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EFFECT OF IRRIGATION LEVELS AND SOIL AMENDMENT ON GROWTH AND YIELD OF SWEET PEPPER CROP UNDER EL-ARISH REGION CONDITIONS

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ABSTRACT

Two field experiments were carried out during summer seasons of 2017 and 2018 at the Experimental Farm, Faculty of Environmental Agricultural Sciences, Arish University, Egypt to study the effect of three levels of irrigation (100, 80 and 60% of irrigation water requirement) and three types of soil amendments (without, gypsum and pressed olive cake) and their combinations on growth and yield of sweet pepper (Capsicum annuum L. cv. "Top Star") crop under El-Arish region conditions. Plants were irrigated using drip irrigation system. The highest values of all studied traits; viz., vegetative growth, plant fresh and dry weights, yield of grad A and B and total yield were recorded with using 100 % followed by 80% irrigation level both + pressed olive cake that followed by applying 80% irrigation level + gypsum as soil amendment, respectively in both growing seasons. While the lowest values were obtained by application 60% of water requirements with or without using soil amendments.

INTRODUCTION

Sweet pepper is an important crop in the Mediterranean area, grown commercially in semi-arid regions. Capsicum has a little energy value but the nutritive value of sweet pepper is high as it contains 1.29 mg protein, 11 mg calcium, 870 I.U vitamins-A, 175 mg ascorbic acid, 0.06 mg thiamine, 0.03 mg riboflavin and 0.55 mg niacin per 100 grams of fruit **Joshi and Singh *(*1975)**. In addition, pepper is sensitive to drought stress and is moderately sensitive to salt stress **Rhoades *et al.* (1992). Dimitrov and Ovtcharrova (1995**) indicated that water deficit, particularly during the period between flowering and fruit development, reduced final fruit production. **Marschner (1995)** reported that under sufficient water conditions there was a decrease in abscisic acid (AB) and increases in CYT, GA and IAA reflecting good plant growth and dry matter content.

Define *et al.* (2000) reported that *Capsicum annum* L. is one of the most susceptible crops to water stress because of wide transpiring leaf surface and elevated stomatal openings and yet relatively copious amounts of water may be undesirable in terms of resultant fruit yield and quality. The quality of paprika therefore depends on a moisture regime. Also, **Palada and O'Keefe (2001)** investigated the response of hot pepper cultivars to levels of drip irrigation in the Virgin Islands and observed increasing yield trends with increasing amounts of irrigation water. In addition, **Shaozhong *et al.* (2001), Ismail *et al.* (2002) and Dorji *et al.* (2005)** found that under water stress conditions, there were reductions in fruit size, number of fruits and fresh fruit yield.

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Abdel-Rheem (2003) reported that increasing levels of irrigation to the soil increased the moisture content that makes minerals more available to the plant that led to enhance mineral concentration and their uptake by plant. Also, **Anwar (2005)** found that means of water use efficiency (WUE) gradually decreased with increasing water quantity up to the highest level and showed opposite trend to that of total yield, it could be suggest that increasing the quantity of water applied to the soil increases the soil moisture content, that makes the nutritional elements more available to the plant, and this in turn might favored the plant growth characters and most of the physiological process, that directly affect the yield and its components. In addition, higher water quantity applied to plants led to keep higher water content in the plant tissues.

Kirnak *et al.* (2001) found that the highest amount of proline was found at 40% by 4.80 and the lowest at 100% by 2.36 field moisture capacity. Also, **Del Amor *et al.* (2010)** found that proline concentration was significantly increased by 41.2%, at moderate stress however, severe drought increased proline from 2.4 to 120.6 m mol kg^{-1}.

Khan *et al.* (2009) found that water stress produced lower values of studied parameters (plant height, root length, root volume, leaf dry weight, stem dry weight, and root dry weight), this effect was due to that water stress had negative effect for all the parameters studied of chilli pepper crop. **Al-Amran (2010)** or **Al-Omran *et al.* (2010)** showed that soil water content has specific distribution patterns in amended soil when compared with the control soil in both high and low irrigation rates. **Silva *et al.* (2016)** reported that high levels of irrigation 100% and 80% had better results of pepper plant compared to other irrigation levels. 60.40 and 20%, there was a 24.44% increase in the number of leaves in the 80% when there was reduction of 20% of water available to the plant, 80% irrigation level was considered adequate influencing positively the amount of pepper leaves., Also, they found in the number of sheets of the nozzle pepper there was an increase in the number of sheets when there was increased availability of water based on the water requirement 80% and 100%.

Organic additives offer a simple, sustainable tool for managing agricultural wastes throw converting agricultural waste into a powerful soil enhancer, improve their physicochemical properties, and improves its biological properties. So, increases water holding capacity, cation exchange capacity, available mineral nutrients and this in turn stimulates plant growth and plant productivity. **Anwar (2005)** reported that soil amendment improved sandy soil characteristics, particularly the available water content, nutrient and improves soil physical and chemical properties that promote nutrient uptake from soil minerals into plants it is reflect of photosynthetic pigments.

Kavdir and Killi (2008) reported that application of olive solid waste (OSW) increased soil total organic nitrogen contents. Also, **Alburquerque *et al.* (2006)** reported that olive cake, had high C/N ratio. (nearly half of its high organic matter (OM) content was lignin, which is considered to be an important precursor of soil humic substances and responsible for the above-mentioned high C/N values, other important constituents were cellulose and hemicellulose). They added that it produces quality end-products, which are non-phytotoxic and rich in partially humified organic matter, and this led to both water and nutrients available for plant which reflected positive effect for plant growth and metabolic.

Gypsum has many benefits, it is a direct source of macro nutrients (calcium and sulfur) for plants, improves soil physical and chemical properties that promote nutrient uptake from soil minerals into plants and increases water infiltration and percolation (**Norton *et al.,* 1993; Dontsova *et al.,* 2004; Norton, 2008**). **Saeed and Ahmad (2009**) found that application of organic mulch and gypsum helped to increase amount of chlorophyll and carbohydrate biosynthesis.

