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EFFECT OF IRRIGATION SYSTEM AND IRRIGATION INTERVALS ON THE WATER APPLICATION EFFICIENCY, GROWTH, YIELD, WATER PRODUCTIVITY AND QUALITY OF SQUASH UNDER CLAY SOIL CONDITIONS

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Abstract

In recent years, cultivation under deficit irrigation has been widely investigated as a strategy to maximize value and sustainable agriculture production in Egypt. Two field experiments were conducted during the two successive seasons of 2017 and 2018 at Kafer El-Khawazim, Talkha district, Dakahlia Governorate, Egypt in a clay soil to study the effects of three irrigation systems (drip, gated pipe and flood), three irrigation intervals (7, 9 and 11 days) and their interaction on squash (water application efficiency, vegetative growth, the nutritional status, total yield, marketable yield and some of quality traits). Drip irrigation system gave the highest results for all the studied traits. Irrigation the plants every 7 days showed the same trend. The interaction between irrigation system and irrigation intervals showed significant positive effects on the studied traits, especially, crop yield, water productivity, and squash quality attributes. Combination between drip irrigation and 7 days irrigation interval gave the highest significant positive effect for most of studied traits.

***Keywords*: ** Drip irrigation, Gated pipe, Flood irrigation, Squash, Growth, Fruits yield, Nutritional status.

Introduction

The global water crisis has drawn worldwide attention to the urgency of achieving a more efficient use of water resources, particularly in agriculture, to increase crop production and achieve world food security. The water scarcity are one of the serious problems which facing crops production in arid Egypt, and it is important to reduce the irrigation water consumption by developing the innovative technologies that can be an effective technique (El-Metwally *et al*., 2015; Abdelraouf *et al*., 2013a). In the semi-arid and arid regions with large population and limitation of fresh water, there is a significant stress on the agricultural sector to reduce the consumption of limited fresh water for irrigation for the other sectors (Hozayn, *et al*., 2016; Abdelraouf and Abuarab 2012; Abdelraouf, *et al*., 2020 a, b). In Egypt, the agricultural sector faces a serious challenge for increasing the food production with less water, which can be accomplished by increasing the crop water productivity (Abdelraouf *et al*., 2013 b,c). Increasing the crop water productivity is an important aim to increase the demand while increasing high population growth (Okasha *et al*., 2013; Abdelraouf and Ragab 2018; Bakry *et al*., 2012 and Eid and Negm 2019). Water resources in Egypt suffer from severe water scarcity, which increases with increasing population growth. The increasing competition for scarce water resources is competing by using new irrigation techniques to increase water productivity and improve the crop productivity and quality traits (Marwa *et al*., 2017). Water productivity of crops in Egypt is extremely important, because of the limitation of water resources and precipitation and rainfall is a very limited and low factor (Hozayn *et al*., 2013; Abdelraouf *et al*., 2016). The application of modern irrigation methods and accompanying technologies is an important concept that must be done in the arid areas as in Egypt for saving a part of irrigation water (El-Habbasha *et al*., 2014; Abdelraouf *et al*., 2012 a,b). Egypt has been suffering from a shortage of water in recent years, in addition to climate change, there are frequent water shortages. Water sources in Egypt are still limited compared to increasing demand for water. Therefore, adjusting water management in both new and old lands comes as a major component of agricultural development.

Irrigated agriculture is the major contributor of agricultural production, faces the challenge of improving irrigation water use efficiency and meanwhile ensuring food security (Li *et al*., 2016). The global water consumption for irrigation has been steadily growing over the last 50 years and today it makes 70% of all water consumption (Tian *et al*., 2017). The great challenge of the agricultural sector is to produce more food from less water, which can be achieved by increasing crop water productivity (CWP) (Zwart and Bastiaanessen, 2004). Deficiency of fresh water increased in high places around the world. According to forecasts of FAO and IFPRI global demand for water resources according to the scenario of usual development by 2030 will increase twice. Improved on farm irrigation systems is considered as an important part for Egyptian agriculture development. The main reason of such high-water demand is high production of the aboveground mass of leaves with the high coefficient of transpiration. Generally, irrigation of cucurbitaceous vegetables, clearly affects both yield and fruit quality. In the studies of Peil *et al*. (2012), Yavuz *et al*. (2015), with the rise of irrigation quantity, the yield characteristics increased significantly. On the other hand, although the irrigation usually increases the yield, it often causes the decrease in the fruit chemical composition.

