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# RESPONSES OF MATURE NAVEL ORANGE TREES TO THREE METHODS OF FLOOD IRRIGATION UNDER NORTH EL-TAHREER CONDITIONS

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## ABSTRACT

Responses of mature navel orange [*Citrus sinensis* (L.) Osb.] trees grafted on sour orange (*C.aurantium* L.) rootstock spaced 6 × 6 m, and arranged in hedgerows system at a north - south direction, in a sandy clay loam soil of an orchard of North El-Tahrer Agric Co. were studied in relation to basin (B), modified border (MB) and blind border (BB) irrigation methods. All trees received 13 irrigations / year and using 3120 $m^3$.,1755$m^3$ and 1365 $m^3$ water/ feddan/ year for B,MB and BB methods,respectively.A gradual reduction in production of the new leaves,leaf density and fruit yield was observed as the amount of irrigation water decreased. The reduction in leaf density was primarily due to a reduction in the number of new leaves mainly during summer and autumn growth cycles. The yield reduction was more consistent with the reduction of leaf density rather than with that of the leaf efficiency. Water savings in excess of 40% and 55% resulted in a reduction of 10% and 25% fruit yield of the trees under MB and BB methods, respectively. The total soluble solids and acidity of fruit juice were reversibly related and affected by the irrigation methods. The salt accumulation along the border was in acceptable levels. The modified border irrigation method was recommended to displace the basin irrigation method to overcome the shortage of irrigation water and to keep the load on the drainage system at a minimum level.

***Key words:*** *border irrigation, leaf efficiency, water use efficiency.*

## 1.INTRODUCTION

Egyptian citrus orchards are mainly located in the Delta where basin irrigation is the common method. The need to achieve a higher degree of water use efficiency has recently become one of the most important strategies of the agricultural policy to face the increased competition between agricultural and nonagricultural water uses and to keep the load on the drainage system at a minimum level.

The concept of localized irrigation has been recently developed since the wide spread use of low volume irrigation techniques. The major idea consists of wetting the soil mass occupied by the " majority" of the root system. It was suggested that at least 60 to 70% of the root zone should be covered by irrigation water (Koo, 1980).

Under flood irrigation, like in humid regions of abundant rainfull, tree roots extend to longer distance from the trunk to cover a larger area out of the ground area (the area covered by the tree canopy), compared to the case under trickle irrigation, especially in arid regions (Koo, 1980; Feld *et al.*, 1990; Swietlik, 1992; Smajstrla, 1993). The vertical root distribution is also modified by irrigation method. Flood irrigated roots are more concentrated above 60 cm. depth in contrast to the uniform distribution to deeper depth of drip irrigated roots (Swietlik, 1992).

The proper irrigation maintains the soil suction in the root zone between 5 to 30 centibar (cb) (Marsh, 1973). At soil suction equal to or more than 50 cb or under increased water stress, a reduction in fruit growth rate, yield, canopy volume, trunk cross-sectional area, shoot growth, leaf area and root growth was reported (Marsh,1973; Levy *et al.*, 1979; Chalmers *et al.*, 1981; Bevington and Castle, 1985; Marler and Davies, 1990). Marsh (1973) reviewed evidences that yield of Valencia orange trees was reduced gradually as soil suction increased from 30 cb to 50 cb or 70 cb, *i.e.* equivalent to 55% , 70% and 95% of available water depletion, respectively. Levin *et al.*, (1996) found that yield of Star Ruby grapefruit and Sweetie (a triploid pummelo-grapefruit hybrid) was 17% greater when irrigation was scheduled at -20 kPa soil metric potential than at - 40 kPa.

Despite the border irrigation is one of the recommended methods to replace the wide spread basin irrigation in Delta citrus orchards, there are few quantitative descriptions of its efficiency and the responses of the trees in respect to tree growth, yield and fruit quality. This paper reports responses of mature navel orange trees to basin, blind border, and modified border irrigation methods under North El-Tahreer conditions.

