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IRRIGATION REQUIREMENTS OF SWEET PEPPER (*Capsicum annuum* L.) GROWN IN PLASTIC GREENHOUSES UNDER EL-ARISH CONDITIONS: I: SOIL MOISTURE DISTRIBUTION PATTERN

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ABSTRACT

Two greenhouse experiments were carried out at The Experimental Farm of the Faculty of Environmental Agriculture Sciences, in El-Arish, Suez Canal University, during 1999-2000 and 2000-2001 early summer seasons. Sweet pepper (*Capsicum annuum L.*) plants *cv.* Sonar were grown in plastic greenhouse (9 x 60 m.) under drip irrigation system. The main object of this research was to study the effect of some irrigation treatments on sweet pepper growth and yield. Also, it included the effect of these treatments on soil moisture distribution and sweet pepper actual evapotranspiration. Five irrigation treatments were carried out as follow: 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, and treatment E: one irrigation per 3 days. Every treatment was irrigated with the same quantity of irrigation water (based on water requirements for one day), which gradually increased from December to June. A complete block design in three replicates was used. The area of the plot was 18 m^2 (10 m long x 1.8 m wide). The distance between plants along the lateral irrigation line was 50-cm. Transplanting was carried out at December 25^{th} and harvest began after (121) days from transplanting and extended for (67) days in both seasons. Before and after irrigation, soil moisture decreased with both depth and distance from the emitter. Moreover, it is noticed that, soil moisture content almost reached permanent wilting point, 3.17%, particularly for the studied deeper soil depths, 20-30 cm. and at a far distance from the emitter, 15-25 cm. The sequence of weighed average of soil moisture contents are B >A>D>C>E. We can recommended by using treatment (B) which gave the best results and should be avoided irrigated with treatment (E) which gave the lowest results.

Keywords: Irrigation requirements, soil moisture distribution, dip irrigation. sweet pepper plants, -Evapotranspiration.

INTRODUCTION

Soil moisture distribution is definitely affected by the amount, rate and method of water application. Under trickle irrigation system in clay loam soils, Rolland (1973) found that, soil moisture spreaded fairly wide on the surface, but little infiltration occurred downward due to the low rate of vertical flow.

Rawlins (1973) reported that, irrigation management under high frequency irrigation revolves around controlling the quantity of water passing through the root zone to avoid salinity build up, rather than around the question when to irrigate?. It requires some estimate of deep percolation flux rather than measurements of soil water potential.

Jury and Earl (1977) reported that, weekly application of irrigation water through trickle irrigation resulted in more lateral and down movement of water than did daily irrigation in a barren sandy loam soil. Observation of the wetted radius at the surface indicated that substantial amounts of water running off laterally during weekly irrigation could account for the storage changes seen at large radial distance from the emitter. They concluded that, one should avoid using models, which do not include the effect of surface pounding. If such behavior extend to circumstances with crop growing, one would in fact be tempted to recommend a periodic rather than a continuous irrigation regime for widely spacing trickle emitters, provided that the soil hydraulic conductivity was low enough to result in surface pounding. Clothier *et al* (1985) stated that, trickle irrigation is quite different from other methods of irrigation. Water moves across the soil surface away from the drip emitter until the infiltration rate of the pounded area matches the emitter discharge rate. Beyond this free-water pond, water moves into the soil by unsaturated flow.

Martin and Chesness (1984) found that, soil water distribution in the wetted zone did not appear to be affected by soil layering. The differences in the shape and extent of the wetted volume between the non-layered and layered soil plots were small. They also reported that, soil characteristics affecting water distribution vary from soil to another. Phene and Howell (1984) reported that, non-homogeneous soil properties might cause differences in the size and the shape of the wetting patterns under drip irrigation.

Abd El-Razek *et al* (1992) studied soil moisture distribution patterns in clay soils as affected by drip irrigation system. The drip irrigation system was installed with flexible black poly-ethylene lateral lines, 12-mm in diameter, laid on the soil surface at 90-cm spacing. The emitter discharge was 4 $L.hr^{-1}$ at working pressure of 1 $kg.cm^{-2}$. Emitters spacings were 70 and 100 cm. They found that, moisture content is relatively higher along the laterals having 70-cm emitter spacing than along the laterals having 100-cm emitter spacing. Their result showed also that close emitter spacing induced very less fluctuation in soil moisture content in the surface soil layer between emitters. Wider emitters spacing resulted in gradual decrease in soil moisture content from the drippers. Across the laterals, the rate of increase in soil moisture content ranged between 48.5 and 15.9 % and between 44.1 and 15.7 % with standard deviation values of 13.68 and 12.15% for the close and wide emitters spacings, respectively. These results indicated a non-uniformity distribution of soil moisture content under drip irrigation between drip lines. Along the laterals, the 70-cm emitter spacing treatment resulted in a better uniformity of soil moisture distribution.