It is will know that sandy soils have their own problems as very poor soil in mineral nutrients, and has low moisture holding capacity, single grain structure, low levels of microorganisms. Therefore, adding both of organic additives (pressed olive cake) and chemical additives (gypsum) as soil amendments to sandy soil cultivated with pepper plants may help in overcoming some of sandy soil problems in El-Arish region and similar areas. So, this study aimed to solve the problem of water scarcity in El Arish region and improve the growth and yield of pepper plants by using the suitable irrigation level and soil amendment.

MATERIALS AND METHODS

Two field experiments were carried out during summer season of 2017 and 2018 at the Experimental Farm, Faculty of Environmental Agricultural Sciences, Arish University, Egypt. The aim was studying the effect of irrigation level and soil amendment on growth and productivity of sweet pepper under El-Arish region condition. Initial physical chemical analysis of soil and chemical analysis of irrigation water are presented in Tables 1 and 2.

Soil parameters determined before conducting the experiments were particles size distribution **(Piper, 1950),** total carbonate **(Jackson, 1967)** and soil pH value was determined in 1:2.5 soil water suspension. The soil water extract for the 1:5 soil water ratio was chemically analyzed for electrical conductivity (EC) according to **Richard (1954)** and **Jackson (1967)**.

The complete Randomized Block Design was used for a factorial experiment contained two factors, the first was irrigation levels (100, 80 and 60% of irrigation water requirements) and the second was soil amendments (without, agricultural gypsum and pressed olive cake). Sweet pepper seeds of "Top Star" cv. we're transplanting in plastic seedling trays on 14^{th} March and transplanting was carried out on 23^{th} April in both seasons. Plants were irrigated using drip irrigation system, the distance between dripper lines centers was 1.2 m., while the distance between plants in the same row was 50 cm. The plot area was 14.4 m^2 (12 m length and 1.2 m wide).

Data Recorded

At 45, 60 and 75 days after transplanting samples of three plants were randomly taken from each experimental plot to determine vegetative measurements, plant fresh and plant dry weight for leaves and stem. At ripening stage, fruits were harvested and the mean fruit weight, number of fruits per plant, fruit yield per square meter and fruit yield (ton fad^{-1}) all for grad A and B as well as total yield (ton fad^{-1} for grad A+B) were estimated for the marketable yield. Rotten fruits and fruits with more than 20% of blossom-end rot (BER) were not taken into account for the marketable yield.

Statistical Analysis

Statistical analysis of the obtained data was carried out according to statistical analysis of variance according to **Snedecor and Cochran (1980). Duncan's** multiple range tests at 0.05 level was used for comparison among means **(Duncan, 1958).**

Table 1. The initial physical and chemical analyses of the experimental soil site

Particles size distribution (%)		
	First season 2017	**Second season 2018**
Coarse sand (%)	58.3	58.4
Fine sand (%)	19.2	19.3
Silt (%)	12.3	12.0
Clay (%)	10.0	10.1
Soil texture	**Sandy loam**	**Sandy loam**
Bulk density (Mgm^{-3})	1662	1661
Chemical properties (Soluble ions, in 1:5 soil water extract)		
Ca^{++} (meq.$^{L-1}$)	3.90	3.90
Mg^{++} (meq.$^{L-1}$)	3.42	3.43
Na^{+} (meq.$^{L-1}$)	2.74	2.55
K^{+} (meq.$^{L-1}$)	0.34	0.32
CO_3^{-} (meq.$^{L-1}$)	-	-
HCO_3^{-} (meq.$^{L-1}$)	4.50	4.40
Cl- (meq.$^{L-1}$)	4.40	4.35
SO_4 (meq.$^{L-1}$)	1.50	1.45
EC (dSm-1) in 1:5 water extract)	1.04	1.03
pH (in1:2.5 Soil water suspension extract)	8.10	8.13
Organic matter (%)	0.153	0.160
$CaCO_3$ (%)	22.43	22.48

Table 2. Chemical analysis of irrigation water

pH	EC (dSm^{-1})	Soluble ions (meq.$^{L-1}$)							
		Cations				Anions			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_{3-}	CO_{3--}	SO_{4--}
First season (2017)									
7.55	5.56	19.50	17.36	18.50	0.24	45.92	2.90	-	6.78
Second season (2018)									
7.60	5.71	21.00	17.05	18.80	0.25	46.77	2.99	-	7.34

RESULTS AND DISCUSSION

Effect of Irrigation Water Levels

Vegetative growth

Results in Table 3 show significant effects for irrigation levels on vegetative growth traits of sweet pepper plant; viz., plant height, number of leaves and branches as well as leaf area at all sampling dates in both seasons. The highest values of all studied traits were recorded with applying 100% irrigation level followed by 80% irrigation level in both seasons at 45, 60 and 75 days after transplanting, except number of branches per plant, where the highest values were recorded with applying 80% irrigation level followed by 100% irrigation level in both seasons at 60 and 75 days after transplanting.

It could say that increasing levels of water (quantity) applied led to save higher soil moisture content and this in turn might favored the plant metabolism that leads to increase plant growth characters and produce higher dry matter. On the other hand, water stress led to reduction in the

Table 3. Effect of irrigation water levels on vegetative growth of pepper plant at 45, 60 and 75 days after transplanting in 2017 and 2018 seasons

Parameter	Plant height (cm)			No. Leaves			No. Branches		Leaf area (m^2)		
Irrigation water level (%)	Days after transplanting										
	45	60	75	45	60	75	60	75	45	60	75
	First season (2017)										
100	28.61a	44.27a	70.77a	29.22a	42.83a	95.72a	1.27b	2.22b	0.119a	0.126a	0.141a
80	25.38b	39.16b	54.00b	25.16b	38.38b	70.38b	1.55a	2.38a	0.083b	0.099b	0.138ab
60	22.22c	32.38c	45.27c	20.77c	32.50c	42.94c	1.05b	2.27b	0.067c	0.075c	0.135b
	Second season (2018)										
100	28.44a	44.33a	70.50a	28.38a	44.16a	93.72a	1.16b	2.28b	0.115a	0.126a	0.142a
80	25.61b	39.22b	53.88b	25.33b	37.83b	71.38b	1.61a	2.33a	0.081b	0.099b	0.140ab
60	21.83c	32.16c	45.61c	21.16c	31.83c	43.61c	1.00b	2.22b	0.066c	0.075c	0.135b

