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Irrigation Scheduling of Potato to Increase the Water Productivity under Drip Irrigation System on Sandy Soil

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ABSTRACT

The use of irrigation scheduling in modern irrigation systems are a vital role to improve water productivity in arid regions. In Egypt, annually total cultivated area of potatoes on average 160 thousand feddan and this area is estimated at about 15% of the total allocated space for growing vegetables. Surface (SDI) and subsurface drip (SSDI) irrigation are highly efficient, but is not usually used properly. The object of this experiment is to to enhance yield and to save water on potato crop under irrigation methods. Results show that the water requirements was 1993.66 m^3/fed. in summer season compared with 1838.18 in Nili season after taking into account the proportion of crop coefficient, with irrigation efficiency was 90% and the rate of leaching were 10% .While the total water applied crop growth period were 1810, 1971, 1713 and 1892 m^3/fed./season in the Nili season at T_{11}, T_{12}, T_{21} and T_{22} respectively, compared with traditional irrigation was 2750 m^3/fed./season, while in the Summer season were 2050, 2243, 1900 and 2155 m^3/fed./season at T_{11}, T_{12}, T_{21} and T_{22} respectively, compared with traditional irrigation was 2920 m^3/fed./season. The water storage (water consumed) were 715.8 and 730.4 m^3/fed./season in the Nili season at T_{11}(SDI), T_{21}(SSDI) respectively, while its values were 814.8 and 769.2 m^3/fed./season in the Summery season at T_{11}(SDI), T_{21}(SSDI) respectively. The storage efficiency were 79.7 and 74.7% in the Nili season at T_{11}(SDI), T_{21}(SSDI) respectively, while it's were 83.1 and 78.2 % in the Summer season at T_{11}(SDI), T_{21}(SSDI) respectively. The irrigation water productivity ranges from 4.9 to 7.1 kg/m^3 in Nili seasons and 5 to 7.1 in Summery seasons. The irrigation water productivity were 7.0 and 7.1 kg/m^3 under T_{21} in Nili and Summery seasons respectively using subsurface drip. However it's were 6.5 and 6.1 kg/m^3 under T_{21} in Nili and Summery seasons respectively using surface drip, compared with traditional irrigation treatment (T_{00}) was 4.9 and 5 kg/m^3 in Nili and Summery seasons respectively. The results were for water saving 34.2, 28.3, 37.7, 31.2% at the Nili season and 29.8, 23.2, 34.9, 26.2%, in Summery season under treatments T_{11}, T_{12}, T_{21} and T_{22} respectively.

Keywords: Potato, Surface drip and Subsurface Drip Irrigation, Irrigation Scheduling, Water Requirement, Irrigation Water Productivity, Water Save, Water Storage and Storage Efficiency .

INTRODUCTION

Egyptian population has increased more than three times, from 30 million in 1953 to more than 100 million at the beginning of the year 2017, while the area of its cultivated land has changed slightly from 2.3 million hectares to approximately 3.6 million hectares during the same period. This has led to a shortage in food supplies. Consequently, management of sandy soils through proper reclamation measures to increase crop productivity assumes a great deal of interest in a day where in the available land area for cultivation is declining all the time.

Potatoes is one of the main vegetables crops in the world table, and it is grown in a large scale. It occupies the second site after the grain in importance. It is a source of energy instead of bread and rice. Potatoes is planted in many of the same moderate climate countries. In Egypt, annually total cultivated area of potatoes on average 160 thousand feddan and this area is estimated at about 15% of the total allocated space for growing vegetables. Although, it is imported annually no less than 40 thousand tons of potatoes tuber from Western European countries. It is one of the major economic importance in export (Ramadan and Shalaby 2017). Potato is an important vegetable crop for Egypt with a national cultivation area for 2012 crop year, summer seasons 145115 feddan, Nili seasons 55353 feddan and winter seasons 170963 feddan approximately 370 thousand feddans (fed. = 0.42 ha) yearly, (Farag *et al.* 2015).

Irrigation Scheduling should provide the crop with the right amount of water, when the crop needs it, at the lowest cost and with least impact on the environment. Irrigation scheduling is the process of determining and planning: - when to irrigate - how much water your crop requires -how fast to apply water to your crop (application rate) - how often to irrigate. Irrigation is a significant production expense. The maximum economic response to irrigation can only be achieved with a practical and effective scheduling system, (Shock *et al.* 2013).

Scheduling water application enhancing drip irrigation method, by increasing water use efficiency, while inadequate irrigation causes water stress and reduces production (Wang *et al.* 2006). However, Hedi Ben Ali *et al.* (2014) found that water content within the root zone was always higher under surface drip irrigation (SDI) system and that its fluctuation is especially more restricted than that recorded under drip irrigation (DI) system. This could explain high irrigation efficiency values recorded with surface drip irrigation (SDI) treatments where laterals buried at 15 cm depth's have generated the highest water productivity. However, for laterals buried at 20 cm depth's and with emitters delivering 4 l/h, deep water percolation is more evident.