Ponnuswamy et al (1998) stated that, the moisture content at the soil surface (below the dripper) decreased from 33.8 to 23.8% and from 32.2 to 22.7% for drip irrigation with 100 and 50% of surface applied water, respectively. The antecedent soil moisture content varied from 22.4 to 23.8% in the 0-45 cm soil depth. More water penetrated into the deeper layers in drip system of irrigation, therefore, the crop utilized the water very effectively.

Mostafa *et al* (2001) reported that, under drip irrigation system soil moisture content, in general, tends to decrease by going away from the dripper orifice in both vertical and horizontal directions. The soil moisture content was higher under irrigation treatment by 125 % of the soil F.C. compared with other irrigation treatments. This is expected since this treatment received an amount of water more than the soil field capacity. Generally, increasing irrigation water level was accompanied by an increase in soil moisture content. Moisture contents in the 0-5 cm soil layer were 20.8, 23.7, 27.8 and 30.3 % at 50, 75, 100 and 125 % of the soil F.C., respectively.

The aim of this work was to study soil moisture distribution under drip irrigation system on sweet pepper plants cv. Sonar.

MATERIALS AND METHODS

Two greenhouse 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	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy
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
Chemical analysis [soluble ions in (1:5) extract]								
Ca^{++} (meq.l^{-1})	3.03	3.03	3.03	2.01	2.10	2.30	2.00	1.90
Mg^{++} (meq.l^{-1})	2.11	2.57	2.02	1.38	2.2	2.4	1.95	1.42
Na^{+} (meq.l^{-1})	1.18	1.14	0.75	0.86	4.49	3.56	3.49	2.07
K^{+} (meq.l^{-1})	0.48	0.36	0.30	0.34	0.31	0.24	0.26	0.21
CO_3^{--} (meq.l^{-1})	-	-	-	-	-	-	-	-
HCO_3^{-} (meq.l^{-1})	2.00	2.30	2.50	2.60	2.40	2.60	2.90	2.50
Cl^{-} (meq.l^{-1})	1.02	1.70	1.65	1.61	2.30	2.40	2.10	1.70
SO_4^{--} (meq.l^{-1})	3.78	3.10	1.95	0.38	4.40	3.50	2.70	1.40
EC(dS m^{-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}	ppm	Cations				Anions			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{--}	SO_4^{--}
6.7	5.65	3616	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

Soil parameters were investigated before conducting the experiments as follow:

1- Particles size distribution was determined using the international A.C.A. pipette method (Piper, 1950).
2- Bulk density was determined using J.R.H. Coutts cylinder (Piper, 1950).
3- Calcium carbonate was determined as $CaCO_3$ % by means of Collin's calcimeter (Jackson, 1967).
4- Soil pH value was determined in (1:2.5) soil water suspension.
5- Water holding capacity, field capacity and wilting point were determined by the weighing method using the pressure membrane method (Richards, 1954).
6- The soil water extract for the (1:5) soil water suspension was chemically analyzed for:
   a)-Electrical conductivity (E.C), conductimetrically using Radiometer compenhagen N.V. type CDM 2d (Jackson,1967).
   b)-Carbonate and bicarbonate, titremetrically using $KHSO_4$ and phenophthalein and bromocresol green as indicators.
   c)-Chloride following Mohr's method, (Richards,1954).
   d)-Soluble sulfate was calculated by the difference between the summation of soluble cations and anions.
   e)-Soluble potassium and sodium, by the Flame Photometer.
   f)-Calcium and magnesium, by the versenate method using ammonium purpurate as an indicator for Ca^{++} and eriochrome black T for Ca^{++} plus Mg^{++} (Jackson,1967).

Soil moisture was determined by the weighing method after and before irrigation (Richards, 1954). Air temperature and relative humidity were measured using thermohigrometer located inside the greenhouse.

Sweet pepper (*cv.* Sonar) seeds were planted at November 10th on sterophome seedling 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 trues 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 started 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 of water (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 of water (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 for one 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 for 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 halfs 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 choosen to be applied daily in treatment A was applied 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 common recommendation. A complete block design in three replicates was used. The harvest began on April 25th after 121 days from transplanting and extended for 67 days till the end of June.

Data recorded:

A) Soil moisture content were determined at three depths; 10,20 and 30 cm. and at three distances from plants; 5,15 and 25 cm.
B) Sweet pepper potential evapotranspiration (ET) $mm.day^{-1}$, was estimated by the following methods using the available meteorological data as follow:
1-Modified Blaney and Criddle method.
2-Class A pan evaporation method.
C) Water use efficiency (W.U.E.):
The consumed water by sweet pepper was calculated according to Yaron *et al.,* (1973) as follow:

$$W.U.E. = \frac{Y}{ETa}$$

Where:
Y = Seasonal yield ($kg.fed^{-1}$.).
ETa = Evapotranspiration ($m^3.fed^{-1}$.).