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance, according to **Duncan's** multiple range test.

uptake of nutritional elements that might cause a disturbance in the physiological processes of plant growth as reported by **(Salter and Goode, 1967)**. In this direction, **El-Beltagy *et al.* (1984)** stated that reduction in the vegetative growth of plants under drought, particularly in shoot growth, reduced cyclin-dependent kinase activity resulting in slower cell division as well as inhibition of growth, and relatively sever reduce in plant tissues (cell size and number of cells per unit or intercellular spaces). In this direction **Kandil *et al.* (2001)** reported that drought stress also reduced the uptake of essential elements and photosynthetic capacity. Also, **Kirnak *et al.* (2001)** found that water deficit reduced the growth of each plant component, where plant height, stem diameter and dry weight of water-stressed plants were smaller to the equivalent component in the well-watered plants of eggplant. In addition, **Abdalla (2011)** and **Yazdanpanah *et al.* (2011)** reported that water stress leads to increases in abscisic acid levels in roots which is transported from roots to shoot, where it acts in the apical region of the plant as an antagonist of the auxin and cytokinin, responsible for growth and cell division as well as inhibiting DNA synthesis, as well as the excessive accumulation of intermediate compounds such as reactive oxygen species which cause oxidative damage to DNA, lipid and proteins, consequently caused a decrease in plant growth.

Fresh and dry weights

Results in Tables 4 and 5 show significant effect for levels of irrigation on fresh and dry weights of stem, leaves, and shoot of sweet pepper plant at all sampling dates. The highest values of all studied traits were recorded with applying 100% irrigation level followed by 80 % irrigation level at 45, 60 and 75 days after planting in both seasons, except fresh and dry weights of branches, where the highest values were recorded with applying 80% irrigation level followed by 100% irrigation level at 60 and 75 days after transplanting in both seasons.

These results may be due to that plants had their requirements from water and nutrients with application of 100% or 80% levels of irrigation using drip irrigation system. Also, due to that water stress affects carbohydrate metabolism, protein synthesis and the activities of many enzymes that may reflect a change in the balance between

Table 4. Effect of irrigation water levels on fresh weight of pepper plant at 45, 60 and 75 days after transplanting in 2017 and 2018 seasons

Parameter / Irrigation water level (%)	Stem (g)			Leaves (g)			Branches (g)		Shoot (stem + leaves + branches) (g)		
	Days after transplanting										
	45	60	75	45	60	75	60	75	45	60	75
	First season 2017										
100	6.28a	9.47a	15.79a	8.03a	11.39a	15.29a	4.18b	7.91a	14.31a	25.04a	38.99a
80	4.68b	8.20b	11.28b	7.11b	10.17b	11.63b	4.47a	8.07a	11.79b	22.84b	30.98b
60	4.11c	6.81c	7.87c	5.86c	8.60c	7.09c	2.79c	6.17b	9.97c	18.20c	21.13c
	Second season 2018										
100	6.11a	9.62a	15.89a	8.25a	11.64a	15.63a	4.08b	7.96b	14.36a	25.34a	39.48a
80	4.66b	8.34b	11.18b	7.11b	10.02b	11.47b	4.42a	7.68a	11.77b	22.78b	30.33b
60	4.03c	6.76c	7.65c	5.85c	8.37c	6.97c	2.79c	6.39b	9.88c	17.92c	21.01c

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance, according to **Duncan's** multiple range test.

Table 5. Effect of irrigation water levels on dry weight (g) of pepper plant at 45, 60 and 75 days after transplanting in 2017 and 2018 seasons

Parameter / Irrigation water level (%)	Stem (g)			Leaves (g)			Branches (g)		Shoot (stem + leaves + branches) (g)		
	Days after transplanting										
	45	60	75	45	60	75	60	75	45	60	75
	First season (2017)										
100	1.08a	1.66a	3.18a	1.38a	2.34a	3.12a	0.83b	1.61a	2.46a	4.83a	7.91a
80	0.86b	1.44b	2.23b	1.11b	2.01b	2.29b	0.89a	1.58a	1.97b	4.34b	6.11b
60	0.73c	1.17c	1.53c	0.84c	1.70c	1.39c	0.55c	1.23b	1.57c	3.43c	4.15c
	Second season (2018)										
100	1.08a	1.62a	3.15a	1.37a	2.27a	3.05a	0.81b	1.59a	2.45a	4.71a	7.80a
80	0.87b	1.42b	2.25b	1.11b	2.03b	2.32b	0.88a	1.53a	1.98b	4.33b	6.10b
60	0.73c	1.19c	1.57c	0.85c	1.72c	1.41c	0.55c	1.27b	1.58c	3.47c	4.26c

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance, according to **Duncan's** multiple range test.

rates of synthesis and degradation leading to decrease in plant growth and dry matter accumulation as reported by **Hamlyn (1986)**. On the other hand, **Marschner (1995)** reported that under sufficient water conditions there were a decrease in AB and increase in CYT, GA and IAA reflecting good growth and dry matter content. Also, **Kirnak *et al.* (2001)** reported that soil water content either directly or indirectly influences plant growth as well as transpiration rate, since they are mainly turgor-dependent processes. At the onset of stress extension growth and leaf expansion are first affected, followed by a decrease in rates of transpiration due to partial stomatal closure potentially. Also, there were significant reductions in dry matter and chlorophyll content at high water stress compared to the control. In addition, **Boutraa (2010)** concluded that, water stress conditions cause a multitude of molecular, biochemical and physiological changes, thereby affecting plant growth and development.