Abdel-Moneim and Salem, (2014) found that the response of some potato cultivars to the method of drip irrigation under the soil surface were a significant increases comparing with surface drip irrigation method. They added that studied the influence of surface and subsurface drip irrigation systems on growth and potato yield. They found that, the response of some potato cultivars to the method of drip irrigation under the soil surface were a significant increases in growth and yield during comparing with surface drip irrigation system. Amer, *et al.* (2016) found that the water use by potato in the fall growing season was 35% lower compared to the spring growing season. Water saving per season was 28%, 18%, and 11% in spring growing season and 17.5%, 11.0%, and 7.0% in fall for furrow partial, trickle point, and trickle line methods compared with furrow traditional method, respectively.

The goal of this experiment was to determine the influence of irrigation scheduling on productivity of potato crop under irrigation methods, surface and subsurface drip irrigation with sandy soil condition.

MATERIALS AND METHODS

1 Experimental site

Field experiments were conducted during two seasons. Nili season starting from September to January of 2016 – 2017 and the Summer season starting from January to May 2017 at El-Nubaria district, Beheira Governorate, Egypt (latitude 300 45\ 52\\ N, and longitude 300 05\ 10\\ E, and mean altitude 21 m above sea level). The experimental of design was split plot for three irrigation system, surface drip irrigation (SDI), subsurface drip irrigation (SSDI) and furrow irrigation (Traditional irrigation). The area of each plot is 210 m2 (7 m × 30 m). The total area of the field experiment was 1050 m2. Plants row spacing was 0.7 m, and the distance between each plant was 0.3 m. The soil was ridged to 0.25 m above the tubers and the distance from top of the ridge to the base of the furrow was around 0.35 m. The surface drip irrigation lines were (GR) with outlets spacing every 0.3 m and the discharge of the emitter was 4 L/h at 1.5 bar working pressure. Subsurface drip irrigation lines laid above and under ridges of plant rows, and the installation depth of the subsurface drip lines was 0.25 m, plants were spaced 0.3 m along the rows, with distance between the rows equal to 0.7 m. All plots irrigated water was obtained from open channel and ECi of 1.35 ds./m.

The experiment consisted of three irrigation systems, Surface and Subsurface drip irrigation systems and two irrigation scheduling methods:

* T11(SDI) and T21(SSDI) represent both surface and subsurface drip irrigation respectively, the method fixed amount of water applied to crop every one day in initial stage, each two days in develop and middle stage and each three days in maturity stage from planting till harvest.
* T12(SDI) and T22(SSDI) represent both surface and subsurface drip irrigation respectively. Applying irrigation just before the available soil water is depleted to 70-65% (i.e. 30-35% allowable depletion) of tuber initiation and 65-60% (i.e. 35 - 40% allowable depletion) 35% of total available water (TAW) in the root zone, for other growth stages, and replenishing available soil water near field capacity in the root zone will greatly assist in producing a high-quality and high-yielding potato crop. (Alberta Agriculture and Forestry, 2011).
* T_{00} Traditional surface furrow irrigation.

2 Soil type and its characteristics

The soil of experimental site is classified as sandy loam soil. Some physical properties of the experimental soil is presented in Table (1). Irrigation water was obtained from an irrigation channel passing through the experimental area, with pH 7.35, and an ECe of 1.35 dS/m.

Table 1. Soil physical properties of the experimental site.

Soil Depth (Cm)	Particle size distribution			Soil Texture	Bulk Density Mg/m^3	F.C, %	W.P, %	SP, %
	Sand, %	Silt, %	Clay, %					
0-20	66.5	17.5	16	Sandy Loam	1.47	16.1	8.5	33.2
20-40	65.3	18.6	16.1		1.46	15.9	8.3	32.8
40-60	66.8	17.2	16		1.47	16.0	8.4	33.2

3 Potato cultivation and harvesting seasons:

There are two major cultivation seasons for potato, Nili season cultivated during September 20/9/2016. It was harvested in 13/1/2017 with about 115 day duration crop and may be divided into four stages namely initial: 20 days, developmental: 30 days, middle: 35 days and tuber maturity 30 days. Summer season cultivated during February 3/2/2017. It was harvested in 8/6/2017 with about 125 day duration crop. It may be divided into four stages namely initial: 25 days, developmental: 30 days, middle: 40 days and tuber maturity 30 days.

4 Nutrient management

The application of farmyard manure compost was applied uniformly at the rate of 20 m3/fed. during soil preparation, and followed by recommended potassium (as potassium sulphate); phosphorus (as triple super phosphate) and nitrogen (as ammonium nitrate) fertilizers at the rate of 50; 150; and 120 kg/fed., respectively, (Abdel-Ati, 1998). In all treatments, neither diseases were noticed throughout the crop season nor insecticides and fungicides were applied.

5 Estimation of crop evapotranspiration and grass water requirements

The meteorological data were taken from El-Nubaria meteorological station according to the formal data from the Egyptian Ministry of Agriculture. Reference evapotranspiration (ET0, mm/day) was calculated according to the Penman-Monteith (PM) equation as specified by the FAO protocol (Allen *et al*., 1998) for irrigation scheduling.

