

## IMPACT OF CHEMICAL AND NATURAL WATER SAVING SOIL AMENDMENTS ON GROWTH, YIELD AND WATER USE EFFICIENCY OF "WASHINGTON NAVEL" ORANGE TREES UNDER DEFICIT IRRIGATION CONDITIONS

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**ABSTRACT:** *Due to the limited water resources, it is necessary to study the best ways to reduce the use of irrigation water, increase the efficiency of water use without affecting the growth of trees and maintain the production of citrus productivity under these circumstances. A field experiment was conducted during 2015 and 2016 seasons at El-Nubaria region, Beheira Governorate to investigate the effect of three irrigation water regimes (100, 75 and 50% of actual irrigation practiced in the orchard) and soil application of hydrogel (50 and 100g/tree) and organic plant residues (3.5 and 6.5kg/tree) as chemical and natural water absorbing soil amendments on growth, yield and water use efficiency on "Washington Navel" orange trees grown on a sandy soil under drip irrigation system. The obtained results point out that, applied organic plant residues at rate 6.5 kg/tree or 100g/tree hydrogel under moderate irrigation rate (T<sub>5</sub> and T<sub>3</sub>) significantly increased the most growth parameters (canopy volume, number of shoots/branch and leaf area), fruit set, leaf relative water content and decrease fruit drop%. Moderate irrigation rate + 100g/tree hydrogel (T<sub>3</sub>) and control (T<sub>1</sub>) were the best treatments in increasing leaf N,P,K and Ca contents. The highest yield (78.8 and 78.47) and (80.36 and 79.06 kg/tree) was obtained by T<sub>3</sub> and T<sub>5</sub> in 2015 and 2016 seasons, respectively. All treatments increased water use efficiency especially T<sub>9</sub> (5.64 and 5.46 kg/m<sup>3</sup>) compared with the control which recorded the lowest values (3.16 and 2.93 kg/m<sup>3</sup>). Control (T<sub>1</sub>) followed by T<sub>3</sub> and T<sub>5</sub> tended to improve the physical fruit properties meanwhile T<sub>8</sub> and T<sub>9</sub> increased the most of chemical fruit quality. The lowest fruit splitting% (6.58 and 5.87 %) coated with T<sub>3</sub> and T<sub>5</sub>. Soil microorganisms content and dehydrogenase activity were increased under moderate irrigation rate + 3.5 or 6.5 organic plant residues (T<sub>4</sub> and T<sub>5</sub>) compared to the control (T<sub>1</sub>).*

**Key words:** *Water absorbing soil amendments, Citrus trees, growth, yield and fruit splitting.*

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### INTRODUCTION

Citrus is the most important fruit crops in Egypt, which occupies the first position among fruit crops, with more than 3237157 fed. and an average annual production of about 3438030 tons (FAO, 2016). "Washington Navel" orange is one of the most common cultivars and has one of the best fruit exportation in Egypt. In arid and semiarid regions, drought stress is the main factor limiting crop

growth and productivity (Todorov *et al.*, 1998). Efficient management of soil moisture is critical for agricultural production in areas with scarce water resources (Eneji *et al.*, 2013).

Under climate change conditions and limitation of water resources which faces Egypt, we should do our best towards effective renationalization of irrigation water on the orchards level.

In Egypt, water is one of the most critical factors in crop production. Rainfall is low, So, most of agricultural production is mostly dependent upon irrigation. Water resources are limited and concentrated upon the Nile River.

Minimizing water losses can be applied using soil amendments, which improve the soil physical properties and increase water irrigation efficiency as well as rationalization of irrigation water (Ezzat *et al.*, 2011). One of the newest soil amendments used in this respect is the use of water saving amendments i.e. hydrogel polymers for enhancing water and nutrient use efficiency which become more vital over time, particularly in arid and semiarid regions with limiting water sources, hydrogel is a superabsorbent polymer which absorbs water hundreds of times of its own dry weight. Soil water and nutrients stored in hydrogel are released gradually for plant growth under water limiting conditions (Yazdani *et al.*, 2007). Hydrogel is occasionally referred to “Root watering crystals” or “water retention granules” because it swells like sponges to be as several times of its original size, when it contacts with a water, therefore increases soil water holding capacity and decreases irrigation frequency (Jamnicka *et al.*, 2013). Hydrogel can which it can absorb water until 400% over its dry weight so decrease drought stress and improve the vegetative growth parameters (Khoshnevis, 2003), it can increase the efficiency of coefficient agriculture water and decrease cost and irrigation quantity (Tongo *et al.*, 2014). Plant residues (organic residues) is an important

biological resource so the return it to the field is a valuable cultural practice to increase both soil water- holding capacity and providing nutrients and organic matters as well as improving soil physical properties (Lou *et al.*, 2011). So, improved water productivity (WP) using different strategies, is a key concept to solve the water scarcity. Hence today, efforts are being focused on developing not only alternative irrigation methods but also new water management methods in order to reduce water amounts with maintaining maximum tree growth, without significantly affecting fruits yield.

The objective of this study was to investigate the impact of some water saving substances on growth, yield, fruit quality and water use efficiency of "Washington Navel" orange trees under deficit irrigation conditions.

## MATERIALS AND METHODS

The present study was carried out during 2015 and 2016 seasons on 10 years old "Washington Navel" orange trees (*Citrus sinensis* (L.) Osbeck) budded on Volkamer lemon (*Citrus volkameriana* L.), spaced at 4 x 6 meters (175 trees/fed.) grown on a sandy soil under drip irrigation system at El-Nubaria region, Beheira Governorate, Egypt. The trees subjected to cultural practices usually done in this area.

The soil orchard is classified as sandy soil. Some chemical, physical properties and moisture content of soil experimental site are presented in Tables 1 and 2 .

Table (1): Some chemical and physical properties of the experimental soil.

Characters	Particle size distribution (%)			Textural class	PH	Ec (dSm <sup>-1</sup> )	O.M (%)	Available (ppm)		
	Sand	Silt	Clay					N	P	K
Value	88.57	4.73	6.70	Sandy	8.20	1.47	0.10	17.1	5.2	58.47

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**Table (2): Soil moisture constant for the experimental site.**

Soil depth (cm)	Field capacity (%)	Wilting point (%)	Available water (%)	Bulk density(g/cm <sup>3</sup> )
0-30	12.32	4.25	8.07	1.65
30-60	12.10	4.21	7.89	1.66
60-90	11.80	4.19	7.61	1.68
Average	12.07	4.22	7.85	1.66

Eighty one trees were selected as uniform as possible in size and load, and arranged in a randomized complete block design, each treatment replicated three times with three trees for each replicate. The experiment included 9 treatments as follow:

- T<sub>1</sub>. Control (Actual irrigation practiced in the orchard):
- T<sub>2</sub>. Moderate irrigation treatment (75% from the control) + Hydrogel polymer at rate 50g/tree.
- T<sub>3</sub>. Moderate irrigation treatment + Hydrogel polymer at rate 100g/tree.
- T<sub>4</sub>. Moderate irrigation treatment + organic plant residues at rate 3.5 kg/tree.
- T<sub>5</sub>. Moderate irrigation treatment + organic plant residues at rate 6.5 kg/tree.
- T<sub>6</sub>. Deficit irrigation treatment (50%from the control) + Hydrogel polymer at rate 50g/tree.
- T<sub>7</sub>. Deficit irrigation treatment + Hydrogel polymer at rate 100g/tree.
- T<sub>8</sub>. Deficit irrigation treatment + organic plant residues at rate 3.5 kg/tree.
- T<sub>9</sub>. Deficit irrigation treatment) + organic plant residues at rate 6.5 kg/tree.