Finally, our results are in agreement with **Silva *et al.* (2016)** who reported that high levels of irrigation (100% and 80%) had better results on pepper plant growth compared to other irrigation levels (60. 40 and 20%), where there was a 24.44% increase in the number of leaves with 80% level, while there was a reduction of about 20% of water available to the plant, 80% irrigation level was considered adequate as influencing positively the number of pepper leaves. Also, they found that in the number of shoots of the nozzle pepper there was an increase in the number of shoots, where there was increased availability of water based on the water requirement of 80% and 100% levels.

Yield and its components

Results in Table 6 show significant effect of irrigation levels on yield and its components; viz., mean fruit weight, and number of fruits per plant for grade A and B as well as total yield per faddan. The highest values of total yield and mean fruit weight were recorded with increasing irrigation levels, while the lowest values were recorded with applying 60% irrigation water level in both seasons.

The increase in total yield was clearly achieved owing to the increases in weight of fruits/plant. This result reflects similar trend to that obtained with plant growth. Also, these results may be due to that increasing levels of irrigation water led to increase the moisture soil content that make the nutritional elements more available to the plant that favored plant growth and most of the physiological processes, that directly affect yield and its components. Additionally, higher water levels applied to plants led to keep higher water content in the plant tissues, that led to increasing plant height and number of branches, resulting in an increase in the number of fruits and total yield.

Results of yield and its components are in agreement with those of **Dimitrov and Ovtcharrova (1995)** who cleared that water deficit, particularly during the period between flowering and fruit development, reduced final fruit production. Also, results are in agreement with those of **Ghosh *et al.* (2000), El-Banna *et al.* (2001) Shaozhong *et al.* (2001), Belanger *et al.* (2002), Ismail *et al.* (2002), Dorji *et al.* (2005)**, and **Fernandez *et al.* (2005)** on pepper plant, who found that under water stress conditions there were a reduction in fruit size, number of fruits and fresh fruit yield. It is meaning that the pepper physiological responses to deficit irrigation were completely negative (**Jaimez *et al.*, 2000).**

Effect of Soil Amendments

Vegetative growth

Results in Table 7 show significant effects for soil amendments on vegetative growth traits; i.e., plant height, number of leaves, and leaf area at all sampling dates, except number of branches in both seasons that had no significant effects. The highest values of all studied traits were recorded with applying olive pressed cake and there was no significant difference between control and gypsum treatment in both seasons.

These result are in agreement with the findings of **Kavdir and Killi (2008)** who evaluated the effects of olive solid waste (OSW) and OSW compost (OSWC) on tomatoes growth and they found that, application of OSWC increased tomatoes growth; *i.e.*, plant length, dry and fresh weights significantly in sandy and loamy soils, whereas application of OSW increased soil total organic nitrogen contents.

Plant fresh and dry weight

Results in Tables 8 and 9 show significant effect of soil amendments on fresh and dry weights of stem, leaves, branches and total shoot weight at all sampling dates, except fresh weight of branches that had no significant effect in both seasons. The highest values of all studied traits were recorded with applying olive pressed cake in both seasons at 45, 60 and 75 days after transplanting, these results may be due to that olive cake had high C/N ratio (nearly half

Table 6. Effect of irrigation water level son marketable fruit yield of pepper plant in 2017 and 2018 seasons

Parameter / Irrigation water level (%)	Grade A: Mean fruit Weight (g)	Grade A: No. Fruits (m^2)	Grade A: Yield (ton fed^{-1})	Grade B: Mean fruit weight (g)	Grade B: No. Fruits (m^2)	Grade B: Yield (ton fed^{-1})	Total yield: No. Fruits (m^2)	Total yield: Yield (ton fed^{-1})
				First season (2017)				
100	78.80a	43.82a	6.04a	40.98a	56.61a	4.03a	100.44a	10.07a
80	77.85a	39.62b	5.40b	39.36c	52.47b	3.60b	92.10c	9.00b
60	59.62b	44.14a	4.61c	34.08b	51.87b	3.07c	96.01b	7.68c
				Second season (2018)				
100	79.26a	44.90a	6.23a	42.13a	56.99a	4.15a	101.90a	10.38a
80	79.48a	39.82b	5.54b	38.57b	55.18b	3.70b	95.00b	9.24b
60	60.86c	45.01a	4.80c	34.49c	53.42b	3.20c	98.43ab	8.00c

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance, according to **Duncan's** multiple range test.

Table 7. Effect of soil amendment on vegetative growth of pepper plant at 45, 60 and 75 days after transplanting in 2017 and 2018 seasons

Parameter	Plant height (cm)			No. Leaves			No. Branches		Leaf area (cm^2)		
	Days after transplanting										
Amendments	**45**	**60**	**75**	**45**	**60**	**75**	**60**	**75**	**45**	**60**	**75**
					First season (2017)						
Control (without amendment)	24.33b	37.05b	55.11b	24.66b	37.05b	68.77b	1.33a	2.22a	0.085b	0.097b	0.135b
Agricultural gypsum	24.50b	37.55b	55.55b	23.88b	35.72b	66.27b	1.38a	2.27a	0.085b	0.098b	0.142a
Pressed olive cake	27.38a	41.22a	59.38a	26.61a	40.94a	74.00a	1.16a	2.38a	0.099a	0.105a	0.137b
					Second season (2018)						
Control (without amendment)	24.16b	37.05b	55.00b	24.61b	37.38b	68.33b	1.22a	2.35a	0.079b	0.097b	0.137b
Agricultural gypsum	24.50b	37.61b	55.38b	23.50b	35.94b	65.88b	1.27a	2.44a	0.066b	0.084b	0.144a
Pressed olive cake	27.22a	41.05a	59.61a	26.77a	40.50a	74.50a	1.27a	2.44a	0.099a	0.104a	0.136b

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance, according to **Duncan's** multiple range test.

