Effect of Pulse Trickle Irrigation on Soil Moisture Distribution Patterns, Irrigation Efficiencies and Sunflower Productivity in Sandy Soils

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ABSTRACT

Two successive growing seasons of sunflower production were conducted at Yashaa village Al-Intlaq, West Delta, Egypt during 2009 and 2010 for evaluating either soil moisture distribution patterns or sunflower yield under pulse irrigation technique. The split plot design with 4 replicates was used to achieve the study objectives, main plots were frequency treatments (daily "D_1", every 2 days "D_2" and every 3 days "D_3") and subplots as times events were pulse (P) (10 min on 10 min off) and continuous (C) irrigation treatments.

Results indicated that the average amount of water was 3033.31 m^3/fed for both treatments. Also there were no significant differences between the two irrigation techniques and the three irrigation period on saving applied water. The pulse trickle irrigation gave a good distribution of moisture content within the root zone, especially with irrigation every two days (D_2) before and after irrigation during the different stages of plant growth.

The pulsing trickle irrigation had the highest yield, and yield components. Also the lowest performance was obtained by the continuous treatment. The trend obtained indicates that every 2 days trickle irrigation might improve yields and yield components. The results revealed that the water use efficiency increased as the irrigation frequency increased from D_1 to D_2 with percent of 12.3 % then decline for D_3 with percent of 27.0 %.

The results indicate that the application of pulsed irrigation led to improve the water storage efficiency in the effective root zone compared to the continuous irrigation, although the continuous irrigation led to improvement of efficiency in the depths away from the root zone and horizontal distances not far to the emitter. The results refer that there is no significant differences between daily irrigation D_1 and irrigation every two days D_2 but water storage efficiency, significantly decreased with irrigation every three days D_3 under both pulsed trickle irrigation and continuous irrigation

Keywords: frequency, performance, water requirement, yield components, storage efficiency

INTRODUCTION

Oil crops are the source of edible and industrial oil with a wide variety of uses as well as of protein meals. Oleic sunflower (*Helionthus annuus* L.) is one of the major oil crops in Egypt. The local variety of sunflower and other oil crops production does not meet the current demand for oils, and each year additional amounts have to be imported. The rapid growth of the country's population, the economic stress of reliance on food imports, and the limited area for agriculture (most of the country is a desert) require Egyptians to adapt new techniques to increase agricultural production in general and oil crops in particularly. These also require small amounts of water consumption to the root zone of plants and apply an irrigation technique to penetrate the full depth of the root zone, without passing below the root zone or running off at the surface and being wasted.

El- Gindy et al. (2001a and b) cited that irrigation systems, irrigation water amounts and timing had the majority of reducing run off losses, decreasing percolation of water beneath the root zone and reducing water evaporation.

Literature reviews showed that pulse technique may decrease water losses and increase crop production. Pulse irrigation is suggested as an irrigation technique for achieving a relatively low application rate while using an irrigation device with a higher application efficiency. Complete pulse irrigation is composed of a series of irrigation time cycles where each cycle includes two phases: the operating phase followed by the resting or nonoperative phase, Karmeli and Peri (1974).

Zin El-Abedin (2006) evaluated the effects of the traditional and the pulse trickle irrigation (5 min on 5 min off) on the process of soil water depletion, replenishment, distribution pattern, application efficiency, emission uniformity, distribution efficiency, crop yield characteristics and water use efficiency for maize crop. He found that the pulse trickle irrigation was highly significant than that continuous trickle irrigation technique for each of efficient of uniformity (Eu.) and efficient of distribution (Ed.) The root distribution for pulse trickle irrigation was higher than the continuous trickle irrigation by 3.28%.

Mostaghimi and Mitchell (2007) found that pulse applications resulted in significant reduction in water loss below the root zone. Pulse applications rates can replace continuous small discharge rates to reduce irrigation water runoff problems on heavy soils and with restricted infiltration allow the use of larger emitter orifices to decrease potential clogging of the trickle system.

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Segal et al. (2000) found that pulsating can be applied in any irrigation systems however, is primary applicable in trickle irrigation one. Also, they found that the higher the irrigation frequency, the smaller the soil wetting volume and the higher soil water content in a small range can be maintained. High irrigation frequency might provide desirable conditions for water movement in soil and plant uptake by root. In their study some crops have positive responses to high frequent trickle irrigation.

The pulse-irrigated plants tented to accumulate less daily water stress: plants grew faster and remained healthier than plants that were stressed on daily basis. Another benefit is that disease prevention is less difficult. Alternatively the major drawback with pulsing is the possible increase of soluble salts. To prevent this, low level of fertilizer in solution keep soluble salts from building up rapidly in the media and reduce the need for leaching (Beeson 1992).

Sunflower is a crop of medium water requirement. The water requirements of sunflower vary from 600 to 1000 mm, Evapotranspiration increases form Development to flowering, and can be as high as 12 to 15 mm/day. High evapotranspiration rates are maintained during seed setting and early ripening period. Percentage of total crop water use over the different growth period is about 20 percent during vegetative period, 55 percent during flowering period and the remaining 25 percent during yield formation and ripening period. The crop coefficient (Kc) equals to 0.3-0.4 at initial stage (15 to 30 days), 0.7 – 0.8 at the crop Development stage (35 to 40 days), 1.05 – 1.2 at the mid-season stage (40 to 50 days), and 0.7 – 0.8 at the late -season stage (20 to 25 days) and 0.4 at harvest stage. (Doorenbos and Kassam 1979).

The aims of this study were to:

a) Compare between both pulse trickle irrigation and continuous trickle irrigation techniques in terms of the moisture distribution within the soil sector, application, emission, distribution and storage efficiencies.

b) Evaluate the effect of both previous irrigation techniques on the sunflower yield, yield components, irrigation system performance and water use efficiency.

MATERIALS AND METHODS

Filed experimental site:

Sunflower (cv. Sakha 53) was grown in an experimental field at Yashaa village, Al- Antlaq area, West Delta, Egypt from 26 June to 23 Oct. 2009 and 25 June to 22 Oct 2010 using recommended agricultural practices for the region. Some soil physical properties were determined according to Black et al. (1982) such as organic matter (O.M),. bulk density (B.D), saturated moisture content (θ_σ),. field capacity (F.C),permanent welting point (P.W.P), available water (AW) and saturated hydraulic conductivity (k_s) Results of the soil physical properties are presented in Tables (1)

The field was plowed, and leveled to provide a smooth seedbed. The field had a fairly constant slope of 0%. Presowing management included application of 100, 150, and 50 kg/faddan N, P, and K, respectively. and weeds control. Sowing was on 26 June, at 3 seeds per hill, with a distance of 0.25 m between hills and 1.0 m between rows. The pressure at lateral inlet, outlet and emitter were measured by pressure gauge. The actual emitter flow rate was evaluated by using the stop watch and cans, after divided the lateral lines into four quarters. Average discharge, the lowest four discharges and the general average discharge were calculated.