The irrigation levels 100% as control, moderate and deficit irrigation (75 and 50% of the control) were controlled by using 16, 12, 8 emitters/tree (4L/hr), respectively at two lateral JR line for each row of the trees with emitters each 50 cm. The amount of irrigation was calculated as follow: The amount of irrigation water = number of drippers x discharge of irrigation water (L/hr) x operating time.

The quantity of irrigation water applied in the different irrigation treatments during each growing season were showed in Table (3).

Hydrogel polymer known "Barbary Plant G3" (40% Hydro polymer, 6.5%N, 4.8%P, 8.2%K and hold capacity at 300-500%) produced by Lucky Star TG., Egypt and organic plant residues named "HUNDZsoil®" is a natural soil conditioner that is made out of 100% cellulose, shaped in grains, and varies in size 0.2 into 2mm (78.16% organic matter,1.28%N, 0.07%P, 0.11%K and hold capacity at 278-300%) were obtained from Hundz soil Company., Egypt., were added once at last week of January in two trenches (100 cm length x 50 cm width x 50 cm depth) on both sides of the tree in both seasons.

**The following data was recorded:**

**1- Vegetative growth parameters:**

Four main branches, in different direction on each tree were labeled. All current shoots developed on these branches in spring were used for measuring growth parameters i.e. average number of shoots, shoot length and number of leaves. Also, canopy volume of tree was calculated at the beginning and the end of experimental according to the following equation:  $CV = 0.528 \times H \times D^2$ . Whereas, H = tree height, D = tree diameter (Castle, 1983) then increment of canopy volume was calculated, leaf area (cm<sup>2</sup>) was estimated using formula: Leaf area = 2/3 x length x width (Chou, 1966).

Table (3): The quantity of irrigation water applied (m<sup>3</sup>/fed.) in the different irrigation treatments during 2015 and 2016 seasons.

Treatment	Control (100%)		Moderate (75% of control )		Deficit (50% of control)	
	2015	2016	2015	2016	2015	2016
Total irrigation water (l/tree/year)	22235	24060	16676.25	18045	11117.5	12030
Total irrigation water (m <sup>3</sup> /fed/year)	3891.125	4210.5	2918.34	3157.87	1945.56	2105.25

## 2- Leaf mineral content:

At the end of September from non-fruiting spring flush shoots 40 mature leaves/ tree were sampled in both seasons, washed, dried at 70°C to constant weight ground and digested for determination leaf mineral content. Nitrogen were determined by Microkjeldahl method as outlined by Chapman and Pratt (1978). Phosphorus was determined using spectrophotometer according to Murphy and Riely (1962). Potassium determined by flame photometer according to Jackson (1967).

## 3- Relative water content (RWC):

Was determined according to Morgan (1984) as follow:

RWC% =

$$\frac{(\text{leaf fresh weight(g)} - \text{leaf dry weight (g)}) \times 100}{(\text{turgid weight} - \text{leaf dry weight})}$$

## 4- Fruit set and drop%

Initial and final fruit set% calculated by the following equations: Initial fruit set % = (No. of fruitlettes / Total No. of flowers) x 100. Meanwhile, final fruit set % = (No. of fruits at end of June / Total No. of flowers) x 100. also, The percentage of June drop was calculated according the equations: June drop % = (No. of fruitlettes- No. of fruits at end of June / No. of fruitlettes) x 100

## 5- Yield and Water use efficiency (WUE):

At harvest time (December 15<sup>th</sup> in both seasons), number of fruit and kg/tree, yield as kg/ tree as well as ton/fed. were calculated. Water use efficiency (WUE) was calculated according to Ali *et al.*, (2007) as follow: WUE = yield(kg/fed.) / water applied (m<sup>3</sup> /fed.)

## 6- Fruit quality:

A sample of 10 healthy fruits were taken at random from each tree at harvest time (15<sup>th</sup> December) and prepared for determination physical and chemical fruit properties according to (A.O.A.C., 1995). i.e. fruit weight (g), fruit height, diameter (cm), peel thickness (mm) and fruit juice %, Total soluble solids (TSS %) was determined by using hand refractmeter, total acidity was determined as citric acid, ascorbic acid as mg/100 ml/juice and TSS/acid ratio was calculated. The number of splitting fruits was counted at weekly intervals from 15<sup>th</sup> July till the time of harvesting and the percentage of splitting fruits was calculated as: No. of splitted fruits / Total No. of harvested fruits x 100.

## 7- Soil properties

Microorganisms were calculated as number of colonies/gram soil according to Saleh (2002) and dehydrogenase

activity ( $\text{mg g}^{-1}$  dry soil/96h) was estimated according to Tabatabai (1982).

Data were analyzed by MSTATC computer software program (Bricker, 1991). The obtained data were subjected to analysis of variance according to Snedecor and Cochran (1990). Duncan's multiple range test (Duncan, 1955) at 5% level was used to compare the means.

## **RESULTS AND DISCUSSION**

### **1- Vegetative growth parameters:**

Results in Table (4) and Fig. (1) revealed that moderate irrigation rate + 6.5 kg/tree organic plant residues ( $T_5$ ) followed by ( $T_3$ ) significantly increased canopy volume and increment of canopy volume compared with the other treatments except for the control in the first season, while the lowest values obtained with  $T_6$  in both seasons. Regarding to number of shoots/branch and leaf area, there was no significant differences observed among treatments in the first season, while in the second one the differences were significantly, however, moderate irrigation rate + 100g/tree hydrogel ( $T_3$ ) and 6.5 kg/tree organic plant residues ( $T_5$ ) gave the highest values in this respect meanwhile, the lowest number obtained with  $T_6$ . The other treatments gave intermediate values. The highest number of leaves/shoot, resulted by treatment of moderate irrigation rate + 100g/tree hydrogel ( $T_3$ ) compared with the lowest number obtained by ( $T_6$ ) in the first season. But in the second one all treatments increased the number of leaves without significant differences among them except of  $T_8$  and  $T_9$  which recorded the lowest number.