D) Consumptive use of water (C.U.):

Consumptive use of water (C.U.) was calculated using the equation given by Israelson and Hansen (1962) as follow:

$$C.U. = D \times AD \times \frac{Ez - ei}{100}$$

Where:

C.U. = Consumptive use in cm.
D = Irrigated soil depth in cm.
AD = Bulk density in gm $cm.^{-3}$ of the chosen soil depth.
ez = Soil moisture percent after irrigation.
ei = Soil moisture percent before the next irrigation.

The actual evapotranspiration, ETa, is synonymous to the calculated consumptive use of water (CU). Consequently, daily and monthly consumptive use of water was calculated for specified soil depths for all treatments from January 25 to June 30.

RESULTS AND DISCUSSION

Data in Table (2) show that, ETo values calculated by either Blaney and Criddle or class A pan evaporation methods increased gradually in the first and second seasons from January and reached its maximum values in May then decreased at June. The calculated ETo values from Blaney and Criddle equation were higher than the values calculated by class A pan, except during May and June for both seasons. Data in table (3) show that, temperature and relative humidity increased from January to May. This result reflects the same trend obtained for the calculated ETo values. The decrease in temperature and relative humidity during June was due to the removal of the plastic covers from the greenhouse.

Concerning sweet pepper actual evapotranspiration (ETo) calculated values, it should be stated that it was estimated as 90 mm during the nursing period, which lasted from November 10^{th} to December 24^{th}. During the irrigation treatments period, the obtained sweet pepper ETa values are given in Table (4). The data show in the first season that, it increased from January to April, then decreased. This result agrees with the (f) values calculated from Blaney and Criddle formula, which increased from 17.38mm day^{-1} during January to 22.31 $mm.day^{-1}$ during April, (Table 2). In the second season, ETa values given in Table (4) increased from 2.59mm day^{-1} during January to 6.59 $mm.day^{-1}$ during May then decreased at June. Similarly, these results agree with the (f) values calculated from Blaney and Criddle formula, which increased from 15.987mm day^{-1} during January to 19.349 $mm.day^{-1}$ during May, Table (2). The data given in Table (4) also show that, the highest ETa value was found for (B) treatment followed by A, D, C and E treatments, respectively. These results are related to the increase of air temperature during plant development and to the increasing water requirements of the growing plants to fulfill their demands. Hence, narrow irrigation interval increased ETa. These results somewhat agree with those reported by

Table (2): Calculated daily sweet pepper ETo values by Blaney and Criddle, and class A pan evaporation methods.

ET method	Month											
	January		February		March		April		May		June	
	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001
Blaney and Criddle method												
Calculated **f** values	17.38	15.99	18.57	16.14	19.87	18.04	22.31	18.54	21.72	19.35	19.39	19.04
Numerical **C** values	0.161	0.213	0.189	0.236	0.213	0.261	0.323	0.351	0.341	0.331	0.320	0.315
Calculated ETo (mm.day-1)	2.80	3.40	3.50	3.80	4.20	4.70	7.20	6.51	7.40	6.40	6.20	6.00
Class A pan method												
Epan	2.91	3.74	4.28	5.35	5.17	6.68	8.32	8.91	10.32	11.12	9.56	10.55
Kpan	0.75	0.65	0.75	0.65	0.75	0.65	0.75	0.65	0.75	0.65	0.75	0.75
Calculated ETo (mm.day-1)	2.18	2.43	3.21	3.48	3.88	4.34	6.24	5.79	7.74	7.22	7.17	7.91

Table (3): Monthly mean maximum, minimum and average values for temperatures and relative humidies in a plastic greenhouse for 2 seasons.

Parameters		Month													
		December		January		February		March		April		May		June	
		1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001
Temperature (C^o)	Maximum	27.71	27.14	26.64	27.19	34.78	28.34	35.76	31.95	40.73	31.67	38.96	33.19	28.56	28.22
	Minimum	11.71	11.71	13.55	8.16	10.61	6.48	14.58	11.15	20.93	13.60	20.14	15.58	20.40	19.32
	Average	19.71	19.43	20.10	17.68	22.70	17.41	25.17	21.55	30.83	22.64	29.55	24.39	24.48	23.72
Relative Humidity (%)	Maximum	100.00	100.00	100.00	98.97	100.00	99.38	100.00	98.58	100.00	95.27	100.00	94.58	88.69	86.47
	Minimum	57.14	55.18	62.73	39.74	50.13	34.78	51.61	33.10	42.13	31.57	48.40	36.94	57.45	55.02
	Average	78.57	77.59	81.37	69.36	75.07	67.08	75.81	65.84	71.07	63.42	74.20	65.76	73.07	70.75

Table (4): Sweet pepper averages daily, monthly and total actual evapotranspiration (ETa) affected by irrigation treatments.