On this basis, the emission uniformity (E_u) of water emitted from the drippers was calculated according to karmeli and keller (1975) as follows:

$$E_u = \frac{q_{lowest}}{q_{general}} \times 100 \text{ ------------------ } (1)$$

E_u = emission uniformity, %

q_{lowest} = average of low-quarter for emitter discharge, l/day

$q_{general}$ = general average discharge of the emitter, l/day

Also the application uniformity (Ea) was calculated as 90% of emission uniformity (Eu) on the basis that the deep percolation, evaporation and losses in runoff are currently only 10% Karmeli and Keller (1975) as follows:

$$Ea = E_u \times 0.9 \text{ ------------------------------- } (2)$$

Table 1. Some soil physical properties for the experimental site

Soil depth (cm)	Particle size distribution (%)			Soil texture class	O.M %	BD gcm^{-3}	θ_σ m^3m^{-3}	FC m^3m^{-3}	PWP m3m-3	AW m^3m^{-3}	k_s mm h^{-1}
	Sand	Silt	Clay								
0.0-30	90.6	3.5	5.9	Sandy	0.58	1.54	0.530	0.152	0.071	0.087	199.01
30-60	90.1	3.7	5.8	Sandy	0.57	1.54	0.530	0.154	0.070	0.084	193.01
Aver.	90.55	3.6	5.85	Sandy	0.575	1.54	0.530	0.156	0.071	0.086	196.01

The irrigation applied was scheduled using combined pan evaporation and growth stage based crop coefficient, according to recommended irrigation practice for the region. The crop water consumption (Cu) in liters per day was calculated (Ismail, 2002) as follows:

$$Cu = ET_o \times K_c \times A \qquad l/day \quad \text{---------} (3)$$

Cu= the crop water consumption, l/day

K_c= crop coefficient

A= irrigated area for plant, m^2

The estimated time of irrigation per hour was calculated as follows:

$$T_i = \frac{Cu}{N \times Q_{dripper} \times E_a(1 - LR)} \qquad hour/day \quad \text{--------}(4)$$

T_i = time of irrigation, hr/day

N = number of emitter per lateral.

$Q_{emitter}$ = discharge of emitter, l/hr

LR = leaching requirement to keep soil salinity within tolerable limits for crop production was calculated according to Doorenbos and Pruitt 1977 as follows:

$$LR = \frac{EC_{iw}}{2(\max \ EC_e)} \quad \text{-------------------------} (5)$$

Where: EC_{iw}: the electrical conductivity of irrigation water (dS/m) and max EC_e

The electrical conductivity of irrigation water used and the soil saturation paste for sunflower crop soil were 4.8 and 43.5 ds/m, respectively.

ET_o= potential evapotranspiration, mm/day was calculated by using the climatic weather data of Nobaria meteorological weather station according to Penman-Monteith (Allen et.al., 1998).

During the growing season, the soil water content distribution with depth was determined gravimetrically to a depth of 0.60 m at 0.20 m intervals at three locations (near the lateral's inlet, at the middle and near the end). Each location was represented by 6 emitters. The soil samples were taken at 6 points for each emitter, addition to one place under the emitter to calculate the soil moisture content. The soil moisture content was measured before irrigation around the selected emitters for each point.

Applied water of irrigation *(Wa)*

Applied water of irrigation (Wa) was calculated as follow

$$Wa = N \times Q_{dripper} \times T_i \qquad m^3/lateral \quad \text{-----}(6)$$

• Where *Wa* is water volume per lateral (m3/ lateral); Q is discharge of emitter (m^3/hr); N is number of emitters / lateral and T_i is total irrigation time recorded by stop watch (hr);

The series of irrigation time cycles for pulsing tickle irrigation

An experiment was conducted to determine the most appropriate on and off time, the results obtained that the most appropriate time is 10 min on and 10 min off for the following reasons:

1- The time of irrigation at the initial stage of plant age was small,
2- 5 minutes on and off to start not enough amount of water absorbed by soil and difficult application.
3- 15 minutes can not be applied with the early stages of plant age.

Experimental design

The experimental design (Fig. 1) was carried out through a split plot design (SPD) with four replicates was used with one variable each irrigation alone, two treatments of pulsing (10 minutes on and 10 minutes off) and continuous applications were used to represent the main plots. Three different irrigation period represented the sub-plots. Four replicates distributed randomly. A strip with ten emitter line considered as one specified treatment. The treatments can be summarized as

A- Main plot, included three irrigation frequencies, employing one trickle line per row.

1- Daily irrigation (D_1)
2- Irrigation every 2 days (irrigation one applications day followed by resting one day) (D_2)
3- Irrigation every 3 days (irrigation one day followed by resting two days) (D_3)

B- The sub-plots included two application methods for applying water of irrigation

1- pulse trickle irrigation (P) with (10 minutes irrigate, 10 minutes wait, repeated until the completion of irrigation water to be supplied).
2- The other, continuous supply (C) (commonly supplied in the region),

Only the two central rows were used for sampling for each treatment.

Yield and yield components.

At harvest, the sample of plants (2 m of the row × 0.75 m width of the row = 1.5 m^2) of the two central ridges.

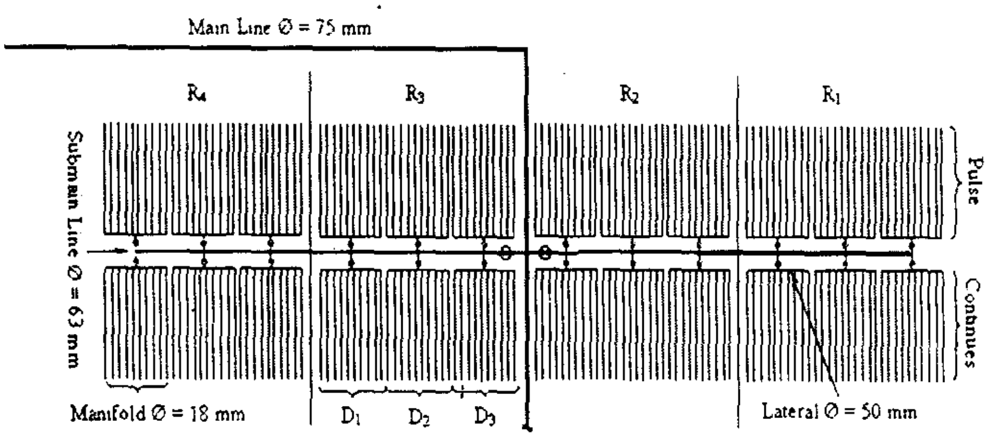

Figure 1. Experimental networks layout

These samples were uprooted from each treatment randomly and topped to determine head diameter, stem diameter, weight of 100 seeds, oil yield, protein yield and total seeds yield per faddan. The total yield per faddan was calculated as follows:

$$Total\ yield\ per\ faddan = \frac{sample\ seeds\ weight\,(g) \times 4200}{sample\ area\,(m^2) \times 1000}\ (kg/fad) \text{---} (7)$$

Water use efficiency

The water use efficiency (WUE) was calculated according to Jensen (1983) as:

$$WUE = \frac{Average\ yield\,(kg\ seeds/fad)}{Applied\ water\,(m^3/fad)}\ (kg\ seeds/m^3) \text{----}(8)$$

The storage efficiency

The storage efficiency (E_s) can be calculated according to Michael. (1978) as follows:

$$E_S = \frac{W_S}{W_n} \times 100$$

W_s = water stored in the root zone

W_n= water needed in the root zone

$$W_n = C_e \left(\frac{Fc - PWP}{100}\right) \times BD \times D_{Root}$$

C_e = extraction for high yield ≅ 75%

Fc = field capacity of the soil

PWP= permanent welting point

Data analysis

The data were analyzed using Costat 6.311 win statistical program CoHort Software (2005). Average values from the three replicates of each treatment were interpreted using the analysis of variance (ANOVA). The Duncan's Multiple Range Test (SNK) was used for comparisons among different sources of variance.

RESULTS AND DISCUSSION

Crop Water Consumptive Use (Cu)

The irrigation system at this study was managed to supply the potential evapotranspiration of sunflower based on the appropriate crop coefficient and reference crop evapotranspiration. The daily weather data were collected at Nobaria Meteorological Station to calculate ET_o (water consumptive use mm/day) for each day. Data in Table (2) represented the average consumptive use Cu (mm/month) during the growth season. The results demonstrated that a maximum crop water requirement was 8.24 mm/day during the mid season. It could be noticed that, the daily crop evapotranspiration values were varied as the climatic conditions and plant growth stages were changed. Initially, the rate of crop water requirement was low, and then increased and reached its maximum value (224.07mm) at the end of flowering stage (August month) 75-80 days after the planting date.

