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The Effect of Change the Flood Irrigation System to Drip Irrigation System of Potato Yield in the North Nile Delta Region

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Abstract: Planning for the application of drip irrigation becomes necessary to rationalize water. This study aimed to compare the effects of drip irrigation at three water regimes (65 %, 75 % and 85 % ETc) with flood irrigation in a furrow (farmer practices) on potato plant growth, yield, quality, nutrient uptake and irrigation water productivity. Two field experiments were carried out during the summer season of 2016/2017 and 2017/2018 on potato cv. Valor in the North Nile Delta Region, Egypt (31° 20' 326.7" N and 31° 45' 286.0" E). The results demonstrated that the application of a drip irrigation system at the rate of 85 % ETc enhanced plant growth, total yield (13.167 t. fed^{-1}), yield quality, marketable yield percentage and its content of nutrients, without significant differences with flood irrigation in-furrow. Application of drip irrigation method significantly increased the yield of dry matter and starch (2951 and 2103 kg fed^{-1}, respectively) and maximized irrigation water productivity (8.681 kg m^{-3}). In contrast, furrow irrigation increased plant height and foliage fresh and dry weights and had recorded the lowest value of irrigation water productivity (5.472 kg m^{-3}). Results demonstrated that the application of drip irrigation at the rate of 85 % ETc could save water applied by about 27.3 % and improve nutrient uptake as compared with flood irrigation.

Key words: Potato Yield · Quality · Nutrient uptake · Irrigation Scheduling & Water Productivity

INTRODUCTION

In Egypt, water is the most limited factor in crops production. Under limitation of fresh water resources, we should do our best towards effective rationalization of irrigation on the farm level. Therefore, the knowledge of the amount of water required to produce the highest economical yield is essential.

Potato (*Solanum tuberosum* L.) is an important vegetable crop for Egypt with a national cultivation area approximately 415 thousand feddans (fed. = 0.42 hectare) in year of 2017 with total productivity 3.8 million ton [1]. Potato is one of the most sensitive crops to water stress due to its shallow rooting system and the sensitivity of the potato foliage characteristics. Therefore, the suitable irrigation water regime and nutritional program are the effective tools for increasing yield and improving its quality [2-4].

Planning for the application of drip irrigation of potato crop becomes necessary to rationalize the quantity of irrigation water and maximizes the efficiency of the applied water. Surface drip irrigation obtains the greatest water use efficiency and should be recommended under Mediterranean conditions for potato production [5, 6].

Studies showed that number of tubers per plant, tuber yield, weight and number of marketable tubers were increased by applying drip irrigation method as compared with furrow irrigation [7, 8]. Also, Awari and Hiwase [9] reported that the highest tuber yield and water use efficiency were obtained with drip irrigation system.

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In clay loam soil under the conditions of Nile Delta Region, El-Banna *et al*. [10] reported that using drip irrigation at the rate of 1650 m^3 fed^{-1} recorded the highest total tubers yield and higher water use efficiency than irrigation in furrow (2350 m^3 fed^{-1}).

Abdel-Moneim and Salem, [11] found that, the response of some potato cultivars to the method of drip irrigation under the soil surface were a significant increase in growth and yield during comparing with surface drip irrigation system. Amer, *et al*. [12] 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.

In sandy loam soil, irrigation water productivity (IWP) increased with application surface and subsurface drip irrigation systems compared with traditional irrigation. IWP were 7.1 kg m^{-3} in Summery season using subsurface drip at 1900 m^3 water fed^{-1}; however it's were 6.1 kg m^{-3} with surface drip at 2050 m^3 water fed^{-1}. Where, with traditional irrigation treatment (2920 m^3 fed^{-1}) IWP was 5 kg m^{-3} [13].

The aim of this investigation was optimize the irrigation water productivity and potato yield quality by using drip irrigation as compared with traditional irrigation in furrow under conditions of North Nile Delta soils, Egypt.

MATERIALS AND METHODS

Two field experiments were carried out during the seasons of 2016/2017 and 2017/2018 on potato cv. Valor at a farm in Besendela Village, Belqas District, Dakahlia Governorate, Egypt (31° 20' 326.7" N and 31° 45' 286.0" E).

Four treatments of irrigation (drip and furrow) were arranged in 1 Way Randomized Blocks Design with 3 replicates as follows:

- Drip1: Irrigation with amount of water equals 65 % of potential evapotranspiration (ETcrop).
- Drip2: Irrigation with amount of water equals 75 % of potential evapotranspiration (ETcrop).
- Drip3: Irrigation with amount of water equals 85 % of potential evapotranspiration (ETcrop).
- Furrow: flood irrigation (farmer practices).

This investigation aimed to compare between the effect of drip irrigation at three water regimes (65%, 75% and 85% ETcrop) and irrigation in furrow (farmer practices) on potato plant growth, yield, tuber quality and its contents of N, P and K, as well as the water use efficiency.

Samples of soil were taken of the experiment fields (0-30 cm) before planting, where some physical and chemical properties were carried out according to Hesse [14] and Page [15], as shown in Table (1). EC was determined in soil paste extract, where pH was measured in 1:2.5 soil: water suspension.

Potato tuber seeds cv. Valor were planted in 1st week of January 2017 and 2018 for the two seasons, respectively. Experimental design was a randomized complete blocks with three replications.

