

Response of Sweet Pepper Grown in Sandy and Clay Soil Lysimeters to Water Regimes

¹M.I. Ezzo, ¹A.A. Glala, ²Hoda A.M. Habib and ³A.A. Helaly

¹Horticultural Crops Technology Department, National Research Center, Dokki, Giza, Egypt

²Vegetable Research Department, National Research Center, Dokki, Giza, Egypt

³Horticulture Department, Faculty of Agriculture, AL-Azhar University, Cairo, Egypt

Abstract: This investigation was carried out in lysimeters at the Experimental Station of Arid Land Cultivation Research Institute, Ain Shams University, Cairo, in the early summer seasons of 2008 and 2009. This work aimed to study the response of sweet pepper *CV. Mader* grown in two soil types (sandy and clay) to four water regimes (50, 70, 90 and 110 % of ET_0 , calculated by Penman equation). The results revealed that moderate (90 % ET_0) and medium (70 % ET_0) irrigation regimes were able to compete high irrigation levels (110 % of ET_0) regarding sweet pepper vegetative growth traits i.e., plant length, stem diameter, total fresh and dry weight of plants and root/ shoot ratio as well as early yield. Since there were no recorded significant differences among them, even there were high or very high significance for investigated irrigation regimes on most recorded vegetative growth traits. Concerning early yield also, there were significant effects of investigated irrigation regimes at 5% levels. Regarding total yield, average fruit weight and water use efficiency, high irrigation levels exhibited significantly higher values than those obtained from moderate irrigation levels which exceeded medium irrigation levels without significant differences between moderate and medium irrigation levels. Opposite trend was detected in sweet pepper fruits total soluble solids. Plants grown in clay soil were significantly superior to those grown in sandy soil, regarding the vegetative growth traits, yield components and most of recorded fruits characters. There were no significant effects of soil types on water use efficiency. Plants grown in clay soil and irrigated with high or moderate levels of ET_0 (110 or 90 %) produced the highest values of most investigated characters under the present condition. Meanwhile, under limited irrigation water supply medium (70% of ET_0) irrigation regime might be applied since, only minor reduction in yield occurred parallel with great water consumption could be reduced.

Key words: Pepper • Water requirements • Soil types • Yield • Fruit quality • TSS • Water use efficiency.

INTRODUCTION

Water is a major constituent of living plant tissues, which consists of about 90 % water. Whereas, all biological processes within the living plants depend on it. Further, the optimal moisture conditions for any crop vary depending on many factors such as soil type, climate conditions, growth rate and habit... etc. The favourable soil moisture tension should be maintained throughout the entire growth period of plants due to the relationship between evapotranspiration and biomass production [1]. Moreover, non stable irrigation schedule widely affected vegetative growth, yield and fruit quality of plants [2]. On the other hand, Egyptian water resources are limited, so it is advised to evaluate new possible approaches to

minimize the plant water consumption and hence to rationalize irrigation water use.

Sweet pepper is considered one of the most important vegetable crops in Egypt. The average Egyptian annual consumption from pepper is about 5.4 kg/ capita, which mean that the total Egyptian consumption is around 446 tons/ year [3]. In addition pepper is one of the most important exportable crops in Egypt. Since water management is very important to produce economic yield and good fruit quality of pepper, many investigations were carried out to determine the best irrigation regime for pepper plants. Some of them reported that the higher irrigation treatment was associated with higher yield and good quality. Sirjacobs and Slama [4] studied the effect of water supply on peppers grown in plastic house with drip

irrigation treatments corresponding to 110, 125, 150 and 160% Class A pan evaporation. They found that the highest yield was obtained using 125% pan evaporation. Tedeschi and Zerbi [5] showed that total and marketable yields per plant were linearly related to actual evapotranspiration and that yield depended on the number of fruits per plant and the mean fruit weight. Hassan *et al.* [6] found that plant fresh weight and fruit number was the greatest at the highest irrigation level (6610 m³/feddan), when compared with low irrigation (2150 m³/feddan). Wiertz and Lenz [7] found that the dry matter and yield were negatively affected by low water supply. They also, found that yield was more negatively affected by low water supply. However fruit quality was best with continuous water supply and low nutrient concentrations. Zhong and Kato [8] studied the effect of different soil moisture contents maintenance of 15-20, 23-28, or 30-35% on pepper plants. It was reported that plant dry weight and yield increased with increasing the soil moisture. Moreover, Boicet *et al.* [9] and Pujol *et al.* [10] found that irrigation throughout the vegetative cycle when soil water levels had decreased to 85% field capacity resulted in the highest total yield of pepper plants, the highest yield of grade one fruits and the largest fruits. On the other hand, many investigations recommended decreasing irrigation water amount to maintain economic yield and good fruit quality. EL-Beltagy *et al.* [11] studied the effect of soil water availability level (9, 27, 54 and 90% of field capacity "FC") on vegetative growth and yield of sweet pepper. They found that increasing FC percentage from 9 to 54 % significantly increased the plant height, number of leaves, average fruit weight and total yield. However, they were decreased with increasing the FC from 54% to 90%. Ferreyra *et al.* [12, 13] studied the effect of different water levels (0.3, 0.7, 1.0 or 1.3 time of reference evapotranspiration) on pepper plants. They found that root dry matter decreased with the excessive water application (≥ 1.0 of ET₀). Their results also indicated that fruit yields were the highest when irrigated with 0.7 time of ET₀.