As crop evapotranspiration ETc can be calculated as:

$$ETc = Kc \times ET_0 \text{................} \quad (1)$$

Where:-

ETc : Crop evapotranspiration (mm/day),
Kc : Crop coefficient (dimensionless),
ET_0 : Reference crop evapotranspiration (mm/day).

In turn the Grass water requirement (GWR), is calculated by following (Allen *et al*., 1998).

$$GWR = (ET_o * Kc) * LR * 4.2/Ea \text{ ………} \quad (2)$$

Where:-

GWR:Grass water irrigation requirement for crop m^3/Fed./day
Kc: Crop coefficient [dimensionless]. (as well as, The crop coefficient was taken as 0.5, 0.56, 0.88, 0.99 and 0.92 in Nili season and 0.47, 0.62, 0.93, 0.95 and 0.74 in Summer season respectively, depend on the day stages, As discussed by (Amer *et al*., 2016)).
ET_o : Reference crop evapotranspiration [mm/day].
LR: Leaching requirement as a fraction LR (%) (Assumed 10% of the total applied water).
Ea: Efficiency of irrigation water system, % (Assumed 90% under surface drip irrigation and subsurface drip system).
4.2 is a conversion factor transforming the estimate from millimetres per day to cubic meters per Fadden per day (Feddan = 4200 m^2).

6 Measurement of soil water content, storage and water balance

Once the experiment began, the volumetric soil water content (θv) was measured daily to a depth of 0.5 m at 0.1 m intervals in each of the irrigation treatments using sensor capacitance probes (Terra Sen Dacom). The Terra Sen Dacom device is a complete soil moisture monitoring system (model, Dacom company, Nertherlands) that continuously monitors the θv over several depths in the root zone. The sensor Terra Sen devices were installed 0.5 m deep in the potato row between two healthy plants in the field. Soil moisture content and storage calculate the water storage in soil layers of 0–10, 10–20, 20–30, 30–40 and 40–50 cm. Soil water storage was calculated for each depth of a soil profile, using the following formula (Biniak-Pierog 2014):

$$\text{Storage (mm)} = 10 \times \theta_v \times h \text{ ....(3)}$$

Where:-

θ_v : soil moisture content (m^2 m^{-2}) and

h : the thickness (cm) of the soil profile.

Soil water storage was the sum of water storage for each soil level to a depth of 0.5 m. All measurements were taken at daily time intervals.

Soil water storage efficiency, (Es) is defined as the ratio of the volume of water stored in the root zone to the volume of water required to fill the root zone to near field capacity (Suat *et al*., 2011). It is expressed as:

$$Es = [Vs / (Vfc - Va)] \times 100 \text{.................. (4)}$$

Where:-

E_s = soil water storage efficiency (%)

V_s = volume of water stored in the soil root zone from an irrigation event (m^3/fed)

V_{fc} = volume capacity at field capacity in the crop root zone (m^3/fed)

V_a = volume of water in the soil root zone prior to an irrigation event (m^3/fed)

The water balance method in the soil was accomplished counting the irrigation depths applied (I), the difference of soil moisture content between two irrigations (ΔSW) measuring changes in moisture content after and before irrigation at the root zone and effective precipitation (P_e) (Equation 5). As Garcia *et al.* (2009), other variables such as water balance as superficial drainage, deep drainage, capillary rise, and variation of subsurface flows of input and output were considered null, having in mind the characteristics of the area and the irrigation system used.

$$ET_c = I + P_e \pm \Delta SW \text{ .... (5)}$$

To evaluate the effective precipitation (Pe), it was considered the precipitated water blade (mm) which provided changes in soil humidity, via Terra-Sen sensor, and which was effectively available for the culture.

The irrigation depth was calculated adopted the percentage of wetted area of 50%, due to the increased representation of the operation area of drippers in the rows of cultivation. Due to the increase in the percentage of shading of the potato under the cultivation area, the percentage of shaded area (PSA) started to be used in the calculation of the depth, considering an application efficiency of 90% (Mantovani *et al*., 2009).

7 Potato yield

Harvesting potato was started manually after 115 day from sowing In the Nili season and 125 day from sowing in the Summer season. Yield samples of potato tubers from each treatment and its replications were recorded.

8 Irrigation Water Productivity (IWP, kg/m³)

The total irrigation water productivity (IWP, kg/m³) as follows by Paredes *et al*. (2017). As discussed by Pereira *et al*. (2012), the term IWP is used instead of water use efficiency.

$$IWP = \frac{Ya}{TWU} \text{ .... (6)}$$

Where:-

IWP: Irrigation Water Productivity, kg/m³:

Ya: Total yield Kg /fed., and

TWU: Total water use, m³/fed/season.

