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IRRIGATION REQUIREMENTS OF SWEET PEPPER (*Capsicum annuum L.*) GROWN IN PLASTIC GREENHOUSES UNDER EL-ARISH CONDITIONS: III:VEGETATIVE GROWTH, YIELD AND ITS COMPONENTS AND WATER USE EFFICIENCY

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ABSTRACT

This study was carried out at the Experimental Farm of the Faculty of Environmental Agriculture Sciences in El-Arish, Suez Canal University, during the early summer seasons of 1999-2000 and 2000-2001. Sweet pepper (*Capsicum annuum L.*) plants *cv.* Sonar were grown in plastic greenhouse (9 x 60 m.). Irrigation water was supplied through trickle irrigation system. Five irrigation treatments were carried out as follow: (A) one irrigation per day,(B) two irrigations with the same quantity per day (half in the morning and half at evening),(C) one irrigation per 2 days, (D) two irrigations with the same quantity per 2 days (half in the morning and half at evening), and (E) one irrigation per 3 days. Every treatment was irrigated with the same quantity of irrigation (based on water requirement for one day), which gradually increased from December to June.

Vegetative growth, yield and its components, fruit dimensions, leaves phosphorous and potassium contents, uptake of N, P and K and actual evapotranspiration (ETa) increased with increasing irrigation water quantity. Treatment (D) gave the highest value of water use efficiency (W.U.E) followed by (B), (C), (E), (A), respectively. While, leaves total chlorophyll content, leaves nitrogen content, fruit content of total soluble solids and fruit content of vitamin (C) increased with decreasing irrigation water quantity.

INTRODUCTION

Sweet pepper is one of the most important vegetable crops in Egypt. The early summer season is the main season for its production in North Sinai under greenhouses, which demands high costs and special care. Under such conditions, groundwater is the main source of irrigation water. Generally, irrigation water is limited and has low quality.

Water is a limiting factor with respect to its quantity and quality in crop production. Vegetable Crops production in arid and semi-arid regions is particularly sensitive to deficiencies of soil moisture content (Tompson and Doerge, 1995). Irrigation plays quantitative and qualitative effects on the production of sweet pepper as stated by Hamar and Wanaes (1986) and Goyal et al (1987). Doorenbos and Kassam (1979) stated that seasonal pepper evapotranspiration is 600-900 mm and reaches 1250 mm for long growing periods and several pickings.

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Hegde (1987) found that, irrigation at 40% of the available soil moisture (ASM) resulted in the highest bell pepper water use efficiency (W.U.E.). He reported that, irrigation of sweet pepper when soil matric potential reached –65 kP_a at 15-cm depth resulted in maximum W.U.E compared with irrigation when soil matric potential reached –25, -45 and –85 kP_a at the same depth. Imposing stress of –85 kP_a, either till the first sweet pepper picking or thereafter, significantly reduced W.U.E compared with maintaining a uniform soil matric potential at –45 to –65 kP_a.

Hegde (1989) found that nitrogen content in leaves of pepper plants increased with decreasing soil moisture content. The opposite was found true for both leaves phosphorus and potassium contents. He explained these results based on the effect of soil moisture on the nitrification of soil organic matter. Therefor, a decline in nitrogen availability was expected

Ibrahim *et al* (1996) concluded that, the positive effect of irrigation water on sweet pepper plants height might be attributed to the availability of soil water. The abundance of soil moisture content led to healthy growing plants, taller and heavier. He found also that, fruit length of sweet pepper increased while fruit diameter decreased with increasing the volumes of applied irrigation water. Decreasing the applied irrigation water from 7.2 to 2.7 liters per plant at each irrigation decreased fruit thickness. Decreasing the applied volumes of irrigation water to sweet pepper increased its water use efficiency from 17.6 to 21.6 grams per liter. The volumes of applied water were 7.2, 5.4, 3.6 and 2.7 liter per plant. On the average, irrigation water was applied once or twice a week during winter and summer months, respectively.

El-Nemr (1997) under protected cultivation conditions on clay soil found that, plant height, number of leaves, leaf area per plant, stem and leaves fresh weight increased for the high quantity of irrigation water treatment, 125% of class pan evaporation than the low quantity, 100 and 75% of class pan evaporation. Decreasing the volume of applied irrigation water resulted in increasing pepper plant N, P, K leaf contents and plants dry weight increased for the low irrigation water treatments. Water use efficiency of sweet pepper increased with reducing the rate of applied water more than with applying high rates of irrigation water. Fruit weight per plant, number of fruits per plant, early yield and total yield increased with high irrigation water level, while, they decreased with the low irrigation water levels, respectively.

Byari and Al-Sayed (1999a) reported that, dry weight of sweet pepper plants and fruit thickness decreased with increasing irrigation intervals. Fruit content of vitamin (C) increased with increasing irrigation intervals. This increase might be related to the loss of water from fruits during water stress period.

De Pascale *et al* (2000) found that, leaf area decreased with decreasing irrigation levels from 100% to 50% of class A pan evaporation due to the fact that, pepper plants are very sensitive to drought. He reported also that, decreasing the irrigation level from 100% to 50% of class A pan evaporation increased the non-marketable yield and decreased fruits number per plant, marketable yield, total and individual fruit weights. Decreasing the levels of irrigation from 100% to 50% and increasing water salinity from 0% to 1% NaCl resulted in increasing pepper plant leaf N, P and K contents.

Jaimez *et al* (2000) found that, low water availability during the period between flowering and fruit development reduced final fruit production.

. This work aimed to study the effect of some irrigation treatments on sweet pepper growth, yield parameters and water use efficiency.

MATERIALS AND METHOD

Experiments were carried out at the Experimental Farm of the Faculty of Environmental Agricultural Sciences at El-Arish, Suez Canal University, during the early summer seasons of 1999-2000 and 2000-2001. Sweet pepper (*Capsicum annuum* L.) plants were grown in plastic greenhouse (9 x 60 m.). Before planting in both seasons, collected soil samples from the greenhouse were subjected to mechanical and chemical analysis according to Richards, 1954 (Table 1a). Chemical analysis of irrigation water is given in (Table 1b). Initial soil moisture contents were determined for both seasons (Table 1c).

Table (1a): Initial soil mechanical and chemical analysis.