Table 8. Effect of soil amendment on fresh weight of pepper plant at 45, 60 and 75 days after transplanting in 2017 and 2018 seasons

Parameter	Stems (g)			Leaves (g)			Branches (g)		Shoot (stem + leaves + branches) (g)		
Amendments	Days after transplanting										
	45	**60**	**75**	**45**	**60**	**75**	**60**	**75**	**45**	**60**	**75**
					First season 2017						
Control (without amendment)	4.78b	7.79b	11.24b	6.89b	9.833b	11.13b	3.84a	7.17a	11.67b	21.46b	29.55b
Agricultural gypsum	4.97b	7.90b	11.07b	6.67c	9.447b	10.74b	3.80a	7.30a	11.64b	21.15b	29.12b
Pressed olive cake	5.32a	8.79a	12.63a	7.45a	10.90a	12.13a	3.80a	7.67a	12.78a	23.49a	32.44a
					Second season 2018						
Control (without amendment)	4.67b	7.83b	11.05b	6.89b	9.85b	11.20b	3.7a	7.13a	11.56b	21.39b	29.38b
Agricultural gypsum	4.82b	8.05b	11.11b	6.64c	9.47b	10.81b	3.77a	7.41a	11.46b	21.29b	29.34b
Pressed olive cake	5.32a	8.84a	12.57a	7.68a	10.71a	12.06a	3.81a	7.47a	13.00a	23.37a	32.11a

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance, according to **Duncan's** multiple range test.

Table 9. Effect of soil amendment on dry weight of pepper plant at 45, 60 and 75 days after transplanting in 2017 and 2018 seasons

Parameter / Amendments	Stems (g)			Leaves (g)			Branches (g)		Shoot (stem + leaves + branches) (g)		
	Days after transplanting										
	45	60	75	45	60	45	60	75	45	60	45
	First season 2017										
Control (without amendment)	0.87a	1.35b	2.21b	1.08b	1.99b	2.24b	0.76a	1.43a	1.95b	4.11b	5.88b
Agricultural gypsum	0.85a	1.39b	2.22b	1.01c	1.91b	2.16b	0.75a	1.46a	1.87b	4.06b	5.84b
Pressed olive cake	0.93a	1.52a	2.51a	1.24a	2.15a	2.41a	0.76a	1.53a	2.18a	4.44a	6.46a
	Second season 2018										
Control (without amendment)	0.88a	1.35b	2.25b	1.08b	1.97b	2.22b	0.74a	1.42a	1.97b	4.06b	5.90b
Agricultural gypsum	0.87a	1.35b	2.21b	1.02c	1.89b	2.15b	0.75a	1.48a	1.90b	3.99b	5.84b
Pressed olive cake	0.93a	1.53a	2.52a	1.23a	2.17a	2.42a	0.76a	1.49a	2.16a	4.46a	6.44a

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance, according to **Duncan's** multiple range test.

of its high organic matter (OM) content was lignin, which is considered to be an important precursor of soil humic substances and responsible for the above mentioned high C/N values, other important constituents were cellulose and hemicellulose) as reported by **Alburquerque *et al.* (2006)** who added that it produces quality end-products, which are non-phytotoxic and rich in partially humified organic matter, and this led to both water and nutrients available for plant which reflected positive effect for plant growth and metabolic process.

Yield and its components

Results in Table 10 show significant effect for soil amendments on yield and its components; viz., mean fruit weight, number of fruits and yield of grade A and B as well as total yield fad^{-1}. The highest values were recorded with applying pressed olive cake as a soil amendment followed by gypsum, while the lowest values were recorded with control treatment (without soil amendment) in both seasons, except number of fruits of grade B that had the highest value with applying control treatment (no soil amendment), but the mean might of these fruits was the lowest one. On the other hand, there was no significant difference between number of fruits with applying olive pressed cake and control treatments for total yield fad^{-1}, but the mean fruit weight with applying pressed olive cake was higher than control treatment in both seasons.

These results may be due to that olive cake improved sandy soil characteristics, particularly the available water content and nutrient as reported in other studies **(Al-Omran *et al.*, 2004, 2005; Sheta *et al.*, 2006)**. Also, gypsum (calcium sulfate dihydrate) improved sandy soil characteristics due to direct source of macronutrients (calcium and sulfur) for plants and improving soil physical and chemical properties that promote nutrient uptake from soil minerals into plants.

Effect of Interaction between Levels of Irrigation and Soil Amendment

Vegetative growth

Results in Table 11 show significant effect for interaction between irrigation, levels and soil amendments on plant growth traits; *i.e.,* plant height, number of leaves, number of branches and leaf area of plant at all sampling dates. The highest values of all studied traits were recorded with applying the levels of 100% irrigation + pressed olive cake, except number of branches and

Table 10. Effect of soil amendments on marketable fruit yield of pepper plant in 2017 and 2018 seasons

Parameter	Grade A fruit			Grade B fruit			Total yield	
Amendment	Mean fruit weight (g)	No. fruits (m^{-2})	Yield -1 (ton fed. $^{-1}$)	Mean fruit weight (g)	No. fruits (m^{-2})	Yield -1 (ton fed. $^{-1}$)	No. fruits (m^{-2})	Yield -1 (ton fed. $^{-1}$)
				First season 2017				
Control (without amendment)	69.39c	41.77b	5.06b	34.46b	55.96a	3.37c	97.73a	8.43c
Agricultural gypsum	72.00b	42.16b	5.29b	39.18a	51.50c	3.53b	93.66b	8.82b
Pressed olive cake	74.87a	43.66a	5.70a	40.78a	53.49b	3.80a	97.16a	9.51a
				Second season 2018				
Control (without amendment)	70.11c	42.72b	5.22c	35.18b	57.01a	3.48c	99.73a	8.71c
Agricultural gypsum	73.33b	42.53b	5.44b	39.32a	53.17c	3.63b	95.70b	9.07b
Pressed olive cake	76.17a	44.48a	5.90a	40.69a	55.41b	3.94a	99.90a	9.84a

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance, according to **Duncan's** multiple range test.