Soil moisture constants (Table 2) were determined using the pressure membrane apparatus, considering the saturation percent "SP" at 0 kPa, field capacity "FC" at 33 kPa (0.33 bar) and wilting point "WP" at 1.5 MPa (15 bar). Available water was considered as the difference between FC and WP [16]. Soil bulk density values were determined using the core method. Meteorological data for the Agricultural Research Station is shown in Table 3.

Irrigation System

Drip Irrigation System: The irrigation system was surface drip irrigation consisting of an electric irrigation pump (2 hp). The conveying pipeline system consisted of a PVC main line with 76.2 mm Ø connected to sub-main line of 50.8 mm Ø and a manifold of 38.1 mm Ø. The drip lateral lines of 16 mm Ø were connected to the manifold line. Each line was served with one line about 20 m apart. Lateral irrigation lines were equipped with built-in emitters of 3.4 L h^{-1} discharge and spaced at 0.25 m apart. Irrigation was every 3 days for the drip treatments, started 20th days after planting and stopped 10th days before harvest. The quantity of irrigation water applied was measured using a water meter attached to the irrigation pump.

Surface Irrigation System: For irrigation in furrows, it started after planting by 20th days and stopped before harvest by 15th days, where plants were received 7 irrigations (as shown in Table 4). The rate of irrigation pump was 350m^3h^{-1} and the length of furrow was 10 m.

Submerged flow orifice with fixed dimension was used to measure the amount of water applied, according to Michael [17] as the following equation:

Table 1: Some physical and chemical properties for the experimental site soil

Properties	Particle size distribution (%) Sand	Silt	Clay	Texture Class	B.D (Mg m^{-3})	SP %	O.M %	$CaCO_3$ %
Values	25.73	28.96	45.31	Clay	1.40	70.3	2.08	5.84
Properties	pH*	EC**	Ca^{2+}	Mg^{2+}	Na^{+}	SO_4^{2-}		
Values	8.09	3.40	13.0	9.0	11.75	9.6		
Properties	N	P	K	Ca	Mg	B		
Values	52	12.0	245	800	180	0.50		

Table 2: Soil field capacity, wilting point, available water and bulk density for the experimental site soil

Depth (cm)	Field capacity (FC) %	cm	Wilting point (WP) %	cm	Available water (AW) %	cm	Bulk density Mg m^{-3}
0–15	40.8	7.22	19.8	3.50	21.0	3.72	1.18
15–30	39.4	7.15	18.5	3.36	20.9	3.79	1.21
30–45	37.9	6.99	17.8	3.28	20.1	3.71	1.23

Table 3: Average meteorological data of the experimental site in the 2016 and 2017 seasons

Month	T.max. (°C)	T.min. (°C)	Wind speed (m s^{-1})	Relative humidity (%)	Sunshine duration (h)	Solar radiation ($cal/cm^2/day$). S.R))	Rainfall (mm $month^{-1}$)
				1st season 2017			
February	24.2	9.8	2.4	63	9.5	363	3.0
March	26.4	11.6	2.8	57	10.4	439	9.9
April	33.4	14.8	2.8	50	11.1	570	2.5
May	34.4	17.6	3.3	47	12.3	606	0.0
				2nd season 2018			
February	20.9	8.1	2.2	68	9.4	353	5.4
March	25.0	10.9	2.8	60	10.6	454	0.2
April	28.7	12.6	2.8	58	10.5	545	40.8
May	34.6	17.3	3.0	49	11.8	623	0.0

$$Q = CA\sqrt{2gh}$$

where:

Q = Discharge through orifice, (1/sec).
C = Coefficient of discharge, (0.61).
A = Cross-sectional area of the orifice, cm^2.
g = Acceleration due to gravity, cm $sec.^{-2}$ (981 cm sec^{-2}).
h = Pressure head, causing discharge through the orifice, cm.

Crop-Soil-Water Relations:

Reference Crop Evapotranspiration (Et_o): The water requirements were calculated by meteorological parameters using the "WATER" computer model [18], based on calculation using Doorenbos and Pruitt [19] equation and the Kc values (Table 5).

Doorenbos and Pruitt [19] adapted the radiation formula to predict potential evapotranspiration as follows:

$$Etp = bw\ Rs/L - 03$$

where:

Etp = Daily potential evapotranspiration (mm day^{-1}).
b = Adjustment factor based on wind and mean relative humidity.
W = Weighting factor based on temperature and elevation above sea level.
Rs = Daily total incoming solar radiation for the period of consideration ($cal/cm^2/day$).
L = Latent heat of vaporization of water ($cal/\ cm^2/$ day)

Factors (b) and (w) could be obtained from the tables cited by Doorenbos and Pruitt [19].