Month	Irrigation treatments									
	A		B		C		D		E	
	Monthly Eta (mm.)	Daily Eta (mm.)	Monthly Eta (mm.)	Daily Eta (mm.)	Monthly Eta (mm.)	Daily Eta (mm.)	Monthly Eta (mm.)	Daily Eta (mm.)	Monthly Eta (mm.)	Daily Eta (mm.)
First season 1999-2000										
January (1)	16.87	2.41	17.99	2.57	8.61	1.23	9.31	1.33	5.81	0.83
February (2)	92.22	3.18	95.41	3.29	41.47	1.43	44.95	1.55	33.35	1.15
March	111.91	3.61	118.42	3.82	57.04	1.84	59.52	1.92	37.51	1.21
April	195.00	6.50	197.40	6.58	95.70	3.19	97.50	3.25	62.10	2.07
May	192.20	6.20	196.54	6.34	98.58	3.18	100.13	3.23	70.37	2.27
June	189.00	6.30	192.30	6.41	97.50	3.25	99.00	3.30	68.70	2.29
Total	797.20		818.06		398.90		410.41		277.84	
Second season 2000-2001										
January (1)	18.13	2.59	18.41	2.63	8.89	1.27	9.45	1.35	6.09	0.87
February (3)	94.08	3.36	98.28	3.51	45.08	1.61	50.68	1.81	33.04	1.18
March	131.13	4.23	132.37	4.27	65.72	2.12	67.58	2.18	41.85	1.35
April	196.50	6.55	197.40	6.58	97.20	3.24	99.31	3.31	66.30	2.21
May	204.29	6.59	210.18	6.78	105.71	3.41	106.95	3.45	71.92	2.32
June	197.40	6.58	198.30	6.61	97.50	3.25	98.10	3.27	70.20	2.34
Total	841.53		854.94		420.10		432.07		289.40	

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. (1)= 7 days during January, (2)= 29 days during February, (3)= 28days during February.

Ibrahim *et al.*, 1996 and El-Naggar, 1997 who found an increase in evapotranspiration with increasing the quantity of irrigation water.

Results presented in Tables (5 to 10) show that, soil moisture decreased with both of increasing soil depth and distance from the emitter after and before irrigation. It increased gradually from the beginning of the establishment growth period until harvest as a result to increasing plant irrigation water requirements with advancing plant development. The compiled data representing weighed averages for soil moisture contents, Table (11), indicate only for January that the highest soil moisture content before irrigation was found for treatment (A) followed by B, D, C and E treatments. The superiority of treatments A and B is related to their daily irrigation. However, the highest soil moisture after irrigation was found for treatment B. In general, the sequence of soil moisture contents before or after irrigation from February to the end of June are B > A > D > C > E.

The lowest soil moisture content, whether before or after irrigation, obtained for treatment E is probably due to the fact that its soil was subjected to the widest irrigation interval i.e., every 3 days. Moreover, it is noticed from the data given in Tables (5 to 10) that, soil moisture content almost reached permanent wilting point, 3.17%, particularly for the studied deeper soil depths, 20-30 cm. and at a far distance from the emitter, 15-25 cm. Consequently, irrigating pepper plants every 3 days should be avoided based on the conclusion of (De Pascale *et al* (2000) and Chartzoulakis *et al* (1997) who stated that, pepper plants are sensitive to soil moisture deficit,

It is interestingly noticed that percents depleted soil moisture, presented in table (11), did not vary markedly among the studied treatments. They gradually increased from 4.76 and 5.00 % at January for 1999-2000 and 2000-2001 seasons, respectively to 7.28 and 8.4 % at March, respectively. The values sharply increased to 13.10 and 13.74 %, respectively, during April and almost remained at such levels till the end of June. These results prove the importance of how to deal with irrigation water in order to achieve the highest crop production. Therefore, it is anticipated that sweet pepper plants depleted almost similar percentages of soil moisture to maintain its existence, yet fruit yield must be conditioned by the ease with which water is depleted by plants. The obtained values for soil moisture depletion indicate that actual evapotranspiration (ETa) values gradually increased from the beginning of the establishment growth period until harvest. The highest value of (ETa) is found for (B) treatment followed by A, D, C and E treatments, respectively.

Table (5): Soil moisture distribution (%) as affected by drip irrigation frequency during January.