## 2. MATERIALS AND METHODS

This experiment was conducted during 1996 and 1997 seasons on 14- to 15-year-old navel orange [ *Citrus sinensis* (L.) Osb.] trees grafted on sour orange (*C. aurantium* L.) rootstock spaced 6 × 6 m in an orchard of the North El-Tahreer Company. The trees were arranged in the hedgerows system oriented in a north -south direction.

### 2.1. Irrigation treatments

Three methods of flood irrigation were established during winter of 1995 season:1) basin (B), 2) blind border (BB),and 3) modified border (MB) by making a narrow canal across the border between each two adjacent trees in the row. The border width was 3 m. perpendicular on the hedgerow direction. For BB and MB methods, an irrigation canal was established between the adjacent rows (north-south direction) with a maximum depth of about 15cm. The treatments were randomily arranged in five blocks with an experimental plot consisting of 3 rows with 20 trees per row.

Nubaria canal was the source of the irrigation water. According to El-Fayoumy *et al.*, (1999), pH and EC of Nubaria canal water ranged between 7.79 to 7.88 and 1.07 to 1.13 d $S.m^{-1}$, respectively. The irrigation water was applied by an irrigation machine with an engine of 6 cylinders, bore/stroke 112mm./115mm., displacement 6.798 l., rating 81 Hp at 1500 rpm. and a pump of discharge 150 $m^3$ / hr., speed 1450 rpm. suction / delivery pip conn. 150 mm./125 mm.

As the prevailing practice in the region, all trees received 13 irrigations per year : 4 during March to May, 5 during June to Aug., 2 during Sept. to Oct., and 2 irrigations during Nov. to Feb. The time to finish irrigation was recorded for each treatment 4 times a year, and hence the average of annual amount of irrigation water was calculated giving 3 different amounts : 3120 $m^3$., 1755 $m^3$., and 1365 $m^3$. / feddan / year for B , MB and BB treatments, respectively.

Soil moisture content at 0-30 cm. and 30-60 cm. depth was recorded just before irrigation on representative samples for each treatment at north - south (N-S) and west - east (W-E) directions of the tree (Table 1) . The samples were taken during the four seasons of the year from the midway between two adjacent trees in the row (N-S) and between rows (W-E).

**Table(1): Average soil* moisture content% immediately before applying irrigation water.**

| Treatment | Depth (cm) | Winter | | Spring | | Summer | | Autumn | |
|---|---|---|---|---|---|---|---|---|---|
| | | N-S | W-E | N-S | W-E | N-S | W-E | N-S | W-E |
| B (3120 $m^3$) | 0 - 30 | 22.19 | 22.69 | 23.69 | 24.76 | 24.15 | 24.66 | 24.95 | 25.36 |
| | 30-60 | 23.25 | 23.45 | 24.85 | 25.67 | 25.60 | 25.75 | 25.88 | 26.00 |
| MB(1755 $m^3$) | 0 -30 | 18.10 | 19.65 | 19.13 | 22.09 | 20.35 | 22.89 | 20.85 | 23.15 |
| | 30-60 | 19.50 | 20.59 | 20.75 | 23.29 | 21.15 | 23.43 | 21.65 | 24.97 |
| BB(1365 $m^3$) | 0-30 | 19.12 | 18.42 | 18.42 | 21.15 | 19.62 | 21.65 | 20.00 | 22.18 |
| | 30-60 | 18.20 | 19.15 | 19.26 | 22.29 | 20.13 | 22.15 | 21.35 | 23.08 |

*The soil field capacity = 27.63 %; wilting point = 13.59 % .

### 2.2. Determination of soil properties

Representative soil samples for each treatment at N-S and W-E axes of the tree, *i.e.*, one composite sample from 5 samples (one sample/ replicate) of about / one kilogram each/ treatment / each axis of the tree, were collected manually from 0-30 cm. and 30-60 cm. depth. The samples were taken twice: during Dec. 1995 and 1997.

Particle size distribution was determined by the hydrometer (Day, 1953). Total $CaCO_3$ was measured by calcimeter (Black , 1965). Electrical conductivity was measured according to Bower and Wilcox (1965). Soil reaction (pH) was determined in 1:2.5 soil : water suspension by pH-meter (Jackson , 1956) .The data are given in Table (2).