As may already well known there are two soil types (sandy and clay) dominate in most Egyptian cultivated area. Regarding to previous investigations on the influence of soil type, on plant growth, yield and fruit quality, El-Tantawy *et al.* [14] reported that tomato plants grown in clay lysimeter had significantly better growth for plant length, vegetative fresh weight, number of leaves, chlorophyll content, average leaf area and yield compared

to those grown in sandy lysimeter. El-Zeiny and Ibrahim [15] found that irrigated tomato plants grown in clay soil by 80-100% of ET₀ encouraged the capability of plants to produce the vigorous vegetative growth, total yield and acceptable fruit quality. They added that the performance of tomato plants grown in clay was better than those grown in sandy soil at all investigated irrigation levels. This investigation aimed to investigate the response of sweet pepper growth, yield, fruit quality and water use efficiency to limited irrigation water supply (from 110, 90, 70, to 50% of ET₀) under sandy and clay soil cultivation conditions.

MATERIALS AND METHODS

The present experiments were carried out in Arid Land Cultivation Research Institute, Ain Shams University, Cairo, in the early summer seasons of 2008 and 2009. Sweet pepper (*Capsicum annum L.*) Hybrid *Madera* seeds were sown in trays in the middle of February in both growing seasons. Four pepper seedlings of 45 days old were transplanted on the lysimeters (1 m width x 1 m length x 3 m depth) at 50 cm apart between plants. The experiment included eight treatments, which were the combination of four irrigation levels (50, 70, 90 and 110 % of ET₀), with two types of soil, (sandy and clay). The experimental design was split plot with three replications, the irrigation levels occupied the main plots and soil types treatments were distributed in the sub-plots. The physical and chemical properties of the experimental soils are presented in Table 1. Climatic data (Table 2) were recorded daily by using automatic weather station (Campbell Scientific Ltd, CR10X Measurement and control, USA) and the sensors were installed in the middle of the experiment area.

Calculation of potential evapotranspiration (ET₀) was made according to the original method of Penman [16] and the amount of irrigation water was calculated according to Doorenbos and Pruitt [17]. The total seasonal irrigation water amounts were 326.5, 457.13, 587.74 and 718.35 l/m² for the low, medium, moderate and high irrigation level, respectively. All other agricultural practices were carried out according to the recommendation of the Egyptian Ministry of Agriculture. Fruits from each plot were harvested five times at green maturity stage and the early and total yield (weights and numbers) per plant were recorded then a sample at the fourth picking from each plot was taken to measure average fruit weight, fruit length, fruit diameter, fruit shape index and TSS. At the end of

Table 1: Physical and chemical analyses of the experimental soils

Variables	Soil types	
	Sand	Clay
Field capacity (%)	13.40	47.60
Wilting point (%)	6.70	23.60
Sand %	96.62	18.50
Silt %	0.67	21.30
Clay %	2.71	60.20
pH	7.20	7.30
EC dS /m	1.40	2.70
CaCo ₃ %	1.50	2.83
Soluble ions mg/100 g soil		
Ca ⁺⁺	9.00	18.00
Mg ⁺⁺	5.00	8.00
Na ⁺	2.80	3.20
K ⁺	2.70	4.00
CO ₃ ⁻⁻	--	--
HCO ₃ ⁻	3.10	4.20
Cl ⁻	4.20	5.10

Table 2: Monthly average climatic data at Ain shams site during of 2008 and 2009 seasons

Climate data	First season (2008)				Second season (2009)			
	March	April	May	June	March	April	May	June
Temperature °C	18.7	20.9	27.7	28.6	21.7	22.6	27.5	29.1
RH %	51.5	46.8	47.5	48.2	50.5	46.5	47.2	42.5
Wend S. (m/sec)	3.7	4.3	4.0	3.9	3.5	5.2	3.7	3.5
Radiation WM	10.9	12.6	11.9	11.8	11.4	13.5	11.3	12.6
Et ₀ mm/day	2.9	3.5	4.2	4.9	3.1	3.7	3.9	4.8

experiments, plant height, stem diameter, fresh and dry weight of stems leaves and roots were recorded and then root / shoot ratio were calculated based on fresh and dry weight. Total yield and fruit number per plant were culculated. The first picking yield was considered as early yield. Water use efficiency (kg/m³ of irrigation water) was calculated for different treatments, according to the equation of Monteith [18].