Soil properties	Seasons							
	1999-2000				2000-2001			
	Depth(cm.)							
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Mechanical analysis								
Coarse sand %	68.00	65.60	64.50	65.70	67.99	65.64	64.54	65.73
Fine sand %	20.60	22.90	25.20	25.20	20.55	22.88	25.15	25.17
Silt %	3.50	3.80	3.20	1.80	3.52	3.83	3.18	1.84
Clay %	7.90	7.70	7.10	7.30	7.94	7.65	7.13	7.26
Soil texture	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Bulk density ($g.cm^{-3}$)	1.53	1.52	1.56	1.53	1.53	1.52	1.56	1.53
Particle density ($g.cm^{-3}$)	2.49	2.49	2.66	2.66	2.49	2.49	2.66	2.66
soluble ions extract mel^{-1} (1:5)								
Ca^{++}	3.03	3.03	3.03	2.01	2.10	2.30	2.00	1.90
Mg^{++}	2.11	2.57	2.02	1.38	2.2	2.4	1.95	1.42
Na^{+}	1.18	1.14	0.75	0.86	4.49	3.56	3.49	2.07
K^{+}	0.48	0.36	0.30	0.34	0.31	0.24	0.26	0.21
CO_3^{--}	-	-	-	-	-	-	-	-
HCO_3^{-}	2.00	2.30	2.50	2.60	2.40	2.60	2.90	2.50
Cl^{-}	1.02	1.70	1.65	1.61	2.30	2.40	2.10	1.70
SO_4^{--}	3.78	3.10	1.95	0.38	4.40	3.50	2.70	1.40
EC(dSm^{-1}) in (1:5) extract)	0.68	0.72	0.61	0.46	0.91	0.85	0.77	0.56
PH in (1:2.5) extract)	8.10	8.30	8.50	8.70	8.20	8.40	8.30	8.50
Organic matter %	0.16	0.14	0.12	0.10	0.21	0.195	0.16	0.12
$CaCO_3$ %	3.95	4.67	4.15	4.03	3.95	4.65	4.16	4.21

Table (1b): Chemical analysis of irrigation water.

PH	EC	Soluble ions ($meq.l^{-1}$)							
	dSm^{-1}	Cations				Anions			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{--}	SO_4^{--}
6.7	5.65	18.12	20.20	17.72	0.25	38.40	6.25	-	11.64

Table (1c): Soil moisture constants for the chosen soil site.

Depth (cm.)	Saturation percentage		Field capacity		Wilting point		Available water	
	% $g.g^{-1}$	Soil moisture (mm/15cm)	% $g.g^{-1}$	Soil moisture (mm/15cm)	% gg^{-1}	Soil moisture (mm/15cm)	% $g.g^{-1}$	Soil moisture (mm/15cm)
0-15	28.92	66.37	7.50	17.21	3.21	7.37	4.29	9.85
15-30	28.29	64.50	7.71	17.58	3.13	7.14	4.58	10.44
30-45	30.04	70.29	7.32	17.13	3.14	7.35	4.18	9.78
45-60	26.16	60.04	7.43	17.05	3.10	7.11	4.33	9.94

Sweet pepper (*cv.* Sonar) seeds were planted at November 10th on sterophome speedling trays, 209 holes. Nursing period lasted 45 days. Seedlings were transplanted to 18 m^2 plots, 10 m x 1.8 m, at December 25th 1999 and 2000 at the age of four true leaves. Each plot had 2 rows of seedlings spaced 90 cm from each other, the distance between seedlings on each row was 50 cm. The number of seedlings per plot was 40, therefore, planting density was 2.22 plants m^{-2}. During the nursing period, the seedlings were irrigated daily by constant volume. In-line drippers, G.R. polyethylene pipes 16-mm. in diameter having 4 liters discharge per hour were used for drip irrigation after transplanting.Irrigation treatments were applied on December 25th and continued to June 30th. The number of treatments were 5 as follows:

-Treatment A: one irrigation per day.
-Treatment B: two irrigations with the same quantity (half in the morning and half at evening) per day.
-Treatment C: one irrigation per 2 days.
-Treatment D: two irrigations with the same quantity (half in the morning and half at evening) per 2 days.
-Treatment E: one irrigation per 3 days.

All treatments were irrigated with the same quantity of water (based on water requirements pere day) which gradually increased from December 25th till the end of June. The rates of applied irrigation water, according to Khalil (1998) were 0.97, 1.18, 1.64, 2.25, 2.89, 3.50 and 3.65 liters per plant each irrigation during December, January, February, March, April, May and June, respectively. The quantity of water chosen to be applied daily as in treatment A was divided into 2 halves for treatments B and D. One half was applied daily in the morning for treatment B or every 2 days for treatment D. Similarly, the second half was applied in the evening. The quantity of water to be applied daily in treatment A was added every 2 days in treatment C or applied every 3 days in treatment E.

Chemical fertigation was done through the drip irrigation system according to the recommendation for sweet pepper. A complete block design in three replicates was used. The harvest began on April 25th after 121 days from transplanting and extended 67 days till the end of June.

Data recorded:

Vegetative growth characters:

Three plants were randomly taken from each plot after 45,65,85 and 105 days from transplanting. The following vegetative parameters were studied:

1 -Mean plant height (cm.).
2 -Mean stem length to the first branch (cm.).
3 -Number of leaves per plant.
4 -Number of branches per plant.
5 -Leaf area per plant (cm^2) determined by the fresh weight method where certain known disks were taken from the leaves with a cork borer and weighed. The leaf area was calculated according to the following formula:

$$\text{Leaf area } (cm^2) = \frac{\text{(Fresh weight of leaves)}}{\text{(Fresh weight of disks)}} \times \text{leaf area of the disks}$$

6-Fresh and oven dry weight at 70 C^0 for roots, stem and leaves (gm.).

Fruit yield and its component:

Fruits were harvested after reaching the mature green stage, graded, counted and weighed. The first harvest was at April 25^{th} in both seasons.
The following data were recorded:

1 -Total yield ($kg.m^{-2}$)
2 -Total fruit number per m^2.
4 -Total early yield ($kg.m^{-2}$) (first and second harvests).
5 -Early yield of the first class ($kg.m^{-2}$).
6 -Total fruit number of the first class ($fruit.m^{-2}$).
7-Total yield of the first class ($kg.m^{-2}$).
8 -First class yield as % of early yield.