### 2.3. Tree selection

On the basis of the high yield and foliage density, one tree per each experimental plot was selected from the middle row to record leaf growth , tree volume, " maximum" yield (number and weight) and fruit quality. In addition, yield of the center 10 trees of the middle row was recorded to represent the "average" yield. All the measurements were recorded one year after the start of applying the treatments.

**Table(2):Chemical properties of soil*of the experimental plots under flood irrigation methods at the different directions of the tree .**

| Treatment | Depth (cm) | CaCO3 (%) | | EC (dS/m) | | pH (1:2.5) | |
|---|---|---|---|---|---|---|---|
| | | N-S | W-E | N-S | W-E | N-S | W-E |
| | | **1995 season** | | | | | |
| B (3120 $m^3$ ) | 0 - 30 | 10.6 | 12.4 | 0.75 | 0.65 | 8.1 | 7.9 |
| | 30-60 | 12.8 | 13.5 | 0.79 | 0.74 | 8.2 | 8.1 |
| | 0 -30 | 12.4 | 12.8 | 0.79 | 0.74 | 8.2 | 8.0 |
| MB(1755 $m^3$) | 30-60 | 13.9 | 13.2 | 0.80 | 0.81 | 8.2 | 8.1 |
| | 0-30 | 10.9 | 11.8 | 0.78 | 0.76 | 8.2 | 8.1 |
| | 30-60 | 12.2 | 13.9 | 0.81 | 0.79 | 8.3 | 8.2 |
| BB(1365 $m^3$) | | | | | | | |
| | | **1997 season** | | | | | |
| B (3120 $m^3$ ) | 0 - 30 | 10.5 | 12.1 | 0.79 | 0.80 | 8.2 | 8.1 |
| | 30-60 | 12.6 | 13..2 | 0.80 | 0.82 | 8.3 | 8.2 |
| MB(1755 $m^3$) | 0 -30 | 12.8 | 13.1 | 0.94 | 0.82 | 8.2 | 8.1 |
| | 30-60 | 13.6 | 14.8 | 1.12 | 0.85 | 8.3 | 8.2 |
| | 0-30 | 11.8 | 12.2 | 1.34 | 0.86 | 8.2 | 8.2 |
| BB(1365 $m^3$) | 30-60 | 12.5 | 13.3 | 1.55 | 0.90 | 8.3 | 8.3 |

* Soil texture: sandy clay loam, bulk density : 1.18 g.$cm^{-3}$.
N-S : north –south direction.
W-E : west - east direction.

### 2.4. Vegetative growth measurements

Average tree diameter and height were measured during Dec. 1996 and 1997. Tree volume was calculated according to Turrell (1946). At north, south, west and east directions of the tree, four branches of 20 - 30 mm. diameter were selected to record all the new produced leaves. Leaf area and leaf specific weight were estimated according to Chou (1966) and Barnes *et al.,* (1969), respectively, on a collective sample of 60 leaves per each branch. The total dry weight and leaf area were calculated per each branch. The leaf density was estimated from information of the total area per branch and its diameter as described by Khalil (1999).

### 2.5 Fruit quality measurements

On a sample of 20 fruits per each selected tree, the various physical and chemical fruit characters were determined according to the standard procedures. Average fruit weight was determined from knowledge of the fruit yield per tree as weight and number.

The standard methods of statistical analysis were followed according to Snedeocr and Cochran (1981).

## 3. RESULTS

### 3.1. Soil conditions

The soil was sandy clay loam with 14.04 % average available water content, 1.18 $g.cm^{-3}$ mean bulk density, 7.9 - 8.3 % pH, and 10.5 - 14.8 % total $CaCO_3$. The minimum soil moisture was recorded just before irrigation at N-S direction of the BB and MBtrees (Table1). Values of the electrical conductivity (EC) increased gradually in 1997 season as the amount of applied water decreased (Table 2). The highest values reached 1.34 dS/m and 1.55 dS/m at 0 to 30 and 30 to 60 cm depths, respectively, at N-S direction of the BB trees.

### 3.2.Vegetative growth

Leaf production (Table3), tree size and leaf density (Table 4) reduced remarkably as the amount of irrigation water decreased.