Data were subjected to statistical analysis of ANOVA and the entries means were compared by using Duncan multiple range test method, as reported by Gomez and Gomez [19]. All statistical processs were practiced by SAS computer program.

RESULTS AND DISCUSSION

Plant Growth Characters

Effect of Irrigation Water Levels: Significant differences were detected among the irrigation levels treatments regarding most plant growth traits i.e. plant length, stem diameter, fresh weight of roots, stem, leaves and total plant, dry weight of root, stem and total plant and root/ shoot ratio based on dry weight. However, there were no

significant effects for irrigation levels on leaves dry weight in both investigation seasons. Data presented in Tables 3 and 4 showed that most of pepper plants vegetative growth traits, recorded at the end of growing season was increased with increasing irrigation levels. The vigorous growth as well as plant length, stem diameter, fresh weights of stems, roots and total plant, roots dry wieght and root/ shoot ratio based on fresh weight were obtained by the high irrigation level (110%). Meanwhile, the medium (70%) and/or moderate (90%) irrigation levels recorded higher values of leaves fresh weight, dry weight of leaves, stem and total plant. The improvement of pepper plants vegetative growth with increasing irrigation level may be due to the proper balance of moisture in plant, which creates favourable conditions for nutrients uptake, photosynthesis and metabolites translocation, which ultimately accelerated the rate of vegetative growth. Hassan *et al.* [6], EL- Beltagy *et al.* [11] and Beese *et al.* [20] repoted that Plant fresh weight produced was the greatest at the highest irrigation level. Moreover, our results were harmony with those of Ezzo [21] on strawberry. El-Zeiny and Ibrahim [15] found that tomato plants grown with 80%

Table 3: Effect of irrigation regimes, soil types and their interaction on plant length, stem diameter, total fresh weight of pepper plants and its parts in 2008 and 2009 seasons

				Fresh weight (g)			
Irrigation Regimes	Soil type	Plant length (cm)	Stem diameter (cm)	Leaves	Stems	Roots	Total plant
First season(2008)							
Low	Clay	58.38 ^b	18.66 ^b	79.28 ^{cd}	122.80 ^b	21.82 ^c	223.90 ^b
	Sand	46.14 ^c	14.33 ^c	60.34 ^d	75.15 ^c	11.38 ^d	146.87 ^c
Medium	Clay	62.72 ^b	20.66 ^{ab}	117.31 ^{bc}	188.91 ^a	32.46 ^b	338.67 ^a
	Sand	63.69 ^b	19.45 ^b	111.02 ^{bc}	158.90 ^{ab}	29.19 ^{bc}	299.11 ^a
Moderate	Clay	65.16 ^{ab}	20.91 ^{ab}	102.01 ^{bcd}	143.67 ^b	31.45 ^b	277.13 ^{ab}
	Sand	63.72 ^b	20.33 ^{ab}	159.55 ^a	146.22 ^b	27.83 ^{bc}	333.60 ^a
High	Clay	71.20 ^a	22.52 ^a	89.36 ^{cd}	189.69 ^a	37.62 ^a	316.67 ^a
	Sand	64.22 ^b	21.16 ^{ab}	132.70 ^{a b}	164.18 ^{a b}	33.88 ^a	330.76 ^a
Irrigation Regimes (IR)	Low	52.27 ^b	16.50 ^c	69.82 ^b	98.98 ^c	16.60 ^c	185.39 ^b
	Medium	63.20 ^a	20.06 ^b	114.17 ^a	173.91 ^a	30.50 ^{ab}	318.89 ^a
	Moderate	64.44 ^a	20.63 ^{ab}	130.78 ^a	144.95 ^b	29.64 ^b	305.36 ^a
	High	67.71 ^a	21.85 ^a	111.03 ^a	176.94 ^a	35.75 ^a	323.72 ^a
Soil type (ST)	Clay	64.37 ^a	20.69 ^a	96.99 ^a	161.26 ^a	30.84 ^a	289.09 ^a
	Sand	59.44 ^b	18.82 ^b	115.90 ^a	136.11 ^b	25.57 ^b	277.58 ^a
Significant levels	IR	***	***	***	***	***	***
	ST	**	**	NS	*	**	NS
	IR xST	*	NS	*	NS	NS	*
Second season(2009)							
Low	Clay	55.76 ^b	17.82 ^b	75.72 ^{cd}	117.28 ^d	20.27 ^c	213.27 ^c
	Sand	44.08 ^c	13.68 ^c	57.63 ^c	71.77 ^c	10.87 ^d	140.27 ^d
Medium	Clay	59.90 ^b	19.73 ^{ab}	102.65 ^{bcd}	170.68 ^{ab}	29.67 ^{abc}	302.97 ^{ab}
	Sand	60.82 ^b	18.57 ^b	91.82 ^{cd}	151.75 ^{bc}	26.16 ^{bc}	273.67 ^b
Moderate	Clay	62.23 ^{ab}	19.97 ^{ab}	104.65 ^{bc}	137.20 ^{cd}	30.96 ^b	272.81 ^b
	Sand	60.85 ^b	19.41 ^{ab}	152.37 ^a	139.64 ^{bcd}	26.57 ^{bc}	318.58 ^{ab}
High	Clay	68.00 ^a	21.51 ^a	102.43 ^{bcd}	195.22 ^a	35.93 ^a	333.20 ^a
	Sand	61.33 ^b	20.21 ^{ab}	126.73 ^{ab}	168.99 ^{abc}	32.35 ^{ab}	315.88 ^{ab}
Irrigation Regimes (IR)	Low	49.92 ^b	15.75 ^c	66.67 ^c	94.52 ^c	15.57 ^c	176.77 ^b
	Medium	60.36 ^a	19.15 ^b	97.23 ^b	161.21 ^a	27.91 ^b	288.33 ^a
	Moderate	61.54 ^a	19.69 ^{ab}	128.51 ^a	138.42 ^b	28.67 ^b	295.69 ^a
	High	64.66 ^a	20.86 ^a	114.57 ^{ab}	181.60 ^a	34.14 ^a	324.54 ^a
Soil type (ST)	Clay	61.47 ^a	19.76 ^a	96.36 ^a	155.09 ^a	29.21 ^a	280.56 ^a
	Sand	56.77 ^b	17.97 ^b	107.13 ^a	132.79 ^b	23.99 ^b	262.10 ^a
Significant levels	IR	***	***	***	***	***	***
	ST	**	**	NS	*	**	NS
	IR x ST	*	NS	*	NS	NS	*