Crop Evapotranspiration (ETc): The ETc values were calculated according to the following equation given by FAO [20]:

Table 4: The time and quantities of irrigation water applied through irrigation in furrows during the growing season of potato

Plant Growth stages	Time of irrigation from planting (days)	Quantity of Irrigation water applied (m^3 fed^{-1}) 1st season 2017	Quantity of Irrigation water applied (m^3 fed^{-1}) 2nd season 2018	Time of every irrigation by (min) 1st season 2017	Time of every irrigation by (min) 2nd season 2018
1st irrigation	20	161	144	28	25
2nd irrigation	40	286	255	49	44
3rd irrigation	60	351	312	60	53
4th irrigation	75	515	455	88	78
5th irrigation	90	518	455	89	78
6th irrigation	105	365	374	63	64
7th irrigation	120	342	350	59	60
Total water applied (m^3 fed^{-1})		2537	2345		

Table 5: Doorenbos and Pruitt formulae in 2016 and 2017 seasons

Season		ETo				ETc			
		1st season 2017		2nd season 2018		1st season 2017		2nd season 2018	
Month	Kc	$mmday^{-1}$	mm $month^{-1}$	$mmday^{-1}$	mm $month^{-1}$	$mmday^{-1}$	mm $month^{-1}$	$mmday^{-1}$	mm $month^{-1}$
February	0.50	2.95	82.6	2.65	74.2	1.48	41.3	1.33	37.1
March	0.78	4.32	133.9	3.86	119.66	3.37	104.5	3.01	93.3
April	1.11	5.7	171.0	5.01	150.3	6.33	189.8	5.56	166.8
May	0.67	6.2	193.4	6.39	198.09	4.18	129.6	4.28	132.7
Seasonal (mm)			581		542		465		430

$$Etc = Eto \times Kc$$

where:

ETc: crop evapotranspiration (mm day^{-1})

ET_o: reference crop evapotranspiration (mm day^{-1})

Kc: crop coefficient (the Kc values used in this study were 0.50, 0.78, 1.11 and 0.67 for the initial, development, mid-season and maturity growth stages, respectively, as reported by FAO [21].

Applied Irrigation Water (AIW): The amounts of applied irrigation water were calculated according to the equation given by Vermeiren and Jopling [22] as:

$$AIW = ETc \times I/Ea\ (1 - LR)$$

where:

AIW : Depth of applied irrigation water (mm)

ETc : Crop evapotranspiration (mm day^{-1}).

I : Irrigation interval (days)

Ea : Irrigation application efficiency for the drip irrigation system (˜ 90% at the site location).

LR : Leaching requirements: the extra amount of applied water needed for salt leaching, calculated according to FAO [23] as follows:

$$LR = ECiw\ ECe$$

where:

ECiw : salinity of irrigation water (dS m^{-1}) and ECe: average soil salinity tolerated by the crop as measured by soil saturated extracts (dS m^{-1}). Under the current experimental conditions, no additional water was added for leaching to avoid any effect on stress treatments

Fertilizers were applied as follows: calcium super phosphate (15.5 % P_2O_5) was added at the rate of 75 kg P_2O_5 fed^{-1} (fed= 0.42ha) during the soil preparation for all treatments (drip and furrow irrigation treatments). Nitrogen was applied as ammonium nitrate fertilizer (33.5% N) at the rate of 150 kg N fed^{-1} for irrigation in furrow, where the amount of N split into three doses; 20% at planting, 40 % after 4 weeks and 40% after 8 weeks later. Potassium sulphate (48% K_2O) was added at rate of 96 kg K_2O fed^{-1} in irrigation in furrow, where the amount of K divided into three equal parts and applied at planting and 5 and 8 weeks later. In treatments of drip irrigation, nitrogen and potassium were applied through irrigation system as a fertigation. Nitrogen was applied at the rate of 150 kg N fed^{-1}as ammonium nitrate fertilizer (33.5% N), where potassium was added at rate of 96 kg K_2O fed^{-1} as potassium sulphate (48% K_2O). Furthermore, other agricultural practices were carried out according to the recommendation of the Ministry of Agriculture and Land Reclamation, Egypt.

Vegetative growth characters: 5 plants from each plot were taken at 90 days after planting as a representative sample for measuring the vegetative growth parameters i.e., plant height, number of main stem per plant and foliage fresh and dry weight (g $plant^{-1}$).

Tubers yield and its quality: at harvest (after 135 days) the following data were recorded, tubers number per plant, average of tuber weight, total yield (t. fed^{-1}) and the percentage of tuber sixes grade (large >60, medium 35-60 and small<35 mm in diameter), as well as specific gravity dry matter and starch content in the tuber. Starch % was calculated as {17.457+ 0.891× (dry matter% -24.182)} according to Burton [24].

Chemical analysis: total nitrogen, phosphorus and potassium content in tuber were determined in the tubers dry matter according to Chapman and Pratt [25].

Irrigation Water Productivity (IWP): Water productivity is an efficiency term calculated as a ratio of product output over water input. The output could be biological goods such as crop grain, fodder, bulbs …., etc. So, water productivity, in the present study, is expressed as kilograms of tuber yield obtained per the unit of applied irrigation water by Ali *et al*. [26] as follows:

IWP (*Kg* m^{-3})
Total tuber yield (*kg* fed^{-1}) / *Seasonal applied water* (m^3 fed^{-1})

All the obtained data were subjected to statistical analysis according to Gomez and Gomez [27] and means of treatments were compared against L.S.D. Test at confidence level 5% and Duncan's multiple comparisons Test (used CoStat- statistical software program).