Fruit quality:

Three fruits at mature green stage of grade "A" were chosen randomly from each plot for the following investigations:

1. Fruit thickness:

Fruit wall thickness was measured in centimeter

2. Chemical properties:

Some chemical properties were determined in fruit juice as follow:

a)Total soluble solids (T.S.S):

A hand refractometer module WYT-4 was used. Readings obtained had been corrected to 20 C^0.

b) Ascorbic acid content (V.C) :

Ascorbic acid content (mg/100g) in mature green sweet pepper fruits was determined by titration with 2,6-dichlorophenolindophenol blue dye (Cox and Person ,1962)

Total chlorophyll content:

A portable leaf Chlorophyll Meter, SPAD-501, was used for greenness measurements according to Tenga *et al.*, (1989)) on fully expanded and apical leaves, third leaf from the shoot tip.

Leaves chemical analysis:

Plant leaves were dried at 70 C^0, grounded and kept for N, P and k analysis. The crude dry materials were wet digested with sulfuric- perchloric acid mixture (Piper, 1947). The total N, P and K were determined in the digested product according to the following methods:

a) Total nitrogen: It was determined colorimetrically, Allen (1959).

b) Total Phosphorus: It was determined colorimetrically, Jackson (1967).

c) Total potassium: It was determined using the flame photometer, Brown and Lilliand, (1946).

Analysis of variance was used to test the degree of variability among the obtained data. Duncan's Multiple rang test was used for comparison among the treatment means, Duncan, (1955).

RESULTS AND DISCUSSION

Vegetative growth:

Plant height:

Data in table (2) show that, significant differences were observed among irrigation treatments at all sampling dates. The largest plant height was found for irrigation treatment (B) in all stages of plant growth, whereas the lowest plant height was recorded for irrigation treatment (E) in both seasons. Variations among treatments may be due to the effective use of water applied to plants. The application of irrigation water to the soil for treatment (B) every day in two doses provided the plants with water with minimum or no percolation compared to the addition of the whole volume of irrigation water at one time every day. However, treatment (D) exhibited better results than treatments (C or E). These results agree with the findings of El-Shinawy, 1992; Ibrahim *et al*, 1996 and Byari and Al-Sayed, 1999a who reported that, mean plant height differed significantly among irrigation water quantity.

Stem length to the first branch:

Data in table (2) indicated that, stem length to the first branch was affected significantly by irrigation treatments at all sampling dates in both seasons. The highest stem length was found for irrigation treatment (B) in all stages of plant growth. On the other hand, the lowest values were recorded for irrigation treatment (E) in both seasons. However, treatment (D) exhibited better results than treatments (C or E). Variations among treatments may be due to the same causes discussed previously for plant height. These results agree with the findings of Ibrahim *et al*, 1996 who reported that, decreasing the applied irrigation water volumes resulted in decreasing stem length.

Table (2): Effect of irrigation treatments on plant height, stem length to the first branching, leaves number and leaf area of sweet pepper plant .

Treatments	Plant height (cm.)				Stem length to the first branch (cm.)				Leaves number				Leaf area (cm.^{2})			
	Days after transplanting															
	45	65	85	105	45	65	85	105	45	65	85	105	45	65	85	105
First season 1999-2000																
A	28.50 a	35.90 a	44.61 b	57.64 ab	18.28 ab	20.42 ab	21.56 ab	21.86 ab	14.88 b	28.89 a	57.56 a	93.89 a	276.9 b	667.5 a	1888.6 b	2551.5 b
B	29.92 a	36.06 a	46.83 a	58.55 a	18.72 a	20.58 a	21.98 a	22.07 a	15.77 a	28.80 a	57.90 a	94.55 a	310.3 a	669.3 a	2248.2 a	2779.4 a
C	27.83 ab	34.39 b	41.68 cd	50.77 b	16.63 c	19.73 ab	20.34 cd	20.98 cd	14.29 b	25.56 b	50.82 b	87.55 b	203.6 cd	569.1 b	1621.2 c	2228.8 c
D	28.05 ab	35.33 ab	43.09 bc	51.67 b	17.29 b	19.42 bc	20.78 bc	21.56 bc	14.81 b	26.84 b	51.14 b	89.89 b	233.5 c	643.7 a	1848.4 b	2340.2 bc
E	26.39 b	31.78 c	40.55 d	43.89 c	16.89 c	18.57 c	19.83 d	20.83 d	14.11 b	23.05 c	42.88 c	46.22 c	179.0 d	548.8 b	1188.4 d	1509.7 d
Second season 2000-2001																
A	27.78 bc	37.18 b	40.66 b	57.66 b	17.36 ab	20.52 ab	21.27 ab	21.76 ab	14.55 b	30.22 b	50.41 b	97.99 b	270.50 b	818.90 a	1805.0 a	3125.0 b
B	30.11 a	38.51 a	44.44 a	64.40 a	18.44 a	21.33 a	21.98 a	22.55 a	15.77 a	36.22 a	55.56 a	115.3 a	310.30 a	930.30 a	1888.0 a	3476.0 a
C	28.50 b	30.89 c	37.77 d	46.88 d	15.96 c	17.89 c	20.22 c	20.63 c	14.29 b	26.66 d	41.89 c	83.11 c	203.60 c	521.50 b	1187.0 b	1910.0 c
D	27.39 c	36.89 b	39.30 c	51.83 c	16.68 b	19.83 b	20.81 b	20.98 b	14.41 b	29.31 c	49.17 b	96.44 b	208.30 c	778.30 a	1757.0 a	2958.0 b
E	22.05 d	25.83 d	36.33 e	42.22 e	15.23 d	17.78 d	18.50 d	16.44 d	14.11 b	20.44 e	35.22 d	53.55 d	191.70 c	447.00 b	1162.0 b	1703.0 c

*Means having the same alphabetical letter within each column is not significantly different at the 0.05 level, according to Duncan's multiple range test.

A = one irrigation per day

B = two irrigations with the same quantity per day (half in the morning and half at evening).

C = one irrigation per 2 days

D = two irrigations with the same quantity per 2 days (half in the morning and half at evening).