NS= non significant *= significant at 5% ** = significant at 1% ***= significant at < 0.1%

Table 4: Effect of irrigation regimes, soil types and their interaction on total dry weight of pepper plants, its parts and root shoots ratio in 2008 and 2009 seasons

		Dry weight(g)				Root/ Shoot ratio based on	
Irrigation Regimes	Soil type	leaves	Stems	Roots	Total	Fresh weight	Dry weight
First season(2008)							
Low	Clay	14.50 ^a	16.08 ^b	3.59 ^{ab}	34.17 ^b	0.108 ^{abc}	0.117 ^b
	Sand	6. 8 ^c	8.65 ^c	1.58 ^d	17.03 ^c	0.084 ^c	0.102 ^b
Medium	Clay	14. 95 ^a	23.20 ^a	5.27 ^a	43.42 ^a	0.106 ^{abc}	0.138 ^b
	Sand	10. 97 ^{ab}	14.38 ^b	3.93 ^{bc}	29.28 ^b	0.108 ^{abc}	0.155 ^b
Moderate	Clay	11. 83 ^{ab}	17.07 ^b	4.52 ^{ab}	33.42 ^b	0.128 ^{ab}	0.156 ^b
	Sand	14.73 ^a	13.44 ^b	3.49 ^c	31.66 ^b	0.091 ^{bc}	0.124 ^b
High	Clay	8.87 ^{bc}	17.36 ^b	5.53 ^a	31.76 ^b	0.135 ^a	0.211 ^a
	Sand	11.58 ^{ab}	14.53 ^b	4.15 ^{bc}	30.26 ^b	0.114 ^{abc}	0.158 ^b
Irrigation Regimes (IR)	Low	10.65 ^{ab}	12.36 ^c	2.58 ^c	25.59 ^c	0.095 ^b	0.110 ^c
	Medium	12.96 ^{ab}	18.79 ^a	4.60 ^{ab}	36.35 ^a	0.106 ^{ab}	0.144 ^b
	Moderate	13.28 ^a	15.23 ^b	4.01 ^b	32.52 ^{ab}	0.113 ^{ab}	0.141 ^b
	High	10.22 ^b	15. 94 ^b	4.84 ^a	31.00 ^b	0.124 ^a	0.1 85 ^a
Soil type (ST)	Clay	12.54 ^a	18.41 ^a	4.73 ^a	35.68 ^a	0.118 ^a	0.156 ^a
	Sand	11.02 ^a	12.75 ^b	3.29 ^b	27.06 ^b	0.100 ^b	0.138 ^b
Significant levels	IR	NS	***	**	**	*	**
	ST	NS	***	***	***	*	*
	IR x ST	**	NS	*	***	NS	NS