The increment in vegetative growth parameters due to organic plant residues and hydrogel may be due to increase in organic materials and availability of proper amounts of nutrients in the soil, on the other hand,

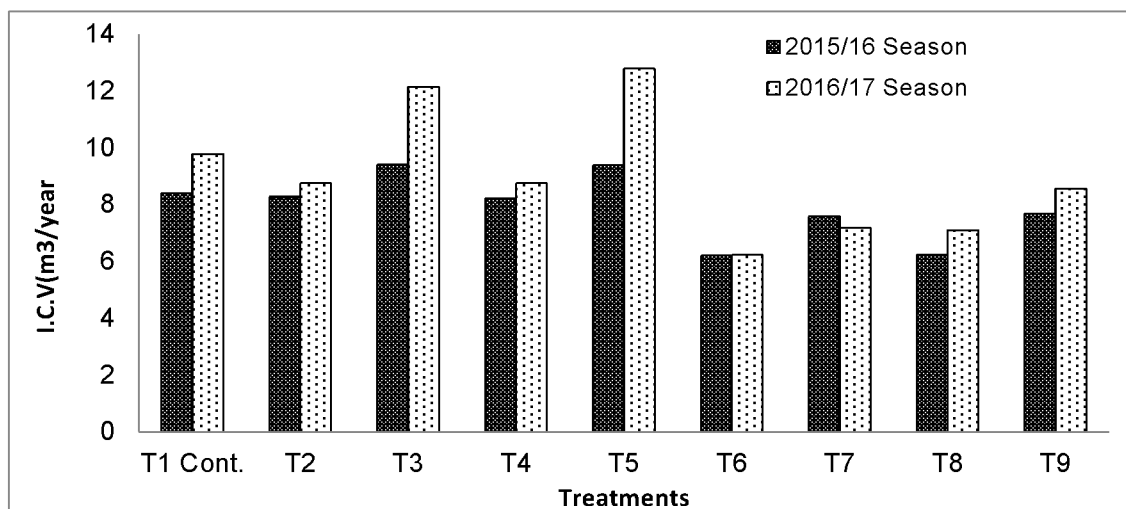
improvement of water holding capacity and physical properties of the soil, better absorption of irrigation water and its storage in the soil and so, prevent the moisture stresses which reflected on vegetative growth (Sheikh *et al.*, 2010). In addition, Andry *et al.*, (2009) confirmed the effects of superabsorbent polymers in density and growth of the root due to improvement in physical condition of the soil. This growth increase is caused by indirect role of amendment materials increase N, P and k uptake by the plant, appropriate aeration and available water by increasing the water holding capacity of the soil which reduce water stress of plants resulting in increased growth and plant performance. However, Moldes *et al.*, (2007) who stated that applying compost enhanced the root uptake activity of such nutrients as N, P, K, Ca and Mg. The root vigor reflects the growth performance of plants and the nutrient absorptive capacity of the roots. Barki *et al.*, (2018) found that treatments of superabsorbent and organic wastes enhancement the growth parameters of olive trees. In the same line, Fagundes *et al.*, (2014) and Pattanaaik *et al.*, (2015) on citrus trees.

### **2- Leaf mineral content**

Results in Table (5) showed that irrigated Washington Navel trees with actual irrigation practiced in orchard ( $T_1$ ) and moderate irrigation treatment + 100g/tree Hydrogel polymer ( $T_3$ ) or 6.5 kg/tree organic plant residues ( $T_5$ ) had statistically the richest leaves in N content in the first season without significant differences among them, while in the second one ( $T_3$ ) increased leaf N content compared with the other treatments, the reverse was true with ( $T_4$  and  $T_8$ ). The control ( $T_1$ ) gave the highest P content in leaves (0.27 and 0.28%) compared to the lowest values (0.20 and 0.20%) which recorded by  $T_8$  in both seasons, respectively.

**Table 4**

**Impact of chemical and natural water saving soil amendments on growth, .....**



**Fig. (1):** Increment in canopy volume (m<sup>3</sup>/year) of "Washington Navel" orange trees as affected by some water saving substances and irrigation treatments in 2015 and 2016 seasons.

**Table (5):** Effect of some water saving substances and irrigation treatments on leaf mineral contents of "Washington Navel" orange trees in 2015 and 2016 seasons.

Treatment	N %		P %		K%		Ca %	
	2015	2016	2015	2016	2015	2016	2015	2016
T <sub>1</sub> (Cont.)	2.63a	2.51ab	0.27a	0.28a	1.52bc	1.52b	2.93b	2.90ab
T <sub>2</sub>	2.54ab	2.66a	0.25bc	0.25abc	1.48c	1.48b	2.96b	2.97a
T <sub>3</sub>	2.67a	2.47b	0.26ab	0.23ab	1.60a	1.61a	3.26a	3.18a
T <sub>4</sub>	2.45b	2.63ab	0.24c	0.25abc	1.50c	1.49b	2.91b	2.93a
T <sub>5</sub>	2.63a	2.50ab	0.26ab	0.26ab	1.59ab	1.60a	3.11ab	3.06a
T <sub>6</sub>	2.46b	2.53ab	0.21e	0.22cd	1.45c	1.46b	2.30cd	2.22b
T <sub>7</sub>	2.54ab	2.46b	0.23d	0.23bcd	1.49c	1.50b	2.51c	2.33b
T <sub>8</sub>	2.45b	2.53ab	0.20e	0.20d	1.46c	1.46b	2.17d	2.15b
T <sub>9</sub>	2.53ab	2.63ab	0.24c	0.24bc	1.50c	1.50b	2.53c	2.39b

T<sub>1</sub>. Control (Actual irrigation practiced in the orchard)

T<sub>2</sub>. Moderate irrigation treatment (75% from the control) + Hydrogel polymer at rate 50g/tree.:

T<sub>3</sub>. Moderate irrigation treatment + Hydrogel polymer at rate 100g/tree.

T<sub>4</sub>. Moderate irrigation treatment + organic plant residues at rate 3.5 kg/tree.

T<sub>5</sub>. Moderate irrigation treatment + organic plant residues at rate 6.5 kg/tree.

T<sub>6</sub>. Deficit irrigation treatment (50% from the control) + Hydrogel polymer at rate 50g/tree.

T<sub>7</sub>. Deficit irrigation treatment + Hydrogel polymer at rate 100g/tree

T<sub>8</sub>. Deficit irrigation treatment + organic plant residues at rate 3.5 kg/tree.

T<sub>9</sub>. Deficit irrigation treatment) + organic plant residues at rate 6.5 kg/tree.

Add the hydrogel polymer at rate 100g/tree (T<sub>3</sub>) under moderate irrigation was the best treatment in increasing leaf K content (1.60 and 1.61%) followed by T<sub>5</sub> (1.59 and 1.60%) compared with the control.

The highest leaf Ca content obtained by T<sub>3</sub> in the first season, meanwhile, in the second one (T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub> and T<sub>5</sub>) increased Ca content without significant differences among them compared to various treatments. According to the previous results, it could be concluded that application of hydrogel and organic west compost enhances leaf mineral contents because hydrogel enables absorbing and retaining considerable amount of water and nutrients that would be slowly released into tree roots. This may be due to increase in the nutrient use efficiency of soil treated with treatments and improving in physio-chemical conditions of soil and affecting the trees response to mitigate drought (Buchholz and Graham, 1998). These results are in harmony with those reported by Vichiato *et al.*, (2004) on

citrus trees, Abd El-Rhman and Mohamed (2017) on Egazy olive trees.