There was a trend but without significant differences between the three methods of irrigation with respect to their effects on the leaf area. Only the tree direction appeared to affect significantly the leaf area, where the west direction had the smallest leaves compared with largest ones at the east. The same case was observed regarding the leaf specific weight, but with opposite trend, *i.e.,* the heaviest and lightest leaves were found at west and east directions, respectively.

**Table(3): Effect of irrigation method (I) and tree direction (D) on leaf growth of mature navel orange trees.**

| | Leaf area ($cm^2$) | | | | | Leaf specific weight ($g.dm^{-2}$) | | | | | Leaf dry weight per branch ($g.br.^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Direction(D) | N | S | E | W | Mean | N | S | E | W | Mean | N | S | E | W | Mean |
| Irrigation method (I) | | | | | | 1996 Season | | | | | | | | | |
| B (3120m³) | 19.42 | 20.10 | 21.88 | 17.90 | 19.58 | 1.261 | 1.260 | 1.182 | 1.340 | 1.261 | 221.4 | 252.8 | 258.3 | 195.7 | 232.1 |
| MB (1755 m³) | 18.52 | 18.36 | 18.32 | 16.28 | 17.62 | 1.234 | 1.334 | 1.256 | 1.400 | 1.316 | 145.6 | 190.6 | 230.8 | 168.2 | 188.8 |
| BB (1365 m³) | 17.52 | 17.42 | 17.86 | 17.30 | 17.53 | 1.258 | 1.300 | 1.264 | 1.384 | 1.302 | 154.3 | 150.3 | 171.8 | 140.6 | 154.2 |
| Mean | 18.49 | 18.63 | 19.35 | 16.83 | 18.32 | 1.251 | 1.298 | 1.247 | 1.374 | 1.293 | 173.8 | 197.9 | 220.3 | 174.8 | 191.7 |
| LSD at 0.05 for : | I : NS , D : 1.74 , I X D : NS | | | | | I : NS , D : 0.072 , I X D : NS | | | | | I : 32.5 , D : 27.6 , I X D : 52.2 | | | | |
| | | | | | | 1997 Season | | | | | | | | | |
| B (3120m³) | 24.06 | 24.10 | 22.32 | 21.22 | 22.93 | 1.248 | 1.250 | 1.194 | 1.302 | 1.249 | 301.1 | 462.8 | 227.1 | 325.8 | 336.9 |
| MB (1755 m³) | 21.50 | 22.42 | 22.96 | 18.22 | 21.28 | 1.202 | 1.222 | 1.260 | 1.268 | 1.238 | 276.6 | 277.6 | 320.5 | 202.8 | 269.4 |
| BB (1365 m³) | 23.54 | 20.30 | 26.26 | 20.76 | 22.72 | 1.160 | 1.152 | 1.198 | 1.180 | 1.173 | 192.0 | 217.8 | 277.4 | 205.7 | 223.2 |
| Mean | 23.03 | 22.27 | 71.78 | 20.07 | 22.31 | 1.203 | 1.208 | 1.217 | 1.250 | 1.220 | 256.6 | 319.4 | 275.2 | 254.8 | 276.5 |
| LSD at 0.05 for : | I : NS , D : 2.28 , I X D : NS | | | | | I : NS , D : NS , I X D : NS | | | | | I : 29.56 , D : 37.43 , I X D : NS | | | | |

Total dry weight of the new leaves reduced greatly and gradually by replacing the B method with MB and BB ones (Table 3). The reduction was mainly due to a reduction in the number of produced leaves, especially during summer and autumn cycles (data not shown). Moreover, the leaf density (as square meter of leaves per cubic meter of canopy volume) reduced gradually as the amount of irrigated water decreased (Table 4).

The tree direction exerted a significant effect on the total leaf dry weight with no definite trends. However, suppression extent of the leaf production was much greater at N-S direction (parallels to the irrigation canal of the two border methods ) than at W-E one (perpendiculars on the irrigation canal). This trend held true for the two seasons of the study (Table 3).

