Misr J. Ag. Eng., 26(2): 736- 765 IRRIGATION AND DRAINAGE

EFFECT OF PULSE DRIP IRRIGATION ON YIELD AND WATER USE EFFICIENCY OF POTATO CROP UNDER ORGANIC AGRICULTURE IN SANDY SOILS

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ABSTRACT

Pulse drip irrigation is a recent concept where small frequent irrigation applications are applied to saturate the soil and meet the plant water requirements. The field experiment was carried out during two summer growing seasons 2006 and 2007, it executed in Abo-Ghaleb farm, Cairo-Alex. Rood, 60 Km away from Cairo and the soil was sandy. Seed tubers were planted on 2 th of February and harvested on 28 th of May in two seasons, and the well water was used as irrigation source having EC 1.9 ds/m, the soil sample were taken up to 45 cm depth. Diameter of the lateral line was 16 mm (OD)with discharge of 2.1 l/h. The distance between emitters was 30 cm and between laterals was 70 cm. The present investigation aimed to study the effect of pulse drip irrigation under organic agriculture for saving water and increasing yield of potato. The following parameters were studied to evaluate the performance of pulse drip irrigation :(1) Soil moisture distribution, (2) Application efficiency "AE", (3) Yield of potato "YP", (4) Water use efficiency of potato "WUE $_{potato}$*". The results indicated that wetted soil volume (more than or equal 100% of field capacity) in root zone"* $WSV_{\geq 100\% FC}$*", application efficiency, yield and water use efficiency of potato were increased by increasing number of irrigation pulses where* ***: (1)*** *$WSV_{\geq 100\% FC}$ in root zone increased from 9617* cm^3 *under continuous drip irrigation "CDI" to maximum value where it become 14272* cm^3 *after applying pulse technique on 4pulses at 100 % from actual irrigation requirements "IRa" under surface drip irrigation, recording an increase of 48%.* ***(2)*** *Maximum values of AE were 93.5%, 97% and 99.2% under 100 %, 75 % and 50% from IRa respectively with 4 pulses under surface drip irrigation.*

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(3)*YP increased from 4.70 (ton/fed.) under CDI to maximum value, where it become 6.57 (ton/fed.) after applying pulse technique with 4 pulses at 100 % from IRa under subsurface drip irrigation, recording an increase 40%.****(4)****Avoid using pulse technique at 50% from irrigation requirements because, small amount of irrigation water with more pulses with increasing in time-off will concentrate the salts around the plant especially under surface drip irrigation hence high decreasing in the yield of potato****.(5)****WUE* $_{potato}$ *increased from 1.59 (kg/m*^{3}*) under CDI to maximum value, where it become 2.62 (kg/m*^{3}*) after applying pulse technique with 4 pulses at 75 % from IRa under SSDI, recording an increase 65%, this mean that we can save 25% of actual irrigation requirements per season which equal 679 m*^{3} *from irrigation water*.

INTRODUCTION

Pulse drip irrigation is applied all over the world because it has positive effects on increasing yield, improving quality, saving water, reducing from clogging emitters and reducing from consumption energy…etc. Drip irrigation, nowadays, is the most efficient plant watering system. In order to get a better and more efficient use of water, we combined between drip irrigation and pulse technique. Pulsing irrigation refer to the practice of irrigating for a short period then waiting for another short period, and repeating this on-off cycle until the entire irrigation water is applied. **(Eric *et al*., 2004)**. Using pulse drip irrigation with organic agriculture if we want to get a major utilization from organic agriculture. The benefits of organically produced food in terms of the food utilization and in comparison to conventionally produced food. (1) Food safety (2) Pesticide poisoning (3) Pesticide residues (4) Food quality (5) Nutritional adequacy (6) Human health (7) Pollution of drinking water (8) Pollution of the environment. If this is a general trend, the benefits of organic farming are much larger than previously estimated. **(Kirsten, 2007**) Potatoes are largest horticultural export in Egypt. In most recent years the Euros united has accounted for about 70% - 90% of Egyptian potato exports. In 1998 the total value of potato exports to the Euros united was about 63 million Euros, about 42.7% of Egypt's agricultural exports to the Euros united **(Brian, 2001)**. Where drip irrigation is used, you may need to irrigate more than once a day to meet peak water requirements. If the drip system drains out after each irrigation, break the irrigation down into the longest pulses possible to reduce losses to drainage. Redesign the irrigation system if the wetted area is too small (limiting) and pulsing is not an option. **(Helen, 2007).** Based on reports from other states (where soil types are different), it is often believed that the size of the wetted zone can be increased if irrigation is pulsed. **(Eric *et al*., 2004)**. Pulse irrigation system, irrigating amount and timing are the objectives for reducing run off, decreasing percolation of water beneath the root zone and reducing water evaporation after irrigation. **(El-Gindy and Abdel Aziz, 2001).** Applying irrigation water in stages or pulses rather than all at one time can save water by giving the media time to moisten from the first pulse of water thereby allowing it to absorb subsequent irrigation more readily and reducing the total amount of water required. For example, instead of irrigating 4 different areas for 1 hour each (four hours total), studies have shown that by watering each area sequentially for 15 minute intervals and repeating this process twice, a 25% reduction in water usage **(Scott, 2000)**. High irrigation frequency might provide desirable conditions for water movement in soil and for uptake by roots. **(Segal *et al*., 2000)**. The systems have undergone immense development in recent years and now allow the simple and accurate timing of irrigation events. The level of control includes the ability to "pulse" irrigation events to meet the needs of soils that have less than desirable infiltration rates, thus minimizing run off. **(Thompson**, **2001**). Continuous water application is associated with increased water percolation under root zone. Intermittent irrigation strategy based on discharge pulses followed by breaks could improve water management in the field and increase irrigation efficiency **(Oron, 1981)**. High frequency irrigation enhanced potato tuber growth and water use efficiency. Reducing irrigation frequency from N1(once every day) to N8 (once every 8 days)resulted in significant yield reductions by 33.4 and 29.1% in 2001 and 2002, respectively. **(Feng-Xin *et al*., 2006).** Total potato tuber yield was highest for the Soil Water Balance scheduling method. Irrigation frequency influenced yield differently for the different scheduling methods. Tuber relative density was improved by pulse irrigation**. (Steyn *et al*., 2005). Segal *et al*., (2000)** reported that high frequency or long lasting, low discharge irrigation can increase water use and yields of crops by providing desirable conditions for water movement in soil and for uptake by roots. As soil water conditions become more constant, plants are able to utilize water and increase production. Further study is necessary to evaluate these finding on other crops and to develop economically feasible methods for low discharge and high frequency irrigation. The studies resulted in the fact that, under the experiment alternatives with low-volume pulse water application close to the evapotranspiration, the yields of cultivated crops (clover, rye grass, timothy, fescue, tip onion, lettuce) were usually 1.3-2.5 times higher than the yields of crops grown under traditional regular irrigation. **(Nosenko, *et al*., 1991)**. The aim of present work was study the effect of pulse drip irrigation under organic agriculture for saving water and increasing yield of potato under Egyptian growing conditions. To achieve the aim of present study the effect of pulse drip irrigation was studied on: (1) Soil moisture distribution, (2) Application efficiency, (3) Yield of potato and (4) Water use efficiency.

MATERIALS AND METHODS

1. Materials

a. Some chemical analysis and some physical properties of soil and irrigation water.

Some physical and chemical characters of soil and analysis of irrigation water for experimental site are presented in tables (1), (2) and (3) respectively.

Table (1) Mechanical analysis and some physical properties of soil for experimental site

Particles Size distribution, (%)	Depth, (cm)			
	0 - 15	15 - 30	30 - 45	45 - 60
Very Coarse Sand, %	26.67	24.80	29.88	9.79
Coarse Sand, %	21.70	23.52	24.71	15.82
Medium Sand, %	24.80	30.64	30.40	24.86
Fine Sand, %	19.10	15.96	12.37	41.60
Very Fine Sand, %	5.23	3.42	1.46	7.01
Silt + Clay, %	2.50	1.66	1.18	0.92

Soil texture		sandy	sandy	sandy	sandy
CaCo3, (%)		8.5	8.5	8.0	7.6
Before adding organic mater	**Field Capacity, (%)**			10	
	Wilting Point, (%)			3.5	
After adding organic mater	**Field Capacity, (%)**			11	
	Wilting Point, (%)			3.8	
Bulk density, g/cm^3		1.61	1.59	1.55	1.49

Table (2) Chemical analysis of soil for experimental site.

		Depth, (cm)			
Item		**0 - 15**	**15 - 30**	**30 - 45**	**45 - 60**
pH		7.43	7.60	7.75	7.79
EC, (1:5) (ds/m)		3.72	3.50	3.20	2.87
Anions (meq./l)	**HCO^-_3&$Co^=_3$**	2.40	1.20	1.50	1.25
	CL^-	23.0	22.5	18.1	14.5
	$SO4^=$	25.0	25.3	17.5	13.9
Cation (meq./l)	**Ca^{++}**	28.5	30.0	17.0	16.7
	K^+	0.70	0.80	0.60	0.65
	Mg^+	8.5	8.0	7.0	5.0
	Na^+	12.7	10.2	12.5	7.3
Organic Matter, (%)		1.36	1.70	1.35	2.00
Boron, (ppm)		2.0	2.1	2.4	2.5

Table (3) Chemical analysis of irrigation water

Item	**Irrigation water quality**
pH	7.55
EC, (ds/m)	1.90

	HCO^{-}_{3}&$Co^{=}_{3}$	2.97
Anions (meq./l)	**CL^{-}**	3.94
	$SO4^{=}$	11.36
	Ca^{++}	6.53
Cation (meq./l)	**K^{+}**	0.22
	Mg^{+}	4.72
	Na^{+}	6.80

b. Description of the irrigation system components.