RESULTS AND DISCUSSION

1. Estimation of reference evapotranspiration and crop water requirements:

Data in Table (2) illustrate the results of the ETo calculations for weather station located in El-Nubaria Station region under current and future conditions, the irrigation seasons, from 26/9/2016 to 8/1/2017 (105 day) Nili season and 9/2/2017 to 3/6/2017 (115 day) Summer season. The average values of daily ET_o through the peanut growing season were 4.35 and 5.0 mm/day in Nili and Summery seasons respectively. And table (2) show estimates of ET_c values, it is clear that ET_c values increased as the plant age progresses till the mid-season growth stages, then the rate was decreased till the end of the season, the average values of daily ET_c through the peanut growing season were 3.13 and 3.54 mm/day in Nili and Summery seasons respectively, where were values 2.9 and 2.08 mm/day in initial and maturity crop growth stage in Nili season respectively while were 1.25 and 5.1 mm/day in initial and maturity crop growth stage in Summer season respectively. Also it the highest values were 3.85 and 5.18 mm/ day in Nili and Summer seasons respectively.

Table 2. Average Reference Evapotranspiration (mm), Crop Coefficients, Crop Evapotranspiration (mm) and Grass Water Requirements (m³/fed./ month)

Month	Days	ET_o, mm	Kc	ET_c, mm	GWR, m³/fed./day	GWR, m³/fed./month
			Nili season			
Sep.	5	5.84	0.5	2.92	14.98	74.95
Oct.	31	5.52	0.56	3.09	15.87	491.90
Nov.	30	4.38	0.88	3.85	19.79	593.58
Dec	31	3.76	0.99	3.72	19.11	592.36
Jan.	8	2.26	0.92	2.08	10.67	85.39
Average, %		4.35		3.13		
Total irrigation water requirements, m³/fed./season.						1838.18
			Summer season			
Feb.	20	2.65	0.47	1.25	6.39	127.87
Mar.	31	3.29	0.62	2.04	10.47	324.60
Apr.	30	4.46	0.93	4.15	21.29	638.76
May.	31	5.45	0.95	5.18	26.59	823.91
June.	3	6.89	0.74	5.10	26.17	78.52
Average, %		5.00		3.54		
Total irrigation water requirements, m³/fed./season.						1993.66

Growing period Nili season (115 days) starting from 20th Sep. till harvesting date 13th Jan.

Growing period Summer season (125 days) starting from 3st February till harvesting date 8th Jun.

Also table (2) showed that the irrigation water requirements (m^3/fed.) after taking into account the proportion of crop coefficient, with irrigation efficiency was 90% and the rate of leaching were 10% and found that average overall irrigation water requirements was 1993.66 m^3/fed./season in Summer season compared with 1838.18 m^3/fed./season in Nili season theses results agree with many researchers Amer *et al*. (2016). But Badr *et al*., (2012) reported the total ETc of potato was 362 mm (1520 m^3/fed.) at the full irrigation supply in Nubaria region, west of Nile Delta, Egypt. They did experiment on late maturity potato variety 'Cara' (Solanum tubero-sum L.) during late summer from September to December, 2010 from FAO recommended value (Allen *et al.,* 1998).

2. Amounts of irrigation water applied

The total amount of water applied during the seasons for different treatments are given in Fig. (1 and 2). The results show that the total water applied was the highest at traditional irrigation (T_{00}) while the lowest values were obtained for subsurface drip irrigation system (SSDI) in the Nili and Summer seasons, where the total amounts of irrigation water applied under subsurface (SSDI) and surface (SDI) drip irrigation system using soil water balance (SWB) and traditional irrigation (T_{00}) were 1713, 1810 and 2750 m^3/fed./seasons respectively for Nili seasons. While the values were given 1900, 2050 and 2920 m^3/fed./seasons respectively for Summer. At using local farmers, the results were 1892, 1971 and 2750 m^3/fed./seasons respectively for Nili seasons, while the values were given 2155, 2243 and 2920 m^3/fed./seasons respectively for Summer seasons, table (3).

The total water applied crop growth period Fig. (3) were 1810, 1971, 1713 and 1892 m^3/fed. in the Nili season at T_{11}, T_{12}, T_{21} and T_{22} respectively, compared with tradition irrigation was 2750 m^3/fed. while in the Summer season were 2050, 2243, 1900 and 2155 m^3/fed. at T_{11}, T_{12}, T_{21} and T_{22} respectively, compared with tradition irrigation was 2920 m^3/fed., table (3).

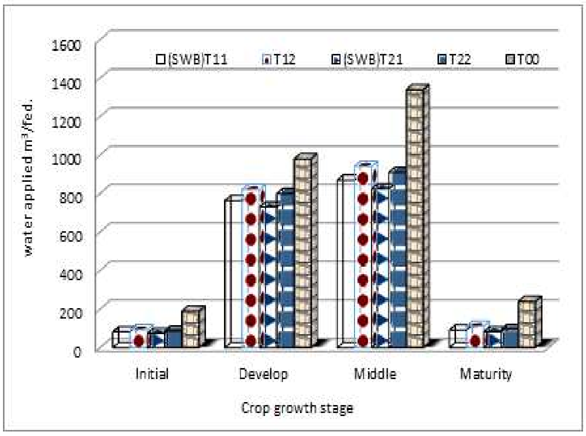

Fig. 1. Irrigation water applied (m^3/fed.) for growth stages of potato crop Nili Season for surface and subsurface drip irrigation system under different treatments.