Table 11. Effect of interaction between irrigation water levels and soil amendments on vegetative growth of pepper plant at 45, 60 and 75 days after transplanting in 2017 and 2018 seasons

Parameter		Plant height (cm)			No. Leaves			No. Branches		Leaf area (m^2)		
Irrigation water level (%)	Soil Amendments	Days after transplanting										
		45	60	75	45	60	75	60	75	45	60	75
		First season (2017)										
100	**Control (without amendment)**	27.16b	42.16b	68.50b	29.50a	42.50ab	96.50a	1.33ab	2.16ab	0.117a	0.122b	0.135ab
	Agricultural gypsum	27.16b	42.50b	69.33b	27.50b	40.33bc	91.33b	1.33ab	2.00b	0.112a	0.123b	0.139ab
	Pressed olive cake	31.50a	48.16a	74.50a	30.66a	45.66a	99.33a	1.16a	2.50ab	0.127a	0.133a	0.137ab
80	**Control (without amendment)**	23.66cd	36.50d	51.83d	24.50c	38.16cd	69.00d	1.66b	2.00b	0.078bc	0.096d	0.138ab
	Agricultural gypsum	24.16c	38.33c	52.00d	23.83c	35.83d	66.50d	1.66b	2.50ab	0.078bc	0.097d	0.146a
	Pressed olive cake	28.33b	42.66b	58.16c	27.16b	41.16bc	75.66c	1.33ab	2.66a	0.092b	0.106c	0.140ab
60	**Control (without amendment)**	22.16d	32.50e	45.00e	20.00e	30.50e	40.83f	1.00b	2.50ab	0.061d	0.073e	0.138ab
	Agricultural gypsum	22.16d	31.83e	45.33e	20.33de	31.00e	41.00f	1.16ab	2.33ab	0.065cd	0.076e	0.141ab
	Pressed olive cake	22.33cd	32.83e	45.50e	22.00d	36.00d	47.ooe	1.00b	2.00b	0.076bcd	0.076e	0.130b
		Second season (2018)										
100	**Control (without amendment)**	27.33bc	42.16b	68.5b	28.16ab	44.5ab	93.16ab	1.16bc	2.00b	0.102a	0.122a	0.138ab
	Agricultural gypsum	26.83c	43.00b	68.33b	26.66bc	41.66bc	89.33b	1.33bc	2.50ab	0.114a	0.126a	0.142ab
	Pressed olive cake	31.16a	47.83a	74.66a	30.33a	46.33a	98.66a	1.00c	2.66a	0.130a	0.130a	0.138ab
80	**Control (without amendment)**	23.66de	37.33c	50.83e	25.33cd	37.00d	71.16cd	1.5ab	2.00b	0.076bc	0.096b	0.135ab
	Agricultural gypsum	24.50d	37.33c	52.83d	23.33de	35.50d	66.83d	1.5ab	2.16ab	0.074bc	0.096b	0.149ab
	Pressed olive cake	28.66b	43.00b	58.0c	27.33bc	41.00c	76.16c	1.83a	2.5ab	0.092b	0.105b	0.141a
60	**Control (without amendment)**	21.50f	31.66d	45.66f	20.33f	30.66e	40.66f	1.00c	2.16ab	0.059d	0.074c	0.137ab
	Agricultural gypsum	22.16ef	32.50d	45.0f	20.50f	30.66e	41.50f	1.00c	2.66a	0.065cd	0.076c	0.14ab
	Pressed olive cake	21.83f	32.33d	46.16f	22.66ef	34.16d	48.66e	1.00c	2.16ab	0.075bcd	0.076c	0.128b

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of probability according to **Duncan's** multiple range test.

leaf area where, the highest values were recorded with applying the irrigation level of 80% + pressed olive cake in the second season at 60 days after planting, while the highest values in the first season were recorded with applying 80%+ pressed olive cake at 75 days after transplanting for number of branches. However, the highest leaf area per plant was recorded with applying 80% irrigation level + applying gypsum at 60 days after transplanting.

Zotarelli *et al.* (2009) reported that, general growth and yield of tomato plants subjected to severe water stress were significantly reduced compared to the well-watered plants. They added that it is possible that at 40% PC the plant tissues did not get enough water for optimum physiological functioning, also, the uniform distribution and adequate availability of nutrients and moisture in the root zone of sweet pepper. Also, our results are in accordance with the findings of **Veeranna *et al.* (2001**) and **Kong *et al*. (2011**)

Fresh and dry weight

Data in Tables 12 and 13 show significant effect for interaction between irrigation levels and soil amendments on stem, leaves, branches and total shoot fresh and dry weights of sweet pepper plant at all sampling dates. The highest values of all studied traits were recorded with applying the level of 100% irrigation water + pressed olive cake, except fresh weight of branches, where the highest values were recorded with applying the level of 80% irrigation water + pressed olive cake in the second season at 60 days after transplanting. This result is in agreement with that reported by **Anwar (2005).**

Yield and its components

Results in Table 14 show significant effect for interaction between levels of irrigation and soil amendments on yield and its components; *i.e.,* mean fruit weight, number and yield of grade A and B as well as total yield fad^{-1}. It is obvious that the higher values for most traits were with the highest level of irrigation (100%) followed by (80%) + applying pressed olive cake in both seasons, while the lowest value was recorded with the irrigation level of 60% + with control treatment (without soil amendment).

As regard to values of number of fruits per plant, the highest values of grade A were recorded with 60% irrigation level in both seasons + gypsum application in the first season or any soil amendment in the second season, while the highest number of fruits for grade B and number of fruits for total yield, were recorded with application of 100% irrigation level + without soil amendment.