Irrigation treatments	Soil depth (cm.)	1999-2000						2000-2001					
		After irrigation			Before irrigation			After irrigation			Before irrigation		
		Distance from emitter (cm.)											
		0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25
A	0-10	18.52	16.32	9.65	11.00	8.76	7.32	18.31	17.30	12.98	11.31	8.45	8.00
	10-20	17.19	12.42	8.82	8.52	6.42	5.93	17.31	13.12	9.90	8.42	7.10	5.68
	20-30	9.42	7.42	7.42	6.45	5.24	4.91	10.12	8.12	6.98	7.00	6.06	4.50
B	0-10	18.32	15.82	11.32	12.07	8.65	8.62	17.31	16.42	13.90	12.45	9.35	8.45
	10-20	16.92	11.85	9.23	9.15	5.87	5.02	16.23	12.14	10.80	9.12	6.12	5.03
	20-30	9.64	7.86	7.56	5.93	4.23	4.23	10.51	9.21	7.23	5.43	5.12	4.12
C	0-10	16.71	13.46	9.43	9.23	5.65	5.32	15.32	14.82	11.30	9.43	8.34	7.15
	10-20	15.34	10.92	7.98	6.45	5.04	4.62	13.03	11.75	8.50	6.34	5.49	5.51
	20-30	8.66	6.40	6.32	5.32	4.02	3.25	9.52	8.77	6.62	5.12	4.91	3.89
D	0-10	17.71	14.54	10.34	9.63	6.31	6.89	16.21	15.95	12.21	9.43	8.62	7.61
	10-20	15.97	10.93	8.52	6.92	5.23	4.98	14.31	11.93	9.32	6.59	5.61	5.52
	20-30	9.11	7.62	6.67	5.63	4.12	3.62	9.92	8.97	6.90	6.41	4.98	4.21
E	0-10	14.34	12.49	8.21	5.21	4.90	3.64	13.12	12.43	9.02	5.31	5.12	4.30
	10-20	12.12	9.92	6.97	4.12	4.63	3.21	11.02	9.94	6.91	4.21	4.14	4.12
	20-30	6.13	7.31	5.12	3.51	3.99	2.98	7.98	7.92	5.97	4.01	3.98	3.45

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): Soil moisture distribution (%) as affected by drip irrigation frequency during February.

Irrigation treatments	Soil depth (cm.)	1999-2000						2000-2001					
		After Irrigation			Before irrigation			After irrigation			Before irrigation		
		Distance from emitter (cm.)											
		0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25
A	0-10	18.23	16.05	12.56	10.41	8.45	7.22	18.06	17.44	15.56	10.98	9.32	7.99
	10-20	14.45	12.56	10.40	7.68	5.31	4.95	16.31	14.35	12.43	9.12	7.56	6.11
	20-30	12.31	10.42	8.56	5.53	4.50	4.13	14.56	13.40	11.16	7.42	6.31	5.68
B	0-10	19.16	17.21	12.96	11.00	8.56	7.64	19.52	17.91	15.71	11.41	10.34	8.53
	10-20	15.23	13.31	10.81	8.77	6.98	5.34	17.43	15.86	13.43	9.43	7.89	7.43
	20-30	13.02	11.20	8.45	5.98	4.67	4.56	15.45	13.97	11.41	7.65	6.52	5.13
C	0-10	16.51	13.31	10.52	9.03	7.36	6.34	16.21	15.66	13.98	9.07	7.29	6.76
	10-20	13.64	11.14	9.56	5.77	4.61	4.21	15.12	13.89	11.02	8.25	6.93	5.15
	20-30	11.31	9.32	7.93	4.73	4.01	3.81	13.10	11.71	9.89	6.50	5.93	3.95
D	0-10	17.31	15.14	11.10	9.89	7.64	6.94	17.56	16.85	14.45	9.89	8.25	6.97
	10-20	13.98	12.14	10.02	6.34	4.81	4.74	15.21	14.25	12.32	8.67	7.52	5.97
	20-30	11.98	10.35	8.12	4.65	4.93	4.18	13.04	12.31	10.46	6.96	6.31	4.85
E	0-10	15.51	13.82	9.50	5.91	4.63	3.81	14.33	14.87	12.29	6.48	6.39	4.75
	10-20	12.42	10.98	9.09	4.20	3.96	3.26	13.56	12.83	11.50	6.05	4.72	3.96
	20-30	10.38	9.83	7.02	3.50	3.10	2.97	11.52	10.86	9.45	5.09	4.33	3.51

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 (7): Soil moisture distribution (%) as affected by drip irrigation frequency during March.