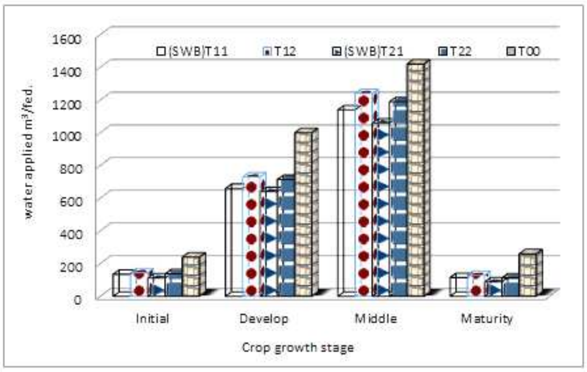

Fig. 2. Irrigation water applied (m^3/fed.) for growth stages of potato crop Summer Season for surface and subsurface drip irrigation system under different treatment.

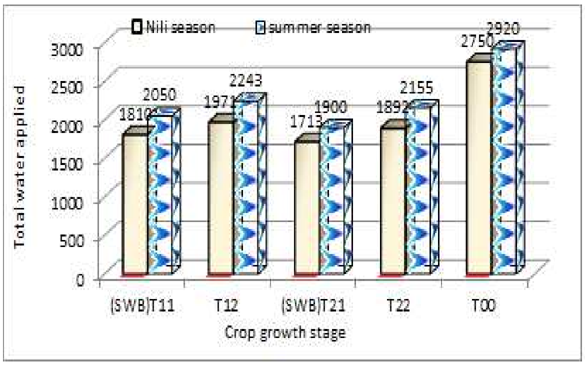

Fig. 3. Total irrigation water applied (m^3/fed.) for surface and subsurface drip irrigation systems under different treatment compared with Traditional irrigation.

3. Soil moisture content, Water storage and Storage efficiency

Fig. (4 and 5) shows the soil moisture before and after irrigated for the different patterns of distribution in response to the different irrigation treatments. So when comparing SDI with SSDI system it was observed that in the subsurface drip irrigation (the drip line was buried at 25 cm from the soil surface), except that surface soil later was not completely wetted as in the case of surface drip. However, the upward capillary movement of water was not sufficient and soil water content at the surface decreased significantly where most wetting occurred close to the water source. Where the average soil moisture values during the initial stage (until 30 - 40 allowable depletion) were similar to each other in different treatments. The average soil moisture values at depths of 0.5 m (0.1, 0.2, 0.3, 0.4 and 0.5 m) were either above or near the F.C after starting the irrigation treatments. But there is a difference between the soil moisture under the subsurface drip irrigation and surface drip irrigation because the water movement up and down in the subsurface drip either in surface irrigation is movement down only, therefore, when applying irrigation scheduling using soil water balance, it is recommended to consider soil moisture in the surface layer (0.1 m) in the difference of soil moisture content between two irrigations (ΔSW) measuring.

Table 3. Average soil water storage (m^3/fed.) and Soil water storage efficiency, % under different treatments.

	Surface drip irrigation system, (SWB)T_{11}	Subsurface drip irrigation system, (SWB)T_{21}
Nili Season		
Water required to fill the root zone to near field capacity, m^3/fed.	897.96	977.97
Water storage in the root zone, m^3/fed.	715.89	730.38
Soil water storage efficiency, %	79.7	74.7
Summer Season		
Water required to fill the root zone to near field capacity, m^3/fed.	980.49	983.64
Water storage in the root zone, m^3/fed.	814.8	769.23
Soil water storage efficiency, %	83.1	78.2

The seasonal volume of water storage in the root zone, m3/fed. (water consumed) and soil water storage efficiency are shows in table (3), the sum of water stored for each soil level to a depth of 0.5 m., The values all measurements were taken at weekly time intervals, the results of the table (3) showed that the seasonal water storage (water consumed) ranged from 715.89 to 730.38 m3/fed./season in the Nili season at T11, T21 respectively, while its values were 814.8 and 769.23 m3/fed./season in the Summer season at T11, T21 respectively. This reduction in total amount of water consumption is mainly due to short depth of the sensor installed in the site (50 cm). The storage efficiency were 79.7 and 74.7 % in the Nili season at T11, T21 respectively, while it's were 83.1 and 78.2 % in the Summer season at T11, T21 respectively.