### 3-Relative water content (RWC)

Results illustrated in Fig. (2) quite evident that T<sub>3</sub> (Average = 81.23%), T<sub>1</sub> (Average = 81.08%) and T<sub>5</sub> (Average = 80.0%) significantly exceeds RWC when compared to the lowest values obtained by T<sub>8</sub> (Average = 64.94%) and T<sub>9</sub> (Average = 67.48%). Other treatments gave intermediate values. Improving relative water content under water saving substances treatments may be due to maintain enough available water for trees to overcome drought stress injuries. In this line, Fernando *et al.*, (2013) who found that, hydrogel amendment significantly increased the plant available water (PAW) in sand soil compared to the control. Also, Arbona *et al.*, (2015) on citrus trees and Barki *et al.*, (2018) on olive trees who found that, hydrogel treatment enhance the capacity to avoid drought damages of trees and improve leaf relative water content

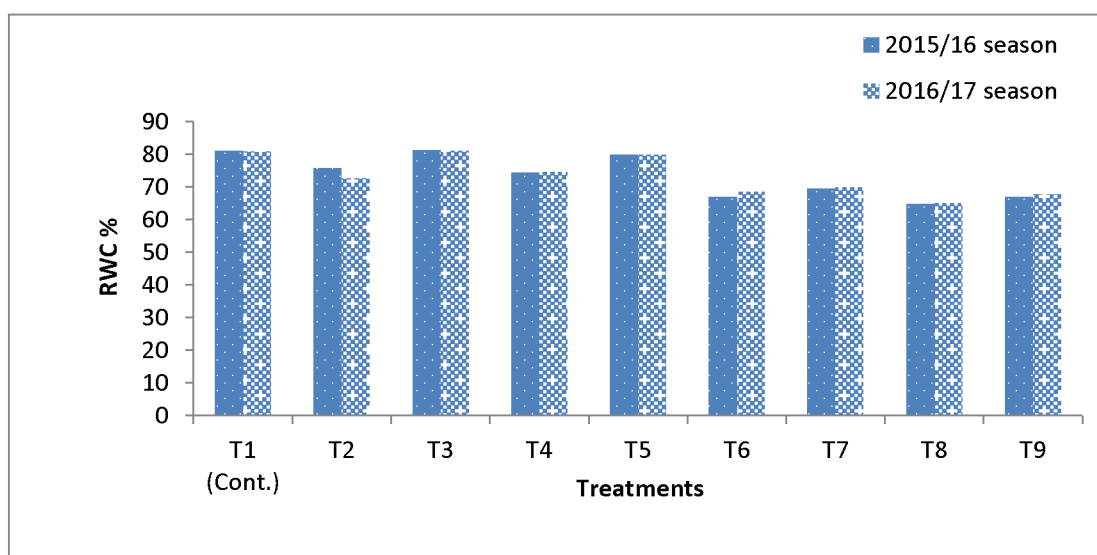


Fig. (2): Effect of some water saving substances and irrigation treatments on leaf relative water content (RWC) of "Washington Navel" orange tree in 2015 and 2016 seasons.



**4-Fruit set and drop%:**

Results in Table (6) showed that the initial fruit set % was significantly higher when the trees treated with 100g hydrogel /tree (T<sub>3</sub>) or 6.5kg/tree organic plant residues (T<sub>5</sub>) under moderate irrigation rate followed by (T<sub>4</sub>) compared to the control and other treatments while, the lowest values obtained by (T<sub>8</sub> and T<sub>9</sub>). The maximum percentage of final fruit set were observed with treatments of T<sub>2</sub> (2.23 and 2.43%), T<sub>3</sub> (2.34 and 2.34%) and T<sub>5</sub> (2.38 and 2.34%) on the other hand the lowest values obtained by the control (1.28 and 1.70%) in both seasons. The lowest percentage of fruit drop resulted by T<sub>3</sub> (5.44 and 5.61%) and T<sub>5</sub> (5.60 and 5.70%) compared to T<sub>8</sub> (deficit irrigation rate + 3.5 kg/tree organic plant residues) which

recorded the highest values (9.71%) , while the highest values in the second season recorded with T<sub>1</sub> (9.60%), T<sub>2</sub> (8.73%), T<sub>4</sub> (9.11%), T<sub>6</sub> (7.3), T<sub>8</sub> (9.47%). This results may be due to the fact that the soil was wet for a longer time increasing the microbial activity as well as increasing fruit set and reducing the fruit drop due to water deficit (Pattanaaik *et al.*, 2015). The same results was obtained by El-Zawily (2016), Zaghloul and Moursi (2017) on "Navel" orange trees who declared that, decreasing or increasing soil moisture content may subject roots to inefficient water which caused the increase of fruit drop % especially during June drop period, so to avoid that stress, soil must be kept fairly wet during summer months.

**Table (6): Effect of some water saving substances and irrigation treatments on fruit set and drop percentage of "Washington Navel" orange trees in 2015 and 2016 seasons.**

Treatment	Initial fruit set (%)		Final fruit set (%)		June drop (%)	
	2015	2016	2015	2016	2015	2016
T <sub>1</sub> (Cont.)	9.49cd	9.25bcd	1.28b	1.70a	9.4ab	9.60a
T <sub>2</sub>	10.01bc	10.00b	2.23a	2.43a	8.81ab	8.73a
T <sub>3</sub>	11.20a	11.14a	2.43a	2.43a	5.44d	5.60c
T <sub>4</sub>	10.22b	9.78bc	2.05ab	2.2a	9.07ab	9.11a
T <sub>5</sub>	11.31a	11.18a	2.38a	2.43a	5.61d	5.70c
T <sub>6</sub>	8.03f	8.46de	1.73ab	1.73a	8.37ab	8.75a
T <sub>7</sub>	8.95de	9.0cde	1.84ab	1.82a	6.8cd	6.73b
T <sub>8</sub>	8.08f	8.16e	1.91ab	1.90a	9.71a	9.47a
T <sub>9</sub>	8.78e	8.39de	1.90ab	1.89a	8.02bc	9.17a

- T<sub>1</sub>. Control (Actual irrigation practiced in the orchard)
- T<sub>2</sub>. Moderate irrigation treatment (75%from the control) + Hydrogel polymer at rate 50g/tree.:
- T<sub>3</sub>. Moderate irrigation treatment + Hydrogel polymer at rate 100g/tree.
- T<sub>4</sub>- Moderate irrigation treatment + organic plant residuesat rate 3.5 kg/tree.
- T<sub>5</sub>- Moderate irrigation treatment + organic plant residuesat rate 6.5 kg/tree.
- T<sub>6</sub>. Deficit irrigation treatment (50%from the control) + Hydrogel polymer at rate 50g/tree.
- T<sub>7</sub>. Deficit irrigation treatment + Hydrogel polymer at rate 100g/tree
- T<sub>8</sub>. Deficit irrigation treatment + organic plant residuesat rate 3.5 kg/tree.

T<sub>9</sub>. Deficit irrigation treatment) + organic plant residues at rate 6.5 kg/tree.

**5-Yield and water use efficiency (kg/m<sup>3</sup>):**

Results in Table (7) showed that the highest number of fruit/tree was recorded by T<sub>3</sub> (311.3 and 295.5) and T<sub>5</sub> (304.96 and 297 fruit/tree) However, the highest yield as kg/tree was obtained also by T<sub>3</sub> (78.8 and 78.47 kg/tree) and T<sub>5</sub> (80.3 and 79.06 kg/tree) followed by T<sub>1</sub> (70.28 and 70.51 kg/tree) compared with the other treatments in both seasons, respectively. Concerning yield as ton/fed, results showed the same trend as that observed for yield as kg/tree. Hydrogel and organic waste compost has no direct nutritional roles in increasing the yield of the plants is due to improvement physical condition of the soil and increasing plant mineral uptake (Panayiotis *et al.*, (2004) which increase the growth as shown in Tables (4 and 5) which reflected on productivity of trees. these results are finding with those of Pattanaaik *et al.*, (2015) on Khasi mandarin.

