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Irrigation Regime and Soil Conditioners Impact on Characteristics of Sandy Soil and Washington Navel Orange Trees

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ABSTRACT

Due to limited water resources it has become needed to study the best ways to decrease irrigation water use, increasing the water use efficiency, improve tree growth and sustain citrus crop production under those circumstances. Afield experiment was conducted during 2015/2016 and 2016/2017 seasons at El-Nubaria city, Beheira Governorate to investigate the effect of irrigation regime (80% and 60% from full irrigation) and soil conditioners (hydrogel at rate of 50 and 100g/tree as synthetic water absorbing soil amendments or organic plant residues at rate of 3.5 and 6.5kg/tree as natural absorbing soil amendments) on some properties of sandy soil, growth, yield, quality and productivity of irrigation water (PIW) for Washington navel orange trees under drip irrigation system. The obtained results pointed out that: The application of soil conditioners led to enhancing the properties and microorganisms activities and macronutrients of sandy soil especially with the high rates. Whereas, the low values of soil field capacity (10.47%), wilting point (4.26%) and available water (6.21%) were recorded with full irrigation without conditioners while, the high values (11.31 to 12.28%), (4.35 to 4.68%), (6.78 to 7.62%) respectively under irrigation regime combined conditioners. Soil conditioners application combined with irrigation regime increased the available nitrogen (up to 22.76%, phosphours (up to 9.98%), potassium (up to 15.14%), organic matter (up to 41.79%, CEC (up to 16.53%) and salinity (up to 4.64%) while soil bulk density was decreased (up to 5.66%) compared to full irrigation without conditioners. Moderate irrigation plus organic plant residues at rate of 6.5 kg/tree (T_5) or plus hydrogel at 100g/tree (T_3) significantly increased the most growth parameters (canopy volume, number of shoots/branch and leaf area), fruit set and decrease the fruit drop. Lowest percentage of fruit splitting (6.58 and 5.87 %) coated with T_3 and T_5 compared to deficit irrigation treatments plus the lowest rate of hydrogel or organic plant residues (T_8 and T_9). The highest yield was obtained by T_3 (78.6 kg/tree) and T_5 (79. 6 kg/tree). Control treatment (T_1) followed by T_3 and T_5 tended to improve the physical fruit quality meanwhile deficit irrigation treatments T_8 and T_9 increased the most of chemical fruit quality. PIW mean values of Washington navel orange with full irrigation without conditioners were low (2.75 kg m^{-3}) while, irrigation regime at 80 % and 60% recorded high values (3.49 kg m^{-3} and 3.88 kg m^{-3}, respectively). PIW was increased with the high rates of soil conditioners.

Keywords: *Citrus trees, drip irrigation, fruit splitting, sandy soil, soil conditioners, yield*

INTRODUCTION

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. The present share of water in Egypt is less than 1000 m^3 /capita/year which equivalent to the international standards of water poverty limits (El- Quosy, 1998). Nowadays water management is considered one of the major challenges for all countries in arid and semi–arid regions, in fact, by 2030, global water demand is probable to be 50% higher than today, resulting in water scarcity, in the same time agricultural sector used over 70 percent of freshwater in most regions of the world (Alcamo *et al*.,2000). In arid and semiarid regions, drought stress is the main limiting factor in 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).

Sandy soils are poor with respect to their physico-chemical properties (El- Hady and El-Dewiny, 2006) that, unfortunately, resulted in a significant loss of irrigation water through drainage. Minimizing water losses can be applied using soil amendments, which improve the soil physical properties and increase irrigation water 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 limiting water 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 decrease drought stress which it can absorb water until 400 over its dry weight and improve the vegetative growth parameters (Allahdadi, 2003 and Khoshnevis, 2003), it can increase the efficiency of coefficient agriculture water and decrease cost and irrigation quantity (Tongo *et al*., 2014).

Plant residues is an important biological resource, including about 50% of the total biomass of crops. The return of residue to the field is a useful cultural practice to improve both soil fertility and soil water- holding capacity (Aynehband *et al.*, 2010; Lou *et al.*, 2011).However, Curtis and Claassen, 2005; Mylavarapu and Zinati, 2009 and Tejada *et al.*, 2009 showed that the return of plant residues to fields as organic manure has recently attracted attention due to the positive benefits like as increasing soil water holding capacity, providing nutrients and organic matter, in addition to improving soil physical properties. 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, 2010). Washington Navel orange is one of the most common cultivars and has one of the best fruit exportation in Egypt. 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 while maintaining maximum tree growth, without significantly affecting fruits yield.

The objective of this study was to investigate the impact of irrigation regime and soil conditioners on some properties of sandy soil, growth, yield, quality and water productivity of Washington navel orange trees.

MATERIALS AND METHODS

The present study was carried out during 2015/2016 and 2016/2017 seasons to investigate the impact of irrigation regime and soil conditioners on some properties of sandy soil, growth, yield, quality and water productivity of Washington navel orange trees (*Citrus sinensis* (L.) Osbeck). Washington Navel orange trees of 10 years old 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 city, Beheira Governorate, Egypt. The experiment is located at 30.6667 Latitude and 30.0667 Longitude. The soil orchard is classified as sandy soil; the average textural analysis for this soil is 86.61% sand, 8.36% silt and 5.03 % clay. Some soil properties before conducting the experiments are presented in Table (1).