The irrigation system consisted of: control head: (pumping and filtration unit and fertilizing unit). It was located at the water source supply. It consists of submersible pump with 45 m^3/h discharge and it is driven by electrical engine and there were screen filter, back flow prevention device, pressure regulator, pressure gauges, flow-meter, and control valves. Main line was of PVC pipes with 110 mm in diameter outside diameter (OD) to convey the water from the source to the main control points in the field. Sub-main lines were of PVC pipes with 75 mm diameter (OD) and connected to the main line. Manifold lines: PE pipes was of 63 mm in diameter (OD) were connected to the sub main line through control valve 2`` and discharge gauge. Emitters were of (GR) type built in laterals tubes of PE with 16 mm in diameter (OD), □ and 30 m in long (emitter discharge was 2.1 lph at 1.0 bar operating pressure and 30 cm spacing between emitters.

d. Potato variety. Spunta Netherland production was used

2. Methods

a. Experimental site

The field experiments were carried out during two summer growing seasons 2006 and 2007, it executed in Abo-Ghaleb farm, Cairo- Alex. Rood, 60 km away from Cairo and the soil was sandy. Seed tubers were planted on 2 th of February and harvested on 28 th of May in the two seasons.

b. Fertilization method and bio-fertigation

Three kinds of fertilizers were used in the experiments .First of all, Microbin **(**bio fertilizers). It was a commercial product purchased by the General Authority of Agriculture Funds and Equalization. Second, compost, which content, 0.91 % nitrogen, 0.85% phosphorus and 0.90% potassium in addition to other elements. Third, compost tea.

Fertilizer requirements of potato crop were added according to the recommendation of Field Crop Research Institute,(ARC), Ministry of Agriculture and Land Reclamation. The recommended dose of fertilizer for potato as a Microbin was 11 kg from Microbin mixed with one ton from seed tubers directly before planting. The compost, according to analyses of compost content, 0.91 % nitrogen and potato requirements from nitrogen was 150 kg nitrogen. This mean that the total amount from compost =150/9.1= 16.48 ton. Researchers mention that more than 50% from applied compost will analyzed during the next year, this mean we should added at least 32.96 ton/fed and they mention also, adding 11 kg from Microbin with one ton from seed tubers will make 25% reduction from applied compost hence actual amount from applied compost were 24.72 ton/fed. The compost was applied 20 days before planting and was added in the middle of the row. Bio-fertigation, adding compost tea which was prepared by using water at a rate of 100 litter of water for each 20 kg of compost and stored for 48 hrs then compost tea was taken and inject in drip irrigation network weekly as shown in fig. (1).

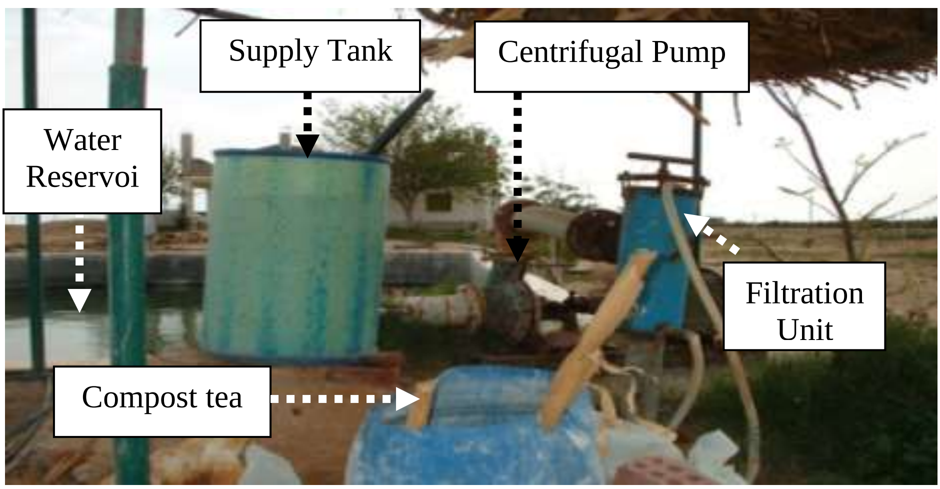

Fig. (1) Injection of compost tea by using fertilizing unit

c. Experimental design and treatments

The experimental design was split-split plot with three replications. Irrigation systems, water regime treatments, and pulse irrigation treatments were put in main plots, sub main plots and sub-sub main plots, respectively. Two irrigation systems were selected to irrigate potato plants. The first was surface drip irrigation "SDI" built-in drip lines system (GR, 2.1 lph emitter's discharge) with 30 cm emitters spacing. Polyethylene laterals with diameter of 16 mm were used at 70 cm spacing .The second system is subsurface drip irrigation "SSDI" the same practices used for laterals but they fixed at 15 cm depth under soil surface. Three water application rates were applied for irrigating potato crop: 50, 75 and 100% from actual irrigation requirements "IRa". Fig.(2) shown layout of irrigation systems with the experimental design. Three types for pulse irrigation(2 times per day, 3 times per day and 4 times per day and time-off between pulses was 30 minutes) with continuous drip irrigation (one time per day).

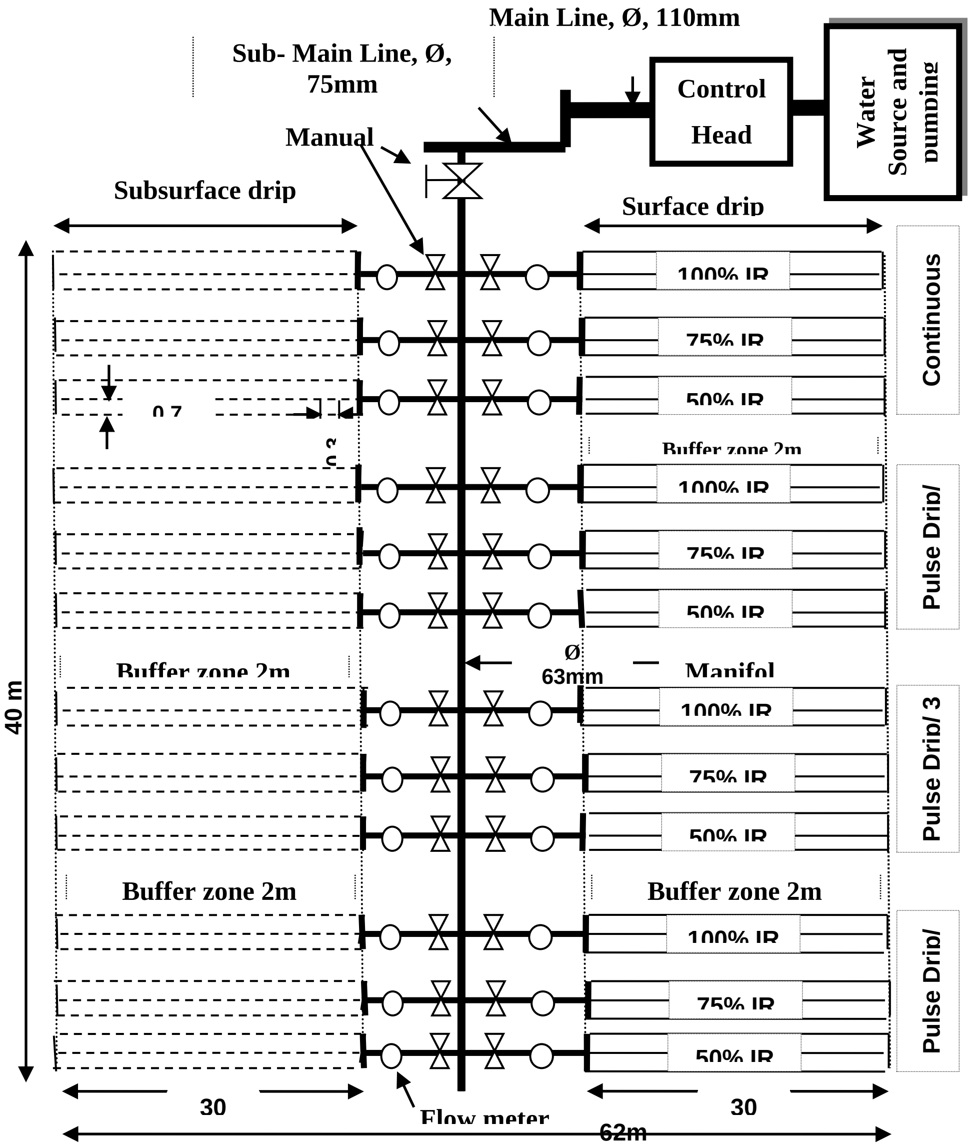

Fig. (2) Layout of irrigation systems with experimental design.

d. Estimation the total irrigation water (m^3/fed. / season)

The total irrigation water was estimated per season by sequence as tabulated in table (4)

Table (4) Estimation total irrigation water per season

No	Parameter/ month	Feb.	Mar.	Apr.	May
1	Et_o (mm/month)	110.7	165.85	210.0	238.9
2	Crop coefficient, Kc	0.7	1.01	0.95	0.78
3	Etc, (mm/month)	77.49	167.51	199.5	186.34
4	Reduction factor, Kr	0.07	0.29	0.79	0.83
5	Emission uniformity, EU	0.88	0.87	0.87	0.86
6	Irrigation efficiency, Ea	0.92	0.91	0.91	0.90
7	Leaching requirement, LR	0.25	0.27	0.27	0.29
8	IR, (mm/month)	8.93	84.05	272.70	281.44
9	IR, (m^3 / fed. / month)	37.51	353.01	1145.3	1182.05
10	$\sum$ IR, (m^3 / fed.)for 4 months				2717.87
11	Amount of applied water before planting,(m^3/fed./season)				400
12	100%IR_a,(m^3/fed./season)=1*2717.87+ 400				3117.87 ~ 3118
13	75%IR_a,(m^3/fed./season)=0.75*2717.87+400				2438.4 ~ 2439
14	50%IR_a,(m^3/fed./season)=0.5*2717.87+ 400				1758.93 ~ 1759

Refrance Evapotranspiration(Eto) and Kc from climatological data, Etc = Eto * Kc Kr = GC/0.85 (Keller and Karmeli, 1975), GC= It is estimated in the field, EU = It is estimated in the field, Ea = It is estimated in the field, LR = (EC_w/2Max.EC_e) (Doorenbos and Pruitt, 1977)

e. Determination of soil moisture distribution

Soil moisture distribution was determined according to **Liven and Van Rooyen (1979).** Taking the samples by auger from the soil before and 2 hours after irrigation directly at 20 cm spacing at the emitter's line side, as well as in spacing between and below the emitters until 45 cm depth. Soil moisture content was measured by the gravimetric methods**.** By using "contouring program Surfer" we obtained on contouring map for different moisture levels with depths.

f. Determination of application efficiency.