**Water use efficiency (kg/m<sup>3</sup>):**

Results illustrated in Fig. (3) showed that all treatments increased water use efficiency compared with the control (T<sub>1</sub>). The highest values of WUE were obtained

with T<sub>6</sub> (5.52 and 5.17 kg/m<sup>3</sup>), T<sub>7</sub> (5.8 and 5.38), T<sub>8</sub> (5.46 and 5.04) and T<sub>9</sub> (5.64 and 5.46 kg/m<sup>3</sup>) compared with the lowest values (3.16 and 2.93 kg/m<sup>3</sup>) which recorded with the control (T<sub>1</sub>) in both seasons, respectively. Addition of organic waste compost or hydrogels in soils can positively affect water use efficiency his may be due to modify the soil structure by stabilizing aggregates (Lentz *et al.*, 1992), increasing the water holding capacity, reducing deep percolation and rising evaporation losses in sandy soils. Moreover, the use of polymers leads to improved water use efficiency since the water that would have then leached beyond the root zone is captured (El-Shafei *et al.*, 1992). A similar observation has been reported by Uckoo *et al.*, (2009) on citrus trees showed that the application of organic plant residues under low water use system increased soil moisture which reflected to increase water use efficiency, also, Chehab *et al.*, (2017) on olive trees who concluded that the application of hydrogel in the root zone of plants significantly increased water use efficiency.

Table (7): Effect of some water saving substances and irrigation treatments on yield components of "Washington Navel" orange trees in 2015 and 2016 seasons.

Treatment	No. of fruits/tree		Yield(Kg/tree)		Yield (Ton/fed)	
	2015	2016	2015	2016	2015	2016
T <sub>1</sub> (Cont.)	254.06b	252.76b	70.28b	70.51ab	12.30b	12.34ab
T <sub>2</sub>	252.43b	252.4b	66.03bc	68.33bc	11.55bc	11.96bc
T <sub>3</sub>	311.3a	295.53a	78.8a	78.47a	13.79a	13.73a
T <sub>4</sub>	252.4b	254.66b	65.85bc	68.20b	11.52bc	11.94bc
T <sub>5</sub>	304.96a	297.0a	80.36a	79.06a	14.06a	13.84a
T <sub>6</sub>	223.6c	222.96c	61.36c	62.26bc	10.74c	10.89bc
T <sub>7</sub>	250.43b	246.7b	64.46bc	64.7bc	11.28bc	11.32bc
T <sub>8</sub>	221.56c	221.8c	60.76c	60.66c	10.63c	10.61c
T <sub>9</sub>	246.16b	244.06b	62.73c	65.66bc	10.97c	11.49bc

- T<sub>1</sub>. Control (Actual irrigation practiced in the orchard)
- T<sub>2</sub>. Moderate irrigation treatment (75%from the control) + Hydrogel polymer at rate 50g/tree.:
- T<sub>3</sub>. Moderate irrigation treatment + Hydrogel polymer at rate 100g/tree.
- T<sub>4</sub>- Moderate irrigation treatment + organic plant residues at rate 3.5 kg/tree.
- T<sub>5</sub>- Moderate irrigation treatment + organic plant residues at rate 6.5 kg/tree.
- T<sub>6</sub>. Deficit irrigation treatment (50%from the control) + Hydrogel polymer at rate 50g/tree.
- T<sub>7</sub>. Deficit irrigation treatment + Hydrogel polymer at rate 100g/tree

***Impact of chemical and natural water saving soil amendments on growth, .....***

T<sub>8</sub>. Deficit irrigation treatment + organic plant residues at rate 3.5 kg/tree.

T<sub>9</sub>. Deficit irrigation treatment) + organic plant residues at rate 6.5 kg/tree.

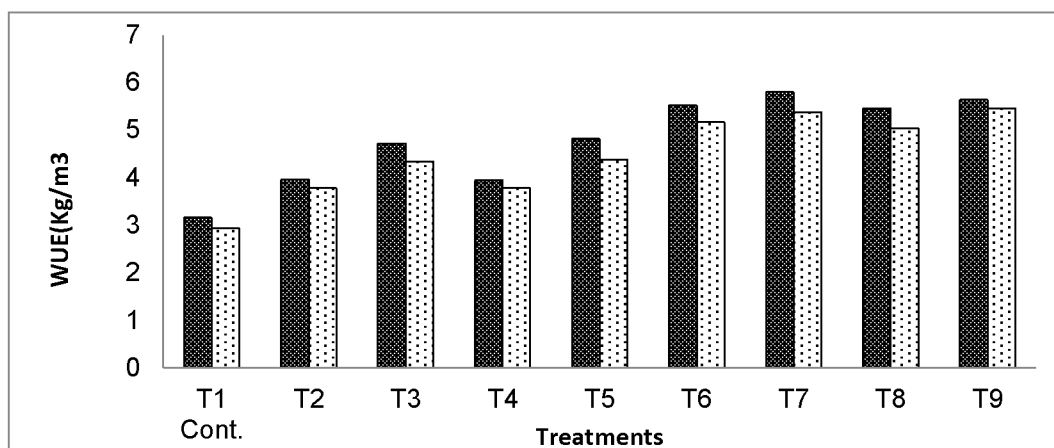


Fig. (3): Effect of some water saving substances and irrigation treatments on water use efficiency (WUE) of "Washington Navel" orange tree in 2015 and 2016 seasons.

**6- Fruit quality:**

About Physical fruit properties data obtained in Table (8) showed that there were no significant differences among treatments regarding to fruit weight in both seasons. The highest fruit diameter (9.48 cm) obtained with control (T<sub>1</sub>) followed by (T<sub>8</sub>) in the first season, but in the second season T<sub>6</sub> (deficit irrigation rate + 50g/tree hydrogel) gave the highest value (9.13cm). Both of (T<sub>3</sub> and T<sub>4</sub>) had significantly lower values than other treatments in both seasons. Concerning fruit height, (T<sub>3</sub> and T<sub>5</sub>) followed by (T<sub>1</sub>) tended to increase fruit diameter than the other treatments in the first season. The Highest juice weight % was recorded with T<sub>5</sub> compared with the lowest values obtained with T<sub>8</sub> in both seasons. With respect to peel thickness all treatments were significantly highest compared with the control (T<sub>1</sub>) without significant differences among them.