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 were applied before the first and second years as follow:

T_{1-} Control (Actual irrigation practiced in the orchard):
T_{2-} Moderate irrigation treatment (80%from the control) + Hydrogel polymer at rate of 0.05 kg/tree.
T_{3-} Moderate irrigation treatment + Hydrogel polymer at rate of 0.1 kg/tree.
T_4- Moderate irrigation treatment + organic waste compost at rate of 3.5 kg/tree.
T_5- Moderate irrigation treatment + organic waste compost at rate of 6.5 kg/tree.
T_{6-} Deficit irrigation treatment (60%from the control) + Hydrogel polymer at rate of 0.05 kg/tree.
T_{7-} Deficit irrigation treatment + Hydrogel polymer at rate of 0.1 kg/tree.
T_{8-} Deficit irrigation treatment + organic waste compost at rate of 3.5 kg/tree.
T_{9-} Deficit irrigation treatment) + organic waste compost at rate of 6.5 kg/tree.

The irrigation treatments as full irrigation ie. full time (control), moderate irrigation (80%from the control) and deficit irrigation treatment (60%from the control) were controlled via the operating time and using16 emitters/tree (4L/hr/emitter), at two lateral JR line for each row of the trees with emitters spaced each 50 cm. The amount of irrigation water was calculated as follow: The amount of irrigation water = number of drippers x discharge of irrigation water (4L/hr) x operating time.

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 waste compost 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 around the tree in both seasons.

Some soil properties

Soil samples (0-60cm, depth) were collected before conducting the experiment and after one and two years from treatments installation for analysis of some chemical soil properties. Salinity was determined in saturated soil paste extract according to Page *et al*. (1982). Cation exchange capacity (CEC) was determined using sodium and ammonium acetate as described by (Black, 1982). Organic matter (O.M.) was determined using the modified Walkly and Black method (Jackson, 1967). Available nitrogen was extracted using 2M KCl and determined by the micro–Kjeldahl method (Cotteine *et al*. (1982)). Available phosphorus, Olsen's Sodium bicarbonate 0.5N extraction method was used to extract available P. Spectronic Milton Roy was used for analysis of (P) by the method outlined by Olsen, *et al.* (1959). Available K Was extracted by ammonium acetate (NH_4OAc) pH 7 as described by Black (1982). Physical characteristics of the studied site such as soil field capacity (FC) was determined at the site. permanent wilting point (PWP) and available water were determined according to James (1988) and soil bulk density were determined according to (Klute, 1986). Microorganisms were calculated as number of colonies/gram soil according to Saleh (2002).

Table 1. Some soil properties at the initial of the experiment.

EC (dSm^{-1})	O.M. (%)	CEC meq/ 100g soil	Bulk density (g/cm^3)	Available macronutrients ($mg\ kg^{-1}$) N	P	K
3.02	0.67	6.11	1.59	17.89	5.31	59.19
Particle size distribution %			Texture class	Soil moisture characteristics %		
Clay	Silt	Sand		Field capacity	Wilting point	Available water (%)
5.02	8.36	86.61	Sandy	10.47	4.26	6.21

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 experiment according to the following equation: CV= 0.528 x H x D^2. Whereas, H = tree height, D = tree diameter in (m) (Castle, 1983) then increment of canopy volume was calculated, leaf area (cm^2) was estimated using formula: Leaf area = 2/3 x length x width (Chou, 1966).

Fruit set and drop%:

Four branches were chosen on each tree, one for each direction. During spring growth cycle they were labeled to carry out the following flowering and fruiting measurements: Initial and final fruit set% calculated by the following equations:

$$\text{Initial fruit set \% (I.F.S.)} = \frac{\text{Total No. of setted fruit}}{\text{Total No. of flowers}} x100$$

$$\text{Final fruit set\%(F.F.S)} = \frac{\text{No. of fruits at end of June}}{\text{Total No. of setted fruit}} x100$$

$$\text{June drop\%} = \frac{\text{Total No. of setted fruit - No. of fruits at late june}}{\text{Total No. of flowers}} x100$$

Yield:

At harvest time (December 15th in both seasons), average fruit weight and number/tree, yield as kg/ tree and yield as ton/fed. were calculated.

Fruit quality:

A sample of 10 healthy fruits were taken at random from each tree at harvest time of both seasons and prepared for determination physical and chemical fruit quality according to (A.O.A.C., 1995). i.e. fruit weight (g), fruit size (cm^3), fruit height (cm), and diameter (cm), peel thickness (cm), fruit juice %., Total soluble solids (TSS %) was determined by using hand refractometer, total acidity was determined as citric acid, ascorbic acid as mg/100 ml juice and SSC/acid ratio was calculated.

Fruit splitting %:

At the harvest time (15th December) the number of fruits per trees in each treatment was counted and the number of splitting fruits was counted at weekly intervals from 15th July till the time of harvesting. The percentage of splitted fruits was calculated as: No. of splitted fruits / Total No. of harvested fruits x 100

Productivity of irrigation water (PIW, kgm^{-3}) was calculated according to Ali *et al*., (2007) as follows:

PIW = Gy/WA, where

Gy= Fruit yield, kg $fed.^{-1}$, WA= Water applied, m^3 $fed.^{-1}$

Statistical analysis:

Data were analyzed by MSTAT 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.

Table 2. Means of Air temperature C°, relative humidity% and wind speed (Km/day) as well as quantity of Evaporation (cm/month) and Rain (mm/mon) at El-Nubaria area during the two growing seasons.