E = one irrigation per 3 days

Leaves number per plant:

Data in table (2) indicate that, irrigation treatments significantly affected the number of leaves per plant at all sampling dates in both seasons. The largest number of leaves per plant was found for irrigation treatment (B) in all stages of plant growth. On the contrary, the lowest values were recorded for irrigation treatment (E) in both seasons. However, treatment (D) exhibited better results than those obtained for treatments (C or E). Variations among treatments may be due to the effect of water stress on plants with increasing irrigation intervals from (A) to (E). These results are in agreement with those reported by El-Shinawy, 1992 and El-Nemr, 1997 who found that, the number of leaves per plant increased with increasing the irrigation water quantity. Also, Byari and Al-Sayed, 1999a found that, the number of leaves per plant decreased with increasing the irrigation intervals.

Leaf area:

Data in table (2) show significant differences among irrigation treatments for leaf area per plant at all sampling dates in both seasons. Treatment (B) produced the highest leaf area while treatment (E) had the lowest one. Among the results obtained for treatments (D, C and E), treatment (D) exhibited the best one. Variations among treatments could be due to increasing the number of leaves per plant in irrigation treatment (B) compared with other treatments and to increasing water stress on plants in treatment (E). These results agree with El-Shinawy, 1992 and De Pascale *et al*, 2000 who found that, leaf area increased with increasing irrigation water quantity.

Plant fresh weight:

Data in table (3) show that, plant fresh weight significantly differed among irrigation treatments at all sampling dates in both seasons. Treatment (B) produced the largest plant fresh weight, while treatment (E) had the lowest one. Comparisons for the results obtained for treatments (D, C and E) proved that treatment (D) exhibited the best one. Variations among treatments could due to the increase in root, stem and leaves fresh weights with which irrigation treatment (B) provided plants with suitable soil moisture. These results are in agreement with that reported by El-Shinawy, 1992; El-Nemr, 1997 and Ibrahim *et al*, 1996 who found that, increasing irrigation water quantity increased fresh weight of plants.

Plant dry weight:

Data in table (4) indicate that, irrigation treatments affected significantly root, stem, leaves and total dry weight per plant at all sampling dates in both seasons. Treatment (B) produced the highest values of root, stem, leaves and total dry weight per plant while treatment (E) had the lowest record in both seasons. Among treatments (C, D and E), treatment (D) was better than the other ones for the investigated parameters. These results may be due to the effect of soil moisture content on photosynthesis and transpiration processes of the plant. These results agree with El-Shinawy, 1992; El-Nemr, 1997; Byari and Al-Sayed, 1999a and Delfine *et al*, 2001 who found that, increasing irrigation water quantity increased root, stem, leaves and total dry weight per plant.

Table (3): Effect of irrigation treatments on fresh weight of sweet pepper plant.

Treatments	Root fresh weight (gm.)				Stem fresh weight (gm.)				Leaves fresh weight (gm.)				Total fresh weight (gm.)			
	Days after transplanting															
	45	65	85	105	45	65	85	105	45	65	85	105	45	65	85	105
First season 1999-2000																
A	7.913 ab	17.98 a	27.44 b	43.61 ab	4.627 b	16.95 a	52.83 b	83.17 a	14.42 b	35.49 ab	103.9 a	140.77 a	26.96 b	72.51 a	254.10 a	544.89 b
B	8.427 a	17.71 a	29.54 a	45.28 a	5.620 a	17.08 a	55.31 a	84.08 a	16.38 a	36.43 a	108.2 a	141.33 a	30.43 a	74.00 a	248.90 a	560.50 a
C	6.700 bc	15.47 bc	26.19 b	31.11 c	4.113 bc	13.00 c	45.40 c	71.64 b	11.27 cd	33.57 c	96.45 b	113.77 c	22.08 cd	63.85 c	228.60 b	503.87 c
D	6.690 bc	16.21 b	27.00 b	33.02 b	4.250 bc	14.33 b	47.15 c	82.00 a	12.04 c	34.29 bc	97.03 b	127.33 b	22.98 c	68.02 b	246.80 a	533.99 b
E	5.620 c	14.85c	23.04 c	24.28 d	3.587 c	10.63 d	34.89 d	47.11 d	10.64 d	27.44 d	66.19 c	76.44 d	19.85 d	54.62 d	195.10 c	197.80 d
Second season 2000-2001																
	7.643 b	11.82 ab	16.42 b	26.89 b	4.293 b	14.82 b	37.92 b	102.00 b	14.09 b	36.66 b	84.16 b	143.30 b	26.03 b	64.02 b	144.3 b	275.30 b
B	9.060 a	15.34 a	18.29 a	33.33 a	5.620 a	16.96 a	40.40 a	108.60 a	16.38 a	40.63 a	88.28 a	174.4 a	31.06 a	73.70 a	147.8 a	317.30 a
C	7.033 b	11.07 bc	11.34 d	23.44 c	4.113 bc	8.117 d	30.03 c	58.22 d	10.94 d	21.88 c	57.53 c	92.66 d	22.09 d	39.86 c	99.69 d	175.10 d
D	7.523 b	10.46 bc	15.57 c	25.56 b	4.250 b	14.20 c	38.16 b	99.44 c	11.52 c	36.57 b	83.16 b	136.40 c	23.29 c	63.40 b	142.10 c	265.00 c
E	5.553 c	7.580 c	9.27 e	16.55 d	3.587 c	6.730 e	23.90 d	43.11 e	10.97 d	18.57 d	47.22d	69.22 e	20.11 d	33.54 d	81.17 e	129.50 e

*Means having the same alphabetical letter within each column is not significantly different at the 0.05 level, according to Duncan's multiple range test.

A = one irrigation per day

B = two irrigations with the same quantity per day (half in the morning and half at evening).

C = one irrigation per 2 days

D = two irrigations with the same quantity per 2 days (half in the morning and half at evening).

E = one irrigation per 3 days

Table (4): Effect of irrigation treatments on dry weight of sweet pepper plant.