As for Chemical fruit properties the present results of fruits TSS % in Table (9) showed that in general, there were non-significant differences among treatments in the first season, but in the second one the highest values of TSS % were in the treatment of (T<sub>4</sub>, T<sub>6</sub>, T<sub>7</sub> and T<sub>8</sub>). Data of fruit acidity % (Table 9)

revealed that the studied treatments (T<sub>7</sub> and T<sub>9</sub>) increased the acidity of fruit juice in the first season, while T<sub>8</sub> and T<sub>9</sub> gave the highest values in this respect compared with control and other treatments in the second one. The control gave the highest TSS / acid ratio (17.06 and 15.76) compared with the other treatments in both seasons, respectively. Data of Vitamin C content in fruit juice (Table 9) showed that most of the tested treatments maintained the higher concentration of vitamin C in fruit juice than the control (T<sub>1</sub>) during 2015 and 2016 seasons. The best treatment in this respect was T<sub>8</sub> (Deficit irrigation rate + 3.5 kg/tree organic plant residues) which gave the highest level of vitamin C (54.00 and 53.11mg) compared with the other treatments in both seasons.

From the previously mentioned results, it could be concluded that application of hydrogel gel and organic west compost enhanced fruit chemical and physical properties due to the fact that the soil was wet for a long time, microbial activity and availability of nutrient increased. These results are in line with those of Pattanaaik *et al.*, (2015) on Khasi mandarin, Abd El-Rhman and Mohamed (2017) on olive trees.

**Table 8**

***Impact of chemical and natural water saving soil amendments on growth, .....***

**Table (9): Effect of some water saving substances and irrigation treatments on chemical fruit properties of "Washington Navel" orange fruits in 2015 and 2016 seasons.**

Treatment	TSS %		Acidity %		TSS /acid ratio		Vitamin C (mg/100 ml fresh juice)	
	2015	2016	2015	2016	2015	2016	2015	2016
T <sub>1</sub> (Cont.)	11.26a	11.30b	0.66c	0.71e	17.06a	15.76a	47.53bc	48.83abc
T <sub>2</sub>	11.33a	11.40ab	0.94b	0.86d	12.93b	13.40b	45.86bc	48.33abc
T <sub>3</sub>	11.50a	11.55ab	0.93b	0.91cd	12.93b	12.6bc	45.83bc	47.20bc
T <sub>4</sub>	12.03a	12.16a	0.93b	0.89d	13.1b	13.70b	43.73c	45.23c
T <sub>5</sub>	11.86a	11.93ab	0.95ab	0.97bcd	12.53b	12.23bc	43.60c	45.56c
T <sub>6</sub>	12.33a	12.36a	1.08ab	1.03abc	11.46b	12.00bc	45bc	47.23bc
T <sub>7</sub>	12.40a	12.41a	1.15a	1.06ab	10.76b	11.70bc	44.96bc	49.30abc
T <sub>8</sub>	12.30a	12.33a	1.11ab	1.11a	11.13b	11.06c	54.00a	53.11a
T <sub>9</sub>	12.10a	12.13ab	1.15a	1.10ab	10.53b	11.00c	50.96ab	51.55ab

- T<sub>1</sub>. Control (Actual irrigation practiced in the orchard)  
T<sub>2</sub>. Moderate irrigation treatment (75% from the control) + Hydrogel polymer at rate 50g/tree.:  
T<sub>3</sub>. Moderate irrigation treatment + Hydrogel polymer at rate 100g/tree.  
T<sub>4</sub>. Moderate irrigation treatment + organic plant residues at rate 3.5 kg/tree.  
T<sub>5</sub>. Moderate irrigation treatment + organic plant residues at rate 6.5 kg/tree.  
T<sub>6</sub>. Deficit irrigation treatment (50% from the control) + Hydrogel polymer at rate 50g/tree.  
T<sub>7</sub>. Deficit irrigation treatment + Hydrogel polymer at rate 100g/tree  
T<sub>8</sub>. Deficit irrigation treatment + organic plant residues at rate 3.5 kg/tree.  
T<sub>9</sub>. Deficit irrigation treatment) + organic plant residues at rate 6.5 kg/tree.

**Fruit splitting %**

Results illustrated in Fig. (4) clarify that the highest percentage of fruit splitting % (11.11 and 10%) and (10.06 and 9.91%) was observed in the treatment of deficit irrigation rate + 3.5 or 6.5 kg/tree organic plant residues (T<sub>8</sub> and T<sub>9</sub>), while the lowest percentage of fruit splitting (6.83 and 6.33%) and (6.9 and 5.14%) coated with moderate irrigation rate + 100g/tree hydrogel (T<sub>3</sub>) and 6.5 kg/tree organic plant residues (T<sub>5</sub>) in both seasons .

Generally, the fruit splitting is mostly likely to occur shortly before maturity,

when rains or irrigation follow a period of drought. Chandra (1988) observed that due to sudden increase in water content of soil and atmospheric humidity after long dry spell, the tissues of fruit skin of lemon did not cope with the rapid increase of the fruit internal tissues, resulting in the bursting of the skin. Gao-Feifei *et al* (1994) observed that water stress caused fruit cracking in citrus. Li and Hunag (1995) reported that drought conditions reduce calcium uptake and increase fruit cracking in litchi. Huang *et al* (2000) observed that water stress during fruit development has been linked to lower rind Ca levels, and in turn has

been associated with increased incidences of albedo breakdown. From the previously mentioned results, it could be concluded that application of hydrogel and organic west compost treatments decreased fruit splitting percentage through optimization of soil moisture by increasing soil hold capacity. The same results were also obtained by Abo El-Enin (2012), El-Zawily (2016), Zaghloul and Moursi (2017) on "Navel orange" trees, who showed that, soil must be kept fairly wet during summer months to avoid that disorders in fruits (creasing, splitting, and scald) which associated with water shortage.

### 7- Soil properties

Soil microorganisms content and dehydrogenase activity:

Results illustrated in Fig. (5 and 6) indicated that soil microorganisms content (Colonies number of fungi, bacteria and yeast) and dehydrogenase activity were increased under treatments of T<sub>4</sub> and T<sub>5</sub> (moderate irrigation rate + 3.5 or 6.5 kg/tree organic plant residues) followed by T<sub>9</sub> (deficit irrigation rate + 6.5 kg/tree organic plant residues) compared to the control (T<sub>1</sub>). This findings may be attributed to organic

amendments improve the soil aeration, water infiltration, and water holding capacity, also many organic amendments contain plant nutrients that act as organic fertilizers and are also energy sources for bacteria, fungi, and earthworms that live in the soil (Davis and Wilson, 2005). However, The polymers improved the physical properties of poorly structured and influence the density, structure, compaction, texture, aggregate stability and crust hardness of the soil as well as the evaporation rates and microbial activity (John, 2011). In addition, increasing number of soil microorganisms under moderate and deficit irrigation rates, possibly due to better soil aeration. Also, soil microorganisms significantly increased during the vigorous plant growth stage. A vigorous root system should produce abundant secretion that may help the reproduction of microbes. The obtained results are in agreement with those reported by Wang *et al.*, (2008) and El-Zawily (2016) who showed that water deficit produced an increase of soil microorganism and dehydrogenase activity.