Months.	Air temp C°		Relative hum %		W.S (Km/day)		Evaporation (mm/month)		Rain (mm/mon)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Jan.	16.3	16.5	66.8	65.5	319.1	320.5	2.3	2.5	9.5	5.5
Feb.	16.2	15.8	66.1	65.0	376.1	377.7	2.7	3.1	36.1	40.0
Mar.	17.7	18.1	59.6	58.7	421.6	400.0	3.5	3.5	7.1	8.0
Apr.	20.5	22.5	58.2	58.0	364.0	365.1	4.5	5.0	3.0	4.5
May	23.5	25.3	55.5	56.3	399.5	401.3	5.3	5.1	1.9	2.0
Jun.	26.0	27.1	58.7	57.5	426.9	428.9	6.8	6.8	4.7	0.0
July	27.4	27.0	62.7	65.1	415.6	412.3	6.9	6.9	0.0	0.0
Aug.	28.6	29.9	62.9	58.9	412.6	402.7	5.4	5.6	0.0	0.0
Sep..	27.7	28.1	61.9	60.1	346.8	355.1	6.0	5.2	0.0	0.0
Oct.	24.6	25.1	60.6	60.5	364.0	365.8	5.3	4.8	0.0	10.2
Nov.	21.3	22.0	62.8	67.3	415.2	400.0	4.0	3.9	19.4	10.0
Dec.	18.6	17.8	65.4	62.3	355.0	356.5	3.0	2.9	12.2	8.5

RESULTS AND DISCUSSION

Irrigation water applied:

The amount of water applied (m^3fed^{-1}) including rainfall through two years of study is shown in Table (3). Data indicated that, the highest amount of irrigation water was recorded with full irrigation followed by irrigation regime at 80 % from control while, the lowest amount was recorded with irrigation regime at 60 % from full irrigation. The values of applied water including rainfall were 4488, 3669 and 2851 $m^3fed.^{-1}$ in the first year and 4495, 3670 and 2846 $m^3fed.^{-1}$ in the second year for full irrigation, irrigation regime at 80 %, and irrigation regime at 60 % from full irrigation, respectively.

Table 3. Irrigation operating time (hr./ month) and amount of irrigation water applied (m^3/fed.) for the different irrigation treatments during 2015/2016 and 2016/2017.

Months	Control (100%)		Moderate (80%)		Deficit (60%)	
	2015	2016	2015	2016	2015	2016
Jan.	18.08	18.08	14.47	14.47	10.85	10.85
Feb.	21.00	21.00	16.80	16.80	12.60	12.60
Mar.	25.83	25.83	20.67	20.67	15.50	15.50
Apr.	30.00	30.00	24.00	24.00	18.00	18.00
May.	38.75	41.33	31.00	33.07	23.25	24.80
Jun.	40.00	40.00	32.00	32.00	24.00	24.00
Jul.	46.50	43.92	37.20	35.13	27.90	26.35
Aug.	38.75	38.75	31.00	31.00	23.25	23.25
Sep.	37.50	37.50	30.00	30.00	22.50	22.50
Oct.	31.00	31.00	24.80	24.80	18.60	18.60
Nov.	22.50	22.50	18.00	18.00	13.50	13.50
Dec.	15.50	18.08	12.40	14.47	9.30	10.85
Total (hr./tree/year)	365.42	368.00	292.33	294.40	219.25	220.80
Total irrigation water (m^3/tree/year)	23.39	23.55	18.71	18.84	14.03	14.13
Total irrigation water (m^3/fed/year)	4093	4122	3274	3297	2456	2473
Total rain m^{-3}/fed/year	395	373	395	373	395	373
Total irrigation water + rain (m^3/fed/year)	4488	4495	3669	3670	2851	2846

Field capacity, wilting point and available water:

Results in Table (4) revealed that, soil field capacity value was low (10.47%) and wilting point somewhat low (4.26%) at the initial and with full irrigation without conditioners application compared to conditioners application. Field capacity and wilting point were increased after application of soil conditioners (hydrogel polymer or organic waste compost) and varies from 11.31 to 12.28% and 4.35 to 4.68%, respectively. The increases of field capacity and wilting point under the high rate of soil conditioners were superior under the low rate in both two years. Field capacity and wilting point of the soil do not affect by irrigation regime at 80 % or 60% from the full irrigation. Field capacity of the soil somewhat increased after the second year compared to the first year while, wilting point values nearly the same for both two years. Available water (Table 4) of sandy soil was low (6.21%) with full irrigation without conditioners application and the increase varied from 6.78 to 7.62% with an average of 7.22% with irrigation regime combined with conditioners application. The increases of available water were more pronounced with the high rates of soil conditioners (hydrogel polymer or organic waste compost) comparing with the low rate. Available water of the soil sowed, somewhat decrease with irrigation regime at 60 % compared to 80% from the full irrigation. Also, values of available water nearly the same for both two years.

In this concern, Jamnicka *et al*. (2013) found that, 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. Aynehband *et al*., 2010 and Lou *et al*., 2011 reported that the return of residue to the field is a useful cultural practice to improve both soil fertility and soil water- holding capacity.

Table 4. Soil moisture characteristics % after one and two years from the treatments application.

Treatments	Soil moisture characteristics %					
	Field capacity		Wilting point		Available (%) water	
	First year	Second year	First year	Second year	First year	Second year
T1	10.47	10.48	4.26	4.26	6.21	6.22
T2	11.58	11.64	4.35	4.35	7.23	7.29
T3	12.09	12.11	4.55	4.53	7.54	7.58
T4	11.47	11.51	4.57	4.58	6.9	6.93
T5	12.21	12.28	4.68	4.66	7.53	7.62
T6	11.31	11.34	4.42	4.43	6.89	6.91
T7	11.89	11.91	4.55	4.54	7.34	7.37
T8	11.34	11.36	4.56	4.57	6.78	6.79
T9	12.09	12.12	4.68	4.67	7.41	7.45

Some soil chemical and physical properties:

Data in Table (5) revealed that, the average value of soil salinity (EC, dSm^{-1}) was 3.02 dSm^{-1} at the initial and increased to some degree after treatments application especially with full irrigation, which varied from 3.03 to 3.16 dSm^{-1}. Salinity of the soil increased to some degree after the second year than the first year. The increasing soil salinity after treatments application and with full irrigation may be due to the irrigation water salinity under drip irrigation system. Results also showed no obvious trend on soil salinity under application of soil conditioners (hydrogel polymer or organic waste compost).