The effect of irrigation treatments on tree size did not appear until the second season of the study (two seasons after application of the treatments). Only the trees under blind border irrigation method became significantly smaller in size in comparison with those under the two other treatments.

### 3.3. Fruit yield efficiencies

Compared with yield of the B trees, the MB ones yielded 88% and 94% during 1996 and 1997 seasons , respectively (Table 4). The corresponding yield of BB trees represented about 75% and 60% of that of B ones. A quite similar trend was observed in respect to the effect of B and MB treatments on the canopy volume efficiency (Kg fruit per cubic meter of CV). The CV efficiency of BB trees represented 74% and 75% of that of B ones.

The yield reduction of the trees under MB and BB treatments was mainly consistent with the reduction in leaf density and partially with the reduction in leaf efficiency (square meter of leaves required to produce one kg. fruits). The leaf efficiency of the trees under B treatment was1.47 $m^2$. $Kg^{-1}$ during the two seasons compared with 1.50$m^2$. $Kg^{-1}$. and 1.63 $m^2$. $Kg^{-1}$ for the trees under MB and BB treatments, respectively. The differences were not significant.

The situation was different with respect to the effects of the treatments on the water use efficiency (as Kg. fruits per cubic meter of water used). There were negative relationships between the amount of irrigated water and its efficiency whether the calculations were made on the maximum or average yield basis.

**3.4. Fruit quality**

The irrigation method had no significant effect on average fruit weight and rind thickness (Table 5). However, the fruit weight tended to increase gradually as the amount of irrigated water decreased. Contrast to the total soluble solids (TSS), the acid content was negatively correlated with the amount of irrigated water. So, the juice of B fruits contained significantly higher TSS/acid ratio compared with those of MB and BB ones.

## 4. DISCUSSION

Two variables were involved in the treatments of the present study on how much and where was the irrigated water. So, there were different levels of soil moisture content (Table 1) and EC (Table 2) at W-E and N-S axes of the tree according to the amount and location of irrigated water. Such situation would serve as a logical point of discussing the present results.

The positive correlation between soil water potential and the tree growth was reported (Marsh , 1973; Chalmers *et al.*, 1981; Bevington and Castle, 1985; Smajstrla *et al.*, 1985 and Marler and Davies , 1990). Our results revealed that the consistent reduction of leaf density with decreasing the amount of irrigation water was primarily due to a reduction of number of the growing new leaves, especially at N-S axis of the tree and mainly during summer and autumn growth cycles. This result is consistent with Bevington and Castle (1985) who stated that the fluctuations in total root growth of young Valencia orange trees due to different levels of water stress were primarily the result of changes in the number of growing roots rather than in the elongation rate of individual roots. In addition, Marler and Davies (1990) reported that summer and fall growth flushes were delayed or did not occur when Hamlin orange trees were irrigated at 45% and 65% of available water depletion.

The reduction of citrus tree yield as a result of decreasing the amount of irrigated water or scheduling the irrigation at a low soil matric potential or at a low content of available water was previously

**Table (4) : Effect of some irrigation methods on canopy volume, leaf density and production efficiency of mature navel orange trees.**

| Irrigation method | Canopy Vol. (CV) $m^3$ | Lea f density $m^2$ Lvs. $m^{-3}$ CV | Yield per tree (Kg) | | Canopy efficiency Kg.fr. $m^{-3}$ CV | Leaf efficiency $m^2$ lvs.kg.$^{-1}$ fruit | Water efficiency ,kg fruit. $m^{-3}$ water | |
|---|---|---|---|---|---|---|---|---|
| | | | On maximum basis* | On average basis** | | | On maximum basis* | On average basis** |
| | | | | **1996 Season** | | | | |
| B(3120$m^3$) | 28.33 | 4.93 | 97.3 | 63.0 | 3.49 | 1.47 | 3.74 | 2.42 |
| MB(1755$m^3$) | 28.78 | 4.48 | 85.8 | 54.90 | 3.03 | 1.50 | 5.87 | 3.76 |
| BB(1365$m^3$) | 29.90 | 4.08 | 72.6 | 47.78 | 2.59 | 1.63 | 6.40 | 4.19 |
| Mean | 28.67 | 4.50 | 85.2 | 55.2 | 3.03 | 1.53 | 5.34 | 3.46 |
| LSD at 0.05 | NS | 0.45 | 15.2 | 8.0 | 0.23 | NS | 0.86 | 0.39 |
| | | | | **1997 Season** | | | | |
| B(3120$m^3$) | 37.40 | 5.42 | 142.2 | 81.6 | 3.76 | 1.47 | 5.42 | 3.14 |
| MB(1755$m^3$) | 38.19 | 5.21 | 133.4 | 74.0 | 3.48 | 1.52 | 9.18 | 5.07 |
| BB(1365$m^3$) | 30.93 | 4.43 | 84.9 | 58.7 | 2.82 | 1.66 | 9.63 | 5.15 |
| Mean | 35.51 | 5.02 | 120.2 | 71.5 | 3.35 | 1.55 | 736 | 4.45 |
| LSD at 0.05 | 3.09 | 0.45 | 23.1 | 6.4 | 0.31 | NS | 1.24 | 0.32 |