According to **El-Meseery (2003)** application efficiency "AE" was calculated using the following relation:

$$AE = V_s / V_a$$

Where: AE = Application efficiency, (%)

$V_s = (\theta_1 - \theta_2) * d * \rho * A$

V_s = Volume of stored water in root zone, l/plant/day
V_a = Volume of applied water, l/plant/day
A = Wetted surface area of root zone, cm^2
θ_1 = Soil moisture content after irrigation, (%)
θ_2 = Soil moisture content before irrigation, (%)
d = Soil layer depth, (cm), ρ = Relative density of soil.

g. Determination yield of potato crop

At the end of growing season, potato yield was determined by ton/ fadden for each treatment by the following steps; step (1) measuring the area to determine the yield and step (2) collection the potato for each treatment on the buffer zone as shown in fig. (3) and step (3) weighing potato for each treatment.

Fig. (3) Collection potato tubers for each treatment on the buffer zone

h. Determination of water use efficiency.

Water use efficiency "WUE" was an indicator of effectiveness use of irrigation unit for increasing crop yield. Water use efficiency of potato yield was calculated according to **James (1988)** as follows:

WUE_{potato} (kg/m^3) =Total yield, (kg/fed.) / Total applied irrigation water, (m^3/fed.)

RESULTS AND DISCUSSION

1. Effect of pulse drip irrigation on soil moisture distribution.

The relevant factors affecting the soil moisture distribution under drip irrigation systems are amount of applied water and number of pulses (frequency of irrigation in one day). Soil moisture distribution was the main factor in the evaluation process for pulse drip irrigation performance.

Figures from (4) through (9) showed the relation between pulse drip irrigation and wetted soil volume (more than or equal 100% of field capacity) "$WSV_{\geq 100\%FC}$" in root zone under 100% ,75% and 50% from actual irrigation requirements, "IRa".
$WSV_{\geq 100\%FC}$ in root zone was determined by determination of the field capacity which was represented by contour line 11 and maximum depth.

Fig. (4) showed the relation between pulse surface drip irrigation "PSDI" on $WSV_{\geq 100\%FC}$ at 100%from IRa.$WSV_{\geq 100\%FC}$ in the root zone increased by increasing number of pulses. Average of maximum width for contour line 11 was 22.5 cm in soil layer (0-15cm), 19 cm in soil layer (15-30cm), 8 cm in soil layer (30-45cm) and maximum depth was 45 cm under continuous drip irrigation "CDI" but it become 25.5 cm in soil layer (0-15cm), 25 cm in soil layer (15-30cm), 16 cm in soil layer (30-45cm) and maximum depth 37 cm after applying the pulse technique on 4 pulses this mean $WSV_{\geq 100\%FC}$ in root zone increased from 9617 cm^3 under CDI to 14272 cm^3 under pulse technique on 4pulses recording an increase of 48 %.

Fig. (5) showed the relation between pulse subsurface drip irrigation "PSSDI" on $WSV_{\geq 100\% FC}$ at 100% from IRa. $WSV_{\geq 100\% FC}$ in the root zone increased by increasing number of pulses. Maximum width for contour line 11 was 16 cm in soil layer (0-15cm) , 20 cm in soil layer (15-30cm), 10 cm in soil layer (30-45cm) and maximum depth was 37 cm under CDI but it become 18 cm in soil layer (0-15cm), 32 cm in soil layer (15-30cm), 15 cm in soil layer (30-45cm) and maximum depth 36 cm after applying the pulse technique on 4 pulses, this mean $WSV_{\geq 100\%FC}$ in root zone increased from 6829 cm^3 under CDI to 13267 cm^3 under pulse technique on 4pulses recording an increase of 94 %.
Fig.(6) showed the relation between PSDI on $WSV_{\geq 100\%FC}$ at 75% from IRa. $WSV_{\geq 100\%FC}$ in the root zone increased by increasing number of pulses. Maximum width for contour line 11 was 20 cm in soil layer (0-15cm), 16 cm in soil layer (15-30cm), 10.5 cm in soil layer (30-45cm) and maximum depth was 38.5 cm under CDI but it become 24 cm in soil layer (0-15cm), 22 cm in soil layer (15-30cm), 13 cm in soil layer (30-45cm) and maximum depth 40 cm after applying the pulse technique on 4pulses this mean $WSV_{\geq 100\%FC}$ in root zone increased from 7261 cm^3 under CDI to 12145 cm^3 under pulse technique on 4pulses recording an increase of 67%.

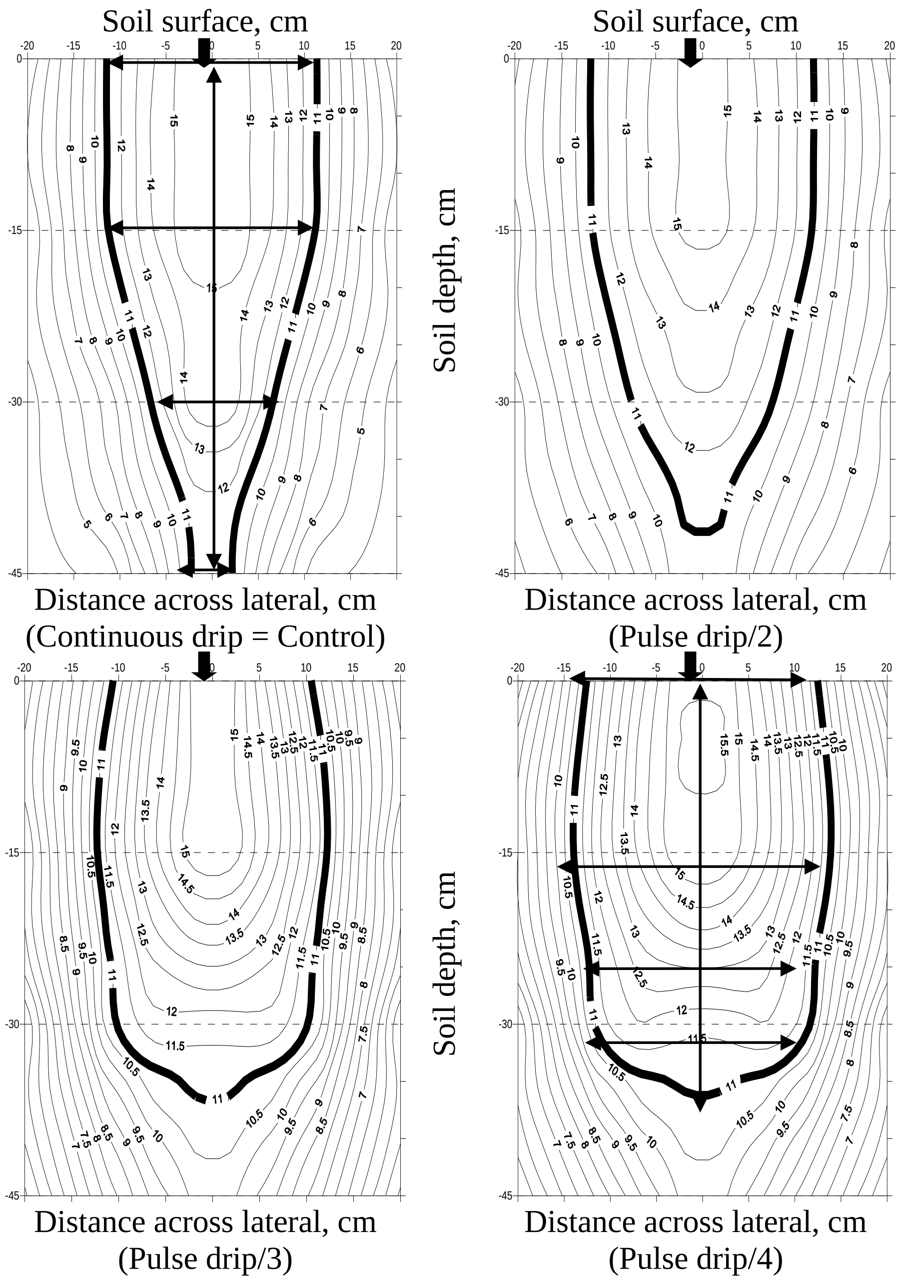

Fig.(4) Effect of pulse surface drip irrigation on wetted soil volume (more than or equal 100% of field capacity) at 100% from actual irrigation requirements