In general, organic matter contents (OM) and Cation exchange capacity (CEC meq/100g soil) values are low in sandy soil. Data in Table (5) showed that, OM and CEC values were 0.67% and 6.11 meq/100g soil, respectively at the initial and with full irrigation without conditioners. After one and two years from application of soil conditioners (hydrogel polymer or organic waste compost) OM was increased and varied from 0.77 to 0.95 % with an average of 0.86% as well as CEC was increased and which ranged from 6.41 to 7.12 with an average of 6.77 meq/100g soil. The increases of OM and CEC were more pronounced with the high rates of soil conditioners compared to the low rates. The holding capacity of hydrogel polymer and organic waste compost varied from 300-500% and 278-300%, respectively. In this concern, Hargreaves *et al*., (2008) and Adugna, (2016) reported that, organic amendments enhance water holding capacity, soil cation exchange capacity and soil aeration. OM and CEC of the sandy soil increased after the second year more than the first year. OM and CEC of the soil decreased to some degree under irrigation regime at 60 % compared to 80% from the full irrigation. In general, CEC of the soil was parallel to the soil organic matter results in this study.

Data in Table (5) revealed that, mean value of soil bulk density was 1.59 gcm^{-3} at the initial or with full irrigation. Soil bulk density was somewhat decreased after soil conditioners application especially with the high rates which, varied from 1.58 to 1.50 gcm^{-3}. Soil bulk density decreased somewhat after the second year compared to the first year. The decreases of soil bulk density after treatments application especially after the two years may be due to the high contents of soil organic matter. 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). Results also showed no obvious trend on soil bulk density under irrigation regime treatments.

Table 5. Some soil properties after one and two years from the treatments application.

Treatments	EC (dSm^{-1})		O.M. (%)		CEC meq/ 100g soil		Bulk density (gcm^{-3})	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T1	3.13	3.16	0.67	0.68	6.11	6.12	1.59	1.59
T2	3.03	3.08	0.78	0.81	6.47	6.49	1.58	1.57
T3	3.03	3.08	0.82	0.85	6.78	6.98	1.57	1.55
T4	3.03	3.10	0.84	0.89	6.45	6.61	1.55	1.52
T5	3.07	3.11	0.88	0.95	6.97	7.12	1.52	1.50
T6	3.07	3.06	0.77	0.79	6.41	6.46	1.58	156
T7	3.07	3.07	0.84	0.82	6.75	6.87	1.57	1.56
T8	3.03	3.08	0.84	0.86	6.42	6.57	1.56	1.53
T9	3.05	3.09	0.88	0.92	6.81	6.97	1.52	1.51

Available of nitrogen, phosphours and potassium of the soil:

Available of nitrogen, phosphours and potassium (NPK) of the soil in Table (6) revealed low values (an average of 17.88, 5.31 and 59.19 mg kg-1, respectively) at the initial and with full irrigation without conditioners. After soil conditioners application (hydrogel polymer or organic waste compost) available N, P and K were increased and varied from 18.25 to 21.95 mg kg-1 with an average of 20.1 mg kg-1 for N. The corresponding values were 5.43 to 5.84 mg kg-1 with an average of 5.64 mg kg-1 for P and 60.62 to 68.15 mg kg-1 with an average of 64.39 mg kg-1 for K, respectively. The high rates of soil conditioners were superior to the low rates in enhancing available macronutrients especially soil nitrogen. The contents of N, P and K for hydrogel polymer and organic waste compost were 6.5, 4.8 and 8.2% and 1.28, 0.07, 0.11%, respectively. Available NPK content of the soil increased after the second year more than the first year, this may be due to the additional of soil conditioners and enhancing the root zone. Available soil macronutrients in almost, do not affect by irrigation regime.

Table 6. Available macronutrients (mg kg^{-1}) of the soil after one and two years from the treatments application.

Treatments	Available macronutrients (mg kg^{-1})					
	N		P		K	
	First year	Second year	First year	Second year	First year	Second year
T1	17.89	17.88	5.31	5.31	59.20	59.18
T2	18.25	19.7	5.43	5.48	60.67	62.26
T3	19.12	20.25	5.48	5.55	61.39	62.53
T4	20.03	20.97	5.65	5.75	63.15	67.75
T5	20.78	21.95	5.74	5.84	64.5	68.15
T6	18.26	19.35	5.44	5.48	60.62	61.93
T7	19.14	20.07	5.49	5.56	61.43	62.18
T8	19.15	20.71	5.51	5.74	62.75	67.45
T9	20.73	21.82	5.63	5.78	63.92	68.13

Soil microorganisms content:

Results illustrated in Fig. 1 indicated that soil microorganisms content (Colonies number of fungi, bacteria and yeast) were increased under soil conditioners application compared to control treatment. This may be attributed to organic amendments that improve the soil aeration 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. In this line, Liu *et al*., (2013), Gandolfi *et al*., (2010), Bernard *et al*., (2012). 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 (Hüttermann *et al*., 1997 and John, 2011).

Effect of irrigation regime and soil conditioners on Vegetative growth parameters:

Results in Table 7 and Fig. 2 revealed that moderate irrigation level + organic plant residues at rate of 6.5 kg/tree (T5) followed by T3 significantly increased canopy volume of trees compared with the lowest values obtained with T8 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, T3 (Moderate irrigation treatment + Hydrogel polymer at rate of 100g/tree) and T5(Moderate irrigation treatment + organic plant residues at rate of 6.5 kg/tree.) gave the highest values in this respect compared with the lowest number obtained with T6. The other treatments gave intermediate values. The highest number of leaves/shoot, resulted from moderate irrigation treatment + hydrogel polymer at rate of 100g/tree (T3) compared with the lowest number obtained by (T6) in the first season. But in the second one all treatments increased the number of leaves without significant differences among them except of T8 and T9 which recorded the lowest number in this respect.