Total of Irrigation Water

The amounts of water applied to the sunflower crop as average in the two seasons are presented in Tables 4 and 5. The amount of water applied for pulse and continues irrigation were calculated for D_1, D_2 and D_3 (m^3/ fed). The irrigation time was used as controlling tool of the volume of applied water. The data that tabulated in Tables 4 and 5 give us an idea about the amounts of applied irrigation water. The results revealed that the volume or depth of applied water increased with the growth of the plant then turned down at the end of the growth season. The seasonal irrigation water applied (irrigation methods × irrigation frequency) was 2997.3, 3025.7 and 3043.2 m^3/fed under pulsing trickle irrigation and 3026.47, 3039.26 and 3061.93 m^3/fed under continuous trickle irrigation for D_1, D_2 and D_3 respectively. The average amount of water values was

3022.07 m^3/fed for pulsing trickle irrigation while was 3044.55 m^3/fed for continuous trickle irrigation. The average amount of applied water for the irrigation frequency were 3011.89, 3035.48 and 3052.57 for D_1, D_2 and D_3 respectively.

The irrigation frequencies do not have a significant effect on the amount of the applied irrigation water which illustrated by the data in table (3 and 4).

The results showing that, there was no significant differences between the two irrigation techniques also between the three irrigation frequencies on saving applied water as shown in table (3 and 4).

Table 2. Calculated consumptive use (mm/day) of sunflower using

Growth Stage	Growth period	Calculated ET_o mm/day	Crop coeff., K_c	Actual Cu mm/day	Water consumptive use .mm/month	.mm/season
Initial St	6 days Jun	5.50	0.31	1.68	10.07	40.36
	14days July	5.63	0.38	2.16	30.29	
Development St	17 days July	6.02	0.71	4.25	72.23	178.31
	18 days Aug	7.37	0.80	5.90	106.08	
Mid-season St	13 days Aug	7.62	1.08	8.24	107.15	343.94
	30 days Sept	6.24	1.20	7.47	224.07	
	2 days Oct	5.30	1.20	6.36	12.72	
Late season St.	20 days Oct	5.38	0.67	3.58	71.55	71.55
				Total	634.16	634.16

Table 3. The amounts of water applied to the sunflower crop as an average in the two seasons for pulsing irrigation

Day	June			July			August			September			October		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
1				8.35	16.7	25.0	24.4	0.00	0.00	36.8	73.7	0.00	31.51	63.02	0.00
2				9.36	0.00	0.00	26.7	53.4	0.00	37.1	0.00	111.55	29.22	0.00	87.66
3				9.69	19.3	0.00	28.6	0.00	85.9	34.9	69.8	0.00	19.38	38.77	0.00
4				9.69	0.00	29.0	26.7	53.4	0.00	36.0	0.00	0.00	18.72	0.00	0.00
5				11.4	22.9	0.00	28.2	0.00	0.00	40.1	80.2	120.32	16.38	32.75	49.13
6				11.0	0.00	0.00	29.7	59.5	89.3	45.8	0.00	0.00	16.04	0.00	0.00
7				12.2	24.4	36.6	27.8	0.00	0.00	45.8	91.6	0.00	16.71	33.42	0.00
8				10.8	0.00	0.00	30.5	61.1	0.00	40.1	0.00	120.32	17.38	0.00	52.14
9				10.5	21.0	0.00	24.8	0.00	74.4	42.9	85.9	0.00	22.92	45.83	0.00
10				10.3	0.00	30.9	29.0	58.0	0.00	42.4	0.00	0.00	20.63	0.00	0.00
11				9.93	19.8	0.00	26.3	0.00	0.00	42.4	84.7	127.19	21.39	42.78	64.17
12				10.1	0.00	0.00	26.7	53.4	80.2	42.9	0.00	0.00	21.01	0.00	0.00
13				10.6	21.3	32.0	24.8	0.00	0.00	36.6	73.3	0.00	21.77	43.54	0.00
14				10.3	0.00	0.00	29.4	58.8	0.00	33.2	0.00	99.6	21.39	0.00	64.17
15				19.0	38.1	0.00	30.5	0.00	91.6	34.3	68.7	0.00	21.39	42.78	0.00
16				18.3	0.00	55.1	29.0	58.0	0.00	37.2	0.00	0.00	22.15	0.00	0.00
17				18.7	37.4	0.00	30.9	0.00	0.00	34.3	68.7	103.13	11.39	22.77	34.16
18				17.3	0.00	0.00	31.7	63.4	95.1	30.3	0.00	0.00	11.39	0.00	0.00
19				17.3	34.7	52.1	37.6	0.00	0.00	32.6	65.3	0.00	10.96	21.91	0.00
20				19.0	0.00	0.00	39.1	78.2	0.00	32.6	0.00	97.9	0.00	0.00	32.23
21				20.1	40.3	0.00	40.1	0.00	120.32	31.5	63.0	0.00	0.00	0.00	0.00
22				20.3	0.00	61.1	37.6	75.2	0.00	26.3	0.00	0.00	0.00	0.00	0.00
23				18.7	37.4	0.00	35.0	0.00	0.00	30.3	60.7	91.1			
24				20.3	0.00	0.00	40.1	80.2	120.32	32.0	0.00	0.00			
25	8.1	16.3	24.4	22.3	44.7	67.1	42.0	0.00	0.00	32.0	64.1	0.00			
26	7.5	0.00	0.00	20.7	0.00	0.00	39.9	79.8	0.00	31.5	0.00	94.5			
27	7.7	15.4	0.00	21.3	42.7	0.00	42.0	0.00	126.05	32.6	65.3	0.00			
28	8.4	0.00	25.3	23.3	0.00	70.1	39.3	78.7	0.00	30.3	0.00	0.00			
29	7.8	15.7	0.00	20.7	41.4	0.00	35.1	0.00	0.00	32.6	65.3	97.9			
30	8.1	0.00	0.00	21.3	0.00	0.00	42.0	84.0	126.05	30.9	0.00	0.00			
31				25.5	51.1	76.7	41.3	0.00	0.00						
Total	48	47.5	49.8	489.	514	536.	1018	995.	1009.5	1069.8	1080.9	1063.8	371.7	387.5	383.6
											Total season		2997.3	3025.7	3043.2

Table 4. The amounts of water applied to the sunflower crop as an average in the two seasons for continuance irrigation