Table 4: Continued

Second season(2009)							
Low	Clay	13.84 ^a	14.50 ^b	3.38 ^d	32.70 ^{bc}	0.105 ^{abc}	0.119 ^c
	Sand	6.49 ^c	8.26 ^e	1.51 ^e	16.26 ^e	0.084 ^c	0.102 ^c
Medium	Clay	13.41 ^a	22.15 ^a	4.67 ^{ab}	40.23 ^a	0.108 ^{abc}	0.134 ^{bc}
	Sand	9.59 ^{bc}	13.74 ^b	3.76 ^{cd}	27.0 ^{9d}	0.107 ^{abc}	0.161 ^{bc}
Moderate	Clay	11.29 ^{ab}	16.26 ^b	4.32 ^{bc}	31.87 ^{bcd}	0.128 ^a	0.157 ^{bc}
	Sand	14.07 ^a	12.83 ^b	3.33 ^d	30.23 ^{bd}	0.091 ^{bc}	0.123 ^{bc}
High	Clay	8.47 ^{bc}	16.57 ^b	5.28 ^a	30.32 ^{bd}	0.121 ^a	0.211 ^a
	Sand	11.06 ^{ab}	13.88 ^b	3.96 ^{bcd}	28.9 ^{cd}	0.109 ^{ab}	0.159 ^b
Irrigation Regimes (IR)	Low	10.17 ^{ab}	11.38 ^c	2.45 ^d	24.50 ^b	0.094 ^b	0.111 ^b
	Medium	11.50 ^{ab}	17.95 ^a	4.21 ^{ab}	33.66 ^a	0.107 ^{ab}	0.143 ^b
	Moderate	12.68 ^a	14.54 ^b	3.82 ^b	31.04 ^a	0.112 ^{ab}	0.140 ^b
	High	9.76 ^b	15.23 ^b	4.62 ^a	29.61 ^a	0.115 ^a	0.193 ^a
Soil type (ST)	Clay	11.75 ^a	17.37 ^a	4.41 ^a	33.78 ^a	0.115 ^a	0.155 ^a
	Sand	10.30 ^a	12.18 ^b	3.14 ^b	25.62 ^b	0.098 ^b	0.139 ^b
Significant levels	IR	NS	***	***	***	NS	**
	ST	NS	***	***	***	**	*
	IR x ST	***	NS	**	***	NS	NS

NS= non significant *= significant at 5% ** = significant at 1% ***= significant at < 0.1%

Fruit yield and its components

and 100% ET₀ gave the vigorous vegetative growth and highest total yield compared to low irrigation level (40%) during growing seasons. On the other hand, there was no significant differences between moderate and high and somewhere medium irrigation levels regarding plant length, stem diameter, fresh weight of leaves, stems, root and total plant and dry weight of leaves, stems, root and total plant as shown in Tables 3 and 4.

Effect of Soil Types: Data in Tables 3 and 4 revealed that there were significant differences between clay and sandy soil, concerning most of morphological vegetative characters of pepper plants, i.e. plant length, stem diameter, fresh weights of stems and roots, dry weight of stems, roots and total plant. Meanwhile, there was no significant effect for soil types on fresh weight of leaves and total plant and leaves dry weight. Clay soil had significant superiority in producing the vigorous vegetative growth expressed as plant length, total fresh and dry weights of plant parts as compared with sandy soil. These results may be due to the abundance of moisture in clay soil that created good conditions for increasing the water holding capacity and accordingly water and nutrient uptake, photosynthesis and metabolite translocation, which led to the increase in the vegetative growth. These results are in agreement with those of Buan [22] on some Fabaceae crops. El-Zeiny and Ibrahim [15] found that tomato plants grown in clay soil had significantly better growth compared to those grown in sandy soil.

Effect of Interaction Between Irrigation Water Levels and Soil Types: Data in Tables 3 and 4 showed that, the lowest values of pepper plant growth traits were obtained

from those plants grown in sandy soil and irrigated by low irrigation level (50%). The highest values of vegetative growth characters were obtained from the plants received high water level in clay soil. The results indicated that positive relationship between type of soil and increasing the levels of water level, however plants grown in clay soil and irrigated with the high level of water (110 %), produced the vigorous vegetative growth expressed as plant length, stem diameter, fresh weight of stems, fresh weight of roots, root/shoot ratio and total fresh weight of plants. On the other hand, there was no significant differences in the most growth parameters between plants grown in clay or sand soil when they irrigated by 110 % of ET₀. The effect of interaction between irrigation levels and soil types was not significant regarding stem diameter, stems and root fresh weight, stems dry weight and root/shoot ratio based on fresh or dry weight.

However the interaction significantly affected plant length, leaves and total fresh weight and root dry weight. The same trend was obtained with the results obtained by Abo-Hussein [23] on potato and Buan [22] on some Fabaceae crops. Moreover, El-Zeiny and Ibrahim [15] found that tomato plants grown in clay soil with (80 % and 100% ET₀) respectively, encouraged the capability of plants to produce the vigorous vegetative growth.