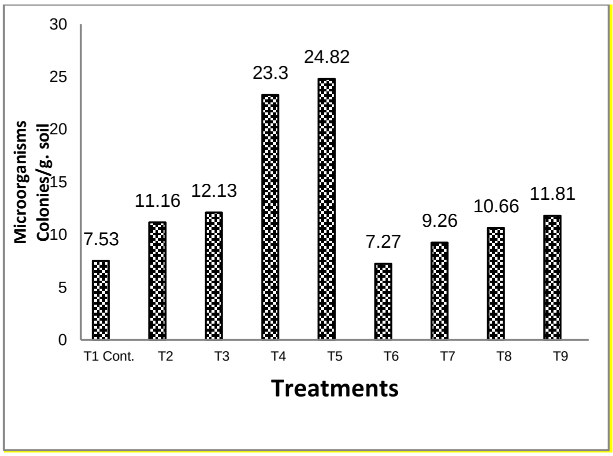

Fig. 1. Effect of irrigation regime and soil conditioners on soil microorganisms content as number of colonies/g soil in 2016 season.

The increase in the growth of trees 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, Panayiotis *et al*., (2004) and 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 in increase the uptake of Nitrogen, Phosphorus and potassium by the plant and growth, 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. Howevre, Tejada and Gonzalez (2006) 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. Torkashvand *et al*., (2017) found that treatments of superabsorbent and organic wastes enhanced the growth parameters of olive trees, . In the same line, Arbona (2005) on citrus trees Pattanaaik *et al*.(2015) on Khasi mandarin trees, Barakat *et al*., (2015) on Grandnain Banana Plants and Barki *et al*., (2018) on olive trees.

Table 7. Effect of irrigation regime and soil conditioners on vegetative growth parameters, of Washington navel orange trees in 2015 and 2016 seasons.

Treatments	Canopy volume (m^3)		No. of shoots /branch		Shoot length (cm)		Leaf area (cm^2)		No. of leaves/shoot	
Season	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T_1 (Cont.)	27.49abc	30.41bc	29.42a	27.44b	9.23b	10.13b	28.90a	29.06a	6.31abc	7.43a
T_2	26.24bcd	25.75d	28.35a	26.20bc	9.12b	10.21b	26.76a	26.76ab	6.21abc	7.13a
T_3	28.41ab	33.42ab	26.66a	31.30a	10.51a	11.56a	28.36a	28.33a	7.06a	7.30a
T_4	26.18bcd	25.5d	29.43a	27.69b	9.15b	10.15b	27.39a	27.73ab	6.20abc	7.13a
T_5	29.8a	36.35a	33.04a	30.66a	10.23a	11.3a	28.75a	28.7a	6.96ab	7.96a
T_6	23.85d	23.82d	25.91a	23.95c	8.31c	9.4bc	23.90a	23.88b	5.966c	7.00ab
T_7	25.83bcd	26.45cd	27.76a	25.76bc	8.7c	9.00c	25.50a	25.50ab	6.14abc	7.16a
T_8	24.23d	24.06d	27.44a	25.47bc	8.29c	9.26bc	24.03a	24.26b	5.50c	6.00b
T_9	23.85d	26.51cd	28.96a	26.83b	8.7c	9.38bc	26.76a	26.93ab	6.11bc	7.00ab

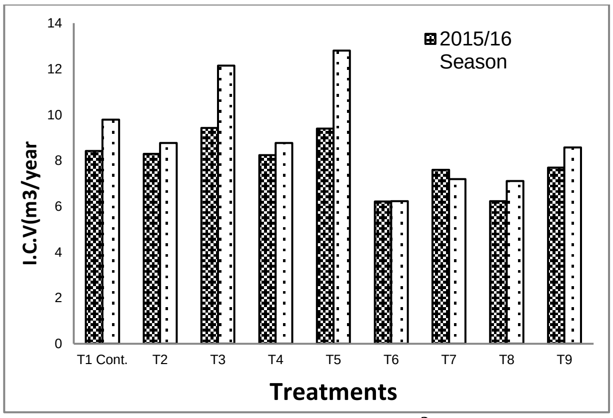

Fig. 2. Increment in canopy volume (m^3/year) as affected by irrigation levels and water saving substances treatments in 2015 and 2016 seasons.

Fruit set and drop%:

Initial fruit set percentage observed in Table 8 was significantly higher with T_3 (Moderate irrigation treatment + Hydrogel polymer at rate of 100g/tree.) and T_5 (Moderate irrigation treatment + organic plant residues at rate of 6.5 kg/tree) followed by T4 (Moderate irrigation treatment + organic plant residues at rate of 3.5 kg/tree.) compared to the lowest values obtained by T_8 and T_9. The maximum percentage of final fruit set were observed with treatments T_2 (Moderate irrigation treatment (80%from the control) + Hydrogel polymer at rate of 50g/tree), T_3 (Moderate irrigation treatment + Hydrogel polymer at rate of 100g/tree) and T_5 compared to control (T_1) in both seasons. The lowest percentage of fruit drop resulted from T_3 (5.44 and 5.61%) and T_5 (5.60 and 5.70%) compared to T_8 (Deficit irrigation treatment + organic plant residues at rate of 3.5 kg/tree.) which recorded the highest values (9.71%) followed by T_1, T_2, T_4 and T_6 in the first season, while the highest values in the second season recorded with T_1 (9.60%), T_2 (8.73%), T_4 (9.11%), T_6 (7.3), T_8 (9.47%). This 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) and 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 8. Effect of irrigation regime and soil conditioners on fruit set and June drop percentage of Washington navel orange trees in 2015 and 2016 seasons.