Day	June			July			August			September			October		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
1				8.45	16.90	25.80	25.00	0.00	0.00	38.0	74.0	0.00	31.8	64.0	0.00
2				9.50	0.00	0.00	26.80	53.55	0.00	37.4	0.00	111.75	29.7	0.00	88.0
3				9.80	19.40	0.00	28.75	0.00	86.0	35.0	70.0	0.00	19.6	38.9	0.00
4				9.85	0.00	29.25	26.90	53.55	0.00	36.4	0.00	0.00	19.0	0.00	0.00
5				11.60	23.00	0.00	28.70	0.00	0.00	40.4	80.5	121.00	16.4	33.0	49.8
6				11.20	0.00	0.00	30.00	59.80	89.5	46.0	0.00	0.00	16.5	0.00	0.00
7				12.30	24.60	36.80	27.95	0.00	0.00	46.0	92.0	0.00	16.5	33.4	0.00
8				11.00	0.00	0.00	30.75	61.45	0.00	40.5	0.00	121.00	17.7	0.00	52.5
9				10.65	21.00	0.00	24.95	0.00	74.4	43.0	85.9	0.00	23.0	46.0	0.00
10				10.50	0.00	31.2	30.05	58.75	0.00	42.7	0.00	0.00	20.7	0.00	0.00
11				10.00	20.01	0.00	26.65	0.00	0.00	42.8	85.0	127.65	21.6	42.9	64.3
12				10.30	0.00	0.00	26.95	53.80	81.0	43.0	0.00	0.00	21.3	0.00	0.00
13				10.80	21.60	32.40	24.90	0.00	0.00	36.8	73.5	0.00	21.8	43.5	0.00
14				10.60	0.00	0.00	29.80	60.00	0.00	33.4	0.00	100.0	21.5	0.00	64.2
15				19.35	38.30	0.00	31.75	0.00	91.9	34.7	68.1	0.00	21.6	42.8	0.00
16				18.40	0.00	55.35	29.55	58.46	0.00	37.2	0.00	0.00	22.3	0.00	0.00
17				18.75	37.50	0.00	31.00	0.00	0.00	34.7	68.9	103.65	11.8	22.8	34.4
18				17.50	0.00	0.00	31.90	63.65	95.7	30.8	0.00	0.00	11.8	0.00	0.00
19				17.48	34.90	52.10	37.90	0.00	0.00	32.8	65.7	0.00	11.0	22.0	0.00
20				19.25	0.00	0.00	39.55	78.55	0.00	33.0	0.00	101.0	0.00	0.00	32.5
21				20.20	40.35	0.00	40.75	0.00	121.00	32.0	63.5	0.00	0.00	0.00	0.00
22				20.50	0.00	61.16	37.90	75.65	0.00	26.4	0.00	0.00	0.00	0.00	0.00
23				18.76	37.50	0.00	35.85	0.00	0.00	30.6	60.8	92.35			
24				20.55	0.00	0.00	40.55	80.67	121.00	32.1	0.00	0.00			
25	8.80	16.2	24.5	22.35	44.90	67.40	43.00	0.00	0.00	32.5	64.7	0.00			
26	7.75	0.00	0.00	20.75	0.00	0.00	40.00	80.00	0.00	31.8	0.00	95.00			
27	7.75	15.5	0.00	21.55	42.85	0.00	42.45	0.00	126.75	32.8	65.3	0.00			
28	8.60	0.00	25.4	23.40	0.00	70.18	40.00	80.00	0.00	30.5	0.00	0.00			
29	7.85	15.8	0.00	21.00	41.60	0.00	35.35	0.00	0.00	32.8	65.4	100.0			
30	8.30	0.00	0.00	21.40	0.00	0.00	42.55	84.75	126.85	31.0	0.00	0.00			
31				25.75	51.36	76.70	41.50	0.00	0.00						
Total	49.05	47.5	49.9	493.4	515.7	538.3	1029.7	1002.6	1014.36	1077.9	1083.74	1073.40	376.33	389.51	385.88
											Total season		3026.47	3039.26	3061.93

The distribution of soil moisture

Figures 2 up to 5 shows the dimensions of the wetted soil volume for both pulsing and continuous irrigation. Data were taken at peak of water consumption for the crop at the mid and last stages before and after irrigation. In the top 30 cm depth of the sandy soil for D_1, D_2 and D_3, the boundaries of the wetted soil volume are reasonably well defined and are surrounded by drier soil. It can be noted from the contour plots that the volumetric soil water content distribution within the wetter volumes are uniform, it decreased with the radial distance from the irrigation water source. A close observation of the wetting fronts showed that the irrigation frequency had an effect on its horizontal location from the emitter. The maximum value of moisture content was below the emitter at any depth for all treatments. Through horizontal distance, pulsed irrigation improved the distribution of soil moisture along the soil covering the root zone, while soil moisture was distributed near the emitter and the extension was limited with continuous irrigation, especially with the daily irrigation (D_1). On the other hand, the continuous irrigation gives the high values of moisture contents in the direction of the depth of the soil after 60 cm depth of irrigation; while the same values of the soil moisture contents under pulse irrigation was observed at depth of 45-50 cm with good distribution. The extents of the wetting fronts were induced as compared to depth pulsing irrigation and the locations were about at 45, 75 and 85 cm for D_1, D_2 and D_3, respectively. From the above we find that the pulse irrigation gave a good distribution of moisture within the root zone, especially with irrigation every two days (D_2) before and after irrigation during the different stages of plant growth. The possible reason for the above might be the movement of more water to a deeper layer at continuous irrigation.

While the impact of irrigation frequencies on the distribution of moisture, the irrigation every two days (D_2) gives uniform distribution of moisture. The location of the maximum percent volumetric moisture content was below the emitter with different depths for D_1, D_2 and D_3.

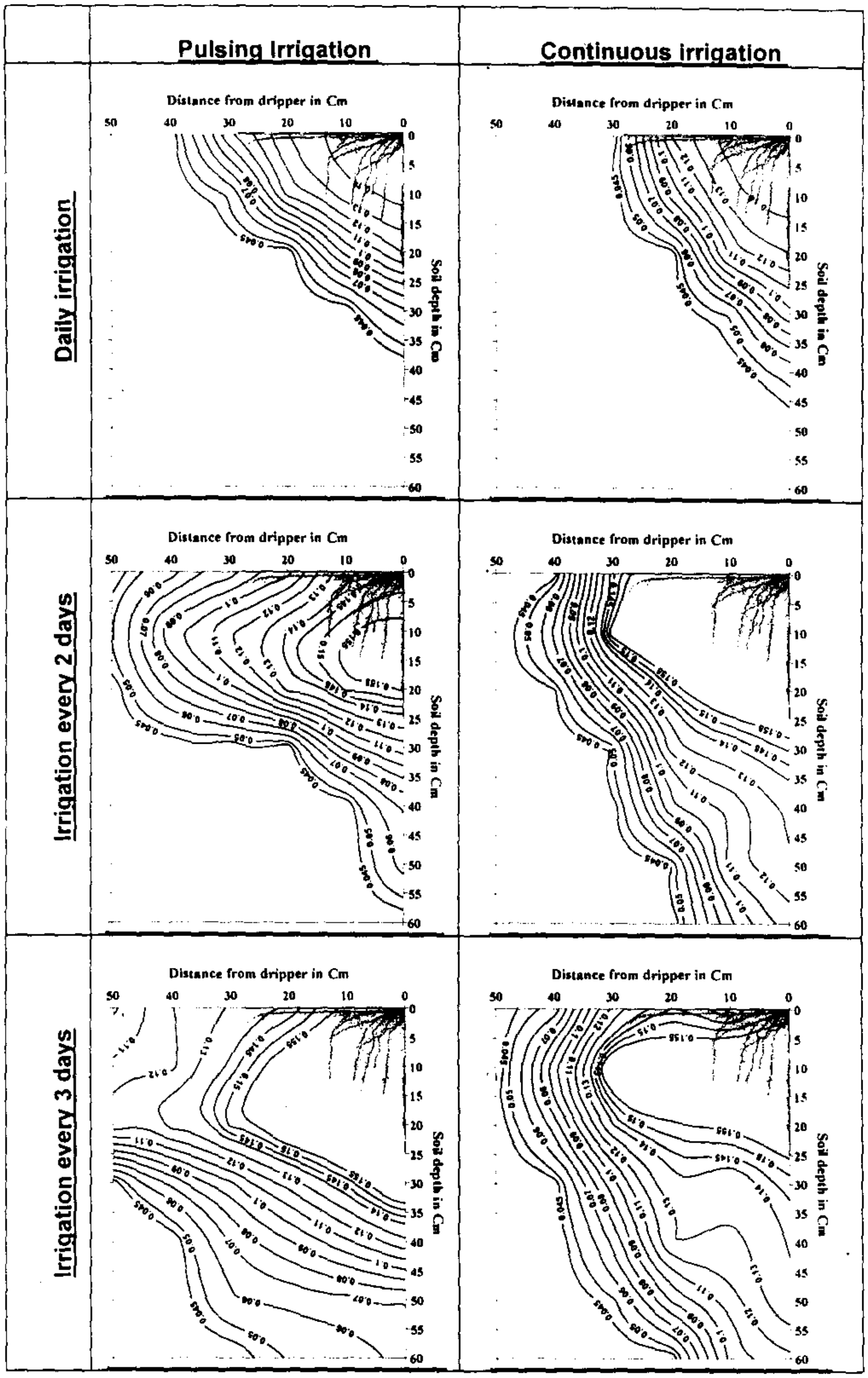

Figure 2. Redistribution of volumetric soil moisture content for both pulsing and continuous irrigation after irrigation at peak of water consumption for the crop (mid stage)