The worldwide use of surface and subsurface drip irrigation systems has increased considerably in recent decades. The main advantages of these systems are the potential to increase crop yields while reducing water application, added fertilizers and consequently, cultivation costs. The soil moisture distribution pattern around a water emitter depends on: (i) the total volume of water applied; (ii) the emitter flow rate, source configuration (surface, subsurface, point or line) and initial boundary conditions; (iii) the soil physical properties and their spatial distribution; (iv) plant root activity; and (v) irrigation management, El-Maloglou *et al*. (2010) also identified that, surface and subsurface drip irrigation systems can increase water use efficiency but only if the system is designed to meet the soil and plant conditions. Drip irrigation can achieve high water use efficiency, but only when the system is designed correctly, with appropriate emitter spacing, flow rate and installation depth (Rafie and El-Boraie, 2017). Nowadays, drip irrigation system, delivering water directly to plant root zone of plants, also it is one of the most economically efficient solution to supply water to the plants. Furthermore, by using drip irrigation, over ground parts of plants remain dry, so they are less susceptible to bacterial or fungal infections.

Squash is considered one of the most important vegetable crops in the world due to it being a commercial crop for fields and greenhouses. Summer squash is produced in most Mediterranean countries as one of the main vegetables and is also a widely grown and consumed vegetable in Egypt. Water supply is one of the most important factors which may greatly affect the yield and quality of summer squash. Squash is predominantly grown on small fields which are less than 1 feddan in spring, summer, and fall seasons. Squash grows best on fertile, well drained soil with high organic matter. Plants should be irrigated during dry weather. The production of cucurbitaceous vegetables in the field depend largely on the thermal and precipitation conditions during the growing season. An important element of receiving the high and good quality yield is to ensure optimum humidity of the soil during plant growth. Amer (2011) found that squash total yield was significantly higher using drip irrigation compared to the furrow irrigation.

Therefore, drip irrigation method is beneficial for the agricultural productivity (Ferreyra and Jeznach, 2007 and Rolbiecki, 2017). Ibrahim and Selim (2007 and 2010) concluded that irrigation every 12 days intervals to summer squash field's cv. Eskandrani gave the chance for increasing water use efficiency and produce satisfactory and good marketable fruit yield. El-Gindy *et al*. (2009) reported that subsurface drip irrigation has the best irrigation water distribution in the soil which consider more suitable for roots and yield of summer squash. The purpose of this study is to evaluate the irrigation systems on fruit yield, yield attributes and nutritional status of summer squash under different irrigation intervals.

Material and Methods

Experimental Site: Two field experiments were conducted during the two successive seasons of 2017 and 2018 at Kafer El-Khawazim, Talkha district, Dakahlia Governorate, Egypt, coordinates: 31.054735°N 31.375644°E and elevation is 18 m. The experimental area has an arid climate with cool winters and hot dry summers.