RESULTS AND DISCUSSIONS

Soil Water Relations

Amount of Applied Irrigation Water (IWA, m^3 fed^{-1}): Results in Table 6 show that seasonal applied irrigation water to potato plants was less under drip irrigation as compared with surface irrigation in both seasons. The effect of tested irrigation treatments on applied irrigation water expressed as m^3/day/fed, m^3/month/fed and m^3/fed/year for the 2016 and 2017 growing seasons are presented in Table 8. Results show that amounts of applied irrigation water under drip irrigation system were 1411, 1628 and 1845 m^3/fed/season (in the 1st season) and 1304, 1505 and 1706 m^3/fed/ season in the second season for the 65 %, 75 % and 85 % ETc irrigation treatments, respectively. The values showed that seasonal water applied by potato is higher in the first than in the second season. Such results are mainly due to differences in climatic factors. On the other hand, the applied seasonal irrigation water was 2537 m^3/fed in the first season and 2345 m^3/fed in the second for flood irrigation system, respectively. Therefore, flood irrigation system showed that seasonal applied irrigation water increases of 44.4, 35.8 and 27.3 % over drip irrigation system for the 65 %, 75 % and 85 % ETc irrigation treatments for the first and second season, respectively.

Such a result might be reasonable since the exposed surface area under the surface system provides high evaporation opportunity from the relatively wet rather than dry soil surface as in drip irrigation. In addition, the high amount of water applied under the surface system reflects the low system efficiency as compared with the drip system. The seasonal water applied values were obtained from the sum of water for all irrigations per treatment, from February until May in each season. The obtained results were in harmony with those reported by Seham *et al*. [28]. Moreover, Sharmasarkar *et al*. [29] reported that the amount of applied irrigation water with the drip system was lower than that applied by surface irrigation. Aujla *et al*. [30] reported a saving of 25% water on drip irrigation compared with furrow irrigation. In general, the results of this study indicated that drip irrigation can save water, time and energy.

Monthly Applied Irrigation Water: Monthly applied irrigation water Fig. 1 was low at the beginning of the growing season. This can be related to less transpiring surface leaves during the period of first growth. Potential evapotranspiration was low through this period Table 4, then increased gradually as the green cover increased with increases in air temperature and solar radiation. The highest applied irrigation water occurred during April reflecting: expansion of the leaf system, growth of tuber on a volume basis and high solar radiation and air temperature. The April values for the treatments averaged 541, 624, 707 and 973 m^3 fed^{-1} for 65 %, 75 %, 85 % ETc and flood irrigation as an average of the two seasons, respectively. Thereafter, the evapotranspiration rate decline to reach its minimum value from May as the plants were approaching the period harvest.

The water content in plants changes depending on soil moisture and air humidity, the season of the year and time of the day as well as plant age [31].

Table 6: Effect of irrigation treatments on the amounts of applied irrigation water (m^3fed^{-1}) for the 2016 and 2017 growing seasons

	Drip irrigation						
	ETc 65 %		ETc 75 %		ETc 85 %		
Month	m^3/day/ fed.	m^3/month/ fed.	m^3/day/ fed.	m^3/month/ fed.	m^3/day/ fed.	m^3/month/ fed.	Flood irrigation (m^3/month/ fed.)
			1st season 2016/2017				
Feb.	4.5	125.3	5.2	144.6	5.9	163.8	225
Mar.	10.2	316.9	11.8	365.6	13.4	414.3	573
Apr.	19.2	575.8	22.1	664.3	25.1	752.9	1035
May	12.7	393.1	14.6	453.6	16.6	514.1	707
Total		1411		1628		1845	2537
			2nd season 2017/2018				
Feb.	4.0	112.5	4.6	129.9	5.3	147.2	202
Mar.	9.1	283.1	10.5	326.7	11.9	370.2	509
Apr.	16.9	506.1	19.5	583.9	22.1	661.8	910
May	13.0	402.6	15.0	464.5	17.0	526.5	724
Total		1304		1505		1706	2345

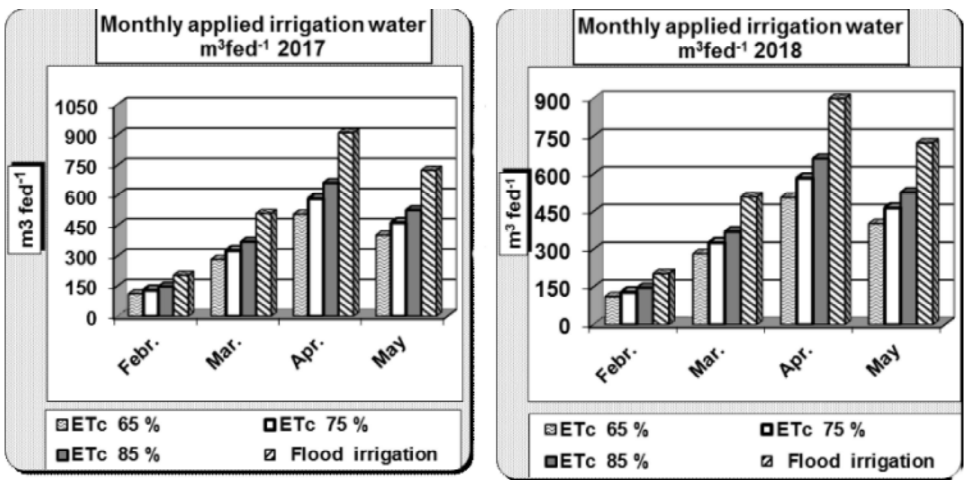

Fig. 1: Monthly applied irrigation water m^3fed^{-1} for potato plants as affected by different irrigation treatments during 2017 and 2018 seasons

Potato Growth: Data in Table 7 show that the growth of plants is significantly affected by irrigation techniques, as drip at three rates (65 %, 75 % and 85 % ETc) or flood irrigation. The number of main stems per plant, foliage fresh and dry weight significantly differed with irrigation methods, with superior drip irrigation at 85 % ETc per fed without significant difference with flood irrigation (traditional followed system under this condition as control). On the other hand, the differences among treatments were insignificant for plant height.