4. Irrigation Water Productivity (IWP) and Water Saved

Data on water productivity for all treatments are presented in table (4). The amount of applied irrigation water gave the higher IWP and subsurface drip method recorded superior values over surface drip especially under (SWB) T21 in Nili and summer seasons treatments. Since the source of water is at a certain depth when subsurface drip is used, the soil surface usually remains drier than for the surface drip irrigation This leads to the reduction of evaporation from the soil surface and consequently to an increase in transpiration and overall IWP the values of water productivity ranges from 4.9 to 7.0 kg/m3 in Nili seasons and 5 to 7.1 in Summery seasons. The subsurface drip irrigation methods is the highest values of water productivity were 7.0 and 7.1 kg/m3 under T21(SWB) treatment in Nili and Summery seasons respectively. However the surface drip irrigation methods is the highest values of water productivity were 6.5 and 6.1 kg/m3 under T21(SWB) treatment in Nili and Summery seasons respectively. Compared with traditional irrigation treatment (T00) was 4.9 and 5 kg/m3 in Nili and Summery seasons respectively. Irrigation water productivity (IWP) was observed to be significantly affected by both the irrigation system and irrigation scheduling (Table 4). IWP was higher under subsurface drip irrigation T21 (SWB) than other treatments. The irrigation system has great effect on water productivity. Subsurface drip irrigation under soil water balance treatment improved water productivity. These results are in accordance with those obtained by Yamac *et al.* 2014. water saving was significantly higher in subsurface drip over surface drip and compared with Traditional irrigation (T00), under all irrigation treatments. Maximum water saving was obtained by (SWB) in the Nili and Summer seasons. The results were for water saving 34.2, 28.3, 37.7, 31.2% at the Nili season and 29.8, 23.2, 34.9, 26.2%, in Summer season under treatments T11, T12, T21 and T22 respectively. Results are in similar with those obtained by Kahlon and Khera (2015) reported that yield water use efficiency values for potato crops in Spain ranged between 6.3 and 8.6 kg/m3. the other hand the treatment, T11(SWB) irrigation water saved was 8.2% compared to T12 under surface drip irrigation system and T21(SWB) irrigation water saved was 8.2% compared to T22 under subsurface drip irrigation system in Nili season, T11(SWB) irrigation water saved was 8.6% compared to T12 under surface drip irrigation system and T21(SWB) irrigation water saved was 11.8 % compared to T22 under subsurface drip irrigation system in summer season.

Table 4. Total water applied (m^3/fed.), Yield (kg/fed.), Irrigation Water Productivity (kg/m^3) and Water saved (%) under different treatment.

Type of irrigation methods	Treatments	Total water applied, m^3/fed.	Yield, kg/fed.	Irrigation Water Productivity, kg/m^3	Water Save, % Traditional	system
				Nili Season		
Surface drip irrigation	T_{11}(SWB)	1810	11750	6.5	34.2	8.2
	T_{12}	1971	11430	5.8	28.3	0
Subsurface drip irrigation	T_{21}(SWB)	1713	12000	7.0	37.7	9.5
	T_{22}	1892	11800	6.2	31.2	0
Traditional irrigation	T_{00}	2750	13500	4.9	0	
				Summer Season		
Surface drip irrigation	T_{11}(SWB)	2050	12600	6.1	29.8	8.6
	T_{12}	2243	11430	5.1	23.2	0
Subsurface drip irrigation	T_{21}(SWB)	1900	13400	7.1	34.9	11.8
	T_{22}	2155	12800	5.9	26.2	0
Traditional irrigation	T_{00}	2920	14600	5.0	0	

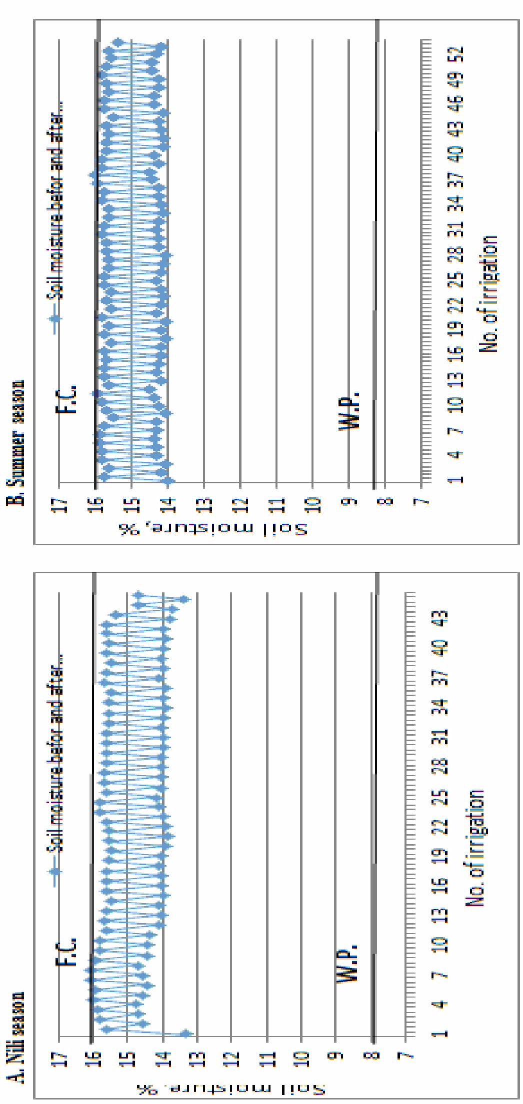

Fig (4) Average soil moisture before and after irrigation under surface drip irrigation (SDI), A.and B. are Nili and summer season.