Irrigation treatments	Soil depth (cm.)	1999-2000						2000-2001					
		After irrigation			Before irrigation			After irrigation			Before irrigation		
		Distance from emitter (cm.)											
		0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25
A	0-10	18.53	17.67	15.89	10.54	9.54	8.26	20.61	18.82	15.75	11.31	9.31	7.83
	10-20	16.76	15.71	13.36	8.53	7.86	7.49	18.76	19.97	14.35	9.05	7.37	5.98
	20-30	14.74	13.82	11.06	8.44	6.20	6.11	16.74	14.55	12.31	7.91	6.01	5.20
B	0-10	19.63	18.86	16.22	12.38	10.59	8.76	20.98	19.02	15.61	11.42	9.51	7.91
	10-20	17.91	16.84	14.69	9.59	8.25	7.91	18.95	17.35	14.69	9.65	7.67	6.46
	20-30	15.41	14.77	12.67	8.60	6.28	6.28	16.31	14.78	12.67	8.12	6.05	5.41
C	0-10	17.21	16.84	14.31	9.71	8.21	6.93	18.63	16.88	13.89	9.56	7.63	6.31
	10-20	15.12	13.78	11.06	7.25	6.31	5.21	16.92	15.78	11.89	7.30	5.92	5.10
	20-30	13.31	12.91	10.87	6.51	4.92	4.32	14.36	13.91	10.08	6.83	5.31	4.21
D	0-10	17.36	17.54	12.42	9.99	8.93	7.34	19.41	17.32	14.42	9.72	7.81	6.43
	10-20	15.59	14.95	11.71	7.97	6.86	6.61	17.31	16.65	12.31	7.41	6.10	5.31
	20-30	13.72	13.67	10.95	6.71	5.32	5.87	14.72	13.82	10.23	7.12	5.37	4.34
E	0-10	15.31	14.35	13.29	6.48	5.56	4.35	16.92	15.38	11.29	6.41	5.84	5.44
	10-20	13.09	12.52	10.40	5.13	4.71	3.91	14.31	13.52	10.51	5.61	4.28	4.69
	20-30	12.61	10.66	8.34	4.31	3.63	3.51	12.64	11.65	9.45	4.60	3.97	3.65

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 (8): Soil moisture distribution (%) as affected by drip irrigation frequency during April.

Irrigation treatments	Soil depth (cm.)	1999-2000						2000-2001					
		After irrigation			Before irrigation			After irrigation			Before irrigation		
		Distance from emitter (cm.)											
		0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25
A	0-10	22.13	20.96	19.21	9.15	6.81	5.26	22.45	20.65	19.65	9.32	6.45	5.12
	10-20	20.81	19.92	17.45	7.53	5.96	4.63	20.06	19.26	17.97	6.42	5.14	3.98
	20-30	18.41	18.61	14.30	6.44	4.21	3.37	18.86	18.39	14.56	5.02	3.91	3.31
B	0-10	23.56	22.44	20.40	9.38	7.99	6.71	23.45	21.91	19.76	9.45	7.35	5.45
	10-20	21.34	21.73	18.53	8.58	6.93	5.41	20.46	19.96	18.35	7.31	5.62	4.21
	20-30	20.15	19.41	15.42	7.60	5.67	3.87	19.06	19.04	15.07	5.31	4.95	3.92
C	0-10	21.49	20.12	18.65	8.72	5.99	5.89	20.94	20.12	19.32	7.31	6.31	4.15
	10-20	20.36	19.85	17.06	6.25	5.61	3.68	20.08	19.35	17.40	5.98	4.81	3.71
	20-30	18.42	17.23	13.50	5.51	3.87	3.22	19.61	17.13	13.61	4.41	3.06	2.91
D	0-10	21.98	21.06	18.97	8.89	6.03	5.35	22.14	20.65	19.07	7.43	6.42	4.35
	10-20	20.40	20.18	17.13	7.67	5.62	4.32	20.14	19.40	17.62	6.31	4.95	3.93
	20-30	18.05	17.27	13.97	5.71	4.43	3.35	18.65	17.98	14.03	4.49	3.35	2.95
E	0-10	20.12	19.56	17.31	5.48	5.34	4.44	20.65	19.96	18.89	5.37	5.21	3.65
	10-20	18.32	17.61	14.91	4.82	4.28	3.29	18.92	18.92	16.56	4.35	4.21	3.34
	20-30	17.06	16.34	11.50	3.65	3.38	3.15	17.97	16.65	12.01	4.12	2.87	2.48

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): Soil moisture distribution (%) as affected by drip irrigation frequency during May.