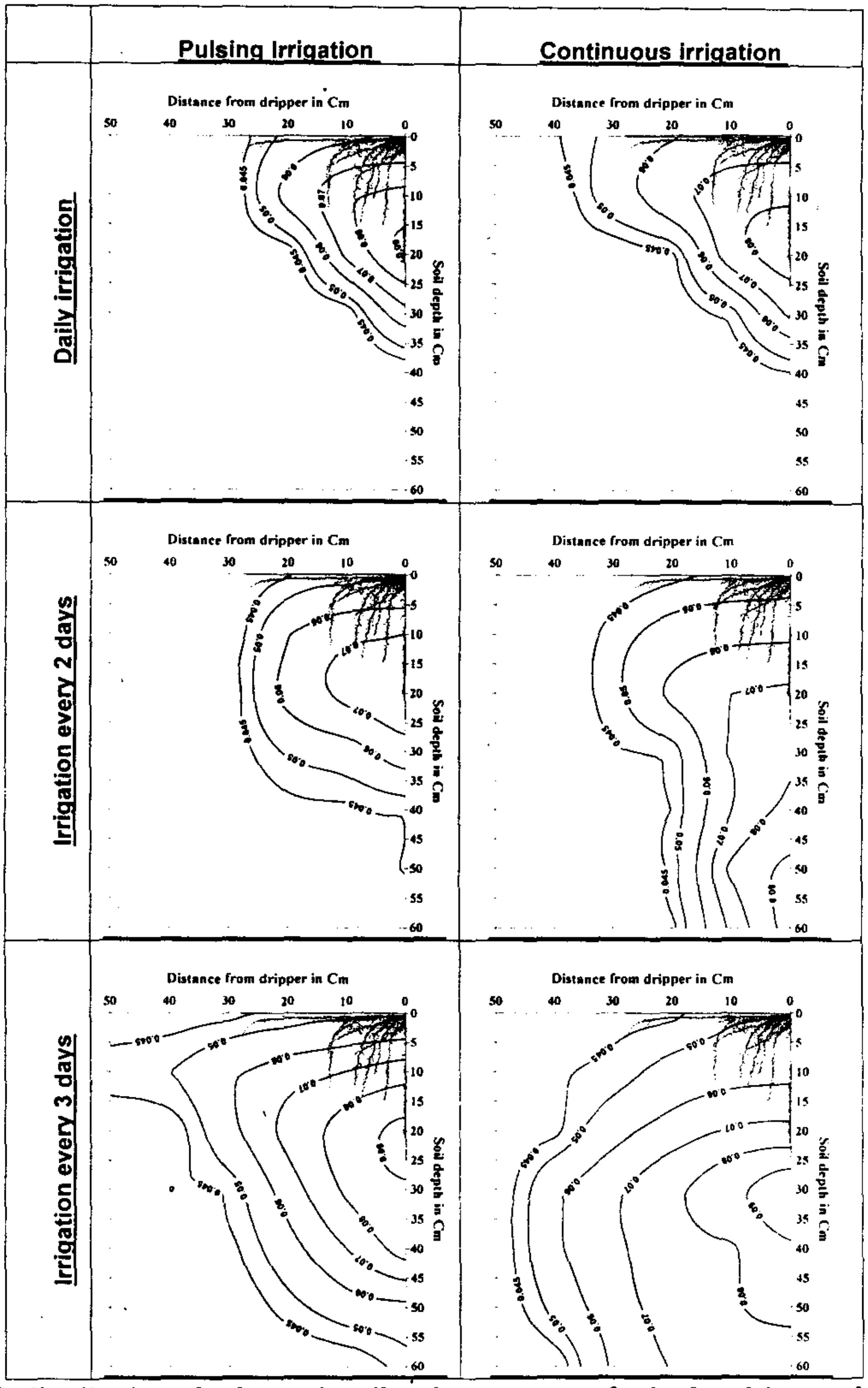

Figure 3. Redistribution of volumetric soil moisture content for both pulsing and continuous irrigation before irrigation at peak of water consumption for the crop (mid stage)

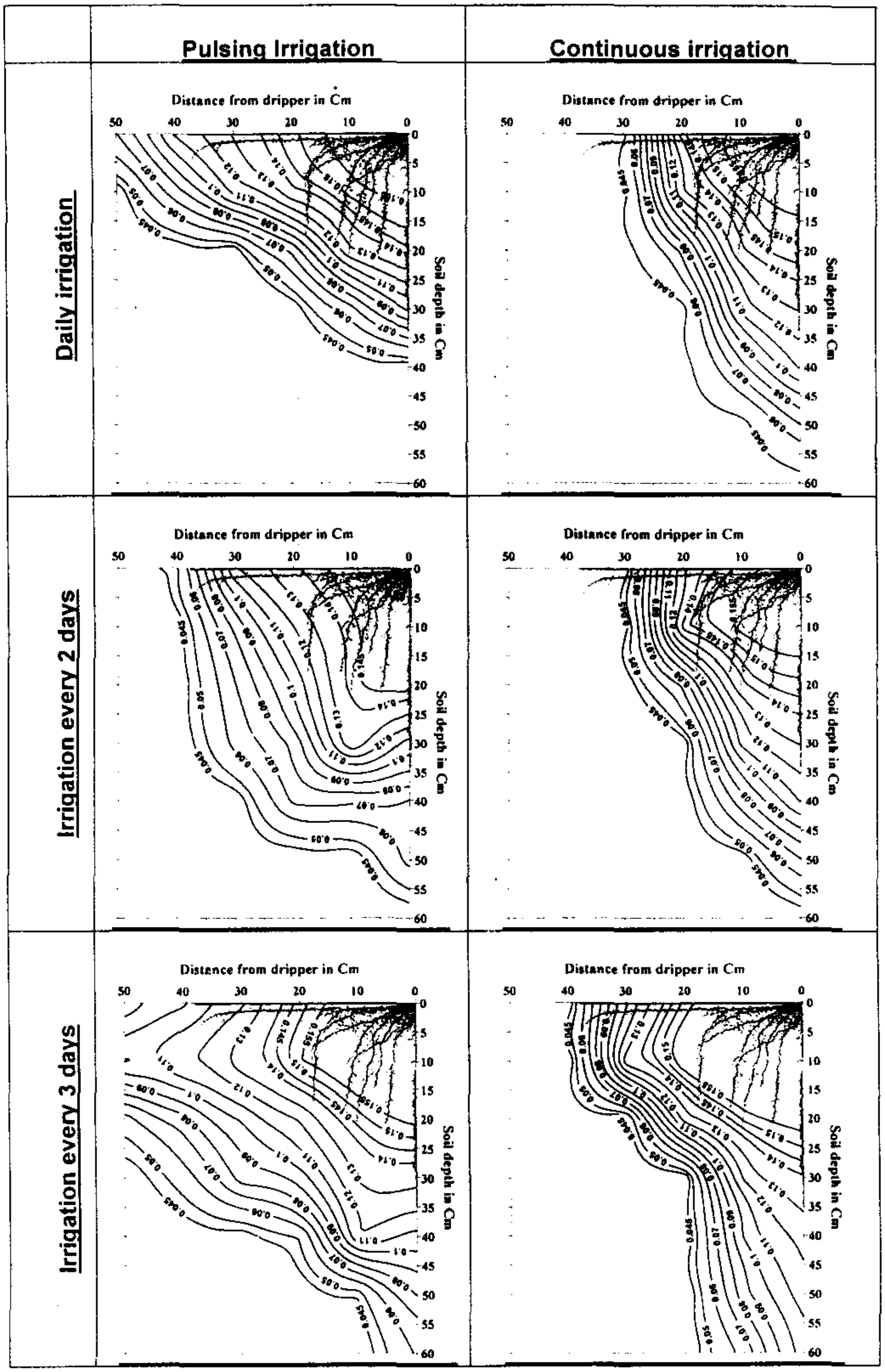

Figure 4. Redistribution of volumetric soil moisture content for both pulsing and continuous irrigation after irrigation at peak of water consumption for the crop (last stage)