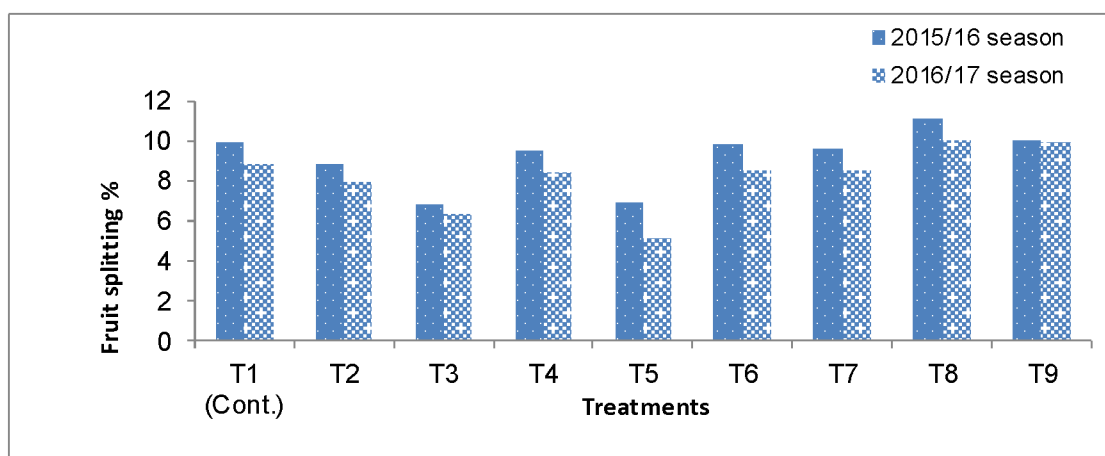
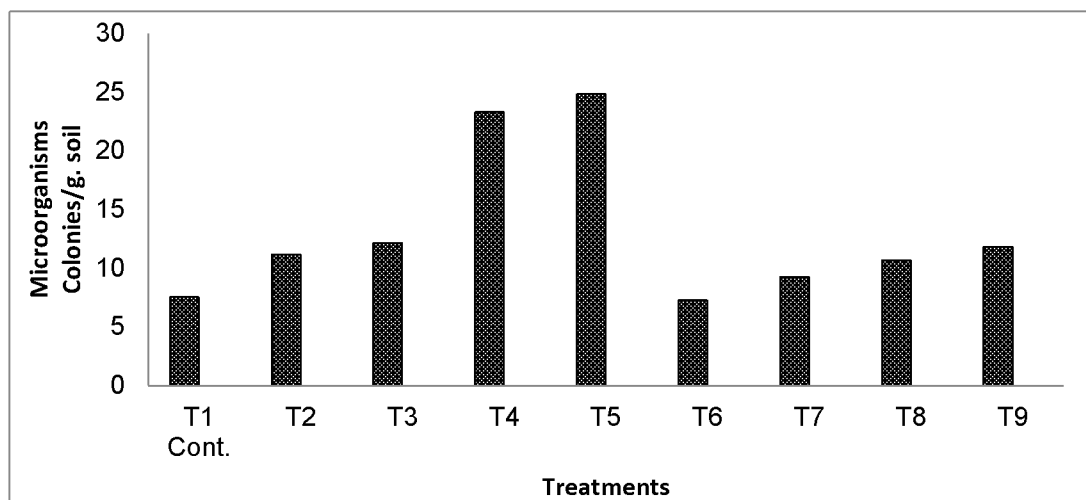
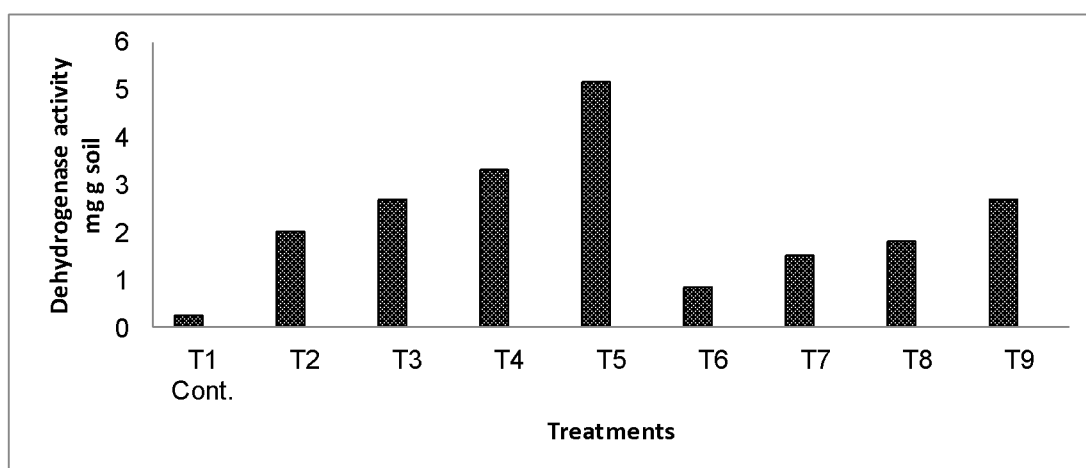


Fig. (4): Effect of some water saving substances and irrigation treatments on fruit splitting % of "Washington Navel" orange fruits in 2015 and 2016 seasons.



**Fig. (5):** Effect of some water saving substances and irrigation treatments on soil microorganisms content as number of colonies/g soil in 2016 season.



**Fig. (6):** Effect of some water saving substances and irrigation treatments on dehydrogenase activity ( $\text{mg g}^{-1}$  dry soil/96h) in 2016 season.

## CONCLUSION

Based on the results obtained from this study, it is recommended to add 100g/tree hydrogel polymer or 6.5 kg/tree organic plant residues of "Washington Navel" orange trees under moderate irrigation (75% actual irrigation practiced in the orchard) which considered the best treatment in the ability to improve the growth attributes, yield, fruit quality characters and rationalize about 25% of the amount of irrigation water/fed./year in sandy soil under the experimental conditions.

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## تأثير محسنات التربة الكيماوية والطبيعية الموفرة للمياه على النمو و المحصول و كفاءة استخدام المياه لأشجار البرتقال ابوسرة تحت ظروف نقص الري

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### المخلص العربي

نظراً لمحدودية موارد المياه ، فقد أصبح من الضروري دراسة أفضل الطرق لتقليل استخدام مياه الري ، وزيادة كفاءة استخدام المياه ، وتحسين نمو الأشجار والحفاظ على إنتاج محصول الموالح في ظل هذه الظروف. لذلك أجريت تجربة حقلية خلال عامي 2015 و 2016 في مزرعة خاصة بمنطقة النوبارية بمحافظة البحيرة مصر. و ذلك لدراسة تأثير ثلاثة مستويات من مياه الري (100 و 75 و 50% من الري المتبع في المزرعة) و الهيدروجيل بمعدل 50 و 100 جم / شجرة أو بقايا النباتات العضوية بمعدل 3,5 و 6,5 كجم / شجرة على النمو والإنتاج وكفاءة استخدام المياه على أشجار البرتقال ابو سرة المنزرعة في تربة رملية تحت نظام الري بالتنقيط وأوضحت النتائج التي تم الحصول عليها إلى أن معاملة الري المعتدل (75% من الكنترول) + بقايا النباتات العضوية بمعدل 6,5 كجم / شجرة (T<sub>5</sub>) أو الهيدروجيل بمعدل 100 جم / شجرة (T<sub>3</sub>) قد ادت إلى زيادة معظم قياسات النمو الخضري كذلك ادت معاملة الري المعتدل + هيدروجيل بمعدل 100 جم / شجرة (T<sub>3</sub>) ومعاملة الكنترول (T<sub>1</sub>) الى زيادة محتوى الأوراق من النيتروجين و الفسفور و البوتاسيوم و الكالسيوم