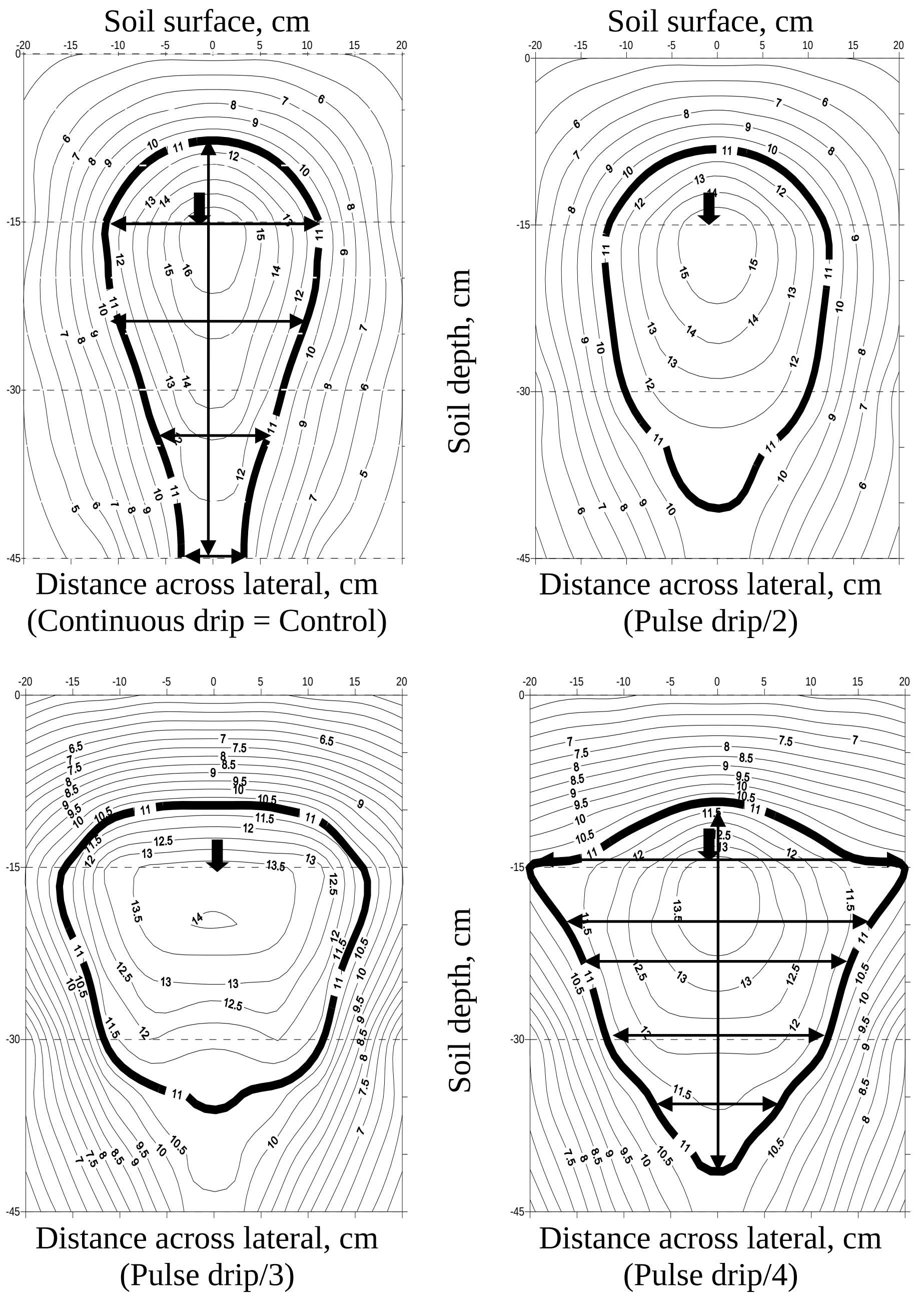

Fig.(5) Effect of pulse subsurface drip irrigation on wetted soil volume (more than or equal 100% of field capacity) at 100% actual irrigation requirements

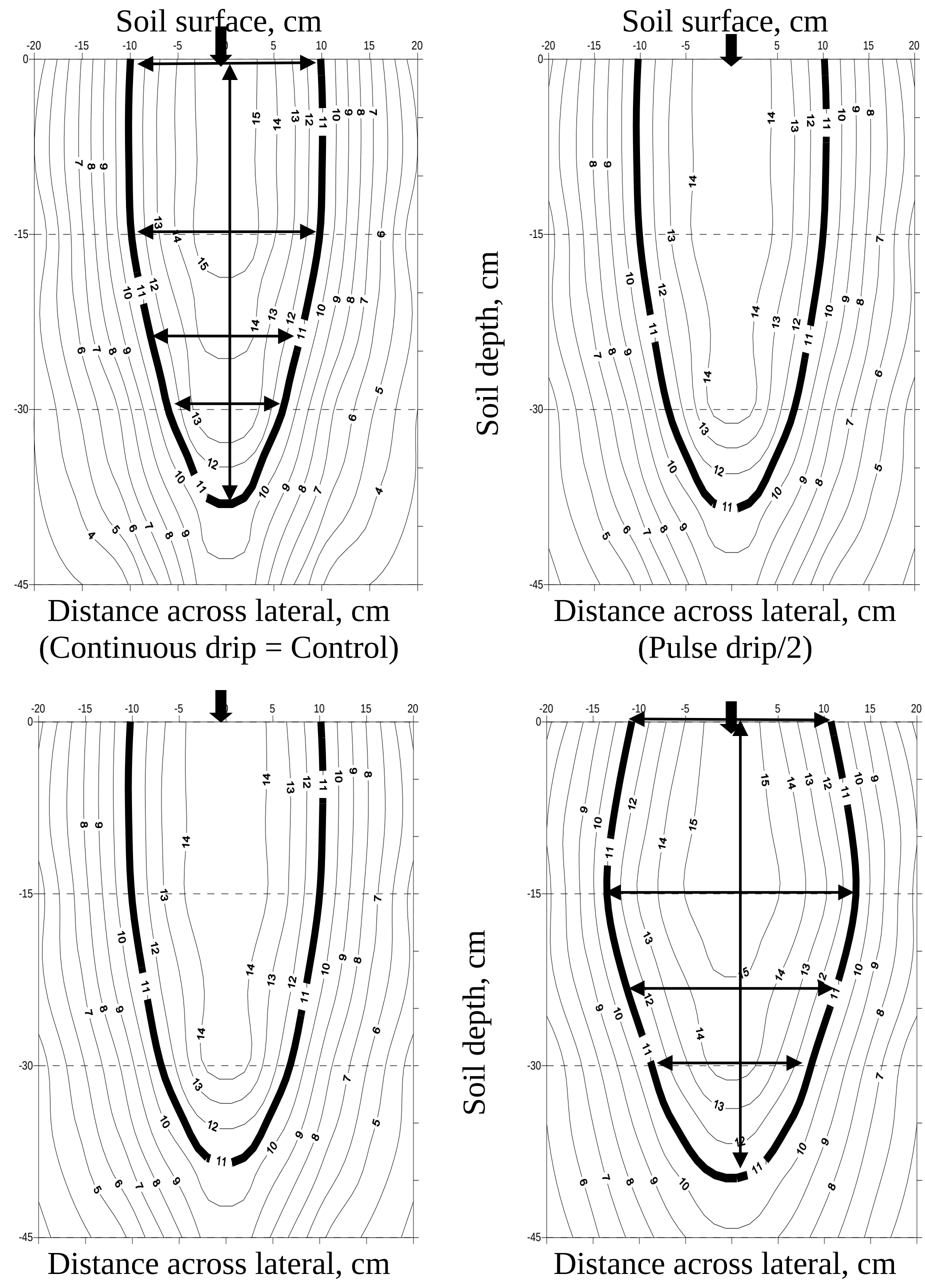

Fig.(6) Effect of pulse surface drip irrigation on wetted soil volume (more than or equal 100% of field capacity) at 75% from actual irrigation requirements

Fig. (7) showed the relation between PSSDI on $WSV_{\geq 100\%FC}$ at 75% from IRa. $WSV_{\geq 100\%FC}$ in the root zone increased by increasing number of pulses. Maximum width for contour line 11 was 16 cm in soil layer (0-15cm), 18 cm in soil layer (15-30cm), 9 cm in soil layer (30-45cm) and maximum depth was 36 cm under CDI but it become 25 cm in soil layer (0-15cm), 22 cm in soil layer (15-30cm), 10 cm in soil layer (30-45cm) and maximum depth 26 cm after applying the pulse technique on 4pulses this mean $WSV_{\geq 100\%FC}$ in root zone increased from 5806 cm^3 under CDI to 7112 cm^3 under pulse technique on 4pulses recording an increase of 22 %.

Fig. (8) showed the relation between PSDI on $WSV_{\geq 100\% FC}$ at 50% from IRa. Under 50% from IRa $WSV_{\geq 100\% FC}$ in the root zone was not form but there was increasing in horizontal movement of contour lines by increasing number of pulses this mean increasing in wetted soil volume in root zone.

Fig. (9) showed the relation between PSSDI on $WSV_{\geq 100\% FC}$ at 50% from IRa. $WSV_{\geq 100\% FC}$ in the root zone increased by increasing number of pulses. Maximum width for contour line 11 was 6.5 cm and maximum depth was 8.5 cm under CDI but it become 9 cm and maximum depth 17 cm after applying the pulse technique on 4 pulses this mean $WSV_{\geq 100\% FC}$ in root zone increased from 282 cm^3 under CDI to 1081cm^3 under pulse technique on 4pulses recording an increase of 283 %.

Maximum $WSV_{\geq 100\% FC}$ was 14272 cm^3 at 100% from IRa on 4 pulses under SDI and minimum $WSV_{\geq 100\% FC}$ was 282 cm^3 at 50% from IRa with CDI under SSDI.