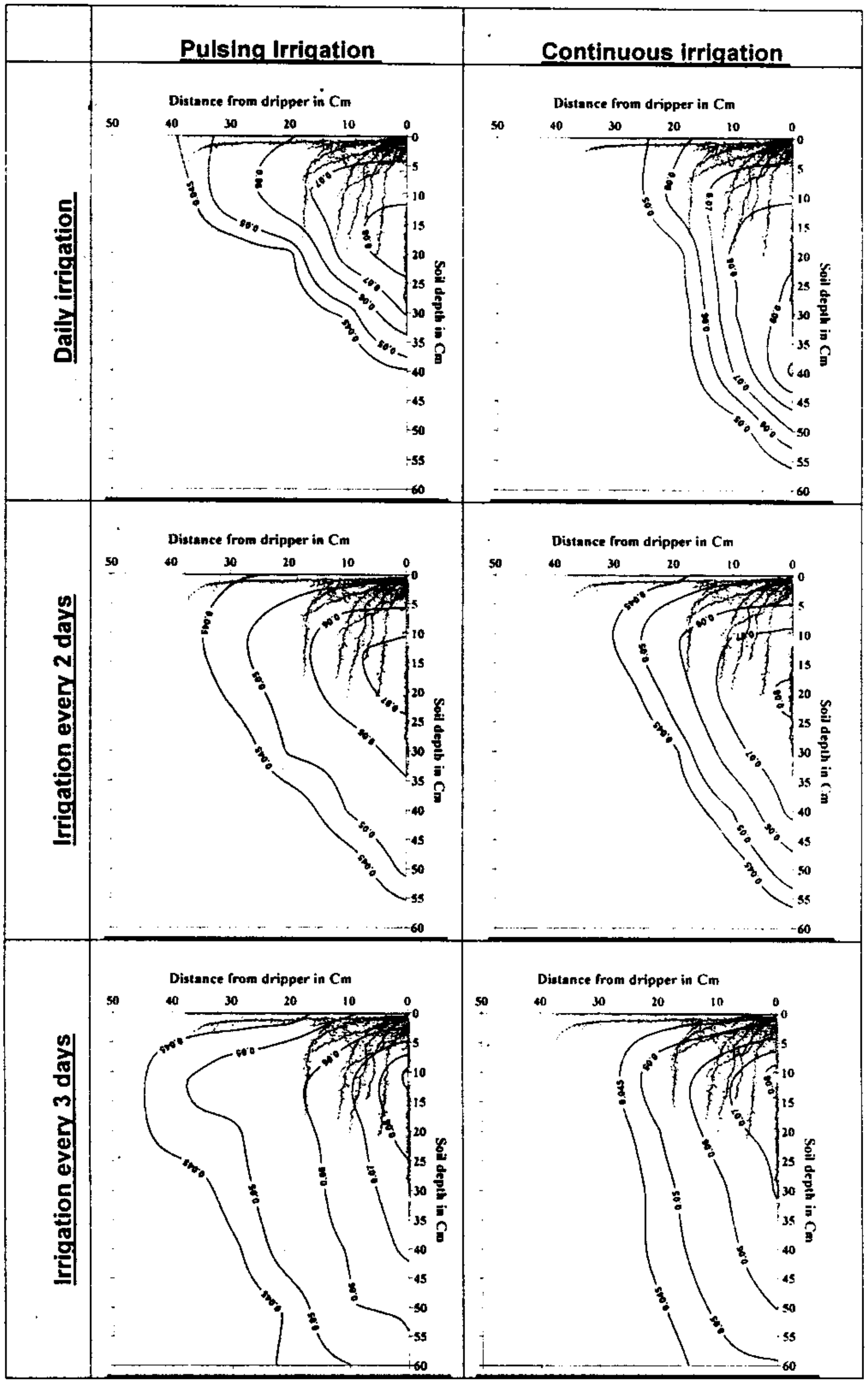

Figure 5. Redistribution of volumetric soil moisture content for both pulsing and continuous irrigation before irrigation at peak of water consumption for the crop (last stage)

The locations of wetting fronts from the irrigation source in the radii were 30, 40, and 45 cm for D_1, D_2 and D_3, respectively under continuous irrigation, While the locations under pulse irrigation were 40, 50 and 55 cm at mid stage. For last stage the results show that the locations of wetting fronts from the irrigation source in the radii were 30, 30, and 40 cm for D_1, D_2 and D_3, respectively under continuous irrigation, while the locations under pulse irrigation were >50, 43 and >50 cm

Performance of irrigation systems

Table 5 show the effect of pulse and continuous trickle irrigation on the application efficiency (Ea), emission uniformity (Eu) and distribution efficiency (Ed), the procurement results show that the trend of each followed the plant growth stages. The values of (Ea), and (Eu) were convergent for both irrigation techniques; trend of each was oscillated between depreciation and rising then reached to the maximum values recorded with pulsing technique during the mid season around 60 days then decreased once again which recorded 90% for both Ea and Eu. At both initial and late stages of plant season applied water were adding more than plant needed causes this oscillation. The same result obtained with the distribution uniformity (Ed) but the maximum value for Ed was 98% after 40 days. The results also, indicated that pulse drip irrigation technique resulted in higher values through over the growth planting season for each of (Ea), (Eu) and (Ed). Along the lateral of dripper line water uniformity distribution recorded higher values. During the interim of the on time for pulse technique, allowed the water to follow through the emitters and inter the soil. While during the interim of the off time the soil moisture was allowed to be redistributed therefore pulse technique causes more improve in uniform distribution pattern than continuous technique. The main values per season were 87.05, 87.15and 96.3 (Ea), (Eu) and(Ed) respectively under pulsing technique, while under continuous technique for the same characters were 85.9%, 86% and 84.9%. The data clear the pulse technique not significant affect on the application efficiency (Ea), emission uniformity (Eu), while this technique was highly significant on distribution efficiency (Ed)

Yield and yield components

The pulsing trickle irrigation had the highest yield, both in terms of yield and yield components (table 6). The lowest performance was obtained by the continuous treatment. Statistical analysis using statistical program CoHort Software (2005) showed that the effect of the treatments on yield and yield components was highly significant. The treatments effect on the oil percent was much less significant, since there was significant effect on oil yield. Duncan's Multiple Range Test showed that the seeds yield was significantly higher for the two daily irrigation treatments than for the daily and third daily irrigation. The trend obtained indicates that two daily trickle irrigation might improve yields and yield components (number of leaf per plant No L/pl, stem diameter St dia, head diameter H dia ,protein percent , oil percent, seeds yield S Y, protein yield and oil yield) and therefore, water use efficiency.

The statistical analysis showed that the head diameter Hdia was significantly higher for the interaction effect irrigation method × two daily treatments, while this treatment recorded the higher values than anther interaction treatments; the increasing in yield and yield components was not significant.

