a}
N_2	33.67 ^{f}	45.50 ^{cd}	50.50 ^{ab}	34.67 ^{f}	41.08 ^{b}
N_3	29.83 ^{g}	41.83 ^{de}	48.83 ^{bc}	31.67 ^{fg}	38.04 ^{c}
Average	34.39 ^{c}	44.67 ^{b}	51.11 ^{a}	35.94 ^{c}	
L.S.D. (0.05)	Irrigation 2.975	Fertilization 1.874		Interaction 3.748	

The values followed by the same letter do not differ at 5% level of significance.

Concerning the effect of the different N levels on the leaf Zn content, irrespective the effect of different irrigation treatments, the data in Table (11) revealed that in the high N level (N_3), the leaf Zn content was significantly lower, as compared with that of the moderate level during the three seasons. Thus, as the N level decreased the leaf Zn content increased. These results were in line with those obtained by Kassem *et al.*, (1994), who mentioned that the application of N decreased leaf Zn content in "Anna" apple trees. Likewise, Fallahi *et al.*, (1997) reported that applied 197 g urea (as soil application) to apple trees resulted in lowest leaf Zn.

9. Copper

Regarding the effect of the different irrigation treatments on the leaf Cu content, irrespective the effect of N levels, the data in Table (12) indicated that it was significantly higher in I_3 and I_2 treatments, as compared with that in I_1 or control treatments through the three seasons. These results are disagreed with those of Williamson and Coston (1990), who found that irrigation treatments did not affect leaf Cu concentration of peach trees.

Table (12): Effect of irrigation and nitrogen fertilization treatments on the leaf copper content (in ppm on the dry weight basis) of "Anna" apple trees in 1997 , 1998 and 1999 seasons.

Fertilization Levels	Irrigation treatments				Average
	I_1	I_2	I_3	Control	
	1997				
N_1	13.67 ^{e}	16.33 ^{bcde}	17.17 ^{abcde}	13.33 ^{e}	15.13 ^{b}
N_2	15.67 ^{de}	19.33 ^{abcd}	19.83 ^{abc}	15.27 ^{de}	17.52 ^{a}
N_3	16.15 ^{bcde}	20.17 ^{ab}	21.17 ^{a}	15.83 ^{cde}	18.33 ^{a}
Average	15.16 ^{b}	18.61 ^{a}	19.39 ^{a}	14.81 ^{b}	
L.S.D. (0.05)	Irrigation 2.876	Fertilization 2.044		Interaction 4.087	
	1998				
N_1	13.17 ^{fg}	15.83 ^{de}	16.83 ^{cd}	12.83 ^{g}	14.67 ^{b}
N_2	15.00 ^{deg}	18.33 ^{bc}	19.00 ^{ab}	14.67 ^{efg}	16.75 ^{a}
N_3	15.50 ^{de}	19.33 ^{ab}	20.67 ^{a}	15.17 ^{de}	17.67 ^{a}
Average	14.56 ^{b}	17.83 ^{a}	18.83 ^{a}	14.22 ^{b}	
L.S.D. (0.05)	Irrigation 1.074	Fertilization 0.978		Interaction 1.956	
	1999				
N_1	12.67 ^{d}	15.17 ^{c}	16.00 ^{bc}	12.83 ^{d}	14.17 ^{b}
N_2	14.17 ^{cd}	17.83 ^{ab}	18.17 ^{a}	14.33 ^{cd}	16.13 ^{a}
N_3	14.83 ^{c}	18.67 ^{a}	19.67 ^{a}	15.00 ^{c}	17.04 ^{a}
Average	13.89 ^{b}	17.22 ^{a}	17.94 ^{a}	14.06 ^{b}	
L.S.D. (0.05)	Irrigation 1.191	Fertilization 0.927		Interaction 1.853	

The values followed by the same letter do not differ at 5% level of significance.

As for the effect of the different N levels on the leaf Cu content irrespective the effect of irrigation treatments, the data in Table (12) indicated that the trees grown at N_3 and N_2 levels had significantly higher leaf Cu content than that of trees grown at N_1 level, during the three seasons of study. These findings disagreed with those obtained by Kassem *et al.*, (1994), who found that the application of N decreased the leaf Cu content of "Anna " apple trees.

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تأثير الرى بالتنقيط والتسميد النيتروجينى على:
٢- الحالة المائية والمظاهر الكيمو حيوية والمحتوى المعدنى لأوراق أشجار التفاح صنف "آنا" النامية فى الأراضى حديثة الاستصلاح

عبد الفتاح حامد شاهين* ومحمد بدر الصبروت* و محمد محمود يحيى**
ووصفى ماهر عبد المسيح*

* قسم الفاكهة – كلية الزراعة – جامعة الإسكندرية – الإسكندرية – مصر
** معهد بحوث البساتين – مركز البحوث الزراعية – الجيزة – مصر

أجريت هذه الدراسة فى أعوام ١٩٩٧ و ١٩٩٨ و ١٩٩٩ على أشجار التفاح صنف "آنا" عمرها خمسة سنوات مطعومة على أصول مولنج مورتن ١٠٦ ونامية فى أرض ذات قوام "طميى رملى" بمحطة بحوث السادات التابعة لمركز تنمية الصحراء التابع للجامعة الأمريكية بالقاهرة والكائنة بمحافظة المنوفية . والهدف من هذا البحث هو دراسة تأثير أربع معاملات رى وثلاثة مستويات نيتروجين على الحالة المائية والمظاهر الكيمو حيوية والمحتوى المعدنى لأوراق أشجار التفاح صنف " آنا" . كمية المياه المضافة إلى كل شجرة تفاح مبنية على أساس جهد الشد الرطوبى فى ثلاث معاملات رى (رى١ ، رى٢ ، رى٣) بالإضافة إلى معاملة الكنترول .
ويمكن تلخيص النتائج الرئيسية فى النقاط التالية:

١- محتوى الأوراق النسبى من الرطوبة فى أشجار التفاح صنف "أنا" انخفض معنويا مع انخفاض معدل الرى بينما لم يكن لمستوى النيتروجين تأثيرا معنويا عليه.
٢- محتوى الأوراق من الكلورفيل الكلى زاد معنويا بزيادة معدل الرى ومستوى التسميد النيتروجينى.
٣- تقليل كمية مياه الرى المضافة إلى كل شجرة أدى إلى زيادة معنوية فى محتوى الأوراق من البرولين الحر وعلى وجه الخصوص معاملة رى٣. بالإضافة إلى ذلك لم يكن هناك تأثير معنوى لمستويات النيتروجين على محتوى الأوراق من البرولين بصفة عامة.
٤- زيادة معدل الرى ومستوى النيتروجين أدت إلى زيادة النيتروجين والفوسفور والكالسيوم والحديد فى الأوراق و أدت إلى تخفيض المنجنيز والزنك فى الأوراق وذلك خلال مواسم الدراسة الثلاثة.
٥- زيادة معدل الرى أيضا أدت إلى زيادة البوتاسيوم وتخفيض المنجنيز والنحاس فى الأوراق بينما زيادة مستوى التسميد النيتروجينى أدت إلى زيادة النحاس وانخفاض المنجنيز والزنك فى الأوراق وذلك خلال الثلاثة مواسم.
٦- زيادة الإجهاد المائى أدت إلى تخفيض حديد الأوراق ولكنه رفع معنويا تركيز كل من منجنيز وزنك ونحاس الأوراق فى الثلاثة مواسم. مستوى النيتروجين أثر معنويا على الحديد والنحاس فى الأوراق ايجابيا ولكن كان له تأثير سلبى على المنجنيز والزنك فى الأوراق.