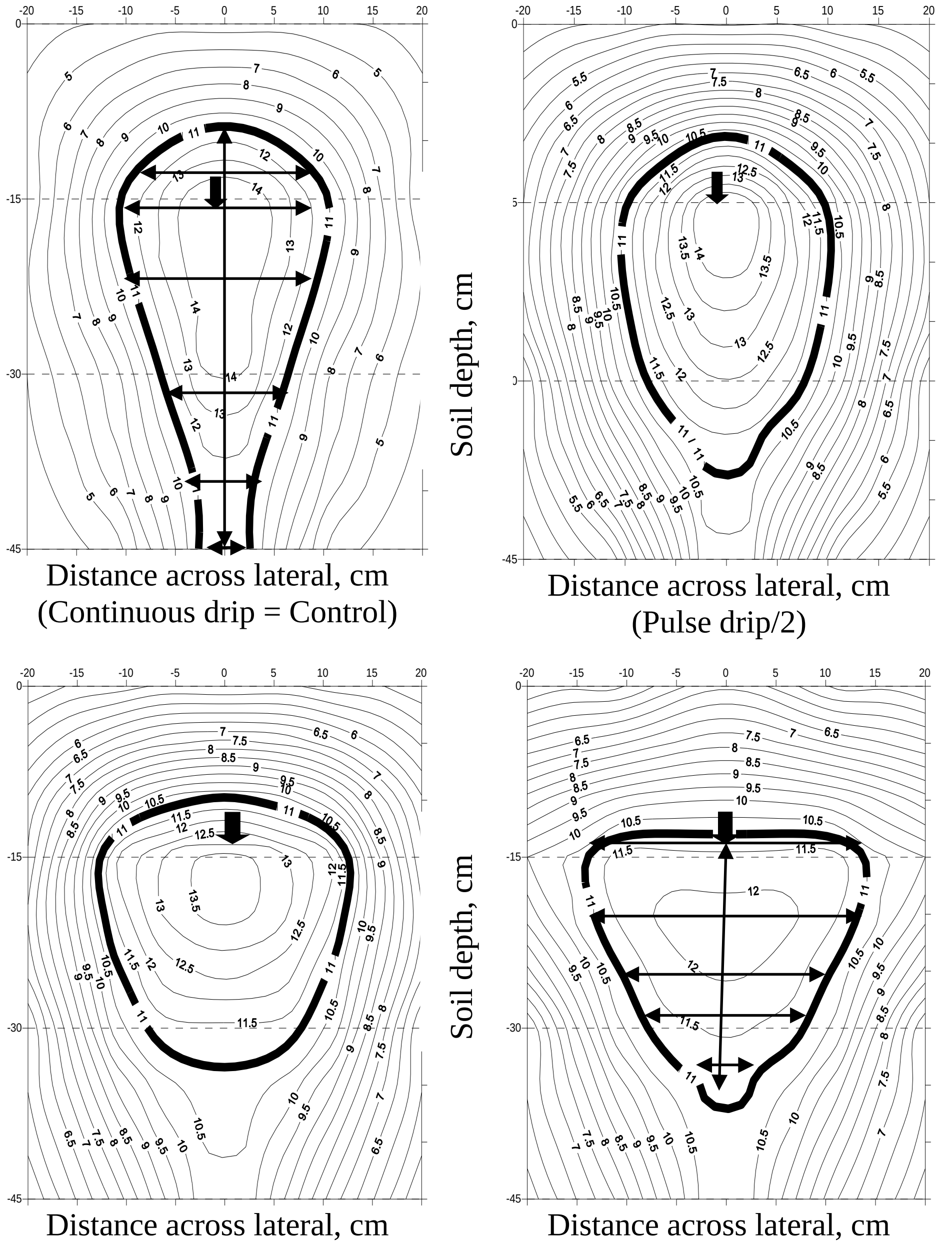

Fig.(7) Effect of pulse subsurface drip irrigation on wetted soil volume (more than or equal 100% of field capacity) at 75% actual irrigation requirements

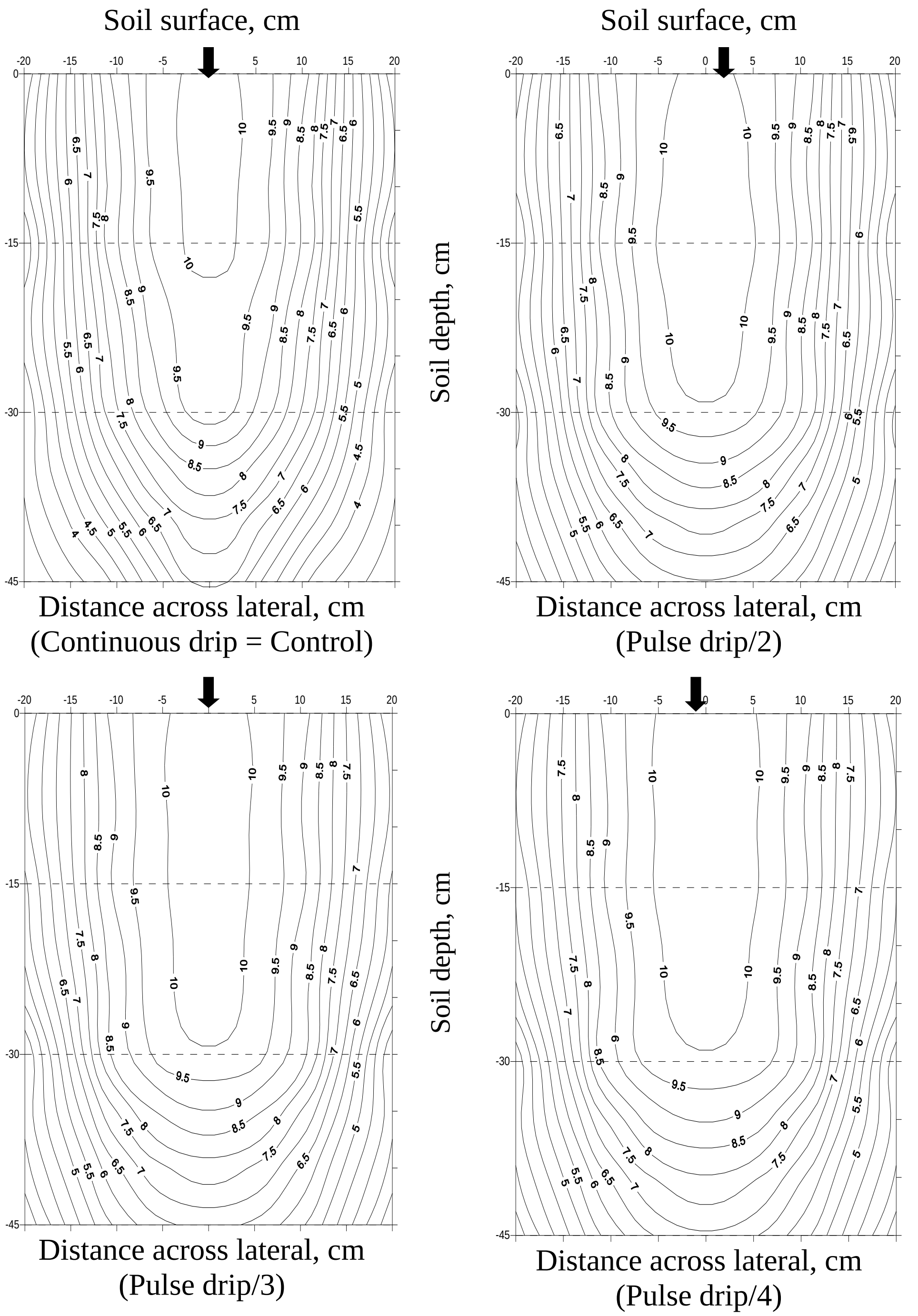

Fig.(8) Effect of pulse surface drip irrigation on wetted soil volume (more than or equal 100% of field capacity) at 50% actual irrigation requirements

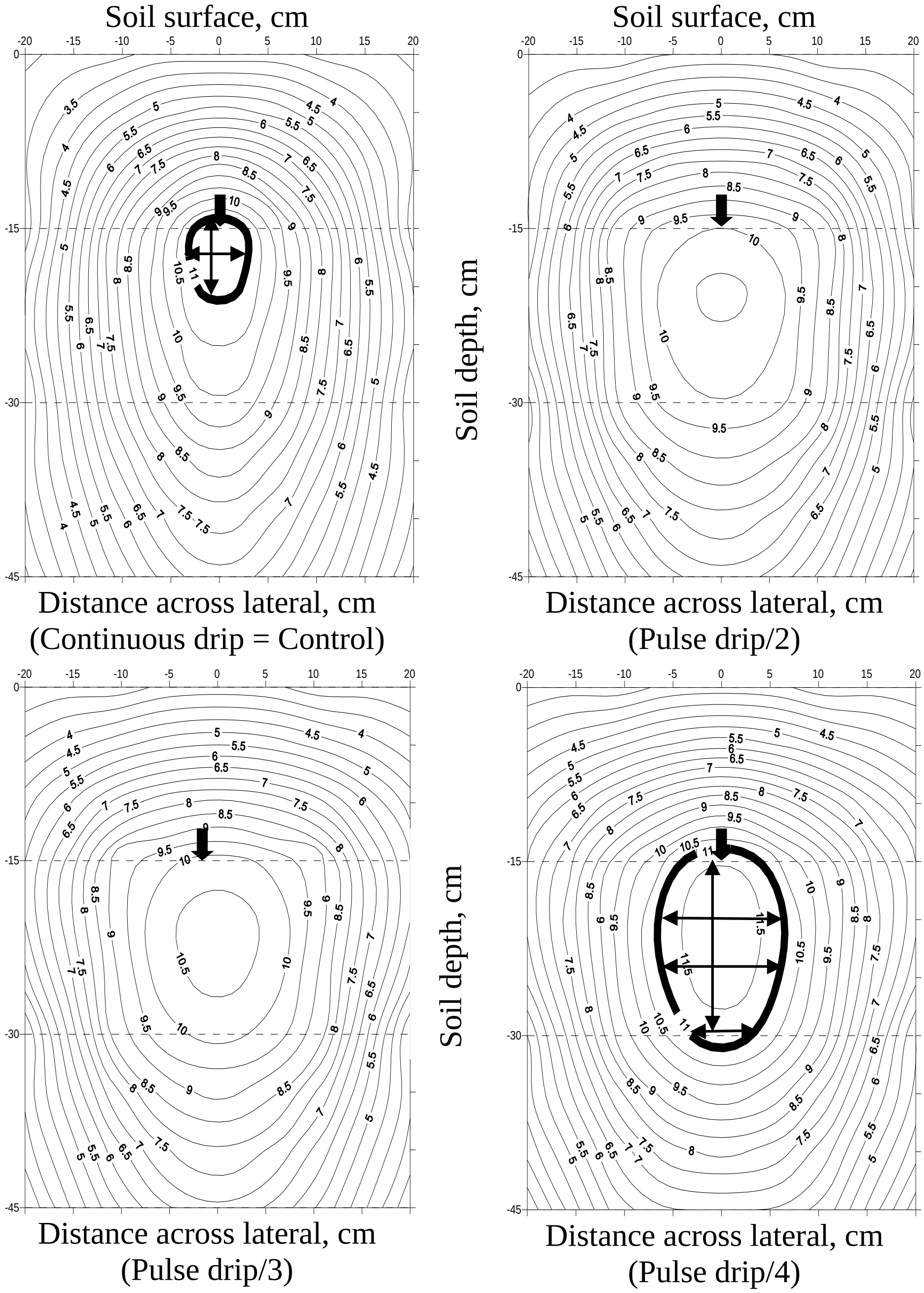

Fig.(9) Effect of pulse subsurface drip irrigation on wetted soil volume (more than or equal 100% of field capacity) at 50% actual irrigation requirements