Effect of Irrigation Water Levels: Data in Tables 5 and 6 showed that the lowest values of total yield and fruit quality were recorded with the plants which received low water level (50 % of the calculated water requirements). The highest early yield, total yield, fruit length, fruit diameter and average fruit weight were achieved when pepper plants were irrigated by 110 % of the calculated

Table 5: Effect of irrigation regimes, soil types and their interaction on early, total yield (weights and numbers) in 2008 and 2009 seasons.

		Earl yield		Total yield			
Irrigation Regimes	Soil type	g /plant	Ton /feddan	g /plant	Ton /feddan	Early fruits numbers /plant	Total fruits numbers / plant
First season(2008)							
Low	Clay	100.00 ^a	1.600 ^a	192.17 ^{de}	2.909 ^{de}	6.05 ^{ab}	19.18 ^e
	Sand	15.61 ^d	0.250 ^d	110.59 ^e	1.674 ^e	1.00 ^d	12.27 ^e
Medium	Clay	98.35 ^a	1.574 ^a	299.85 ^{cd}	4.539 ^{cd}	7.136 ^a	32.37 ^{cd}
	Sand	35.70 ^{cd}	0.571 ^{cd}	333.81 ^{cb}	5.052 ^{cb}	1.416 ^d	31.79 ^d
Moderate	Clay	59.02 ^{bc}	0.944 ^{bc}	440.40 ^b	6.666 ^b	3.50 ^c	40.52 ^{cb}
	Sand	41.52 ^{cd}	0.664 ^{cd}	459.37 ^b	6.953 ^b	2.58 ^c	38.88 ^{bcd}
High	Clay	90.73 ^{ab}	1.452 ^{ab}	641.68 ^a	9.712 ^a	5.08 ^b	46.37 ^b
	Sand	87.66 ^a	1.403 ^a	738.86 ^a	11.183 ^a	4.83 ^b	54.35 ^a
Irrigation Regimes (IR)	Low	57.80 ^b	0.925 ^b	151.38 ^d	2.291 ^d	3.52 ^{bc}	15.72 ^d
	Medium	67.03 ^{ba}	1.072 ^{ba}	316.83 ^c	4.796 ^c	4.27 ^{ab}	32.08 ^c
	Moderate	50.27 ^b	0.804 ^b	449.88 ^b	6.809 ^b	3.04 ^c	39.70 ^b
	High	89.20 ^a	1.427 ^a	690.27 ^a	10.448 ^a	4.95 ^a	50.36 ^a
Soil type (ST)	Clay	87.02 ^a	1.392 ^a	393.52 ^a	5.956 ^a	5.44 ^a	34.61 ^a
	Sand	45.12 ^b	0.722 ^b	410.66 ^a	6.216 ^a	2.45 ^b	34.32 ^a
Significant levels	IR	*	*	***	***	**	***
	ST	***	***	NS	NS	***	NS
	IR x ST	**	**	NS	NS	***	NS
Second season(2009)							
Low	Clay	94.60 ^a	1.514 ^a	181.79 ^{cd}	2.909 ^{cd}	5.73 ^{ab}	18.15 ^e
	Sand	14.77 ^d	0.236 ^d	104.62 ^e	1.674 ^e	0.95 ^e	11.61 ^e
Medium	Clay	93.04 ^a	1.489 ^a	283.66 ^d	4.539 ^d	6.75 ^a	30.63 ^{cd}
	Sand	33.77 ^{cd}	0.540 ^{cd}	315.78 ^{bc}	5.052 ^{bc}	1.34 ^e	30.08 ^d
Moderate	Clay	55.83 ^{bc}	0.893 ^{bc}	416.62 ^b	6.666 ^b	3.31 ^d	38.33 ^{bc}
	Sand	39.28 ^{cd}	0.628 ^{cd}	434.56 ^b	6.953 ^b	2.45 ^d	36.78 ^{bcd}
High	Clay	85.83 ^{ab}	1.373 ^{ab}	607.03 ^a	9.712 ^a	4.81 ^{bc}	43.87 ^b
	Sand	82.92 ^{ab}	1.327 ^{ab}	698.96 ^a	11.183 ^a	4.57 ^c	51.42 ^a
Irrigation Regimes (IR)	Low	54.69 ^b	0.875 ^b	143.21 ^d	2.291 ^d	3.33 ^{bc}	14.88 ^d
	Medium	63.41 ^b	1.014 ^b	299.72 ^c	4.796 ^c	4.04 ^{ab}	30.35 ^c
	Moderate	47.55 ^b	0.761 ^b	425.59 ^b	6.809 ^b	2.87 ^c	37.55 ^b
	High	84.38 ^a	1.350 ^a	652.99 ^a	10.448 ^a	4.68 ^a	47.64 ^a
Soil type (ST)	Clay	82.32 ^a	1.317 ^a	372.27 ^a	5.956 ^a	5.14 ^a	32.74 ^a
	Sand	42.68 ^b	0.683 ^b	388.48 ^a	6.216 ^a	2.32 ^b	32.47 ^a
Significant levels	IR	*	*	***	***	***	***
	ST	***	***	NS	NS	***	NS
	IR XST	**	**	NS	NS	***	NS