Yield of Potato Tubers: Potato yield and its components were significantly affected by irrigation without significant differences between drip irrigation at 85 % ETc and flood irrigation in the furrow and sometimes with drip irrigation at 75 % ETc (Table 8). The highest total tuber yield (12.867 t. fed^{-1} in 1st season and 13.167 t. fed^{-1} in 2nd season, respectively) was gained with the treatment of drip irrigation at the rate of 85 % ETc. For the average weight of tuber, the differences among the treatments of drip irrigation at rates 75 % and 85 % ETc and flood irrigation in-furrow were insignificant.

Fresh potato yield and total dry matter accumulation increase with water supply [32, 33]. Potato tuber number per plant and total yield increase with adequate irrigation water management before and during tuber initiation and the proper irrigation management after tuber initiation increase the size of tubers [34, 35].

Tubers Quality and its Components: Data in Table 9 show the distribution of tuber's yield size grade as a percentage of total yield according to tuber diameter as large (>60 mm), medium (35-60 mm) and small (<35 mm).

Table 7: Effect of drip and furrow irrigation systems and water quantity on growth of potato plant

Treatments	Plant height	No.of main stems plant^{-1}	Foliage fresh weight (g plant^{-1})	Foliage dry weight (g plant^{-1})
	1st season 2016/2017			
I-Drip1	53.0a	3.09 c	290.3 c	52.98 c
I-Drip2	55.3a	3.10 bc	313.8 b	56.29 b
I-Drip3	56.3a	3.13 b	325.3 a	57.93 a
I-Furrow	57.7a	3.32 a	326.2 a	57.57 a
L.S.D.at 5%	ns	0.026	1.02	0.99
	2nd season 2017/2018			
I-Drip1	57.0a	3.10 b	297.4 c	53.95 b
I-Drip2	59.3a	3.11 b	323.7 b	57.47 a
I-Drip3	57.0a	3.13 b	334.8 a	58.68 a
I-Furrow	62.0a	3.33 a	335.8 a	57.70 a
L.S.D.at 5%	ns	0.052	3.10	1.77

Table 8: Effect drip and furrow irrigation systems and water quantity on potato yield and its component

	1st season 2016/2017			2nd season 2017/2018		
Treatments	Total tuber yield (t. fed^{-1})	Tubers No. plant^{-1}	Average weight of tuber (g)	Total tuber yield (t. fed^{-1})	Tubers No. plant^{-1}	Average weight of tuber (g)
I-Drip1	9.873 b	5.77 c	100.2 b	11.320 c	5.79	101.6
I-Drip2	11.860 ab	6.30 ab	118.6 a	12.073 b	6.33	118.9
I-Drip3	12.867 a	5.97 bc	118.1 a	13.167 a	6.10	119.2
I-Furrow	12.207 a	6.43 a	119.8 a	12.833 a	6.37	120.3
L.S.D. at 5%	1.995	0.377	5.58	0.366	ns	ns

Table 9: Effect of drip and furrow irrigation systems and water quantity on grade of tubers yield size as percentage (%) of total yield

	1st season 2016/2017			2nd season 2017/2018		
Treatments	Large (L) >60 mm	Medium (M) 35-60 mm	Small (S) <35 mm	Large (L) >60 mm	Medium (M) 35-60 mm	Small (S) <35 mm
I-Drip1	37.80 c	32.93 a	28.67 a	37.87 c	32.60 a	29.53 a
I-Drip2	56.83 b	25.67 b	27.20 b	56.93 b	25.80 b	17.27 b
I-Drip3	60.90 a	25.37 b	14.93 c	60.77 a	25.43 b	13.80 c
I-Furrow	60.67 a	21.67 c	17.93 d	62.80 a	21.80 c	17.40 b
L.S.D. at 5%	1.354	1.001	0.964	3.374	1.462	1.472

Table 10: Effect of drip and furrow irrigation systems and water quantity on quality of tuber yield

	1st season 2016/2017				2nd season 2017/2018			
Treatments	Dry matter %	Dry matter yield (kg fed^{-1})	Starch yield (kg fed^{-1})	Specific gravity	Dry matter %	Dry matter yield (kg fed^{-1})	Starch yield (kg fed^{-1})	Specific gravity
I-Drip1	22.82a	2253 b	1613 b	1.089a	22.83a	2584 c	1850 c	1.089a
I-Drip2	22.61ab	2907 a	2076 a	1.083b	22.61ab	2730 b	1950 b	1.083ab
I-Drip3	22.41b	2657ab	1893ab	1.080bc	22.41b	2951 a	2103 a	1.080bc
I-Furrow	21.97c	2681 a	1901 a	1.076c	22.08c	2834 b	2012 b	1.077c
L.S.D. at 5%	0.355	410.4	285.2	0.0046	0.295	107.6	82.2	0.0062

It is of quality increase the percent's of large and medium tuber rather than small tuber (which is unmarketable). The highest percentage of large tuber was recorded with the treatment of drip irrigation at 1845 m^3 fed^{-1} (I-Drip3) in 1st season and with flood irrigation in-furrow at 2345 m^3 fed^{-1} in 2nd season. In general, the highest percentage of marketable tuber yield (Large + Medium) was obtained with drip irrigation at 85 % ETc in both seasons, followed by treatments of flood irrigation in-furrow, then drip irrigation at 75 % ETc. On the other hand, the percentage of unmarketable tubers (small) was the lowest with treatment of the drip irrigation at 85 % ETc in both seasons.