* maximum yield based on one selected tree per each experimental plot.

** average yield based on average yield of 10 trees per each experimental plot.

**Table (5) :Effect of some irrigation methods on some fruit quality of navel orange trees.**

| Irrigation Method | Fruit wt. (g) | Rind thick. (mm) | TSS % | Acidity % | TSS/Acid ratio |
|---|---|---|---|---|---|
| | | | **1996 Season** | | |
| B(3120$m^3$) | 287.8 | 5.32 | 12.08 | 1.19 | 10.25 |
| MB(1755$m^3$) | 292.2 | 5.42 | 11.40 | 1.25 | 9.14 |
| BB(1365$m^3$) | 310.0 | 5.28 | 11.50 | 1.26 | 9.21 |
| Mean | 296.7 | 5.34 | 11.66 | 1.23 | 9.53 |
| LSD at 0.05 | NS | NS | 0.47 | 0.05 | 0.42 |
| | | | **1997 Season** | | |
| B(3120$m^3$) | 256.2 | 4.44 | 11.56 | 1.10 | 10.56 |
| MB(1755$m^3$) | 275.2 | 4.78 | 11.38 | 1.12 | 10.17 |
| BB(1365$m^3$) | 290.8 | 4.80 | 11.14 | 1.12 | 9.90 |
| Mean | 274.1 | 4.67 | 11.36 | 1.11 | 10.21 |
| LSD at 0.05 | NS | NS | NS | NS | 0.25 |

reported (Marsh, 1973; Levin *et al.*, 1996) as well as the present data showed. Our results revealed that the gradual reduction of fruit yield was more connected with nearly the same degree of the leaf density reduction rather than with the leaf efficiency. Although the latter had a tendency to decrease with decreasing the amount of irrigated water , yet its reduction was of a slight degree with no significant differences. The high water use efficiency (measured as the ratio of transpiration to photosynthesis rates) was reported (Hoare and Barrs, 1974). Moreover, the photosynthesis rates of citrus leaves are slightly affected with initial decreasing of soil moisture content (Bielorai and Mendel , 1969) or with decreasing the water potential around roots down to -4 bars (Hoare and Barrs, 1974) . In the present study, the minimum soil moisture content during summer reached 19.62% , *i.e.* 57% available water depletion, at N-S axis of the tree in 0-30cm depth (Table 1), and the accumulation of salts was in an acceptable level even after three years from starting of the border methods (Table 2).

The data of Levin *et al.*, (1996) indicated that about 17% reduction in the yield of Star Ruby grapefruit and Sweetie trees was the price of water savings in excess of 45 %. The yield reduction of MB and BB trees was 10% and 25% , respectively, as a result of 43% and 56% savings on water.

Conversely to results of the studies reviewed by Marsh (1973) and that of Levy *et al.*, (1979), the present study showed that the irrigation treatments had no effect on fruit weight and rind thickness in addition to the positive relationship between juice TSS and amount of irrigated water. Only titratable acidity accumulated in the juice with decreasing the amount of irrigated water, and so it was in agreement with the previous studies. In fact, the fruit weight seemed mainly to be negatively correlated with fruit yield rather than to be affected by the amount of irrigated water.