Treatment	Initial fruit set (%)		Final fruit set (%)		June drop (%)	
Season	2015	2016	2015	2016	2015	2016
T_1 (Cont.)	9.49cd	9.25bcd	1.28b	1.70a	9.4ab	9.60a
T_2	10.01bc	10.00b	2.23a	2.43a	8.81ab	8.73a
T_3	11.20a	11.14a	2.43a	2.43a	5.44d	5.60c
T_4	10.22b	9.78bc	2.05ab	2.2a	9.07ab	9.11a
T_5	11.31a	11.18a	2.38a	2.43a	5.61d	5.70c
T_6	8.03f	8.46de	1.73ab	1.73a	8.37ab	8.75a
T_7	8.95de	9.0cde	1.84ab	1.82a	6.8cd	6.73b
T_8	8.08f	8.16e	1.91ab	1.90a	9.71a	9.47a
T_9	8.78e	8.39de	1.90ab	1.89a	8.02bc	9.17a

Yield and its components:

Results in Table 9 showed that there were insignificant differences among treatments in both seasons. Among all the treatments, T3 and T5 were found to be the best with respect to yield which was significantly higher than other treatments. Significant yield was recorded as 311.3 and 295.5 number of fruits for the treatment T_3 and 304.96 and 297 for the treatment T_5. However, the highest yield as kg/tree was obtained by T_3 (78.8 and 78.47 kg/tree) and T_5 (80.3 and 79.06 kg/tree) followed by T_1 (70.28 and 70.51kg/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, increase in yield of the plant is due to improvement in physical condition of the soil. increase uptake of Nitrogen, Phosphorus and Potassium by the plant through increasing the water holding capacity of the soil (Panayiotis *et al*., (2004), this increase in the growth reflected on productivity of trees. The results are in line with those of Pattanaaik *et al.*, (2015) on Khasi mandarin, who found that, Significant yield per tree was recorded for the treatment (60 g of hydrogel/tree) compared with untreated ones, Torkashvand *et al.*, (2017) found that different media containing artificial and natural super-absorbents(10 g per kg soil of zeolite and the substrate including 20% vermicompost + 15% rice wastes + 15% manure + 50% soil) had the best yield of olive trees and can modify the effect of 10 day irrigation interval compared to the 5 day. Abd El-Rhman and Mohamed (2015) study the effect of soil with addition of hydrogel polymer at 0, 100, 150 and 200 g/tree on yield of Egazy olive trees. The obtained results cleared that the yield was increased with hydrogel treatments especially at 200g/tree compared with control under water stress conditions.

Table 9. Effect of irrigation regime and soil conditioners on yield and its components of Washington navel orange trees in 2015 and 2016 seasons.

Treatments	Fruit weight (g)		No. of fruit/tree		Kg/tree		Ton/fed.	
	2015	2016	2015	2016	2015	2016	2015	2016
T_1 (Cont.)	276.72a	278.96a	254.06b	252.76b	70.28b	70.51ab	12.30b	12.34ab
T_2	261.63a	270.72a	252.43b	252.4b	66.03bc	68.33bc	11.55bc	11.96bc
T_3	253.73a	265.48a	311.3a	295.53a	78.8a	78.47a	13.79a	13.73a
T_4	260.96a	268.07a	252.4b	254.66b	65.85bc	68.20b	11.52bc	11.94bc
T_5	263.9a	266.11a	304.96a	297.0a	80.36a	79.06a	14.06a	13.84a
T_6	274.4a	279.80a	223.6c	222.96c	61.36c	62.26bc	10.74c	10.89bc
T_7	257.4a	262.17a	250.43b	246.7b	64.46bc	64.7bc	11.28bc	11.32bc
T_8	274.7a	274.11a	221.56c	221.8c	60.76c	60.66c	10.63c	10.61c
T_9	254.96a	268.95a	246.16b	244.06b	62.73c	65.66bc	10.97c	11.49bc

As for chemical fruit quality the present results of fruits TSS % in Table 11 showed that in general, there were insignificant differences among treatments in the first season, but in the second one the highest values of TSS % were in the treatment of T_4, T_6,T_7 and T_8 compared to the other treatments. Data of acidity% in fruits (Table 11) revealed that the studied treatments T_7 and T_9 increased the acidity of fruit juice in the first season, while T_8 and T_9 gave the highest values in this respect compared with control and other treatments. Data of TSS/acid ratio in fruits was recorded in Table 11. Control treatment gave the highest level of 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 11) showed that most of the tested treatments maintained the higher concentration of vitamin C in fruit juice than the control (T_1) during 2015 and 2016 seasons. The best treatment in this respect was T8 (Deficit irrigation treatment + organic plant residues at rate of 3.5 kg/tree) 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 and organic waste 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, Torkashvand *et al.,* (2017), Abd El-Rhman and Mohamed (2015) on olive trees. However, Barakat *et al.,* (2015) on Grandnain Banana plants.

Table 10. Effect of irrigation regime and soil conditioners on physical fruit quality of Washington navel orange fruits in 2015 and 2016 seasons.

Treatments	Fruit dimensions						Juice weight %		Peel thickness (cm)	
Season	Fruit diameter (g)		Fruit height (cm)		Fruit shape D/H					
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T_1 (Cont.)	9.48a	8.83ab	8.79ab	8.96a	1.08a	0.98abc	30.34ab	30.20ab	4.56b	4.56b
T_2	7.91bc	8.56abc	8.49abc	8.90a	0.93b	0.95bc	28.32ab	28.30abc	5.46a	5.33ab
T_3	8.00bc	8.26c	8.84a	8.58a	0.90b	0.96bc	31.25a	31.05ab	5.16ab	5.40ab
T_4	7.83c	8.50bc	8.51abc	9.07a	0.91b	0.92c	26.89ab	29.08abc	5.43a	5.43ab
T_5	8.00bc	8.56abc	8.88a	8.70a	0.90b	0.98abc	31.28a	31.7a	5.33a	5.33ab
T_6	8.20bc	9.13a	7.81c	8.64a	1.07a	1.05a	27.7ab	27.46bc	5.90a	5.76a
T_7	8.11bc	8.70abc	8.17abc	8.77a	0.99ab	0.99abc	28.32ab	28.57abc	5.66a	5.56a
T_8	8.56b	9.06ab	7.91bc	9.07a	1.08a	1.03ab	25.78b	25.51c	5.66a	6.00a
T_9	8.16bc	8.68abc	8.07abc	9.03a	1.01ab	0.96bc	27.47ab	27.43bc	5.66a	5.66a

Table 11. Effect of irrigation regime and soil conditioners on chemical fruit quality of Washington navel orange fruits in 2015 and 2016 seasons.