Treatments	Root dry weight (gm.)				Stem dry weight (gm.)				Leaves dry weight (gm.)				Total dry weight (gm.)			
	Days after transplanting															
	45	65	85	105	45	65	85	105	45	65	85	105	45	65	85	105
	First season 1999-2000															
A	0.8167 b	2.287 a	5.433 a	6.45 a	0.6267	2.173 b	7.287 a	16.05 a	1.817 ab	6.063 ab	13.70 a	20.87 b	3.293 b	10.52 ab	26.42 a	44.54 b
B	0.9367 a	2.403 a	5.557 a	6.63 a	0.7767 a	2.520 a	7.397 a	16.44 a	2.000 a	6.113 a	13.87 a	22.26 a	3.713 a	11.03 a	26.83 a	46.65 a
C	0.6500 c	1.777 b	4.197 b	4.94 c	0.6033	1.933 c	6.767 a	14.29 b	1.537 cd	5.423 b	12.02 b	15.60 c	2.780 cd	8.867 c	22.32 c	34.04 c
D	0.6933 c	1.917 b	4.397 b	5.64 b	0.6100	2.100 bc	6.833 a	15.47 b	1.720 bc	5.747 ab	12.33 b	20.75 b	2.973 bc	9.863 b	23.56 b	41.47 bc
E	0.6033 c	1.483 c	3.330c	3.59 d	0.5267 b	1.583 d	4.520 b	6.44 d	1.340 d	3.660 c	6.22 c	10.07 d	2.477 d	6.737 d	16.07 d	22.01 d
	Second season 2000-2001															
A	0.8467 a	1.593 b	3.183 b	5.910 b	0.6700	2.133 b	4.313 b	15.34 b	1.907 b	4.403 b	10.54 b	26.00 b	3.360 b	8.000 b	20.12 b	44.20 b
B	0.9333 a	1.743 a	4.140 a	6.647 a	0.8433 a	2.267 a	5.587 a	19.40 a	2.000 a	5.760 a	12.68 a	29.72 a	3.760 a	9.767 a	22.24 a	55.77 a
C	0.6600 b	0.980 d	2.773 c	3.137 d	0.5700 c	1.103 c	3.127 d	8.633 d	1.563 d	3.440 d	7.15 d	18.71 c	2.797 c	5.623 c	13.03 d	30.48 d
D	0.6633 b	1.170 c	3.050 b	5.333 c	0.6500	2.020 b	4.060 c	14.62 c	1.833 c	4.133 c	9.743 c	25.74 b	3.310 b	7.823 b	19.47 c	42.15 c
E	0.6000 b	0.9567 d	1.727 d	2.607 e	0.5267 c	0.9700 d	2.447 e	5.350 e	1.407 e	2.450 e	5.663 e	13.13 d	2.533 d	4.373 d	9.673 e	21.09 e

*Means having the same alphabetical letter within each column is not significantly different at the 0.05 level, according to Duncan's multiple range test.

A = one irrigation per day

B = two irrigations with the same quantity per day (half in the morning and half at evening).

C = one irrigation per 2 days

D = two irrigations with the same quantity per 2 days (half in the morning and half at evening).

E = one irrigation per 3 days

Number of branches:

Data in table (5) show that, number of branches had significant differences among irrigation treatments at both seasons. Treatment (B) produced the largest number of branches while treatment (E) had the lowest one at the end of both seasons. However, among treatments, which were not irrigated daily, treatment (D) produced the largest number of branches. Variations among treatments are due to the effective use of water applied to plants as mentioned previously. These results agree with El-Shinawy, 1992 and Ibrahim *et al*, 1996 who found that, number of branches per plant at the end of the growing season increased with increasing irrigation water quantity.

Root length:

Data in table (5) show significant differences among irrigation treatments for plant root length at the end of 2000-2001 season. Treatment (B) produced the largest root length while treatment (E) had the lowest one. Variations among treatments may be due to the effect of soil moisture distribution with soil depth on roots development . These results agree with that reported by Leskovar and Heineman, 1994.

Leaf chlorophyll content:

Data in table (5) indicate that, leaf chlorophyll content was affected significantly by irrigation treatments at 117 days after transplanting in both seasons. Significant effects for leaf chlorophyll content were found at 72 days in the first season and after 96 days after transplanting in the second one. These results are in agreement with El-Shinawy, 1992 and El-Nemr, 1997 who reported that, decreasing irrigation water quantity resulted in increasing leaf chlorophyll content of the plant.

Yield and Its components:-

Total yield:

Data in table (6) show significant differences among irrigation treatments for total yield, fruit number and fruit yield per plant in both seasons. Treatment (B) produced the highest total yield, fruit number and fruit yield per plant, while treatment (E) had the lowest values for the investigated parameters in both seasons. These results are due to the favorite conditions for plant growth with treatment (B), therefore plant efficiently utilized water in yield production, table (5). The second best treatment for the investigated parameters of fruit production is treatment (A). It is needless to state that both treatments were subjected to daily irrigation. As for the treatments which were not irrigated daily, treatment (D) was the best one. These results are in agreement with Manjunath *et al*, 1994; Smittle *et al*, 1994; Gulati *et al*, 1995; Jaetak *et al*, 1995; Chartzoulakis *et al*, 1997; El-Nemr, 1997; De Pascale *et al*, 2000; and Jaimez *et al*, 2000 who reported that, increasing irrigation water quantity increased total yield, fruit number and fruit yield per plant. Also, Byari and Al-Sayed, 1999b found that, increased total yield, fruit number and fruit yield per plant with increasing irrigation intervals.

Table (5): Effect of irrigation treatments on number of branches, plant root length at the end of the season and leaves total chlorophyll content of sweet pepper plant after different periods from transplanting.

Treatments	Number of branches per plant at the end of the season	plant Root length at the end of the season (cm.)	Total chlorophyll Days after transplanting 72	96	117
First season 1999-2000					
A	50.00 c	-	58.70 a	67.50 ab	66.20 a
B	84.67 a	-	57.57 a	65.13 b	66.54 b
C	41.67 d	-	58.50 a	67.13 ab	68.95 ab
D	61.67 b	-	56.90 a	68.10 ab	67.10 b
E	23.00 e	-	60.83 a	70.50 a	70.47 a
Second season 2000-2001					
A	59.00 b	95.00 b	61.27 bc	62.03 a	66.20 d
B	84.00 a	100.00 a	59.63 c	61.40 a	64.87 e
C	44.67 d	55.00 d	64.73 ab	61.17 a	68.95 b
D	56.00 c	70.00 c	62.03 bc	61.70 a	67.10 c
E	24.67 e	30.00 e	66.43 a	62.83 a	70.47 a

*Means having the same alphabetical letter within each column is not significantly different at the 0.05 level, according to Duncan's multiple range test.