## CONCLUSION

This study revealed that irrigation has the ability to modify the leaf growth . Indeed, other studies have proved that irrigation can be developed into a powerful management strategy to control and modify the tree growth towards specific purposes such as controlling tree size and improving fruit size (Chalmers *et al.,* 1981). Reducing injuries of phytophthora root rot (Feld *et al.,* 1990) or citrus leafminer (studies under publication).

At the expense of 10% reduction in fruit yield, water savings in excess of 40% was realized under modified irrigation method, beside the expected reduction of the load on the drainage system. Under conditions of the citrus orchards of North El-.Tahreer Agric Co. (about 4000 feddans), where the shortage of irrigation water is an obvious problem and the drainage system is overloaded, the modified border irrigation method was suggested and successfully adopted. The borders were mechanically established and maintained at low cost. In additions, the cost of pruning and control of some pests were greatly reduced. The accumulation of salts along the borders was not a problem and could be overcome by covering the borders with water twice a year.

Economic conditions and management practices will determine if it is advantageous, for small citrus orchards in the Delta, to follow the modified border irrigation method. Few growers use this method because savings on water do not compensate for increased cost of building and maintaining the borders, especially that the shortage of water is not obvious enough for them. The matter requires further economic studies with respect to cost of the pruning and control of some pests under such method of irrigation.

Finally, the study was mainly concerned with comparing between basin and border irrigation methods under the same water schedule prevailed in the region. Our results revealed the advantage of the modified border irrigation mainly with respect to water savings. The adjustment of water schedule under such method will probably increase its water use efficiency.

## 5. REFERENCES

Barnes D.K., Pearce R.B.,Carlson G.F., Hatt R.H. and Hanson C.H.(1969). Specific leaf weight differences in alfalfa associated with variety and plant age. Crop Sci., 9 : 421 - 423.

Bevington K.B. and Castle W.S. (1985). Annual root growth pattern of young citrus trees in relation to shoot growth , soil temperature, and soil water content. J.Amer. Soc. Hort. Sci., 110 (6): 480 - 845.

Bielorai H. and Mendel K. (1969). The simultaneous measurement of apparent photosynthesis and transpiration of citrus seedlings at different soil moisture levels. J. Amer. Soc. Hort. Sci., 94 : 201 - 204.

Black C.A. (1965) . Methods of soil analysis .Agron. Monogr. No.9. Amer .Soc. Agronomy, Madison, WI.

Bower A.A. and Wilcox L.V. (1965). Soluble salt . In C.A. Black (ed.) Methods of soil analysis. p. 935. Agron. Monogr. No.9. Amer. Soc. Agronomy, Madison , WI.

Chalmers D.J., Mitchell P.D. and Heek L. (1981). Control of peach tree growth and productivity by regulated water supply, tree density and summer pruning. J. Amer Soc. Hort. Sci., 106 (3) : 307-312.

Chou G.I. (1966) . A new method of measuring the leaf areas of citrus trees. Acta Hort. Sci., 5 :17-20 ( C.F. Hort. Abst. 36 : 7315).

Day P.R. (1953) . Experimented confirmation of hydrometer theory. Soil Sci., 75 : 181 - 186.

El-Fayoumy M.E., Hammad K.M. and Ramadan H.M. (1999). Soil salinity effects on performance of some canola varieties (*Brassica napus* L.) under calcareous soil conditions at Nubaria region. Alex. Sci. Exch., 20(4):201-220.

Feld S.J., Menge J.A. and Stolzy L.H. (1990) . Influence of drip and furrow irrigation on phytophthora root rot of citrus under field and greenhouse conditions. Plant Disease, 74 (1) : 21 - 27.

Hoare E.R.and Barrs H.D. (1974). Water relations and photosynthesis amongst horticultural species as affected by simulated soil water stress. XIXth International Horticultural Congress. Warszowa, 11-18-Sept. 1974. 321-334.

Jackson M.L. (1956). Soil chemical analysis. Prentice – Hall, India.