Yuan *et al*. [36] reported that potato fresh tuber and marketable yield increased with increasing irrigation regimes. Karam *et al*. [37] reported that 50% of tuber yield was constituted with the large size potatoes (>200 g) under the full irrigation treatment while that proportion was 48% under the deficit irrigation at tuber bulking and 46% under deficit irrigation at tuber ripening. Also, a larger number of small tubers was obtained when deficit irrigation was applied during the sustainability 2021, 13, 1504 6 of 19 tubers bulking stage compared to the tuber ripening state [37].

Also, the quality of yield is significantly affected by irrigation techniques, as drip irrigation or flood irrigation in furrows (Table 10). In 1st season the highest yield of dry matter and starch (2907 and 2076 kg fed^{-1}, respectively) was attained with drip irrigation at 75 % ETc (I-Drip2), where these values were not significant with that recorded with I-Drip3 and flood irrigation in the furrow. In the 2nd season, the highest yield of dry matter and starch (2951 and 2103 kg fed^{-1}, respectively) was attained with drip irrigation at 85 % ETc (I-Drip3), with significant differences with other treatments.

In the same trend, El-Banna *et al.* [10] found that with increasing the applied irrigation water through the drip system, the percent of large tubers size increased and the percent of small tubers decreased. Whereas, the tuber content of dry matter and specific gravity were increased with decreasing irrigation water amount. Using drip irrigation at the rate of 1650 m^3 fed^{-1} in clay loam soil under Nile Delta conditions recorded the highest total tubers yield and higher water use efficiency than irrigation in-furrow [10].

Specific gravity is one of the quality characteristics of potato tuber and it is a measurement of the starch or solids content relative to the water content in a potato. High dry matter content is a synonym of low water content and vice versa. Dry matter is used by the potato industry for harvest storability, fry quality appreciation and baking characteristics. Miller and Martin [38] reported that daily irrigation improved total tuber yield, the number of tubers and the specific gravity compared to four-day interval irrigation. Yuan *et al*. [36] indicated that specific gravity tended to decrease with increasing irrigation depth.

Nutrient Uptake by Potato Tubers: The nutrients uptake of potato plant differs with irrigation methods (Table 11), where the tuber content of nutrients (N P K as kg fed^{-1})significantly increased with the application of drip irrigation at the rates of 75 % ETc and 85 % ETc as compared with drip irrigation at 65 % ETc, but it was no significant with irrigation in-furrow. In 1st season differences among treatments of I-Drip2, I-Drip3 and I-furrow for tuber contents of NPK were not significant.

Protein content in potato tubers is an important nutritional characteristic and is usually impacted by the irrigation regime and plant nitrogen fertilizer uptake and remobilization, where plant nitrogen content decreases under drought conditions [39, 40].

Wang *et al*. [41] reported that potato tuber yield, tuber weight, commodity tuber weight, dry matter accumulation and vitamin C content increased with increasing fertilizer application rate and the dripper discharge rate.

Irrigation Water Productivity (kg m^{-3}): Data in Table 12 show total water applied (m^3 fed^{-1}), water could be saved with the application of drip irrigation at different amounts of water and water productivity (kg m^{-3}). Values for water productivity of potato yield increased under drip irrigation system compared to that under furrow irrigation. The irrigation water productivity was the highest with the treatment of drip irrigation I-Drip2 in 1st season (7.285 kg m^{-3}) and with treatment I-Drip1 in 2nd season (8.681 kg m^{-3}), but the lowest value of water productivity was reported with traditional irrigation in the furrow (4.812 and 5.472 kg m^{-3} in both seasons, respectively). Increased water productivity in drip irrigation, averaged 52.0, 49.0 and 43.0 % for the treatments 65 % ETc, 75 % ETc and 85 % ETc in comparison with flood irrigation (average of the two seasons), respectively.

These results in agreed with those reported by Eid, *et al*. [13], who found that irrigation water productivity increased with application surface and subsurface drip irrigation systems in sandy loam soil as compared with traditional irrigation. The results were for water-saving 37.7% at the Nili season and 34.9%, in the Summery season, respectively. Furthermore, this treatment of irrigation as drip irrigation could be rationalizing fertilizers by 25 % as compared with irrigation in a furrow. Application of nitrogen and potassium fertilizers was at three doses in irrigation in a furrow, where it was through the drip irrigation system (fertigation) in their treatments. This application of fertilizers maximizes the uptake of nutrients, as well as the use efficiency of fertilizers as compared with irrigation in the furrow [4, 10, 41].

In the same trend, Oner Cetın and Erhan Akalp [42] reported that drip irrigation can be able to save irrigation water from 30% up to 50% in case it is properly designed, installed and operated compared to surface irrigation and it can also enable increasing crop yields and crop quality.