It was clear from above data that, there are differences in the soil moisture content in the root zone after applying pulse technique compared with continuous drip irrigation, this due to increasing number of pulses cause increasing in water movement in horizontal direction than vertical direction. These results are agreement with those obtained by **El-Adi, (2000), Segal *et al*., (2000), RO-DRIP® User Manual (2001), Helen (2007)**, **Helmy *et al*. (2000)**, **Shock *et al.* (2006), Bouma *et al*. (2003) Eric *et al*. (2004),** and **Zin El-Abedin**, **(2006).** Not only soil moisture content in the root zone increased by increasing number of pulses but also pulse technique made enhancement in soil moisture distribution inside root zone and increased from $WSV_{\geq 100\%FC}$. The best conditions were determined according to the highest values of $WSV_{\geq 100\%FC}$ where increasing in $WSV_{\geq 100\%FC}$ means increasing in volume of available water in root zone.

$WSV_{\geq 100\%FC}$ increased by increasing number of irrigation pulses where $WSV_{\geq 100\% FC}$ in root zone increased from 9617 cm^3 under CDI to maximum value where it become 14272 cm^3 after applying pulse technique on 4pulses at 100 % from IRa under surface drip irrigation, recording an increase of 48%.

2. Effect of pulse drip irrigation on application efficiency.

Application efficiency, "AE" was calculated by dividing the volume of stored water in root zone by the volume of applied water. Volume of stored water was measured under four depths from 0 to 45cm and three distances from emitter center to 20 cm across lateral.

Figures (10 and 11) showed the relation between pulse drip irrigation, "PDI" and AE under 100%, 75% and 50% from IRa.

Fig. (10) showed the relation between PSDI and AE under 100%, 75% and 50% from IRa. First of all, AE increased by increasing number of pulses at 100% from IRa. AE increased from 88.6% under CDI to 93.5% under pulse technique with 4 pulses, recording an increase of 5.5 % from AE. Second, AE increased by increasing the number of pulses at 75% from IRa. AE increased from 92.4% for CDI to 97% under pulse technique on 4 pulses, recording an increase of 5 % from AE. Third; AE increased by increasing number of pulses at 50% from IRa. AE increased from 96.2 % for CDI to 99.2 % under pulse technique on 4 pulses, recording an increase of 3.1%.

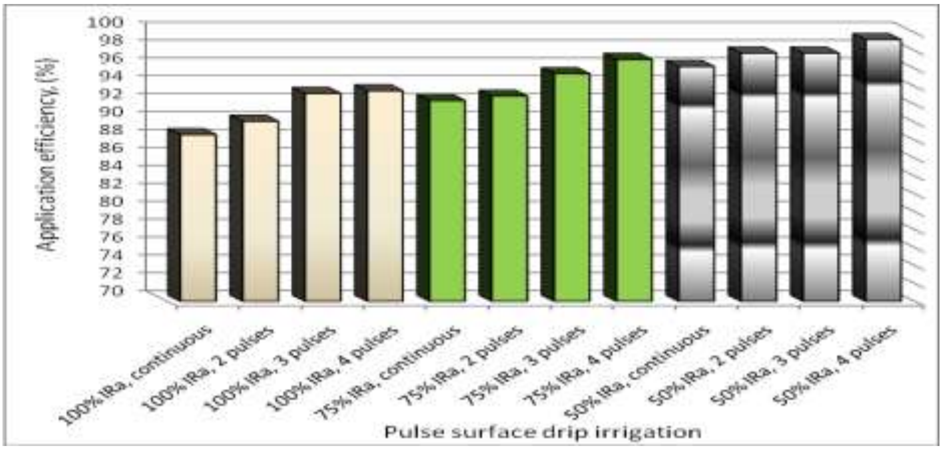

Fig.(10) Effect of pulse surface drip irrigation on application efficiency

Fig.(11) study the relation between PSSDI and AE under 100%, 75% and 50% from IRa. First of all, AE increased by increasing number of pulses at 100% from IRa. AE increased from 86 % for CDI to 92.8 % under pulse technique with 4 pulses, recording an increase of 7.9 % from AE. Second, AE increased by increasing the number of pulses at 75% from IRa. AE increased from 90.4 % for CDI to 95 % under pulse technique with 4 pulses, recording an increase of 5.1% from AE. Third; AE increased by increasing number of pulses at 50% from IRa. AE increased from 95.5% for CDI to 99.2 % under pulse technique on 4 pulses, recording an increase of 3.9 %.

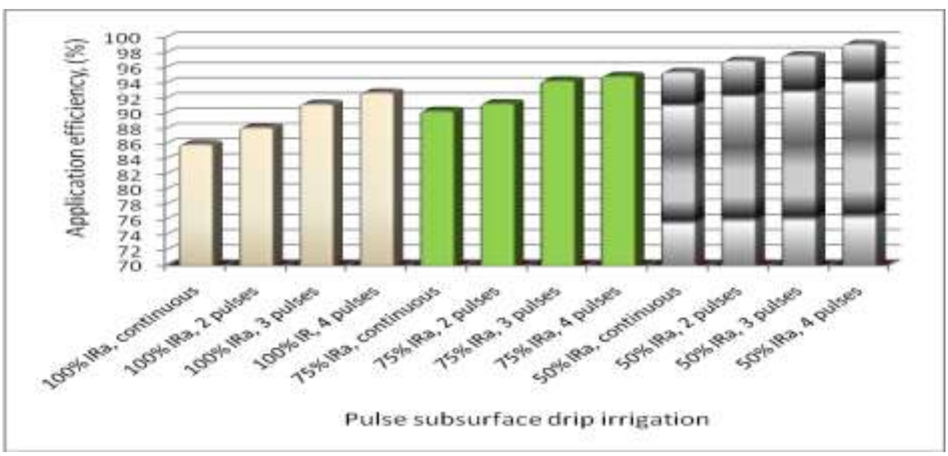

Fig.(11) Effect of pulse subsurface drip irrigation on application efficiency

Maximum value of AE was 99.2 % under the following conditions (50% from IRa with 4Pulses under SDI and SSDI) and minimum value of AE was 86 % under the following conditions (100% from IRa on CDI under SSDI)

From the above data, AE increased by increasing the number of irrigation pulses at (100%, 75% and 50% from IRa) under surface and subsurface drip irrigation. This may be due to pulse technique increased from water movement in horizontal direction than vertical direction. This action increased from wetted soil volume inside root zone and this mean increasing in water volume which was stored in root zone. These results were agreement with those obtained by **Scott (2000) and Oron (1981)**. AE decreased by increasing the amount of applied water. This due to decreasing in volume of stored water in root zone compared with increasing the volume of applied water. The values of AE under surface drip irrigation was higher than values of AE under subsurface drip irrigation this may be due to escaping the water out of root zone by deep percolation.

Application efficiency increased by increasing number of irrigation pulses at (100%, 75% and 50% from IRa) under surface and subsurface drip irrigation. AE increased from 88.6% under CDI to maximum value where it become 93.5% after applying pulse technique with 4pulses at 100 % from IRa under surface drip irrigation, recording an increase of 5.5% on the other hand maximum values of AE under deficit irrigation (75 % and 50% from IRa) were 97% and 99.2% respectively under surface drip irrigation with 4 pulses.

3. Effect of pulse drip irrigation on yield of potato.

The main goal from any development in agriculture is increasing the yields. Yield of potato was studied under the following factors: drip irrigation systems (surface and subsurface), water regime under deficit irrigation (100%, 75% and 50% from IRa) and pulse irrigation (one time per day = CDI, 2 pulses per day, 3 pulses per day and 4 pulses per day)

Figures (12 and 13) showed the relation between pulse drip irrigation and yield of potato, "YP" under 100%, 75% and 50% from irrigation requirements "IRa".

Fig. (12) showed the relation between pulse surface drip irrigation and YP under 100%, 75% and 50% from IRa. First of all, YP increased by increasing the number of pulses at 100% from IRa. YP increased from 4.35 (ton/fed.) for CDI to 6.50 (ton/fed.) under pulse technique on 4 pulses recording an increase of 49%. Second, YP increased by increasing the number of pulses at 75% from IRa. YP increased from 3.54 (ton/fed.)

for CDI to 6.35 (ton/fed.) under pulse technique with 4 pulses recording an increase of 79%.Third; YP decreased by increasing the number of pulses at 50% from IRa. YP decreased from 2.41 (ton/fed.)for CDI to 1.56 (ton/fed.) under pulse technique on 4 pulses recording a decrease of 35%.