Khalil A.A. (1999). Leaf density and its relations to canopy volume under various tree spacing and planting systems of mature navel oragne trees. Bull. Fac. Agric., Cairo Univ., 50 : 693 - 710.

Koo R.C.J. (1980). Results of citrus firtigation studies. Proc. Fla. State Hort. Soc., 93 : 33 - 36.

Levin I. , Asor Z., Ratner O., Rotman N. and Sagee O. (1996). Response of Star Ruby and Sweetie to various irrigation and nitrogen fertilization regimes. VIII Congress of the Inter. Soc. of Citriculture, 12-17 May, 1996, South Africa. P111.

Levy Y., Shalhevet J. and Bielorai H. (1979). Effect of irrigation regime and water salinity on grapefruit quality. J.Amer. Soc. Hort. Sci.,104:356.

Marler T.E. and Davies F.S. (1990). Microsprinkler irrigation and growth of young Hamlin orange trees. J. Amer. Soc. Hort. Sci., 115 : 45-51.

Marsh A.W. (1973). Irrigation. p. 230 - 279. In the citrus industry, W.Reuther (ed.) Univ. California , Berkeley, Vol . 3.

Smajstrla A.G. (1993). Microirrigation for citrus production in Florida. Hort. Science , 28 : 295 - 298.

Smajstrla A.G., Person L.R., Aribi K. and Velledis G. (1985). Response of young citrus trees to irrigation. Proc. Fla. State Hort. Soc.98:25-28.

Snedecor G.W. and Cochran W.G.(1981). Statistical methods. 7th ed., Iowa State Univ. Press, Iowa, USA.

Swietlik D. (1992). Yield , growth and mineral nutrition of young Ray Ruby grapefruit trees under trickle or flood irrigation and various nitrogen rates. J. Amer. Soc. Hort. Sci., 117 : 22 - 27.

Turrell F.M. (1946). Tables of surfaces, volumes of spheres and of prolate and oblate speheroids and spheroidal coefficients. Univ. California, Berkeley.

# إستجابة أشجار البرتقال أبو سرة البالغة لثلاث طرق ري بالغمر تحت ظروف شمال التحرير

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## ملخص

درست استجابة اشجار البرتقال أبو سرة البالغة على أصل النارنج بمسافة 6×6 بنظام السياج من الشمال للجنوب والنامية فى أرض رملية طينية سلتية تابعة لأحد مزارع شركة شمال التحرير الزراعية، لنظام الرى الحوضى (أ) ، البواكى المعدلة (ب) والبواكى العمياء (جـ). رويت الأشجار 13 رية فى السنة واستهلكت 3120م3 ، 1755م3 ، 1365م3 ماء لكل فدان فى السنة للأشجار تحت نظام الرى (أ) ، (ب) ، (جـ) على الترتيب. لوحظ نقص تدريجى فى انتاج الأوراق الجديدة، الكثافة الورقية ومحصول الثمار مع نقص كمية ماء الرى المستخدمة. قل حجم الأشجار تحت نظام الرى (جـ) معنويا فى العام الثانى من الدراسة. كان النقص فى الكثافة الورقية راجعا أساسا إلى نقص فى عدد الأوراق المنتجة خاصة خلال دورات نمو الصيف والخريف، وكان نقص المحصول أكثر اتساقا مع النقص فى الكثافة منه مع النقص فى الكفاءة الورقية. توفير ماء الرى بما يزيد عن 40% و 55% نتج عنه 10% و 25% نقص فى محصول الثمار للأشجار تحت طرق الرى (ب) و (جـ) على الترتيب. ارتبطت المواد الصلبة الذائبة فى عصير الثمار عكسيا مع الحموضة وتأثرا بطريقة الرى. كان تراكم الاملاح على طول بواكى الرى فى مستوى مقبول. يوصى باتباع طريقة الرى بالبواكى المعدلة لتحل محل طريقة الرى الحوضى لمواجهة مشكلة نقص ماء الرى ولتقليل العبء على نظام الصرف.

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المجلة العلمية لكلية الزراعة – جامعة القاهرة – المجلد(51) العدد الثالث (يوليو2000):349-364.