كما سجلت المعاملة (T<sub>5</sub>) أعلى نسبة عقد للثمار و المحتوى المائي للأوراق وأقل نسبة تساقط ايضا سجلت المعاملتين T<sub>3</sub> و T<sub>5</sub> اقل نسبة لتشقق الثمار (6,58 و 5,87%) واعلى محصول للشجرة ( 87,6 و 79,6 كجم / شجرة) كما بين النتائج ان جميع المعاملات قد كانت أعلى كفاءة استخدام للماء خاصة T<sub>9</sub>(5,55 كجم / م 3) مقارنة بالكنترول (3,04 كجم / م 3) كما اوضحت النتائج ان معاملة الكنترول (T<sub>1</sub>) تليها المعاملتين T<sub>3</sub> و T<sub>5</sub> ادت إلى تحسين جودة الثمار الطبيعية في حين سجلت المعاملة T<sub>8</sub> و T<sub>9</sub> أعلى القيم بالنسبة لصفات الثمار الكيماوية. كما أدت المعاملتين T<sub>4</sub> و T<sub>5</sub> إلى زيادة عدد الكائنات الحية الدقيقة (الفطرية والبكتيرية والخمائر) بالإضافة إلى زيادة نشاط إنزيم الديهيدروجينيز بالتربة مقارنة بالكنترول (T<sub>1</sub>) . ولذلك نوصى بإضافة بقايا النباتات العضوية بمعدل 6,5 كجم او الهيدروجيل بمعدل 100 جم / شجرة لأشجار الموالح المنزرعة في الأراض الرملية تحت ظروف الري المعتدل (2918.34-3157.87m<sup>3</sup>/fed) لتأثيرها الإيجابي في ترشيد حوالي 25% من كمية المياه المضافة للفدان في السنة بدون أي تأثيرات سلبية على النمو الخضري والمحصول و صفات جودة الثمار.

### أسماء السادة المحكمين

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Table (4): Effect of water saving substances and irrigation treatments on vegetative growth parameters, of "Washington Navel" orange trees in 2015 and 2016 seasons.

Treatment	Canopy volume (m <sup>3</sup> )		No. of shoots /branch		Shoot length (cm)		Leaf area (cm <sup>2</sup> )		No. of leaves/shoot	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T <sub>1</sub> (Cont.)	27.49abc	30.41bc	29.42a	27.44b	9.23b	10.13b	28.90a	29.06a	6.31abc	7.43a
T <sub>2</sub>	26.24bcd	25.75d	28.35a	26.20bc	9.12b	10.21b	26.76a	26.76ab	6.21abc	7.13a
T <sub>3</sub>	28.41ab	33.42ab	26.66a	31.30a	10.51a	11.56a	28.36a	28.33a	7.06a	7.30a
T <sub>4</sub>	26.18bcd	25.5d	29.43a	27.69b	9.15b	10.15b	27.39a	27.73ab	6.20abc	7.13a
T <sub>5</sub>	29.80a	36.35a	33.04a	30.66a	10.23a	11.3a	28.75a	28.7a	6.96ab	7.96a
T <sub>6</sub>	23.85d	23.82d	25.91a	23.95c	8.31c	9.4bc	23.90a	23.88b	5.966c	7.00ab
T <sub>7</sub>	25.83bcd	26.45cd	27.76a	25.76bc	8.7c	9.00c	25.50a	25.50ab	6.14abc	7.16a
T <sub>8</sub>	24.23d	24.06d	27.44a	25.47bc	8.29c	9.26bc	24.03a	24.26b	5.50c	6.00b
T <sub>9</sub>	23.85d	26.51cd	28.96a	26.83b	8.7c	9.38bc	26.76a	26.93ab	6.11bc	7.00ab

T<sub>1</sub>. Control (Actual irrigation practiced in the orchard) T<sub>2</sub>. Moderate irrigation treatment (75% from the control) + Hydrogel polymer at rate 50g/tree.:

T<sub>3</sub>. Moderate irrigation treatment + Hydrogel polymer at rate 100g/tree. T<sub>4</sub>- Moderate irrigation treatment + organic plant residuesat rate 3.5 kg/tree.

T<sub>5</sub>- Moderate irrigation treatment + organic plant residuesat rate 6.5 kg/tree. T<sub>6</sub>. Deficit irrigation treatment (50%from the control) + Hydrogel polymer at rate 50g/tree.

T<sub>7</sub>. Deficit irrigation treatment + Hydrogel polymer at rate 100g/tree

T<sub>8</sub>. Deficit irrigation treatment + organic plant residuesat rate 3.5 kg/tree.

T<sub>9</sub>. Deficit irrigation treatment) + organic plant residuesat rate 6.5 kg/tree.

Table ( 8 ): Effect of some water saving substances and irrigation treatments physical fruit properties of "Washington Navel" orange fruits in 2015 and 2016 seasons.

Treatment	Fruit weight (g)		Fruit diameter (g)		Fruit height (cm)		Juice weight %		Peel thickness (mm)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T1 (Cont.)	276.72a	278.96a	9.48a	8.83ab	8.79ab	8.96a	30.34ab	30.20ab	4.56b	4.56b
T2	261.63a	270.72a	7.91bc	8.56abc	8.49abc	8.90a	28.32ab	28.30abc	5.46a	5.33ab
T3	253.73a	265.48a	8.00bc	8.26c	8.84a	8.58a	31.25a	31.05ab	5.16ab	5.40ab
T4	260.96a	268.07a	7.83c	8.50bc	8.51abc	9.07a	26.89ab	29.08abc	5.43a	5.43ab
T5	263.9a	266.11a	8.00bc	8.56abc	8.88a	8.70a	31.28a	31.7a	5.33a	5.33ab
T6	274.4a	279.80a	8.20bc	9.13a	7.81c	8.64a	27.7ab	27.46bc	5.90a	5.76a
T7	257.4a	262.17a	8.11bc	8.70abc	8.17abc	8.77a	28.32ab	28.57abc	5.66a	5.56a
T8	274.7a	274.11a	8.56b	9.06ab	7.91bc	9.07a	25.78b	25.51c	5.66a	6.00a
T9	254.96a	268.95a	8.16bc	8.68abc	8.07abc	9.03a	27.47ab	27.43bc	5.66a	5.66a

T1- Control (Actual irrigation practiced in the orchard) T2- Moderate irrigation treatment (75% from the control) + Hydrogel polymer at rate 50g/tree. :  
T3- Moderate irrigation treatment + Hydrogel polymer at rate 100g/tree. T4- Moderate irrigation treatment + organic plant residuesat rate 3.5 kg/tree.  
T5- Moderate irrigation treatment + organic plant residuesat rate 6.5 kg/tree. T6- Deficit irrigation treatment (50%from the control) + Hydrogel polymer at rate 50g/tree.  
T7- Deficit irrigation treatment + Hydrogel polymer at rate 100g/tree T8- Deficit irrigation treatment + organic plant residuesat rate 3.5 kg/tree.  
T9- Deficit irrigation treatment) + organic plant residuesat rate 6.5 kg/tree.