Table 11: Effect of irrigation systems and water regime on tuber yield content of NPK (kg fed^{-1})

	1st season 2016/2017			2nd season 2017/2018		
Treatments	N	P	K	N	P	K
I-Drip1	52.13b	6.33b	71.38b	60.20c	7.31c	82.35c
I-Drip2	69.30a	8.29a	92.18a	65.42b	7.82b	86.91b
I-Drip3	64.20a	7.68a	83.88ab	71.13a	8.54a	93.75a
I-Furrow	65.24a	7.67a	85.61a	68.77a	8.16b	91.25ab
L.S.D. at 5%	10.01	1.153	13.28	2.83	0.353	4.39

Table 12: Effect of drip and furrow irrigation systems and water quantity on tuber yield and irrigation water productivity (kg m^{-3})

Treatments	Total water applied (m^3 fed^{-1})	Total tuber yield (kg fed^{-1})	Water productivity (kg m^{-3})	The rate of increase W.P (%)
		1st season 2016/2017		
I-Drip1	1411	9873 b	6.997	45.4
I-Drip2	1628	11860 ab	7.285	51.4
I-Drip3	1845	12867 a	6.974	44.9
I-Furrow	2537	12207 a	4.812	Control
		2nd season 2017/2018		
I-Drip1	1304	11320 c	8.681	58.6
I-Drip2	1505	12073 b	8.022	46.6
I-Drip3	1706	13167 a	7.718	41.0
I-Furrow	2345	12833 a	5.472	Control

As well as, application of fertilizers together with irrigation water as known as fertigation increases both yield and fertilizer use efficiency. The advantages of fertigation could be mentioned such as saving about 20–40% of fertilizer without affecting growth and yield of crops, saving laburs and energy at the application of fertilizers, reducing environmental contamination and leaching of nutrients. Additionally, fertigation prevents losses of nitrogen due to the fact that there is no leaching because nutrients are directly supplied to the root zone in available forms in the form of portions. Thus, nutrient concentration in soil solution can be controlled and application cost decreased [42].

CONCLUSION

It is obvious from the previous showed results that the application of drip irrigation system at the rate of 85 % ETc enhanced growth of plant, tuber yield, tuber quality, marketable yield percentage and yield content of nutrients (nitrogen, phosphors and potassium), without significant differences with traditional irrigation in furrow. These results could demonstrate that the possibility of application of drip irrigation system under the condition of region study. Furthermore, application of this system (drip irrigation at the rate of 85 % ETc) could be save irrigation water by 665 m^3 fed^{-1} (27.3%) and maximize nutrients uptake as compare with traditional irrigation in furrow, as average of the two seasons approximately.

REFERENCES

1. Aly, M.M. and H.K. El-Nkhalil, 2020. The marketing efficiency of summer potatoes stored in food preservation Refrigerators in Beheira Governorate. J. of Agricultural Economics and Social Sciences (JAESS), 11(2): 75-83.
2. Ahmadi, S.H., F. Plauborg, M.N. Andersen, A.R. Sepaskhah, C.R. Jensen and S. Hansen, 2011. Effects of irrigation strategies and soils on field grown potatoes: root distribution. Agric. Water Manag., 98: 1280-1290.
3. Romero, A.P., A. Alarcon and C. Galeano, 2017. Physiological assessment of water stress in potato using spectral information. Front. Plant Sci., 8: 1608.
4. Djaman, K., S. Irmak, K. Koudaheand and S. Allen, 2021. Irrigation Management in Potato (*Solanum tuberosum* L.) Production: A Review. Sustainability J., 13: 1504.
5. Weatherhead, K. and J. Knox, 1998. Irrigation potatoes three trickle irrigation for potatoes. Irrig. News, 27: 19-28.
6. Onder, S., M.E. Caliskan, D. Onder and S. Caliskan, 2005. Different irrigation methods and water stress effects on potato yield and yield components. Agric. Water Manag., 73: 73-86.
7. Foti, S., G. Mauromicale and A. Irena, 1995. Influence of irrigation regimes on growth and yield of potato cv. spunta. Potato Res., 38(3): 307-318.