Irrigation treatments	Soil depth (cm.)	1999-2000						2000-2001					
		After irrigation			Before irrigation			After irrigation			Before irrigation		
		Distance from emitter (cm.)											
		0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25
A	0-10	22.41	21.12	19.37	9.30	7.42	5.95	23.12	22.10	19.40	8.31	7.56	6.69
	10-20	20.62	19.71	17.56	7.41	6.13	4.91	21.41	20.13	18.56	7.41	6.05	5.32
	20-30	19.56	18.64	13.91	5.98	5.41	4.12	19.65	19.75	14.98	6.31	5.32	4.24
B	0-10	23.56	21.97	19.89	9.42	8.12	6.42	24.01	23.03	20.37	9.61	8.03	6.98
	10-20	21.91	20.62	18.36	8.14	6.91	5.51	21.51	21.41	19.49	8.32	7.31	5.43
	20-30	20.41	19.56	14.85	6.31	5.71	4.91	20.03	20.63	15.61	6.45	5.42	4.41
C	0-10	21.98	20.61	19.51	7.14	6.21	5.30	22.95	21.67	19.16	7.38	6.41	5.91
	10-20	19.89	13.91	17.62	6.59	5.16	4.21	21.01	19.88	18.39	6.64	5.33	4.81
	20-30	19.05	17.79	12.97	5.40	4.32	3.51	19.42	19.37	14.35	5.29	4.61	3.31
D	0-10	22.81	20.91	19.31	7.72	6.82	5.92	23.06	22.03	19.21	7.63	6.52	6.06
	10-20	19.98	19.65	17.30	7.12	5.54	4.51	21.32	20.06	18.42	6.69	5.39	4.52
	20-30	19.41	18.61	13.16	5.82	4.61	3.56	19.57	19.65	14.65	5.91	4.69	3.69
E	0-10	20.65	19.97	19.41	5.98	4.32	3.74	21.42	20.31	18.97	5.31	5.52	4.21
	10-20	19.42	19.02	16.72	4.91	3.91	3.56	19.98	19.83	17.31	4.52	4.53	3.69
	20-30	18.79	17.42	12.46	3.50	3.62	3.41	18.65	19.31	12.98	4.13	3.89	2.92

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 (10): Soil moisture distribution (%) as affected by drip irrigation frequency during June.

Irrigation treatments	Soil depth (cm.)	1999-2000						2000-2001					
		After irrigation			Before irrigation			After irrigation			Before irrigation		
		Distance from emitter (cm.)											
		0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25	0-5	5-15	15-25
A	0-10	22.34	20.31	19.42	8.65	6.36	5.32	22.98	21.26	18.98	8.21	7.42	6.22
	10-20	20.91	19.46	17.92	6.92	5.43	4.13	21.65	20.41	17.42	6.91	6.12	4.93
	20-30	19.54	18.39	13.98	5.95	5.21	3.75	18.16	18.32	13.97	5.89	3.46	4.06
B	0-10	22.98	20.91	19.23	8.72	6.65	5.62	23.31	21.98	19.76	8.41	7.54	6.42
	10-20	21.06	19.98	17.45	7.15	5.74	4.42	20.53	19.91	18.30	7.32	6.33	5.51
	20-30	19.41	18.72	14.02	6.34	5.31	3.93	19.46	19.31	15.12	6.31	4.11	4.21
C	0-10	21.89	20.41	18.65	6.98	5.61	5.43	22.13	20.86	19.32	7.41	6.21	5.02
	10-20	20.16	19.73	17.31	6.21	5.13	3.62	20.41	19.82	17.54	6.13	5.31	4.21
	20-30	18.46	17.42	13.42	5.31	4.31	3.12	18.56	17.68	13.20	5.62	4.30	3.51
D	0-10	22.13	20.86	19.43	7.32	5.91	5.89	22.23	21.85	19.41	7.72	6.71	5.41
	10-20	20.82	19.89	17.54	6.31	5.74	3.91	20.01	19.61	17.67	6.45	5.54	4.63
	20-30	18.61	18.71	13.98	5.65	4.63	3.62	18.65	17.89	13.62	5.71	4.38	3.56
E	0-10	20.94	20.32	19.01	5.43	4.98	4.21	20.94	20.12	19.21	5.43	4.92	4.74
	10-20	19.97	19.61	17.98	5.10	4.13	3.64	20.08	19.35	17.16	4.98	4.31	3.69
	20-30	18.04	17.63	12.56	4.51	3.42	2.98	19.61	17.41	11.98	3.56	3.82	3.21

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 (11): Weighed averages for soil moisture percentages, w/w, at 12.5 cm distance from emitter and at 15 cm soil depth.