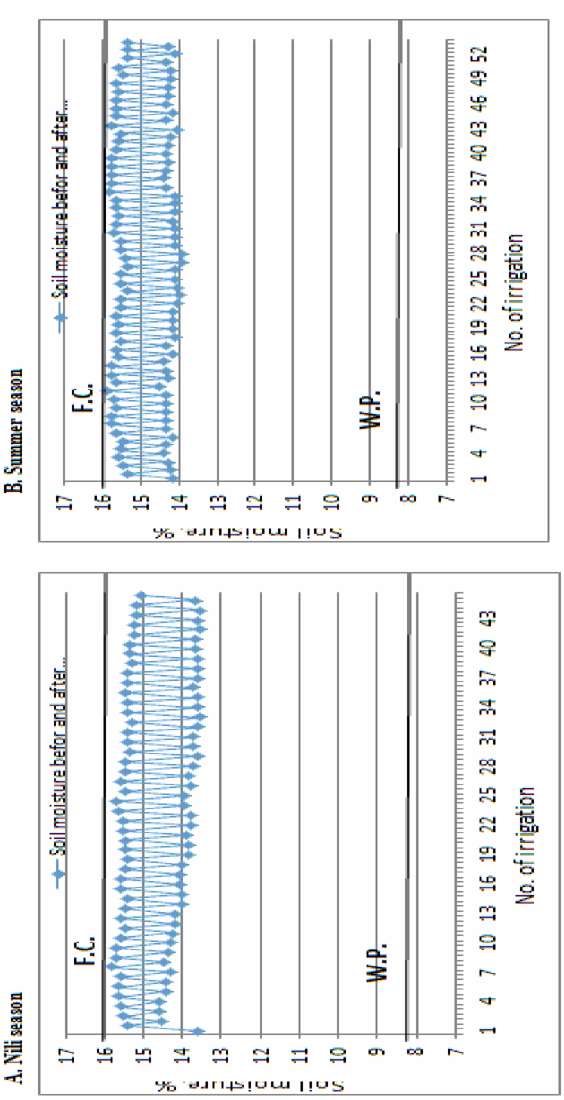

Fig (5) Average soil moisture before and after irrigation under subsurface drip irrigation (SSDI), A.and B. are Nili and summer season.

CONCLUSOIN

The obtained results, it may be concluded that: There was saving in the water applied under subsurface drip irrigation compared with surface drip irrigation system using (SWB) by a percentages of 5.35% (60 m^3) and 7.3% (138.7 m^3) under Nili and Summery seasons respectively, it is enough to irrigate another area equal to 147.11 m^2 (0.035 fed.) and 306.6 m^2 (0.073 fed.) under Nili and Summery seasons, respectively. While using the traditional drip irrigation system the results were as follows, a percentages of 4.01% (75.86 m^3) and 3.9% (84.04 m^3) under Nili and Summery seasons respectively, it is enough to irrigate another area equal to 168.39 m^2 (0.04 fed.) and 163.8 m^2 (0.039 fed.) under Nili and Summery seasons, respectively. This also saves energy and reduces overall costs and thus increases revenue.

The water productivity (kg/m^3) for subsurface drip irrigation treatments gave the highest values using each of (SWB) and (the traditional drip irrigation system) comparing with Surface drip irrigation treatment under the same conditions. Which subsurface or surface drip irrigation treatments using (SWB) gave 7.0 and 7.1 kg/m^3 for both Nili and summer season respectively.

While the lowest values were for traditional irrigation 4.9 and 5.0 kg/m^3 for both Nili and summer seasons respectively. Therefore subsurface or surface drip irrigation treatments using (SWB) methods caused reduction in the total applied water compared with the traditional methods.

The total water applied crop growth period in the summer season increases by 9.8 and 11% compared to the Nili season under subsurface and surface drip irrigation using (SWB) respectively. There were no differences between irrigation methods (subsurface and surface drip irrigation system) using (SWB) on storage efficiency,%.

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جدولة الري لمحصول البطاطس لرفع الكفاءة الإنتاجية المائية تحت نظام الري بالتنقيط بالأراضي الرملية