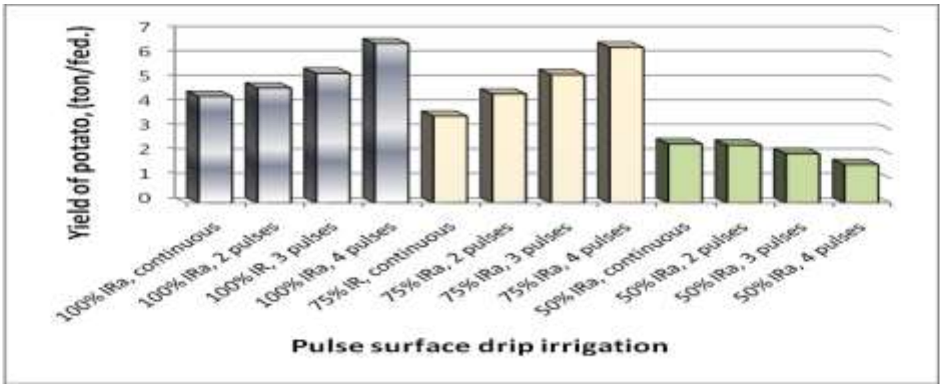

Fig.(12) Effect of pulse surface drip irrigation on yield of potato

Fig.(13) showed the relation between pulse subsurface drip irrigation and YP under 100%, 75% and 50% from IRa. First of all, YP increased by increasing the number of pulses at 100% from IRa. YP increased from 4.70 (ton/fed.) for CDI to 6.57 (ton/fed.) under pulse technique with 4 pulses recording an increase of 40%. Second, YP increased by increasing the number of pulses at 75% from IRa. YP increased from 3.89 (ton/fed.) for CDI to 6.39 (ton/fed.) under pulse technique with 4 pulses recording an increase of 64%.Third; YP decreased by increasing the number of pulses at 50% from IRa. YP decreased from 2.6 (ton/fed.) for CDI to 1.75 (ton/fed.) under pulse technique with 4 pulses recording a decrease of 33%.

Maximum value of YP was 6.57 (ton/fed.) under the following conditions (100% from IRa on 4pulses under SSDI) and minimum value of YP was 1.56 (ton/fed.) under the following conditions (50% from IRa on 4pulses under SDI).

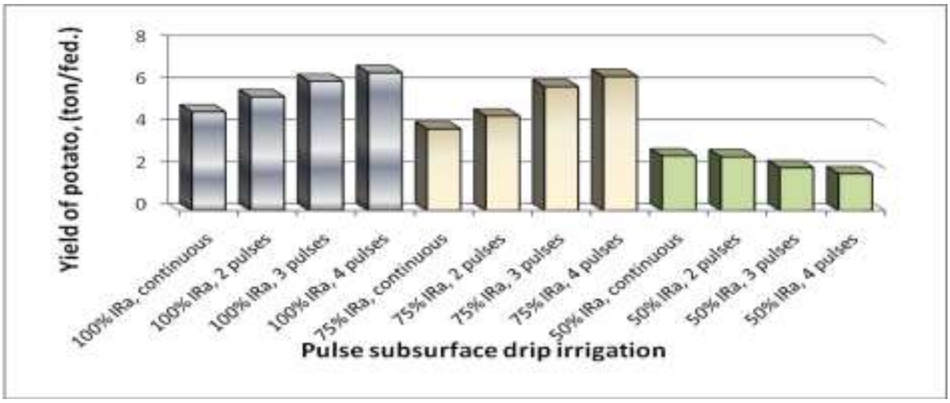

Fig.(13) Effect of pulse subsurface drip irrigation on yield of potato

YP increased by increasing the number of pulses especially at (100% and 75% from IRa). The increasing in YP due to the increasing in the available nutrients in the root zone. These nutrients will be more available for plant by increasing AE. Previous data indicated the positive role of pulse drip irrigation with increasing AE. These results are agreement with those obtained by **Zin El-Abedin (2006), Feng-Xin, *et al*. (2006)**, **Segal *et al*. (2000), Beeson (1992) and Nosenko, *et al*. (1991).** Although, values of AE at 50% from IRa under surface and subsurface drip irrigation were very high but volume of water stored was un-sufficient for growing potato plant and made high stress for plant in addition, the harm effect of pulse drip irrigation with small amount of water and increasing in time-off. Small amount of irrigation water with more pulses with increasing in time-off will concentrate the salts around the plant which increase from osmotic potentional hence decreasing from yield of potato especially under surface drip irrigation as shown in table (5).

Table (5) Effect of pulse drip irrigation on concentration of salts under 50% from actual irrigation requirements at the end of season.

Depth under emitter, cm	**Concentration of salts, (ds/m)**							
	Surface drip irrigation				**Subsurface drip irrigation**			
	Pulse technique				**Pulse technique**			
	CDI	**2** p	**3**	**4** p	**CDI**	**2** p	**3** p	**4** p
15	2.61	2.67	2.92	3.32	2.2	2.33	2.50	2.81
30	2.77	2.91	3.00	3.40	2.42	2.60	2.70	3.10
45	3.00	3.32	3.51	3.71	2.51	3.02	3.21	3.40

CDI = continuous drip irrigation, p = pulses

Using statistical analysis for values of YP indicated that, there were significant differences between pulse drip irrigation and continuous drip irrigation (L.S.D. at 5% level was 0.19).

YP increased by increasing number of irrigation pulses especially at (100% and 75% from IRa). YP increased from 4.70 (ton/fed.) under CDI to maximum value, where it become 6.57 (ton/fed.) after applying pulse technique with 4 pulses at 100 % from IRa under subsurface drip irrigation, recording an decrease 40%.

There were no significant differences between maximum value of YP and the following values of YP 6.50 (ton/fed.) and 6.39 (ton/fed.) under the following conditions (100% of IRa with 4 pulses under SDI) and (75% of IRa on 4 pulses under SSDI) respectively.

4. Effect of pulse drip irrigation on water use efficiency.

Water use efficiency "WUE" is an indicator of effectiveness use of irrigation water unit for increasing crop yield. Water use efficiency of potato "WUE_{potato}" was calculated by dividing total yield by total applied irrigation water. WUE_{potato} was studied under the following factors: drip irrigation systems (surface and subsurface), water regime under deficit irrigation (100%, 75% and 50% from IRa) and pulse irrigation (one time per day = CDI, 2 pulses per day, 3 pulses per day and 4 pulses per day)

Figures (14 and 15) showed the relation between pulse drip irrigation and water use efficiency for potato, "WUE_{potato}" under 100%, 75% and 50% from actual irrigation requirements, "IRa".

Fig. (14) showed the relation between pulse surface drip irrigation and WUE_{potato} under 100%, 75% and 50% from IRa. First of all, WUE_{potato} increased by increasing the number of pulses at 100% from IRa. WUE_{potato} increased from 1.40 (kg/m^3) for continuous drip irrigation, "CDI" to 2.08 (kg/m^3) under pulse technique with 4 pulses recording an increase of 48.5%. Second, WUE_{potato} increased by increasing the number of pulses at 75% from IRa. WUE_{potato} increased from 1.45 (kg/m^3) for CDI to 2.60% under pulse technique with 4 pulses recording an increase of 79%. Third; WUE_{potato} decreased by increasing the number of pulses at 50% from IRa. WUE_{potato} decreased from 1.37 (kg/m^3) for CDI to 0.89 (kg/m^3) under pulse technique with 4 pulses recording a decrease of 35%.

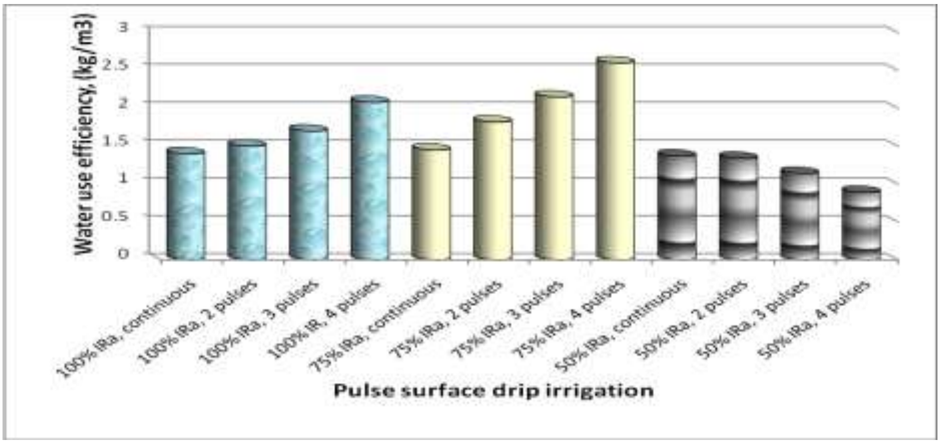

Fig.(14) Effect of pulse surface drip irrigation on water use efficiency

Fig.(15) showed the relation between pulse subsurface drip irrigation and WUE $_{potato}$ under 100%, 75% and 50% from IRa. First of all, WUE $_{potato}$ increased by increasing the number of pulses at 100% from IRa. WUE $_{potato}$ increased from 1.51 (kg/m^3) for CDI to 2.11 (kg/m^3) under pulse technique on 4 pulses recording an increase of 40%. Second, WUE $_{potato}$ increased by increasing the number of pulses at 75% from IRa. WUE $_{potato}$ increased from 1.59 (kg/m^3) for CDI to 2.62 (kg/m^3) under pulse technique on 4 pulses recording an increase of 65%.Third; WUE $_{potato}$ decreased by increasing the number of pulses at 50% from IRa. WUE $_{potato}$ decreased from 1.48 (kg/m^3) for CDI to 0.99 (kg/m^3) under pulse technique with 4 pulses recording a decrease of 33.1%.