Month		Treatments		1999-2000		2000-2001	
		After irrigation	Before irrigation	% depleted moisture	After irrigation	Before irrigation	% depleted moisture
January	A	11.28	6.88	4.40	12.17	7.05	5.12
	B	11.48	6.69	4.79	12.23	6.89	5.34
	C	9.98	5.12	4.86	10.76	6.10	4.66
	D	10.67	5.63	5.04	11.41	6.37	5.04
	E	8.69	3.97	4.72	9.10	4.25	4.85
	Average			**4.76**			**5.00**
February	A	12.40	6.18	6.22	14.51	7.56	6.95
	B	13.02	6.75	6.27	15.26	8.01	7.25
	C	11.00	5.35	5.65	13.12	6.39	6.73
	D	11.80	5.82	5.98	13.81	7.02	6.79
	E	10.59	3.81	6.78	12.20	4.86	7.34
	Average			**6.18**			**7.01**
March	A	15.00	7.90	7.10	16.51	7.45	8.66
	B	16.07	8.45	7.62	16.30	7.68	8.62
	C	13.68	6.35	7.33	14.32	5.39	8.93
	D	13.94	7.10	6.84	14.73	6.33	8.40
	E	12.01	4.48	7.53	11.83	4.82	7.01
	Average			**7.28**			**8.40**
April	A	19.08	5.57	13.51	18.82	5.10	13.72
	B	20.06	6.58	13.48	19.42	5.67	13.75
	C	18.20	5.14	13.07	18.30	4.51	13.79
	D	18.51	5.36	13.15	18.37	4.67	13.70
	E	16.64	4.11	12.53	17.57	3.82	13.75
	Average			**13.15**			**13.74**
May	A	18.88	6.04	12.84	19.62	6.16	13.46
	B	19.76	6.60	13.16	20.44	6.64	13.80
	C	17.71	5.10	12.61	19.27	5.34	13.93
	D	18.05	5.50	12.55	19.47	5.46	14.01
	E	17.92	3.97	13.95	18.50	4.23	14.27
	Average			**13.02**			**13.89**
June	A	18.78	5.44	13.34	18.90	5.70	13.20
	B	18.94	5.70	13.24	19.47	6.02	13.45
	C	18.29	4.86	13.43	18.53	5.08	13.45
	D	18.83	5.25	13.58	18.73	5.36	13.37
	E	18.21	4.12	14.09	18.07	4.22	13.85
	Average			**13.54**			**13.46**

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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الإحتياجات المائية للفلفل الحلو النامي في الصوب البلاستكية تحت ظروف منطقة العريش:
٢-نمط توزيع الرطوبة الأرضية.

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تناول موضوع البحث دراسة تأثير بعض معاملات الري على توزيع الرطوبة ودراسة النتح بخر لنبات الفلفل الحلو تحت نظم الري بالتنقيط.

أجريت التجربة بالمزرعة التجريبية لكلية العلوم الزراعية البيئية بالعريش جامعة قناة السويس خلال الموسم الصيفي المبكر لموسمي ١٩٩٩/٢٠٠٠ – ٢٠٠٠/٢٠٠١ م . حيث زرعت نباتات الفلفل الحلو صنف سونار بالصوب البلاستيكية (٩ × ٦٠م).

تم استخدام خمس معاملات للري كالآتي:
-المعاملة (أ): الرى مرة واحدة يومياً.
-المعاملة (ب): الرى مرتين بنفس الكمية يومياً (نصف الكمية صباحاً ونصف الكمية مساءً).
- المعاملة (ج): الرى مرة واحدة كل يومين.
- المعاملة (د): الرى مرتين بنفس الكمية كل يومين (نصف الكمية صباحاً ونصف الكمية مساءً).
- المعاملة (هـ): الرى مرة واحدة كل ثلاثة أيام.

وقد رويت كل معاملة من المعاملات السابقة بكمية مياه واحدة لكل منها في كل ريه والتي تزايدت تدريجياً من شهر ديسمبر حتى شهر يونيو.

نفذت التجارب باستخدام تصميم القطاعات كاملة العشوائية في ثلاث مكررات وكانت مساحة الوحدة التجريبية ١٨ م٢ (١٠م طول × ١,٨ م عرض). وكانت المسافة بين النباتات في نفس الخط ٥٠ سم. وزرعت النباتات في ٢٥ ديسمبر وبدأ الحصاد بعد (١٢١) يوم من زراعة الشتلة واستمر موسم الجمع لمدة (٦٧) يوم في كل من الموسمين.

وتتلخص النتائج المتحصل عليها في الآتي:-
– تأثير معاملات الري على:

١-النتح-بخر الفعلي:

ازداد النتح-بخر الكلي تدريجياً من بداية موسم النمو حتى الحصاد وأعطت معاملة الري (ب) أعلى قيمة للنتح-بخر الكلي ، تليها المعاملات (أ)، (د)، (ج)، (هـ) على التوالي.

٢- توزيع الرطوبة في التربة:

تناقصت الرطوبة في التربة بزيادة العمق والمسافة من النقاطات قبل وبعد الري وقد تزايدت الرطوبة في التربة تدريجياً من بداية موسم النمو وحتى الحصاد نتيجة لتزايد كميات مياه الري وكان ترتيب المتوسط الموزون للرطوبة لمعاملات الري هو ب>أ>ج>د>هـ. وبالتالي يوصى بإستخدام المعاملة (ب) للري حيث أعطت أفضل النتائج وعدم إستخدام المعاملة (هـ) للري حيث أعطت أقل النتائج.