A = one irrigation per day
B = two irrigations with the same quantity per day (half in the morning and half at evening).
C = one irrigation per 2 days
D = two irrigations with the same quantity per 2 days (half in the morning and half at evening).
E = one irrigation per 3 days

Table (6): Effect of irrigation treatments on fruit yield of sweet pepper plants.

Treatments	Total yield			Early yield		Total yield of first class		
	Fruits number /m^2	Fruits weight (kg/m^2)	Plant yield (kg)	Total (kg/m^2)	First class (kg/m^2)	First class (%)	Fruits number (m^2)	Fruits weight (kg/m^2)
First season1999-2000								
A	64.98 ab	3.497 b	1.590 b	1.407 b	0.4100 b	29.14	3.617 b	0.5300 b
B	78.00 a	5.047 a	2.290 a	2.237 a	1.333 a	59.58	9.410 a	1.393 a
C	56.19 b	2.387 bc	1.083 bc	1.043 bc	0.2167 c	20.77	1.310 bc	0.2367 bc
D	65.78 ab	3.127 b	1.417 b	1.500 b	0.3933 b	26.22	3.343 b	0.550 b
E	25.79 c	1.249 c	0.5667 c	0.610 c	0.1700 d	27.86	0.8533 c	0.170 c
Second season 2000-2001								
A	61.38 ab	3.770 b	1.873 a	1.420 a	0.990 a	69.71 a	6.660 a	1.220 a
B	69.07 a	4.730 a	2.157 a	1.643 a	1.003 a	61.04 a	7.290 a	1.313 a
C	50.57 b	2.330 c	1.047 bc	0.9467 ab	0.2833 b	45.69 ab	2.983 b	0.4067 b
D	60.07 ab	2.603 c	1.280 b	1.087 ab	0.3467 b	45.62 ab	3.337 b	0.4567 b
E	21.99 c	1.120 d	0.7867 c	0.3067 b	0.2300 b	74.38 a	0.6267 c	0.2300 b

*Means having the same alphabetical letter within each column is not significantly different at the 0.05 level, according to Duncan's multiple range test.

A = one irrigation per day

B = two irrigations with the same quantity per day (half in the morning and half at evening).

C = one irrigation per 2 days

D = two irrigations with the same quantity per 2 days (half in the morning and half at evening).

E = one irrigation per 3 days

Early yield:

Data in table (6) show significant differences among irrigation treatments for early yield in both seasons. The highest early yield was produced for Treatment (B), while treatment (E) gave the lowest record in both seasons. These results may be due to the effect of decreasing soil moisture content, which affected fruit growth. These results are in agreement with El-Nemr, 1997 who observed a difference for early yield among irrigation water quantity application.

Yield of first class:

Data in table (6) show that, there were significant differences among irrigation treatments for yield of first class fruits in both seasons. Both highest fruit number and fruit weight of first class was produced by Treatment (B), while treatment (E) gave the lowest record in both seasons. These results may be due to the effect of the good vegetative growth conditions of sweet pepper plants under the (B) irrigation treatment.

Fruit Characters:-

Fruit length:

Data in table (7) show that, there are significant differences among irrigation treatments for fruit length. Treatment (B) had the highest values while treatment (E) had the lowest record in both seasons. These results can be due to the effect of soil water content, which affects fruit growth. These results are in agreement with those of Ibrahim *et al*, 1996 who found an increase in fruit length with increasing irrigation water quantity. On the other hand, Byari and Al-Sayed, 1999b found an increase in fruit length with increasing irrigation intervals.

Table (7): Effect of irrigation treatments on fruit quality of sweet pepper plant.

Treatments	Fruit dimension			Fruit wall thickens (mm.)	Fruit content of vitamin C (mg/100g)	T.S.S (%) of fruit juice
	Fruit length (L)(cm.)	Fruit diameter (D)(cm.)	L/D			
First season 1999-2000						
A	14.00 b	25.67 c	0.5647 ab	5.000 a	122.00 c	5.433 c
B	16.67 a	28.33 a	0.5867 a	5.333 a	127.00 b	4.900 d
C	11.00 c	23.33 d	0.4700 c	3.667 b	144.30 a	6.300 b
D	13.33 b	27.00 b	0.5000 bc	5.333 a	147.00 a	6.233 b
E	9.33 d	19.00 e	0.4767 c	2.500 c	113.00 d	7.500 a
Second season 2000-2001						
A	15.00 b	26.00 b	0.5800 ab	4.333 b	110.73 c	5.467 c
B	17.00 a	28.00 a	0.6100 a	5.667 a	122.00 b	5.000 d
C	11.00 c	22.33 d	0.4933 b	3.833 b	146.00 a	5.900 b
D	13.67 b	24.33 c	0.5600 ab	4.667 ab	147.3 a	5.900 b
E	9.33 d	17.67 e	0.5300 b	2.200 c	110.67 c	7.467 a

*Means having the same alphabetical letter within each column is not significantly different at the 0.05 level, according to Duncan's multiple range test.

A = one irrigation per day

B = two irrigations with the same quantity per day (half in the morning and half at evening).

C = one irrigation per 2 days

D = two irrigations with the same quantity per 2 days (half in the morning and half at evening).

E = one irrigation per 3 days

Fruit diameter:

Data in table (7) show significant differences among irrigation treatments for fruit diameter. Treatment (B) gave the highest values of fruit diameter. Treatment (E) had the lowest record in both seasons due to the effect of decreasing soil moisture content. These results agree with those of Ibrahim *et al*, 1996; Yao *et al*, 2000 who found an increase in fruit diameter with increasing irrigation water quantity. Also, Byari and Al-Sayed, 1999b found an increase in fruit diameter with decreasing irrigation intervals.

Fruit length/diameter (L/D):

Data in table (7) indicate that, irrigation treatments affected significantly the (L/D) in both seasons. Treatment (B) produced the highest record of long fruits while treatment (C) had the shortest fruits in both seasons.