Treatments	TSS %		Acidity %		TSS /acid ratio		Vitamin C (mg ascorbic acid/100 ml fresh juice)	
Season	2015	2016	2015	2016	2015	2016	2015	2016
T_1 (Cont.)	11.26a	11.30b	0.66c	0.71e	17.06a	15.76a	47.53bc	48.83abc
T_2	11.33a	11.40ab	0.94b	0.86d	12.93b	13.40b	45.86bc	48.33abc
T_3	11.50a	11.55ab	0.93b	0.91cd	12.93b	12.6bc	45.83bc	47.20bc
T_4	12.03a	12.16a	0.93b	0.89d	13.1b	13.70b	43.73c	45.23c
T_5	11.86a	11.93ab	0.95ab	0.97bcd	12.53b	12.23bc	43.60c	45.56c
T_6	12.33a	12.36a	1.08ab	1.03abc	11.46b	12.00bc	45bc	47.23bc
T_7	12.40a	12.41a	1.15a	1.06ab	10.76b	11.70bc	44.96bc	49.30abc
T_8	12.30a	12.33a	1.11ab	1.11a	11.13b	11.06c	54.00a	53.11a
T_9	12.10a	12.13ab	1.15a	1.10ab	10.53b	11.00c	50.96ab	51.55ab

Fruit splitting %

With regard to the effect of irrigation levels and some water saving substances treatments on fruit splitting %, the results in Fig. 3 illustrated that the highest percentage of fruit splitting % (11.11 and 10%) and (10.06 and 9.91%) was observed in the treatment of T_8 (Deficit irrigation treatment + organic plant residues at rate of 3.5 kg/tree) and T_9 (Deficit irrigation treatment + organic plant residues at rate of 6.5 kg/tree), while the lowest percentage of fruit splitting (6.83 and 6.33%) and (6.9 and 5.14%) coated with T_3

(Moderate irrigation treatment + Hydrogel polymer at rate of 100g/tree) and T_5 (Moderate irrigation treatment + organic plant residues at rate of 6.5 kg/tree) in both seasons .In addition, Fig.3 showed the effect treatments on decrease (-) or increase(+) of fruit splitting % over the control (0), all treatments of T_2, T_3, T_4, T_5, T_6 and T_7 decreased (-) fruit splitting over the control compared with T_8 and T_9 which increase fruit splitting (+) over control in both seasons. The best treatment in decreasing (-) fruit splitting over the control was T_5 which recorded 32-44% over the control.

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 waste compost treatments decreased fruit splitting percentage through optimization of soil moisture by increasing soil holding capacity. These results are in accordance with those reported by The same results was obtained by Rubino *et al*., (2004) 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 and water irrigation quality.

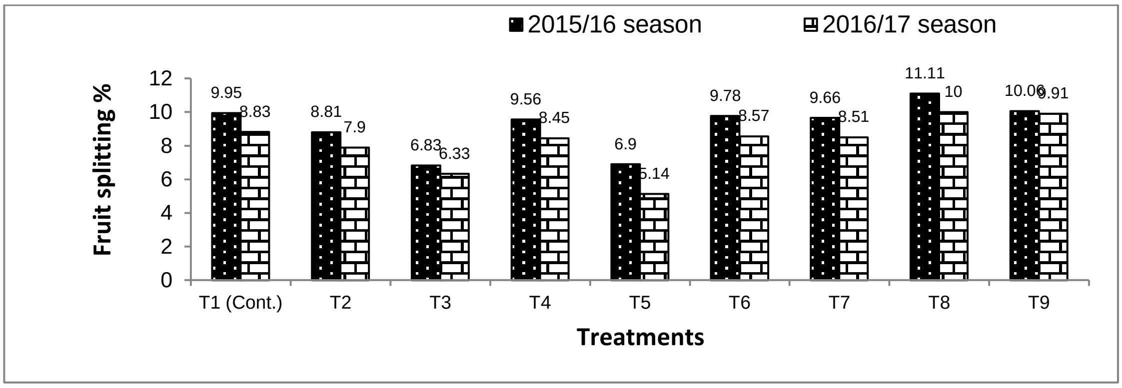

Fig. 3. Effect of irrigation regime and soil conditioners on fruit splitting % of Washington navel orange tress during 2015 and 2016 seasons.

Productivity of irrigation water (PIW, kg m^{-3})

Results in Fig (4) revealed that, the lowest values of PIW for Washington navel orange (2.74 and 2.75 kg m^{-3} for the first and second years, respectively) were obtained with full irrigation. This is due to the high amount of irrigation water with full irrigation. Irrigation regime at 80 %, were recorded high values of PIW (varied from 3.14 to 3.83 kg m^{-3}) while, the highest values (varied from 3.73 to 4.04 kg m^{-3}) were recorded with irrigation regime at 60 %, in both years. Results indicate that, productivity of irrigation water (kg m^{-3}) are more pronounced with the high rates of soil conditioners (hydrogel polymer or organic waste compost) compared to the low rates. On citrus trees showed the application of organic plant residues under low water use system increased soil moisture which reflected to increasing the water holding capacity and water use efficiency (Lobo *et al.*, 2006). In addition, Chehab *et al*., (2017) on olive trees who found that, the application of hydrogel in the root zone of olive trees significantly increased water use efficiency.