One feddan = 4200 m², NS= non significant, *= significant at 5%, ** = significant at 1%, ***= significant at < 0.1%

Table 6: Effect of irrigation regimes, soil types and their interaction on fruit quality and water use efficiency in 2008 and 2009 seasons

Irrigation Regimes	Soil type	Fruit length cm	Fruit Diameter cm	Fruit shape index	Mean fruit weight (g)	TSS%	Water use efficiency kg/m ³
First season(2008)							
Low	Clay	2.96 ^d	2.70 ^e	1.09 ^a	10.21 ^c	16.50 ^a	2.227 ^d
	Sand	3.75 ^{dc}	2.78 ^{de}	1.35 ^a	8.90 ^c	12.33 ^{ab}	1.282 ^e
Medium	Clay	3.02 ^d	2.72 ^e	1.11 ^a	9.28 ^c	15.50 ^a	2.482 ^{cd}
	Sand	4.11 ^c	3.26 ^d	1.26 ^a	10.69 ^c	12.72 ^{abc}	2.763 ^{bc}
Moderate	Clay	3.77 ^{cd}	3.06 ^{d e}	1.23 ^a	10.99 ^{bc}	14.61 ^{ab}	2.835 ^{bc}
	Sand	5.34 ^{ab}	4.10 ^{ab}	1.30 ^a	11.72 ^{abc}	6.77 ^d	2.957 ^{bc}
High	Clay	4.68 ^{bc}	3.66 ^{bc}	1.28 ^a	13.86 ^a	10.50 ^{bcd}	3.380 ^{ab}
	Sand	6.05 ^a	4.48 ^a	1.35 ^a	13.57 ^{ab}	8.66 ^{cd}	3.892 ^a
Irrigation Regimes (IR)	Low	3.36 ^c	2.74 ^c	1.23 ^a	9.55 ^b	14.41 ^a	1.754 ^c
	Medium	3.56 ^c	2.99 ^c	1.19 ^a	9.98 ^b	14.11 ^a	2.623 ^b
	Moderate	4.56 ^b	3.58 ^b	1.27 ^a	11.35 ^b	10.69 ^b	2.896 ^b
	High	5.37 ^a	4.07 ^a	1.32 ^a	13.71 ^a	9.58 ^b	3.636 ^a
Soil type (ST)	Clay	3.61 ^b	3.35 ^b	1.08 ^b	11.08 ^a	14.27 ^a	2.731 ^a
	Sand	4.81 ^a	3.65 ^a	1.32 ^a	11.21 ^a	10.12 ^b	2.724 ^a
Significant levels	IR	***	***	**	***	**	***
	ST	***	***	***	NS	***	NS
	IR x ST	NS	*	**	NS	NS	*

Table 6: Continued

Second season(2009)							
Low	Clay	2.81 ^c	2.57 ^c	1.06 ^a	9.90 ^c	15.76 ^a	2.227 ^d
	Sand	3.55 ^{de}	2.65 ^{de}	1.31 ^a	8.63 ^c	11.77 ^{abc}	1.282 ^c
Medium	Clay	2.86 ^c	2.59 ^c	1.06 ^a	9.00 ^c	14.80 ^a	2.482 ^{cd}
	Sand	3.89 ^{cd}	3.11 ^{cd}	1.20 ^a	10.37 ^c	12.15 ^{abc}	2.763 ^{bc}
Moderate	Clay	3.57 ^{de}	2.92 ^{de}	1.17 ^a	10.66 ^{bc}	13.95 ^{ab}	2.835 ^{bc}
	Sand	5.05 ^{ab}	3.91 ^{ab}	1.25 ^a	11.37 ^{abc}	6.47 ^d	2.957 ^{bc}
High	Clay	3.43 ^{bc}	3.49 ^{bc}	1.23 ^a	13.44 ^a	10.00 ^{bcd}	3.380 ^{ab}
	Sand	5.73 ^a	4.28 ^a	1.29 ^a	13.16 ^{ab}	8.27 ^{cd}	3.892 ^a
Irrigation Regimes (IR)	Low	3.18 ^c	2.61 ^c	1.17 ^a	9.26 ^b	13.76 ^a	1.754 ^c
	Medium	3.37 ^c	2.85 ^c	1.13 ^a	9.68 ^b	13.47 ^a	2.623 ^b
	Moderate	4.31 ^b	3.42 ^b	1.12 ^a	11.23 ^b	10.21 ^b	2.896 ^b
	High	5.08 ^a	3.89 ^a	1.26 ^a	13.29 ^a	9.15 ^b	3.636 ^a
Soil type (ST)	Clay	3.41 ^b	2.89 ^b	1.13 ^b	10.74 ^a	13.63 ^a	2.731 ^a
	Sand	4.55 ^a	3.49 ^a	1.25 ^a	10.87 ^a	9.66 ^b	2.724 ^a
Significant levels	IR	***	***	NS	***	***	**
	ST	***	***	*	NS	***	NS
	IR x ST	NS	*	NS	NS	NS	*