8. Boujelben, A., M.K. Barek and K.S. Chartzoulakis, 1997. Potato crop response to drip irrigation system. Acta Hort., 994(1): 241-243.
9. Awari, H.W. and S.S. Hiwase, 1994. Effect of irrigation systems on growth and yield of potato. Annals of Plant Physiology, 8(2): 185-187.
10. El-Banna, E.N., A.H. Selim and H.Z. Abd-El-Salam, 2001. Effect of irrigation methods and watr regimes on potato plant (*Solanum Tuberosum* L.) under delta soil conditions. Minufiya J. Agric. Res., 26(1): 1-11.
11. Abdel-Moneim, S.K. and A.A. Salem, 2014. Effect of two Drip Irrigation Methods (Surface and Subsurface) in Growth and Yield of three Potato (*Solnum tuberosum* L.) Cultivars. Australian J. Basic and Applied Sciences, 15: 252-258.
12. Amer, K.H., A.A. Samak and J.L. Hatfield, 2016. Effect of irrigation method and non-uniformity of irrigation on potato performance and quality. J. of water Resource and Protection, 8: 277-292.
13. Eid, S.F.M., Tarek, S.M. and E.A. El-Samra, 2017. Irrigation Scheduling of Potato to Increase the Water Productivity under Drip Irrigation System on Sandy Soil. J. Soil Sci. and Agric. Eng., Mansoura Univ., 8(12): 779-785.
14. Hesse, P.R., 1971. "A Text Book of Soil Chemical Analysis". Juan Murry (Publisher) Ltd, London.
15. Page, A.L., 1982. "Methods of soil analysis". 2nd Ed., Am. Soc. At Agron. Inc. Soil Sci. Soc. Of Am. Inc., Madison, Wisconsin, VSA.
16. Stackman, W.P., 1966. Determination of pore size by the air bubbling pressure method proceeding unesce Symp on Water in the Unsaturated Zone., pp: 366-372.
17. Michael, A.M., 1978. "Irrigation theory and practice". Vikas Publishing House PVTLTD, New Delhi, Bombay.
18. Zazueta, F.S. and Smajstrla, 1984. Evapotranspiration estimation utilities “WATER” model. Agricultural Engineering Department, IFAS, Univ. of Florida Gainesville, Florida.
19. Doorenbos, J. and W.D. Pruitt, 1977. Guidelines for predicting crop water requirements. FAO Irrigation and Drainage Paper No. 24 (revised) FAO, Rome, Italy.
20. FAO, 1977. Guidelines for predicting crop water requirements. In Irrigation and Drainage Paper, 24. By Doorenbos, J. and Pruitt, W.O., Eds.; Food and Agricultural Organization: Rome, Italy.
21. FAO, 1979. Yield response to water, Irrigation and Drainage Paper, 33. By Doorenbos, J. and Kassam, A. H., Rome.
22. Vermeiren, L. and G.A. Jopling, 1984. Localized irrigation: Design, installation, operation, evaluation. In FAO Irrigation and Drainage Paper, 36 Food and Agricultural Organization: Rome, Italy.
23. FAO, 1985. Water quality for agriculture. In FAO Irrigation and Drainage Paper, 29 Food and Agricultural Organization: Rome, Italy.
24. Burton, W.G., 1948. "The Potato". Chapman and Hall, London, pp: 319.
25. Chapman, H.D. and P.F. Pratt, 1982. "Methods of Plant Analysis, I. Methods of Analysis for Soil, Plant and Water". Chapman Publishers, Riverside, California, USA.
26. Ali, M.H., M.R. Hoque, A.A. Hassan and A. Khair, 2007. Effects of deficit irrigation on yield, water productivity and economic returns of wheat. Agric. Water Manage., 92(3): 151-161.
27. Gomez, K.A. and A.A. Gomez, 1984. "Statistical Procedures for Agricultural Research". 2nd Ed. John Wiely and Sons, pp: 680.
28. Seham, M. Ali, T.A. Eid and A.M. Abd Elhady, 2015. Effect of different soil moisture levels and nitrogen sources on lettuce yield (*Lactuca sativa* L.) under surface and drip irrigation systems in clay loam soils. J. Plant Production, Mansoura Univ., 6(12): 1957-1974.
29. Sharmasarkar, F., S. Sharmasarkar, S.D. Miller, G.F. Vance and R. Zhang, 2001. Assessment of drip and flood irrigation on water and fertilizer use efficiency for sugar beets. Agricultural Water Management, 46: 241-251.
30. Aujla, M.S., H.S. Thind and G.S. Buttar, 2007. Fruit yield and water use efficiency of eggplant (*Solanum melongema* L.) as influenced by different quantities of nitrogen and water applied through drip and furrow irrigation. Scientia Horticulturae. J. 112: 142-148.
31. Tarantino, E., 1984. L‘irrigazione. L‘Inform. Agr., 23: 49-52.
32. Steyn, J.M., H.F. Du Plessis, P. Fourie and P.S. Hammes, 1998. Yield response of potato genotypes to different soil water regimes incontrasting seasons of a subtropical climate. Potato Res., 41: 239-254.

33. Camargo, D.C., F. Montoya, J.I. Córcoles and J.F. Ortega, 2015. Modeling the impacts of irrigation treatments on potato growth and development. Agric. Water Manag., 150: 119-128.
34. Cappaert, M.R., M.L. Powelson, N.W. Christensen, W.R. Stevenson and D.I. Rouse, 1994. Assessment of irrigation as a method of managing potato early dying. Phytopathology, 84: 792-800.
35. Shock, C.C., E.B.G. Feibert and L.D. Saunders, 1998. Potato yield and quality response to deficit irrigation. Hort. Science , 33: 655-659.
36. Yuan, B.Z., S. Nishiyama and Y. Kang, 2003. Effect different irrigation regimes on the growth and yield of drip-irrigated potato. Agric. Water Manag., 63: 153-167.
37. Karam, F., N. Amacha, S. Fahed, T. El-Asmar and A. Domínguez, 2014. Response of potato to full and deficit irrigation under semiarid climate: Agronomic and economic implications. Agric. Water Manag., 142: 144-151.
38. Miller, D.E. and M.W. Martin, 1990. Responses of three early potato cultivars to subsoiling and irrigation regime on a sandy soil. Am. Potato J., 67: 769-777.
39. He, M. and F.A. Dijkstra, 2014. Drought effect on plant nitrogen and phosphorus: A meta-analysis. New Phytol., 204: 924-931.
40. Sun, Y., X. Cui and F. Liu, 2015. Effect of irrigation regimes and phosphorus rates on water and phosphorus use efficiencies in potato. Sci. Hortic., 190: 64-69.
41. Wang, X., T. Guo, Y. Wang, Y. Xing, Y. Wang and X. He, 2020. Exploring the optimization of water and fertilizer management practices for potato production in the sandy loam soils of Northwest China based on PCA. Agric. Water Manag., 237: 106-180.
42. Oner, C. and A. Erhan, 2019. Efficient use of water and fertilizers in irrigated agriculture: drip irrigation and fertigation. Acta Horticulturae et Regiotecturae 2: 97-102.