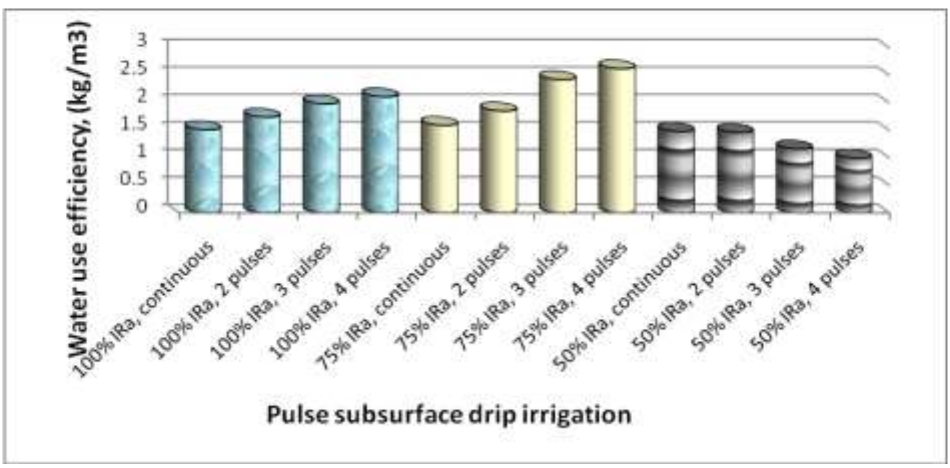

Fig.(15) Effect of pulse subsurface drip irrigation on water use efficiency

Maximum value of WUE $_{potato}$ was 2.62 (kg/m^3) under the following conditions (75%from IRa with 4pulses under SSDI) and minimum value of WUE $_{potato}$ was 0.89 (kg/m^3) under the following conditions (50% from IRa with 4pulses under SDI).

In general, There are significant differences between 2.62 (kg/m^3) under (75% from IRa on 4 Pulses under SSDI) and 2.11 (kg/m^3) under (100%from IRa on 4Pulses under SSDI)**.** This may be due to the reduced amounts of water applied did not change the soil moisture significantly. Yields for both treatments were similar. These results are agreement with those obtained by **Kenig *et al*. (1995) and Segal *et al*. (2000)**.

Using statistical analysis for values of WUE $_{potato}$ indicated that, there are significant differences between pulse drip irrigation and continuous drip irrigation (L.S.D. at 5% level was 0.08).

WUE $_{potato}$ increased by increasing number of irrigation pulses especially at (100% and 75% from IRa). WUE $_{potato}$ increased from 1.59 (kg/m^3) under CDI to maximum value, where it become 2.62 (kg/m^3) after applying pulse technique on 4 pulses at 75 % from IRa under SSDI, recording an decrease 65%, this mean that can save 25% of actual irrigation requirements per season which equal 679 m^3 from irrigation water.

There were no significant differences between maximum value of WUE $_{potato}$ and 2.60 (kg/m^3) under (75% of IRa with 4 pulses under SDI)**.**

CONCLUSION

From the above mentioned investigation, it can conclude the following points;

1. Wetted soil volume (more than or equal 100% of field capacity) increased by increasing number of pulses where $WSV_{\geq 100\% \ FC}$ in root zone increased from 9617 cm^3 under CDI to maximum value where it become 14272 cm^3 after applying pulse technique with 4pulses at 100 % from IRa under surface drip irrigation, recording an increase of 48%.so, it is recommended to use pulse drip irrigation to irrigate sandy soils.

2.Application efficiency increased by increasing number of irrigation pulses at (100%, 75% and 50% from IRa) under surface and subsurface drip irrigation. AE increased from 88.6% under CDI to maximum value where it become 9.35% after applying pulse technique with 4pulses at 100 % from IRa under surface drip irrigation, recording an increase of 5.5% on the other hand maximum values of AE under deficit irrigation (75 % and 50% from IRa) were 97% and 99.2% respectively under surface drip irrigation with 4 pulses.

3. Yield of potato increased by increasing number of irrigation pulses at (100% and 75% from actual irrigation requirements). Yield of potato increased from 4.70 (ton/fed.) under continuous drip irrigation to maximum value, where it become 6.57 (ton/fed.) after applying pulse technique with 4 pulses at 100 % from actual irrigation requirements under subsurface drip irrigation, recording an increase 40%.

4. There were no significant differences between maximum yield of potato and the following values 6.50 (ton/fed.) and 6.39 (ton/fed.) under the following conditions (100% of actual irrigation requirements with 4 pulses under surface drip irrigation) and (75% of actual irrigation requirements with 4 pulses under subsurface drip irrigation) respectively**.**

5. Avoid using pulse technique at 50% from irrigation requirements because, by increasing number of irrigation pulses with small amount of applied water salts accumulation increased inside root zone hence high decreasing in yield of potato

6. Water use efficiency of potato increased by increasing number of irrigation pulses at (100% and 75% from actual irrigation requirements). Water use efficiency of potato increased from 1.59 (kg/m^3) under continuous drip irrigation to maximum value, where it become 2.62 (kg/m^3) after applying pulse technique with 4 pulses at 75 % from actual irrigation requirements under subsurface drip irrigation, recording an increase 65%, this mean that can save 25% of actual irrigation requirements per season which equal 679 m^3 from irrigation water.

7. There were no significant differences between maximum water use efficiency of potato and 2.60 (kg/m^3) under (75% of actual irrigation requirements with 4 pulses under surface drip irrigation)**.**

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الملخص العربى

تأثير الري بالتنقيط النبضي علي إنتاجية وكفاءة إستخدام المياه لمحصول البطاطس تحت الزراعة العضوية في الأراضي الرملية

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عبدالرؤف رمضان عيد عبد الغني (٤)

نظام الري بالتنقيط النبضي من أحدث أساليب الري بالتنقيط حيث تضـاف المياه علـي فترات زمنيـة فـي دورات متتالية (من تشغيل وايقاف) حتي يتم الوصول للإحتياجات المائية للنبات٠ لـذا يعتبـر نظـام الـري بالتنقيط النبضي من أهم أساليب الري بالتنقيط في جدولة الري٠
أجريت التجارب علي تربة رملية بمزرعة أبو غالب بالكيلو ٦٠ بطريـق مصـر- اسكندرية الصـحراوي خلال موسمي ٢٠٠٦ و ٢٠٠٧ وكانت درجـة التوصـيل الكهربـي لميـاه البئـر ١,٩ ديسيسـمنز/متر وقـد اخذت عينات التربة حتي عمق ٤٥ سم ، قطر خطوط الموزعات ١٦مم وكان التصرف الفعلي للنقاط ٢,١ لتر/ساعة و كانت المسافة بين النقاطات ٣٠ سم والمسافة بين الخطوط ٧٠ سم. وقـد أجـري هـذا البحـث بهدف دراسة تأثير الري بالتنقيط النبضي علي إعادة توزيع الرطوبة الأرضية ومدي تأثير ذلك علـي كـل من كفاءة الإضافة و انتاجية المحصول وكفاءة استخدام المياه مقارنة بالتنقيط المستمر٠
ويمكن تلخيص أهم النتائج المتحصل عليها فيما يلي:-

(١) أزداد جحم التربة المبتل (أكبر من أو يساوي ١٠٠٪ من السعة الحقلية) من **٩٦١٧** سم٣ تحت الري بالتنقيط المستمر الي أقصي قيمه له وكانت **١٤٢٧٢** سم٣ بعد تطبيق نظام الـري النبضـي علـي ٤ نبضات عند ١٠٠٪ من الإحتياجات المائية الفعلية عند الـري بـالتنقيط السـطحي محققـا نسـبة زيـادة قدرها ٤٨٪.

(٢) زيادة قيمة كفاءة الإضافة من ٨٨,٦٪ تحت الري بـالتنقيط المسـتمر الـي أقصـي قيمـه لـه وكانـت **٩٣,٥**٪ بعد تطبيق نظام الري النبضي علي ٤ نبضات عند إضافة ١٠٠٪ مـن الإحتياجـات المائيـة الفعلية عند الري بالتنقيط السطحي محققا نسبة زيـادة قـدرها ٥,٥٪ بينمـا كانـت أقصـي قـيم لكفـاءة الإضافة عند نظام الري العجزي ٩٧٪ و ٩٩,٢٪ عند الري بـالتنقيط السـطحي بعـد تطبيـق نظـام الري النبضي علي ٤ نبضات عند إضافة **٧٥**٪ و٥٠٪ من الإحتياجات المائية الفعلية علي الترتيب ٠

(٣) زيادة الإنتاجية من ٤,٧ طن/فدان تحت الري بالتنقيط المستمر الي أقصـي قيمـه لـه وكانـت **٦,٥٧** طن/فدان بعد تطبيق نظام الري النبضي علي ٤ نبضات عند إضافة ١٠٠٪ من الإحتياجـات المائيـة الفعلية عند الري بالتنقيط التحت السطحي محققا نسبة زيادة قـدرها ٤٠٪ مـع تجنـب إسـتحدام الـري النبضي عند إضافة ٥٠٪ من الإحتياجات المائية الفعلية خاصة عند الري بالتنقيط السطحي حيث أنه بزيادة عدد النبضات مع كميات قليلة من المياه المضافة أدي ذلك الي زيادة تراكم الأملاح في الطبقـة السطحية لمنطقة إنتشار الجذور مما أدي الي الإضرار البالغ لإنتاجية الفدان من البطاطس مع التوقع بزيادة التأثير الضار مع زيادة زمن التوقف بين النبضات٠

(٤) زيادة كفاءة استخدام المياه بالنسبة لمحصول البطاطس من ١,٥٩ كج/م٣ تحت الري بالتنقيط المستمر الي أقصي قيمه له وكانت **٢,٦٢** كج/م٣ بعد تطبيق نظام الري النبضي علي ٤ نبضات عند إضافة **٧٥**٪ من الإحتياجات المائية الفعلية عند الري بالتنقيط التحت السطحي محققا نسبة زيادة قدرها ٦٥٪ وهذا يعني توفير ٢٥٪ من الإحتياجات المائية الفعلية في الموسم والتـي تقـدر بـ **٦٧٩** م٣ مـن ميـاه الري.

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