NS= non significant *= significant at 5% ** = significant at 1% ***= significant at < 0.1%

water requirements. These results showed the same trend in both growing seasons. The high level of irrigation water (110 %) encouraged the vegetative growth of pepper plants as shown in Table 3; this in turn reflected its effect on early, total yield and yield quality. These results are in agreement with those found by Sirjacobs and Slama [4], Hassan *et al.* [6], EL-Beltagy *et al.* [11], EL-Gindy [24] and Leon and Montalov [25]. Wiertz and Lenz [7] found that, yield was more negatively affected by low water supply then by low nutrient concentrations. They added that fruit quality was the best with continuous water supply and low nutrient concentrations. Also, our results are in agreement with Ezzo [21] on strawberry, Mahmoud [26] on pea plant and El- Banna *et al.* [27] on potato. Data also cleared that there were significant differences between the two levels 90% and 110 % of water requirements.

Data in Table 6 indicated that the highest significant values of total soluble solids were recorded with the lowest water levels while the lowest values were recorded with the highest water level. Similar results were recorded by Ezzo [28] on cantaloupe. Moreover, Ezzo [21] found that increasing the amount of water irrigation water decreased the TSS concentration of strawberry. On the other hand, the highest water use efficiency (WUE) was attained with the high water level but lowest value was obtained from the low water level. There were significant differences among the high water level and the other irrigation treatments.

Effect of Soil Types: Data in the Tables 5 and 6 indicated that the highest early yield (weight and numbers) were observed with plants grown in the clay soil compared to

the other plants grown in sandy soil. The increase in early yield may be due to the increase in vegetative growth parameters in clay soil as mentioned before and average fruit weight. Also, edaphically environmental factors in clay soil were fair enough to maintain greater early yield. The superiority of clay soil may be also due to the improvement effect of this treatment in plant growth, i.e. plant height, stem diameter, root/shoot ratio as well as fresh and dry weight and this may in turn produced high yield of carbohydrates consequently gave rise to more vigorous vegetative plants, this reflect to produce more early yield. Similar results were obtained by El- Banna *et al.* [27] on potato and El- Beheidi *et al.* [29] on pea plants and. Tables 5 and 6 indicated that the highest total yield (weight and numbers) and mean fruit weight were observed with plants grown in the sandy soil compared to other plants grown in clay soil but the differences were not significant.

Data in the Table 6 indicated that the highest values of total soluble solids were recorded with the clay soil while the lowest values were recorded with the sandy soil and there were significant differences between the two types of soil. On the other hand, the highest water use efficiency was found with the clay soil but the differences between the two soil types did not reach the level of significance.

Effect of Interaction Between Irrigation Water Levels and Soil Types: The plants grown in sandy or clay soil and irrigated with high level of water (110 %) gave the highest total yield and as compared with the other treatments under investigation. However, the plants grown in clay soil and irrigated with high level of water (110 %) gave the

highest mean fruit weight compared to other treatments (Table 6). On the other hand, there were no significant differences between the plants which received 110 % under clay or sandy soil. Moreover, the sandy soil irrigated with low levels of water (50 %) produced the lowest values of total yield and average fruit weight. The superiority of high level of water added to sandy or clay soil may be due to the improvement effect of this treatment in plant growth.

Data in Table 6 indicated that the highest values of total soluble solids were recorded with the low water level under clay soil while the lowest values were recorded with the moderate and high water levels under sandy soil. The lowest significant TSS values were obtained from the high and moderate water levels under sandy soil. On the other hand, the highest water use efficiency was found with the high water level in sandy soil. There were significant differences between the high water levels with clay soil compared to the low water level under clay soil.

Under the conditions of this study, it could be concluded that pepper hybrid Mader grown in both sand and clay soils and irrigated with high level from actual water requirement (110 %) produced the vigorous vegetative growth and increased yield quantity and quality. Also, in clay soil conditions adding the high level of actual water requirement (110 %) to the plants was enough to produce the highest values of the studied characters.

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