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تعتبر البطاطس من محاصيل الخصر التي تزرع علي نطاق واسع، فهي من إحدى المحاصيل الغذائية الرئيسية في مائدة العالم وتحتل الموقع الثاني بعد الغلال في الأهمية، وفي مصر تقدر إجمالي المساحة المنزرعة بمحصول البطاطس حوالي 160 ألف فدان، وهذه المساحة تمثل حوالي 15٪ من المساحة المنزرعة بالخضروات، وأن كفاءة استخدام الري بالتنقيط السطحي والتحت سطحي عاليه، ولكن الاستخدام التقليدي لها يقلل من كفاءتها. لذلك يهدف هذا البحث إلي دراسة جدولة الري تحت نظامي الري بالتنقيط السطحي والتحت سطحي لتحسين الإنتاجية ورفع كفاءة وحدة المياه، وذلك بحساب الاحتياجات المائية باستخدام معادلة بنمان مونتيث المعدلة الفاو(56) وإضافة المياه معتمدا علي جدولة الري تحت كل من نظام الري بالتنقيط السطحي والتحت سطحي والتي تتمثل فى المعاملات T_{12}، T_{22} لنظامى الري بالتنقيط السطحي والتحت سطحي علي الترتيب معتمدا علي الري بنظام المزارع العادي يوم ثم يومين ثم ثلاث أيام حسب موسم النمو والمعاملات T_{11}، T_{21} لنظامى الري بالتنقيط السطحي والتحت سطحي علي الترتيب معتمدا علي الاتزان المائي الذي يعتمد علي أجهزة مراقبة رطوبة التربة (Terra Sen Dacom) المثبتة بعمق 0.5 متر عند صف البطاطس بين نباتين في الحقل. أوضحت النتائج أن الاحتياجات المائية المحسوبة باستخدام معادلة بنمان مونتيث كانت 1993.66 و 1838.18 م^3/فدان/موسم في موسم الصيفي و النيلي علي الترتيب بعد الأخذ في الاعتبار نسبة معامل المحاصيل وكفاءة الري 90٪ ومعامل الغسيل 10٪ وكانت كمية المياه المضافة فعليا خلال موسم النمو 1810، 1971، 1713، 1892 و2050، 2243، 1900، 2155 م^3/فدان/موسم في الموسم النيلي والصيفي علي الترتيب للمعاملات T_{11}، T_{12}، T_{21}، T_{22} على التوالي، بالمقارنة مع الري التقليدي 2750 و 2920 م^3/فدان/موسم في الموسم النيلي والصيفي علي الترتيب. واتضح من المياه المستهلكة ان اعلى قيمة كانت تحت المعاملة (T_{12}) فى الموسم الصيفى حيث كانت 2243 م^3/فدان /موسم بالنسبة للرى بالتنقيط السطحى التقليدى وان اقل كمية من الاستهلاك المائى للمعاملة (T_{21}) 1713 م^3/فدان/موسم في الموسم النيلي والتي يعتمد فيها جدولة الري علي طريقة الاتزان المائي، وكانت المياه المخزنه بمنطقة الجذور (المستهلكة للمياه) 715.8 و 730.4 م^3/فدان/موسم في الموسم النيلي للمعاملات(SDI) T_{11}، T_{21}(SSDI) على التوالي، في حين كانت 814.8 و 769.2 م^3/فدان/موسم في الموسم الصيف للمعاملات(SDI) T_{11}، T_{21}(SSDI) على التوالي. وكانت كفاءة تخزين المياه في التربة 79.7 و 74.7٪ في الموسم النيلي للمعاملات T_{11}، T_{21} على التوالي، في حين كانت 83.1 و 78.2٪ في موسم الصيف للمعاملات (SDI)T_{11} ، T_{21}(SSDI) على التوالي. وتراوحت إنتاجية المياه من 4.9 إلى 7.0 كجم / م^3 في المواسم النيلي و 5 إلى 7.1 كجم/م^3 في المواسم الصيف. وكانت إنتاجية المياه 7.0 و 7.1 كجم/م^3 للمعاملة T_{21} في المواسم النيلي والصيفي على التوالي باستخدام الري بالتنقيط تحت السطح. ومع ذلك فقد كان 6.5 و 6.1 كجم/م^3 للمعاملة T_{21} في مواسم النيلي والصيفي على التوالي باستخدام الري بالتنقيط السطحي، مقارنة مع معاملة الري التقليدية (T_{00}) التي كانت 4.9 و 5 كجم/م^3 في مواسم النيلي والصيفي على التوالي. من حيث وفرة المياه كانت اعلي قيمه لها فى المعاملة T_{21} في الموسم النيلي حيث أعطت 37.7 % وكانت أقل قيمة كانت للمعاملة T_{21} في الموسم الصيفي وكانت 23.2 % بالمقارنة بمعاملة الري السطحي التقليدى T_{00}، وعند مقارنة نظام الري بالتنقيط السطحي والتحت سطحي كانت الأفضلية للري تحت سطحي بنسبة 9.5 % بالنسبة للموسم النيلي و 11.8 % بالنسبة للموسم الصيفي. ومن النتائج اتضح ان استخدام جدولة الري التي تعتمد على نظام الاتزان المائي تحت نظام الري بالتنقيط تحت سطحي مقارنة بالري بالتنقيط التحت سطحي المتبع توفر مياه الري بنسبة 11.8 % بما يعادل 255 م^3/ فدان/ الموسم وهذه الكمية كافية لري مساحة تصل الى 563.68 م^2 (0.134 فدان) مع استخدام نظام الري بالتنقيط تحت سطحي الذى يعتمد على الاتزان المائي، وأيضا تصل هذه النسبة الى 8.6 % في حالة مقارنة الري بالتنقيط السطحي الذى يعتمد في الري على الاتزان المائي بالطرق الأخرى المتبعه.وهذا أيضا يوفر في الطاقة ويقلل من التكاليف الاجمالية.