The water use efficiency

The water use efficiency was illustrated in table (7). The data show that water use efficiency for seeds under pulse trickle irrigation was 0.308 kg/m^3 compare with 0.285 kg/m^3 for continuous trickle irrigation recording an increase of 8.07 %, while for oil under pulse trickle

Table 5. Performance of irrigation systems

day after planting	application efficiency (Ea)%		Emission uniformity (Eu)%		distribution efficiency (Ed)%	
	P.	C.	P.	C.	P.	C.
10	85	85	85	85	95	87
20	87.5	87	87.5	87	95	87
30	88	87	88	88	97	89
40	88	87	89	88	98	89
50	90	89	90	89	95	83
60	90	89	90	89	97	85
70	85	83	85	83	97	85
80	85	85	85	85	97	82
90	87	85	87	85	97	79
100	85	82	85	82	97	83
Average	87.05	85.9	87.15	86	96.3	84.9

Table 6. Effect of irrigation water supply methods and irrigation periods treatments and their interaction on sunflower yield and yield components

Irri. Meth.	Irri. Freq.	No L / Pl	St dia (cm)	H dia (cm)	Protein %	Oil%	W 100 seeds (gm)	S Y/ fad (kgs)	Pro yield/fad .(kgs)	Oil yield /fad.(kgs)
P.		27.7a	3.39a	21.4a	17.4a	40.5a	6.83a	932.1a	126.6a	378.10 a
C.		26.9b	3.31b	20.5b	17.1b	39.9b	6.47b	866.9b	148.28 b	346.12 b
LSD.05		0.249	0.076	0.248	0.056	0.214	0.122	20.27	3.892	9.903
	D_1	27.2b	3.34b	22.5b	17.2b	40.3a	6.73b	908.4b	156.6b	366.00 b
	D_2	29.6a	359a	24.6a	17.7a	40.6a	7.37a	1024.2a	181.2a	415.64a
	D_3	25.0c	3.11c	15.8c	16.7c	39.8b	5.84c	765.9c	128.4c	304.70 c
LSD.05		**0.407**	**0.176**	**0.271**	**0.087**	**0.333**	**0.237**	**31.56**	**5.48**	**11.87**
P.	D_1	27.7	3.4	22.8	17.4	40.7	6.89	936.4	163.2	380.7
	D_2	29.8	3.6	24.9	17.8	40.8	7.56	1068.1	190.4	435.4
	D_3	25.5	3.1	16.5	16.9	40.2	6.04	791.9	134.1	318.1
C.	D_1	26.7	3.3	22.2	17.0	39.9	6.57	880.5	150.0	351.3
	D_2	27.7	3.4	21.4	17.4	40.5	6.83	932.1	162.6	378.1
	D_3	24.5	3.1	15.0	16.6	39.4	5.65	739.9	122.6	291.2
LSD.05		ns	ns	**	ns	ns	ns	ns	ns	ns

Table 7. Water use efficiency for sunflower

Irri. Meth.	Irri. Freq.	Amount of irrigation water	S Y/ fad (kgs)	Oil yield /fad.(kgs)	Water use efficiency (kg seeds/m^{3}water)	Water use efficiency (kg oil/m^{3}water)
P.		3022.07 a	932.1 a	378.10 a	0.308 a	0.125 a
C.		3044.55 a	866.9 b	346.12 b	0.285 a	0.114 a
LSD.05		**22.35**	**20.27**	**9.903**	**0.019**	**0.008**
	D1	3011.89 a	908.4 b	366.00 b	0.302 a	0.122 a
	D2	3035.48 a	1024.2 a	415.64 a	0.337 a	0.137 a
	D3	3052.57 a	765.9 c	304.70 c	0.251 a	0.100 a
LSD.05		**39.55**	**31.56**	**11.87**	**0.075**	**0.011**
P.	D1	2997.3	936.4	380.7	0.312	0.127
	D2	3025.7	1068.1	435.4	0.353	0.144
	D3	3043.2	791.9	318.1	0.260	0.105
C.	D1	3026.47	880.5	351.3	0.291	0.116
	D2	3039.26	932.1	378.1	0.307	0.124
	D3	3061.93	739.9	291.2	0.242	0.095
LSD.05		ns	ns	ns	ns	ns

irrigation was 0.125 kg/m^3 compare with 0.114 kg/m^3 for continuous trickle irrigation recording an increase of 9.65 %. The highly value of water use efficiency for seeds was achieved with D_2 (0.337 kg/m^3) followed by D_1 (0.302 kg/m^3) while the lowest value was 0.251 for D_3. The increasing percent of water use efficiency for seeds was 11.59, 34.26 and 20.31 % from D_2 to D_1, D_3 to D_2 and D_3 to D_1 respectively.

The water use efficiency for oil as shown in table 4 clear that the highest value was 0.137 kg/m3 for D_2 while the lowest value was 0.100 kg/m^3 for D_3. The increasing percent of water use efficiency for oil was 11.59, 34.26 and 20.31 % from D_2 to D_1, D_3 to D_2 and D_3 to D_1 respectively. The results revealed that the water use efficiency increased with the irrigation frequency increased from D_1 to D_2 with percent of 12.3 % then decline for D_3 with percent of 27.0 %. The reason behind the declination was the water stress.

The water Storage efficiency (WSE)

The water storage efficiency values are presented in Table (8). For a given soil, treatments storage efficiency was influenced largely by soil water content immediately prior to irrigation and by amount of irrigation, storage efficiency decreasing as either or both factors increased. Irrigation management during the growing season influenced soil water content. Data in Table (8) show that storage efficiency was low because the soil in experiment location was sandy and water holding capacity was very low. Storage efficiency increased from depth 0-20 and 20-40 and decreased

Table 8. Water storage efficiencies (%) as affected by water supply methods and irrigation frequency

Supply Method	Irrigation Frequency	Storage efficiency, %											
		Horizontal Distance, Cm 0-20				Horizontal Distance, Cm 20-40				Horizontal Distance, Cm 40-60			
		Soil Depth, Cm				Soil Depth, Cm				Soil Depth, Cm			
		0-20	20-40	40-60	60-80	0-20	20-40	40-60	60-80	0-20	20-40	40-60	60-80
P.		28.90a	31.53a	31.12a	26.32b	25.70a	26.73a	25.26a	22.26b	22.32a	20.76a	20.04a	17.22a
C.		28.25a	30.17b	29.97b	30.51a	23.68b	25.60b	25.04a	23.88a	18.26b	17.38b	15.93b	14.59b
LSD 0.5		**0.735**	**0.238**	**0.246**	**0.521**	**0.438**	**0.367**	**0.328**	**0.651**	**0.879**	**0.555**	**0.287**	**0.467**
	D_1	34.76a	35.96a	34.26a	31.14a	28.62a	30.93a	29.46a	27.09a	23.64a	22.00a	20.10a	17.3a
	D_2	34.38a	34.95b	34.03b	29.60b	28.42a	29.82b	28.79b	26.39b	22.85b	20.77b	19.43b	16.30b
	D_3	17.49b	21.64c	24.24c	24.50c	17.02b	17.76c	17.22c	15.75c	14.39c	14.45c	14.43c	14.13c
LSD 0.5		**0.446**	**0.869**	**0.163**	**0.851**	**0.268**	**0.852**	**0.527**	**0.376**	**0.351**	**0.265**	**0.249**	**0.086**
P.	D_1	34.50a	36.06a	33.72b	28.49c	29.74a	31.21a	29.48a	25.64c	26.40a	24.94a	22.76a	19.10a
	D_2	33.75b	35.30a	33.25b	27.12d	29.50a	30.35b	28.56c	25.70c	25.40b	23.03b	22.50a	18.32b
	D_3	18.45c	23.22c	26.40c	23.35f	17.85c	18.65c	17.75d	15.45e	15.17d	14.33d	14.85d	14.25d
C.	D_1	35.01a	35.86a	34.80a	33.79a	27.50b	30.63b	29.49a	28.54a	20.87c	19.06c	17.43b	15.50c
	D_2	33.21b	34.60b	33.02b	32.08b	27.34b	29.29b	29.01b	27.07b	20.30c	18.53c	16.35c	14.28d
	D_3	16.53d	20.06d	22.06d	25.65e	16.04d	16.86d	16.04e	16.04d	13.61e	1456d	14.01e	14.00e
LSD 0.5		***	**	**	**	***	**	**	**	**	**	**	*