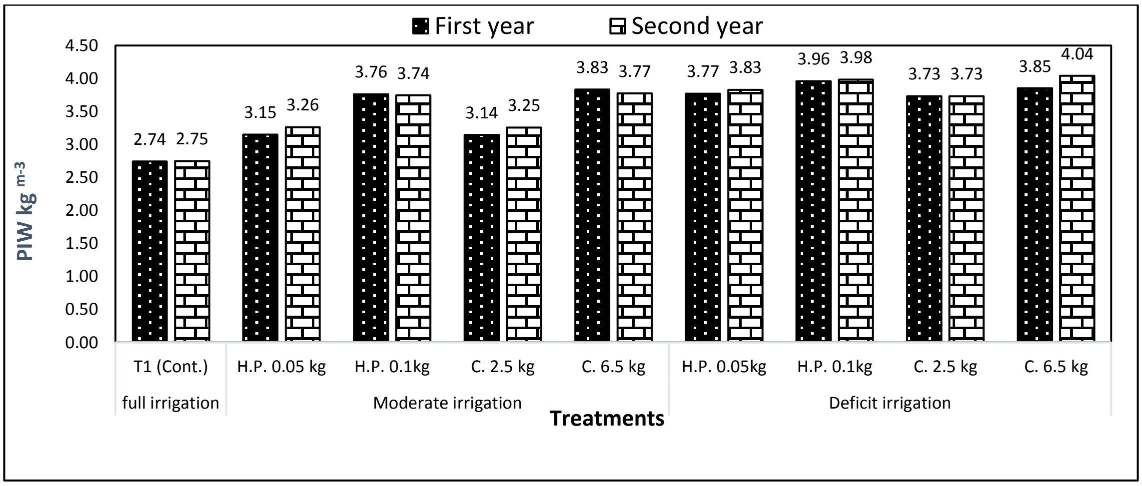

Fig. 4. Productivity of irrigation water (PIW, Kgm^{-3}) for both years of Washington navel orange with different treatments

CONCLUSION

Based on the results obtained from this study, and in order to enhance the properties and water holding capacity of sandy soil, it should be applied the soil conditioners to this soil. Soil conditioners application can be reduced of water and agrochemicals losses and increase water irrigation efficiency in sandy soil. The application of soil conditioners led to enhance growth, yield, quality and water productivity of Washington navel orange trees under drip irrigation system in sandy soil.

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تأثير اسلوب الري ومحسنات التربة على صفات الارض الرملية واشجار البرتقال ابوسرة

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نظرًا 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 بمدينة النوبارية بمحافظة البحيرة مصر. و ذلك لدراسة تأثير ثلاثة مستويات من مياه الري (الري الكامل و 80% من الري الكامل و60% من الري الكامل) وبعض محسنات التربة (الهيدروجيل بمعدل 50 و 100 جم / شجرة أو بقايا النباتات العضوية بمعدل 3.5 و 6.5 كجم / شجرة) على صفات الارض الرملية والنمو والإنتاج والجودة وإنتاجية وحدة المياه لاشجار البرتقال ابو سرة تحت نظام الري بالتنقيط .
وأوضحت النتائج :ان إضافة محسنات التربة أدى إلى تحسين صفات التربة الرملية وكذلك نشاط الكائنات الحية الدقيقة والعناصر الغذائية الكبرى خصوصاً مع المعدلات العالية من المحسنات. حيث وجد ان القيم الأقل من السعة الحقلية (10.47%)، نقطة الزبول (4.26%)، الماء الميسر (6.21%) تحصل عليها مع الري الكامل بدون إضافة محسنات للتربة، بينما القيم العالية (11.31 الى 12.28%)، (4.35 الى 4.68%)، (6.78 الى 7.62) على التوالي تحققت نتيجة التفاعل بين نقص المباة الى 80 و60% من الري الكامل مع إضافة محسنات التربة. وايضاً إضافة محسنات التربة مع نقص الرى ادت الى زيادة النيتروجين الميسر (حتى 22.76%) والفوسفور ((حتى 9.98%) والبوتاسيوم (حتى 15.14%) والمادة العضوية (حتى 41.79%) و السعة التبادلية (حتى 16.53%) والملوحة(حتى 4.64%) بينما تناقصت الكثافة الظاهرية (حتى 5.66%) وذلك مقارنة بالري الكامل بدون إضافة محسنات.أن معاملة الري المعتدل(80% من الكنترول) + بقايا النباتات العضوية بمعدل 6.5 كجم / شجرة (T_5) أو الهيدروجيل بمعدل 100 جم / شجرة (T_3) ادت إلى زيادة معظم قياسات النمو الخضري و أعلى نسبة عقد للثمار وأقل نسبة تساقط ايضا حيث سجلت المعاملة T_3 و T_5 اقل نسبة لتشقق الثمار (6.58 و 5.87٪) واعلى محصول للشجرة (87.6 و6 .79كجم / شجرة). ادت معاملة الكنترول (T_1) تليها T_3 و T_5 إلى تحسين جودة الثمار الطبيعية فى حين سجلت المعاملة T_8 و T_9 اعلى القيم بالنسبة لصفات الثمار الكيميائية. متوسط انتاجية وحدة مياه الري لاشجار البرتقال ابوسرة مع الري الكامل بدون إضافة محسنات كانت منخفضة (2.75 كيلوجرام للمتر المكعب من المياه) بينما نقص المياه الى 80% و60% من الكنترول حققت قيم اعلى لانتاجية مياه الري (3.49 و 3.88 كجم/م^3) على التوالي. وايضاً اشارت النتائج الى زيادة انتاجية وحدة مياه الري لاشجار البرتقال ابوسرة مع زيادة معدلات المواد المحسنة للتربة.