Fruit wall thickness:

Data in table (7) indicate that, irrigation treatments affected significantly fruit wall thickness in both seasons. Treatment (B) gave the highest values of fruit wall thickness, while treatment (E) had the lowest record in both seasons. These results are due to decreasing soil moisture content, which reflected on fruit growth. These results agree with those of Ibrahim *et al*, 1996 who reported that, decreasing applied irrigation water volumes decreased fruit wall thickness.

Chemical composition:-

Leaves nitrogen concentration (N %):

Data presented in table (8) show that, there were significant differences among irrigation treatments at 45, 85 and 105 days after transplanting. The highest nitrogen concentration in plant leaves was found for treatment (E) in all sampling dates. Treatment (A and B) had the lowest values in both seasons. These results may be attributed to the effect of water stress on the plant dry matter. These results are in agreement with Hegde, 1989; El-Nemr, 1997 and De Pascale *et al*, 2000 who found that decreasing irrigation water quantity resulted in an increase in nitrogen content of leaves.

Leaves phosphorous concentration (P %) :

Data given in table (8) show that, at 105 days after transplanting, significant differences among irrigation treatments are found in both seasons. The highest phosphorous concentration in plant leaves is found for treatments (A and B) while treatment (E) had the lowest values in both seasons. At 65 and 85 days after transplanting there were also significant differences among treatments in the second season only. These results agree with Hegde, 1989 who found that phosphorous content in plant leaves was increased with increasing irrigation water quantity applied.

Leaves potassium concentration (K %):

Data in table (8) show that there were significant differences among irrigation treatments at 45, 65, 85 and 105 days after transplanting. At 45, 65 and 105 days after transplanting, the highest and the lowest potassium concentration in plant leaves are found for treatments (E) and (B) in both seasons, respectively. At 85 days after transplanting, the highest potassium content in plant leaves are found for treatment (E), while the lowest potassium content are found for treatment (A) in both seasons. These results are in agreement with El-Nemr, 1997 and De Pascale *et al*, 2000 who concluded that, decreasing the quantity of applied irrigation water caused an increase in leaf potassium content.

Leaves N, P and K uptake:

Data presented in table (9) show that, there were significant differences among irrigation treatments at 45, 85 and 105 days after transplanting. The greatest Leaves N, P and K uptake is observed for treatment (B) in all sampling dates. Treatment (E) had the lowest value in both seasons. These results may be due to the effect of water stress on N,P and K uptake.

Fruit content of total soluble solids (T.S.S):

Data in table (7) show that, there were significant differences among irrigation treatments for total soluble solids of fruit juice in both seasons. The highest T.S.S content in fruit juice is found for treatment (E). The lowest value is found for treatment (B) in both seasons. These results are in agreement with El-Shinawy, 1992 on sweet pepper and Byari and Al-Sayed, 1999b on tomato plants.

Fruit content of vitamin C:

Data in table (7) show significant differences among irrigation treatments for fruit content of vitamin (C) in both seasons. Vitamin C content increased with decreasing irrigation water quantity. These results are in agreement with Byari and Al-Sayed, 1999b who found that, vitamin (C) content was increased with increasing irrigation water intervals.

Water use efficiency (W.U.E):

Data given in table (10) show that, the highest water use efficiency was found with the treatment (D) followed by (B), (C), (A) and (E) treatments, respectively. Therefore, plants irrigated at evening by half the quantity of irrigation water exhibited the highest benefit of the applied water. Moreover, considering the results obtained for treatment (B) as the base of comparison, it can concluded that, applying 2 irrigations per 2 days (half in the morning and half in the evening) is the best treatment to be used owing to saving 45 % of irrigation water resulted in reducing yield by about 45 %. On the other hand, saving about 2, 47 and 60 % of irrigation for A, C and E treatments resulted in reducing yield by about 26, 5 2 and 76 % for the same treatments, respectively. These results are in agreement with those obtained by Hegde. 1987;El-Shinawy, 1992; Manjunath *et al*, 1994; Narayan *et al*, 1994; Ibrahim *et al*, 1996 and El-Nemr, 1997.

Table (8): Effect of irrigation treatments on leaves nitrogen, phosphorus and potassium uptake, of sweet pepper plants.

Treatments	Nitrogen (mg / plant leaves)				Phosphorus (mg / plant leaves)				Potassium (mg / plant leaves)			
	Days after transplanting											
	45	65	85	105	45	65	85	105	45	65	85	105
First season 1999-2000												
A	42.70 a	167.40 a	385.80 a	652.80 a	16.51 a	47.99 a	130.60 a	111.20 a	64.63 a	212.20 a	461.00 a	766.00 a
B	46.00 a	161.00 a	398.20 a	669.00 a	16.87 a	53.62 a	122.90 a	97.03 ab	63.20 a	205.80 a	481.90 a	790.20 a
C	38.94 a	153.60 a	369.40 ab	540.10 b	13.51 a	47.62 a	88.54 ab	66.75 c	56.14 ab	199.40 a	446.00 a	588.70 b
D	43.02 a	156.10 a	357.30 ab	657.80 a	13.91 a	53.40 a	93.02 ab	86.36 bc	62.62 a	210.40 a	451.00 a	766.30 a
E	38.93 a	117.10 b	333.10 b	384.40 c	11.46 a	29.76 b	50.65 b	38.04 d	51.46 b	140.80 b	348.40 b	394.80 c
Second season 2000-2001												
A	46.72 b	109.70 b	275.20 b	684.40 b	9.73 a	34.38 b	50.54 b	91.96 b	51.42 b	123.50 b	289.10 b	728.50 b
B	47.20a b	142.80 a	326.80 a	783.90 a	9.59 a	40.84 a	79.38 a	157.60 a	51.27 b	154.60 a	344.40 a	809.20 a
C	44.08 c	98.23 c	217.70 c	579.30 c	7.54 ab	24.36 c	29.85 c	69.50 bc	48.34 b	107.00 b	223.3 c	587.40 c
D	48.95 a	112.60 b	281.40 b	760.9 a	7.44 ab	25.92 c	47.79 b	102.00 b	55.02 a	124.40 b	292.7 b	778.90 ab
E	40.09 d	71.46 d	173.70 d	421.50 d	5.13 b	16.68 d	22.38 c	39.70 c	44.62 c	77.26 c	179.80 d	422.80 d

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A = one irrigation per day

B = two irrigations with the same quantity per day (half in the morning and half at evening).