These results may be due to increasing soil water content that led to increasing plant height and number of branches, resulting in an increase in number of fruits and total yield as reported by **Antony and Singandhupe (2004**). In this direction, **Palada and O'Keefe (2001**) investigated the response of hot pepper cultivars to levels of drip irrigation in the Virgin Islands and observed increasing yield trends with increasing amounts of irrigation water. Also results are in accordance with **Westgate and Boyer (1985), Veeranna *et al.* (2001**) and **Sharma *et al.* (2012**) who found reduction in the fresh fruit yield of hot pepper due to deficit irrigation because decreasing the soil water content reduced the fruit size and the total fruit weight of hot pepper, also, dry matter transport in dehydrated plants occurred readily but the total yield was less at the lower level of irrigation. In addition, results are in agreement with **Al-Omran *et al.* (2004, 2005), Sheta *et al.* (2006)** and **Kong *et al.* (2011).**

Table 12. Effect of inter action between irrigation water level and soil amendments on fresh weight of pepper plant at 45, 60 and 75 days after transplanting in 2017 and 2018 seasons

Parameter		Stems (g)			Leaves (g)			Branches (g)		Shoot fresh weigh (stem + leaves + branches) (g)		
Irrigation water level (%)	Soil Amendments	Days after transplanting										
		45	60	75	45	60	75	60	75	45	60	75
		First season (2017)										
100	Control (without amendment)	6.01b	9.08b	15.32b	8.17a	11.27b	15.20ab	4.26a	7.74ab	14.19b	24.62b	38.26b
	Agricultural gypsum	6.16b	8.93b	14.77b	7.70ab	10.66bc	14.58b	4.07a	7.87ab	13.86b	23.66b	37.22c
	Pressed olive cake	6.67a	10.41a	17.30a	8.23a	12.25a	16.09a	4.21a	8.60a	14.91a	26.87a	41.99a
80	Control (without amendment)	4.38de	7.56c	10.51d	6.95bc	10.13cd	11.59cd	4.45a	7.53b	11.34d	22.15c	29.63e
	Agricultural gypsum	4.68cd	7.90c	10.64d	6.69c	9.47d	10.90d	4.39a	7.79ab	11.37d	21.75c	29.34e
	Pressed olive cake	5.00c	9.14b	12.70c	7.69ab	10.92bc	12.40c	4.57a	8.39ab	12.69c	24.63b	33.50d
60	Control (without amendment)	3.95e	6.73d	7.91e	5.54d	8.08e	6.61f	2.80b	6.25c	9.49e	17.62e	20.77f
	Agricultural gypsum	4.07e	6.88d	7.81e	5.62d	8.20e	6.75f	2.95b	6.25c	9.69e	18.04e	20.81f
	Pressed olive cake	4.31de	6.82d	7.89e	6.44c	9.52d	7.90e	2.62b	6.02c	10.75d	18.97d	21.82f
		Second season (2018)										
100	Control (without amendment)	5.80b	9.04b	15.02b	8.18b	11.72a	15.75a	3.9c	7.43b	13.99c	24.66b	38.20b
	Agricultural gypsum	5.99b	9.39b	15.33b	7.71c	10.94b	14.93b	4.19bc	8.09ab	13.70b	24.52b	38.35b
	Pressed olive cake	6.54a	10.43a	17.34a	8.86a	12.25a	16.22a	4.15bc	8.34a	15.41a	26.84a	41.91a
80	Control (without amendment)	4.35d	7.82c	10.62d	6.99d	9.78c	11.25d	4.43ab	7.46b	11.34d	22.02c	29.33d
	Agricultural gypsum	4.58d	7.89c	10.34d	6.63e	9.41c	10.84d	4.15bc	7.45b	11.21d	21.45c	28.63d
	Pressed olive cake	5.06c	9.31b	12.59c	7.71c	10.88b	12.34c	4.68a	8.13ab	12.77c	24.88b	33.05c
60	Control (without amendment)	3.85e	6.64d	7.50e	5.51g	8.05e	6.61f	2.79d	6.5cd	9.36e	17.49e	20.61e
	Agricultural gypsum	3.88e	6.86d	7.66e	5.58g	8.06e	6.68f	2.97d	6.7c	9.47e	17.89e	21.04e
	Pressed olive cake	4.36d	6.78d	7.79e	6.46f	9.00d	7.63e	2.61d	5.95d	10.83d	18.39d	21.38e

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of probability according to **Duncan's** multiple range test.

Table 13. Effect of interaction between irrigation water level and soil amendments on dry weight of pepper plant at 45, 60 and 75 days after transplanting in 2017 and 2018 seasons

Parameter		Stems (g)			Leaves (g)			Branches (g)		Shoot (stem + leaves + branches) (g)		
Irrigation water level (%)	Soil Amendments	Days after transplanting										
		45	60	75	45	60	75	60	75	45	60	75
		First season (2017)										
100	Control (without amendment)	1.03ab	1.56b	3.00b	1.37b	2.36a	3.15ab	0.85bc	1.55ab	2.39c	4.77b	7.70b
	Agricultural gypsum	1.06ab	1.62b	3.06b	1.25c	2.21b	2.98b	0.81bc	1.57ab	2.31b	4.64b	7.61b
	Pressed olive cake	1.15a	1.80a	3.46a	1.53a	2.45a	3.24a	0.84bc	1.72a	2.68a	5.09a	8.43a
80	Control (without amendment)	0.82cd	1.35c	2.12d	1.07d	1.96c	2.25d	0.89ab	1.50b	1.90c	4.20c	5.88d
	Agricultural gypsum	0.85c	1.36c	2.06d	1.01de	1.90c	2.16d	0.87ab	1.56ab	1.86c	4.13c	5.79d
	Pressed olive cake	0.90bc	1.61b	2.51c	1.25c	2.17b	2.46c	0.91a	1.68ab	2.15b	4.70b	6.66c
60	Control (without amendment)	0.77cd	1.15d	1.50e	0.80f	1.65d	1.32f	0.56b	1.24c	1.57d	3.36e	4.07c
	Agricultural gypsum	0.66d	1.18d	1.53e	0.77f	1.63d	1.33f	0.59b	1.24c	1.44d	3.40e	4.11e
	Pressed olive cake	0.75cd	1.17d	1.56e	0.95e	1.84c	1.52e	0.52b	1.20c	1.71c	3.54d	4.29e
		Second season (2018)										
100	Control (without amendment)	1.04ab	1.58b	3.06b	1.37b	2.26ab	3.04ab	0.78c	1.48b	2.42b	4.62b	7.58b
	Agricultural gypsum	1.10a	1.49c	2.95b	1.22c	2.13bc	2.91b	0.84bc	1.62ab	2.32b	4.46b	7.49c
	Pressed olive cake	1.11a	1.79a	3.46a	1.51a	2.43a	3.21a	0.83bc	1.66a	2.62a	5.05a	8.34a
80	Control (without amendment)	0.88ab	1.3d	2.1d	1.08d	2.02cd	2.32cd	0.88ab	1.49b	1.97c	4.21c	5.91e
	Agricultural gypsum	0.84ab	1.36d	2.12d	1.01de	1.89d	2.18d	0.83bc	1.49b	1.86d	4.09c	5.79e
	Pressed olive cake	0.89ab	1.58b	2.54c	1.23c	2.17bc	2.48c	0.93a	1.62ab	2.13b	4.70b	6.64d
60	Control (without amendment)	0.74ab	1.17e	1.58e	0.80f	1.63e	1.32f	0.55d	1.3cd	1.53e	3.35e	4.20f
	Agricultural gypsum	0.67b	1.19e	1.56e	0.83f	1.64e	1.35f	0.59d	1.34c	1.51e	3.42e	4.24f
	Pressed olive cake	0.78ab	1.21e	1.57e	0.94e	1.9d	1.58e	0.52d	1.19d	1.72d	3.63d	4.35f