again in 40-60 and 60-80cm. For both pulse trickle irrigation and continuous trickle irrigation water storage efficiency (WSE) increased as the soil depth increased for horizontal distances 0-20 and 20-40 from emitter. Also data in Table (8) clear that pulse trickle irrigation improved the water storage efficiency (WSE) at all horizontal distances, while continuous trickle irrigation caused to increase (WSE) for soil depth of 60-80 at horizontal distances 20-40 then decreased at the same depth with horizontal distances 40-60. The maximum values is 31.53% recorded at depth of 20-40 cm and horizontal distances 0-20 from emitter with pulse trickle irrigation, while the minimum value is 14.59% at depth of 60-80 cm and horizontal distances 40-60 from emitter with continuous trickle irrigation. Data in table 9 show that there is significantly increased in the water storage efficiency (WSE) due to use of the pulse trickle irrigation about 17.19% to 28.45%. By study the impact of irrigation frequency on the water storage efficiency found that there is no significant effect between daily irrigation D_1 and irrigation every two days D_2 but found a significant effect between both previous treatments ($D_1$and D_2) and irrigation every three days D_3 which recorded the lowest values with all depth at al horizontal distance. The highly value of storage efficiency was recorded with D_1 (35.96 %) followed by D_2 (34.95%) at depth of profile of 20-40cm and horizontal distances 0-20 from emitter while the lowest value was 14.43% for D_3 at depth of profile of 60-80cm and horizontal distances 60-80 from emitter. For the effect of the interaction (application methods × irrigation frequencies), data in Table (8) display that there is significantly effect on the water storage efficiency (WSE). The highest values for (WSE) were recorded with pulse trickle irrigation × irrigation piriodspecially in the effective root zone along the horizontal distance. The maximum values was observed with D1 (36.04 %) followed by D2 (35.30%) at depth of profile of 20-40cm under pulse technique while the lowest value was 14.00% for D3 at depth of profile of 60-80cm under. Water storage efficiency under pulse trickle had the highest values. Similarly Lampulanes et al (2002) and Mohamet and Vahdettin (2007) pointed out that sandy soil has lowest water storage efficiency values.

Conclusion

Results concluded that: the daily consumptive use values were assorted as the climatic conditions and plant growth stages were changed. The maximum value was 8.24 mm at the end of flowering stage during mid-season stage 60-70 days after the planting date. In respect to the amount of applied water increased with the growth of the plant then declined at the end of the growth season. The seasonal irrigation water applied was found to be 2997.3, 3025.7 and 3043.2 m^3/fed with pulse drip irrigation for D_1, D_2 and D_3 respectively, while for continuous irrigation under the same treatments were 3026.47, 3039.26 and 3061.93 m^3/fed for D_1, D_2 and D_3 respectively. Pulse flow recorded a good values of soil moisture trend for either (0-20 cm) or (20-40cm) soil depths with ameliorative in the horizontal layers. The pulse drip irrigation resulted higher moisture content level and better uniform moisture distribution pattern for both soil depths and through over the measurement intervals. The pulse drip irrigation was highly significant than that continuous drip irrigation technique for each of Eu and Ed. The results obtained indicates that two daily trickle irrigation might improve yields and yield components (number of leaves per plant, stem diameter, head diameter, protein percent , oil percent, seeds yield, protein yield and oil yield) and therefore, water use efficiency.

Water use efficiency under pulse drip irrigation was 0.308 kg/m^3 compare with 0.285 kg/m^3 for continuous drip irrigation recording an increase of 13.55% which was highly significant as statistical analysis L.S.D. test revealed. In the future, more pulse irrigation research is needed to develop fertilizer recommendations and to investigate media-fertilizer interactions relevant to crop production.

Water storage efficiency is improved by applying pulse trickle irrigation especially in the effective root zone, while the continuous trickle irrigation, led to improve the water storage efficiency in the depths away from the root zone and horizontal distances not far to the emitter. There is no significant effect between daily irrigation D_1 and irrigation every two days D_2 but there is significantly effect on water storage efficiency, with irrigation every three days D_3 under both pulsed trickle irrigation and continuous irrigation.

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الملخص العربي

تأثير الري بالتنقيط النَبضي على توزيعِ رطوبةِ التربةِ وكفاءات الري ومعدلِ إنتاج عبّادِ الشمس في التربة الرملية

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أجريت تجارب حقلية لانتاج محصول عباد الشمس في قرية اليشع منطقة الانطلاق ذات القوام الرملي خلال موسمين صيفيين متتاليين ٢٠٠٩ و ٢٠١٠. لدراسة تأثير الري بالتنقيط النبضي على توزيع الرطوبة في الأراضي الرملية وإنتاجية محصول عباد الشمس واشتملت الدراسة علي اثنين من تقنيات اضافة المياه، الاضافة المنقطعة للمياه او بالنبضات (١٠دقائق اضافة و ١٠دقيقة إيقاف) واضافة مستمرة للمياه بالإضافة إلى ثلاثة فترات مختلفة للري (الري يوميا، الري كل يومين والري كل ٣ايام). والتصميم الاحصائي للتجربة القطع المنشقة مرة واحدة بأربعة مكررات، ومثلت تقنيات الاضافة القطع المنشقة في حين أن فترات الري مثلت القطع الرئيسية. وأظهرت النتائج أن متوسط كمية المياه الموسمية المضافة كانت ٣٠٣٣,٣٧ م^3/الفدان لمعاملتي الاضافة ولم يكن هناك فروق معنوية بين معاملتي الاضافة وكذلك فترات الري في توفير المياه المضافة. كما أظهرت النتائج أن معدل الاحتياجات المائية للمحصول كانت منخفضة في المرحلة العمرية الاولي للنبات، ثم زادت وبلغت القيمة القصوى ٢٢٤,٧مم خلال مرحلة الازهار (خلال شهرأغسطس) ٧٥-٨٠ يوما من تاريخ الزراعة. اما بالنسبة الي الرطوبه النسبيه فاظهرت النتائج المتحصل عليها الي ان الحد الأقصى للمحتوى الرطوبي كان تحت المنقط على الأعماق المختلفة لكافة المعاملات. وقد أدى الري النبضي الي اعطاء قطر ابتلال اكبر في الاتجاه الافقي مما أدى إلى تحسين توزيع رطوبة التربة في منطقة انتشار الجذور وخاصة مع الري كل يومين خلافا للري المستمر الذي ادي استخدامة الي زيادة عمق تسرب المياه. دلت النتائج أن الري بالتنقيط المتقطع زاد الإنتاجية، سواء من حيث المحصول أومكوناته. كما ادي الري النبضي الي تحسن كلا من كفاءة الاضافة للمياه وكذلك في كفاءة الانبعاث وسجلت قيم كفاءة الاضافة ٨٧,٠٥ % للري النبضي بينما كانت مع الري المستمر ٨٥,٩ % وقيم كفاءة الانبعاث ٨٦,١٥ % للري النبضي بينما كانت مع الري المستمر ٨٦% اما بالنسبة لكفاءة التوزيع فكانت الزيادة معنوية وبلغت ٩٦,٣% و٨٤,٩ % مع الري النبضي والري المستمر علي التوالي. وتشير النتائج إلى أن تطبيق الري بالتنقيط النبضي أدى إلى تحسين كفاءة تخزين المياه في منطقة الجذور الفعالة بالمقارنة مع الري المستمر، واوضحت النتائج عدم وجود فروق معنوية بين الري اليومي والري كل يومين علي كفاءة التخزين، ولكن تأثرت تلك الكفاءة مع الري كل ثلاثة أيام، وانخفضت بشكل ملحوظ مع فترات الري كل ثلاث ايام مع كلا من الري بالتنقيط النبضي والري المستمر.