C = one irrigation per 2 days

D = two irrigations with the same quantity per 2 days (half in the morning and half at evening).

E = one irrigation per 3 days.

Table (9): Effect of irrigation treatments on leaves nitrogen, phosphorus and potassium contents (%), of sweet pepper plants.

Treatments	Nitrogen (%)				Phosphorus (%)				Potassium (%)			
	Days after transplanting											
	45	65	85	105	45	65	85	105	45	65	85	105
	First season 1999-2000											
A	2.347 bc	2.760 a	2.817 c	3.127 c	0.8960 a	0.7917 a	0.9583 a	0.5313 a	3.500 c	3.500 c	3.367 d	3.670 d
B	2.300 c	2.670 a	2.870 c	3.010 d	0.8437 a	0.8753 a	0.8857 a	0.4373 ab	3.210 d	3.367 c	3.473 c	3.550 e
C	2.533 b	2.780 a	3.067 b	3.460 b	0.8857 a	0.8753 a	0.7397 a	0.4270 ab	3.653 b	3.677 b	3.710 b	3.773 b
D	2.500 b	3.037 a	2.897 c	3.170 c	0.8127 a	0.9270 a	0.7500 a	0.4163 ab	3.640 b	3.660 b	3.657 b	3.693 c
E	2.907 a	3.200 a	3.613 a	3.817 a	0.8543 a	0.8127 a	0.5520 a	0.3750 b	3.840 a	3.847 a	3.780 a	3.920 a
	Second season 2000-2001											
A	2.450 d	2.560 e	2.950 c	3.010 e	0.5103 a	0.7813 a	0.4797 ab	0.3547 ab	3.300 c	3.467 c	3.353 d	3.520 d
B	2.360 e	2.717 d	3.003 c	3.220 d	0.4793 a	0.7087 ab	0.6257 a	0.5230 a	3.003 d	3.350 d	3.397 d	3.483 e
C	2.820 b	2.920 b	3.510 a	3.640 b	0.4793 a	0.7087 ab	0.4167 b	0.3707 ab	3.663 b	3.717 b	3.747 b	3.790 b
D	2.670 c	2.820 c	3.293 b	3.520 c	0.4063 a	0.6257 b	0.4900 ab	0.3960 ab	3.660 b	3.680 b	3.683 c	3.743 c
E	2.850 a	3.113 a	3.513 a	3.923 a	0.3647 a	0.6770 ab	0.3960 b	0.3023 b	3.833 a	3.850 a	3.843 a	3.940 a

*Means having the same alphabetical letter within each column is not significantly different at the 0.05 level, according to Duncan's multiple range test.

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B = two irrigations with the same quantity per day (half in the morning and half at evening).

C = one irrigation per 2 days

D = two irrigations with the same quantity per 2 days (half in the morning and half at evening).

E = one irrigation per 3 days.

Table (10): Water use efficiency of Sweet pepper plants (kg. m^{-3}) for different irrigation treatments.

Treatments	1999-2000			2000-2001			Mean
	Total yield (kg. fed^{-1})	Total Experimental Etc ($m^3.fed^{-1}$)	Water use efficiency (kg, m^{-1})	Total yield (kg. fed^{-1})	Total experimental Etc ($m^3.fed^{-1}$)	Water use efficiency (kg, m^{-1})	
A	14687.40	3726.24	3.94	15834.00	3912.43	4.05	4.00
B	21197.40	3813.85	5.56	19866.00	3968.75	5.01	5.29
C	10025.40	2053.38	4.88	9786.00	2142.42	4.57	4.73
D	13133.40	2101.72	6.25	10932.60	2192.69	4.99	5.62
E	5245.80	1544.93	3.40	4704.00	1593.48	2.95	3.18

*Means having the same alphabetical letter within each column is not significantly different at the 0.05 level, according to Duncan's multiple range test.

A = one irrigation per day

B = two irrigations with the same quantity per day (half in the morning and half at evening).

C = one irrigation per 2 days

D = two irrigations with the same quantity per 2 days (half in the morning and half at evening).

E = one irrigation per 3 days

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الاحتياجات المائية للفلفل الحلو في الصوب البلاستيكية تحت ظروف العريش ٣- النمو الخضري، والمحصول ومكوناته، وكفاءة استخدام المياه.

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أجريت هذه الدراسة بالمزرعة التجريبية لكلية العلوم الزراعية البيئية بالعريش جامعة قناة السويس خلال العروة الصيفية المبكرة لموسمي ١٩٩٩/٢٠٠٠ و٢٠٠٠/٢٠٠١م، وذلك لدراسة الاحتياجات المائية لمحصول الفلفل الحلو المنزرع تحت الصوب البلاستيكية. حيث زرعت نباتات الفلفل الحلو صنف سونار في الصوب البلاستيكية (٩ X ٦٠ متر) . واستخدمت خمس معاملات للري تضاف من خلال نظام الري بالتنقيط وهي: (ا) الري مرة واحدة يوميا، (ب) الري مرتين يوميا (نصف المكية صباحا ونصف الكمية مساءاً)، (ج) الري مرة واحدة كل يومين، (د) الري مرتين بنفس الكمية كل يومين (نصف الكمية صباحا ونصف الكمية مساءاً)، (ه) الري مرة واحدة كل ثلاثة أيام . وقد رويت كل معاملة من المعاملات السابقة بكمية مياه واحدة لكل منها في كل رية(على أساس الاحتياجات المائية لليوم الواحد)، و التي تزايدت تدريجيا من شهر ديسمبر حتى شهر يونيو.

تزايد كل من النمو الخضري والمحصول ومكوناته وأبعاد الثمرة ومحتوى الأوراق من الفوسفور والبوتاسيوم وامتصاص النبات لكل من النتروجين والفوسفور والبوتاسيوم والنتح بخر الحقيقي بزيادة كمية الماء المضاف، وقد أعطت معاملة الري (د) أعلى قيمة لكفاءة استخدام الماء تلتها المعاملات (ب) و (ج) و (ه) و(ا) على التوالي.ومن ناحية أخرى فإن محتوى الأوراق من الكلوروفيل الكلي والنتروجين، ومحتوى الثمرة من المواد الصلبة الذائبة الكلية وفيتامين ج تزايدت مع تناقص كمية مياه الري.