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of probability according to **Duncan's** multiple range test.

Table 14. Effect of interaction between irrigation water levels and soil amendments on marketable fruit yield of sweet pepper plant in 2017 and 2018 seasons

Irrigation water level (%)	Parameter / soil amendment	Grade A fruit: Mean fruit weight (g)	Grade A fruit: No. fruits (m^2)	Grade A fruit: Yield -1 (ton fed. $^{-1}$)	Grade B fruit: Mean fruits weight (g)	Grade B fruit: No. fruits (m^2)	Grade B fruit: Yield -1 (ton fed. $^{-1}$)	Total yield: No. fruits (m^2)	Total yield: Yield -1 (ton fed. $^{-1}$)
					First season (2017)				
100	Control (without amendment)	75.50c	43.56ab	5.75b	36.52b	60.25a	3.83d	103.82a	9.58b
	Agricultural gypsum	79.31ab	42.93b	5.96b	42.38a	53.77b	3.97b	96.7bcd	9.93b
	Pressed olive cake	81.58a	44.98ab	6.42a	44.05a	55.81ab	4.28a	100.79ab	10.70a
80	Control (without amendment)	75.01c	38.91c	5.10c	36.25b	53.80b	3.40c	92.71cd	8.50cd
	Agricultural gypsum	77.57bc	39.30c	5.33c	39.95ab	51.03c	3.55c	90.33d	8.89c
	Pressed olive cake	80.96a	40.67c	5.76b	41.88a	52.58b	3.84b	93.26cd	9.60b
60	Control (without amendment)	57.65e	42.84b	4.32e	30.62c	53.83b	2.88f	96.67bcd	7.20f
	Agricultural gypsum	59.13e	44.24ab	4.58e	35.21b	49.69d	3.05e	93.93cd	7.63e
	Pressed olive cake	62.08d	45.35a	4.93c	36.40b	52.09b	3.28c	97.44bc	8.21d
					Second season (2018)				
100	Control (without amendment)	76.36bc	44.42a	5.93b	37.09b	61.95a	3.96b	106.38a	9.89b
	Agricultural gypsum	79.41ab	44.23a	6.15b	44.17a	53.18b	4.10b	97.42bcd	10.24b
	Pressed olive cake	82.03ab	46.04a	6.61a	45.14a	55.85ab	4.41a	101.89ab	11.02a
80	Control (without amendment)	75.83c	39.53b	5.25c	36.77bc	54.91ab	3.50cd	94.44de	8.74c
	Agricultural gypsum	79.57bc	39.20b	5.46c	38.63b	54.53b	3.64c	93.73e	9.10c
	Pressed olive cake	83.05a	40.74b	5.92b	40.3ab	56.10ab	3.95b	96.84cd	9.87b
60	Control (without amendment)	58.15e	44.20a	4.49e	31.68c	54.16b	3.00e	98.37bcd	7.49e
	Agricultural gypsum	61.02e	44.15a	4.72e	35.18bc	51.79c	3.15e	95.95cd	7.86e
	Pressed olive cake	63.42a	46.68a	5.18d	36.62bc	54.30b	3.45d	100.98ab	8.64d

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of probability according to **Duncan's** multiple range test.

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الملخص العربي

تأثير مستويات الري ومحسنات التربة على نمو ومحصول الفلفل الحلو تحت ظروف منطقة العريش

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أجريت تجربة حقلية خلال الموسم الصيفي لعامي ٢٠١٧ و٢٠١٨ في المزرعة التجريبية لكلية العلوم الزراعية البيئية، جامعة العريش لدراسة تأثير استخدام ثلاث مستويات من مياه الري وهي ١٠٠%، ٨٠% و٦٠% من الاحتياجات المائية للفلفل مع استخدام ثلاثة أنواع من محسنات التربة وهي: معاملة الكنترول (بدون استخدام أي محسن)، الجبس الزراعي، وتفلة الزيتون بالإضافة إلى التداخل فيما بينهم على نمو وإنتاجية محصول الفلفل الحلو صنف "توب ستار" تحت ظروف منطقة العريش، وذلك في تجربة عامليّة استخدم فيها تصميم القطاعات العشوائية الكاملة بنظام القطع المشقة بثلاث مكررات، تم ري النباتات باستخدام نظام الري بالتنقيط، أظهرت النتائج أن استخدام المستوى ١٠٠% و٨٠% من الاحتياجات المائية للفلفل مع إضافة تفلة الزيتون نتج عنها أعلى القيم لجميع الصفات المدروسة من النمو الخضري، والوزن الطازج، والجاف للنبات، ومحصول الدرجة الأولى والثانية بالإضافة إلى المحصول الكلي، ويليه بعدها المستوى ٨٠% من احتياجات الفلفل من مياه الري مع إضافة الجبس الزراعي، أما استخدام المعاملة ٦٠% من احتياجات الفلفل من المياه مع أو بدون إضافة محسنات التربة فقد نتج عنها أقل القيم لجميع الصفات المدروسة.

الكلمات الاسترشادية: مستويات الري، محسنات التربة، الجبس الزراعي، تفلة الزيتون، الفلفل الحلو.

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