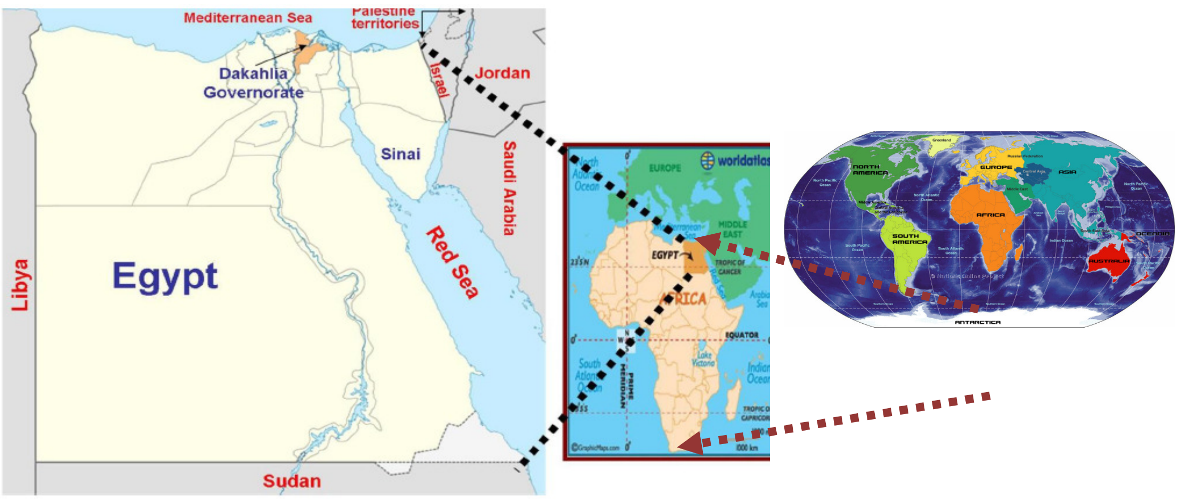

Fig. 1 : Layout of Experimental Site

Physical and Chemical Properties of the Soil and Irrigation Water: Irrigation water was supplied by an open irrigation canal. The irrigation water had a pH of 7.5 and an electrical conductivity of 0.47 dS m^{-1}. The main physical and chemical properties of the soil were determined in situ and in the laboratory at the beginning of the field trial (table 1). The experimental soil was clay in texture with organic matter of 1.83 %, pH 7.9, total N 0.077 % and available P 14.6 ppm.

Table 1 : Some characteristics of the soil of the experimental area

Parameters			
Soil layer (cm)	0–20	20-40	40-60
Texture	Clay	Clay	Clay
Sand (%)	1.53	1.64	1.74
Fine sand (%)	15.27	15.66	16.65
Silt (%)	19.01	18.80	18.50
Clay (%)	62.19	63.90	63.01
Bulk density (t m^{-3})	1.14	1.25	1.35
EC (dS m^{-1})	2.3	2.6	2.4
pH (1:2.5)	8.1	8.1	8.4

Experimental Design: The experiment was established with a split plot design having four replicates. The main plots included three irrigation systems (Drip, gated pipe and flood). Whereas, the sub-plots were occupied with three irrigation intervals (7, 9 and 11 days). Each sub plot area was 16 m^2 and contained 4 furrows; 80 cm width and 5 m length. Each treatment was separated by two guard ridges. Squash seeds "cv. Master 100" were sown on one side of the furrow with 40 cm between hills in 4 and 6 April in both summer seasons of 2017 and 2018, respectively. The normal agricultural practices of growing summer squash plants were followed.

Irrigation Systems: The main components of surface drip irrigation net work were as follow: Control head is located at the source of the water supply. It consists of centrifugal pump (80 m^3/h discharge and 50 m lift), media filter 48" diameter (two tanks) back flow prevention device, pressure regulator, control value, pressure gauges, flow meter, and chemical injection equipment. 110 mm diameter PVC pipes main lines were used to convey the water from the water source to the main control points in the field. 75 mm diameter PVC pipes sub-main lines were used to convey the water from the main line to the manifold line through a control unit consists of screen filter, gate values and pressure gauges.

(1) Drip irrigation: Manifold lines were 32 mm diameter P.E. pipe used to supply laterals (drip lines) with the irrigation water. 16 mm diameter P.E. laterals drip built-in (4.0 L/h / 0.4 m spacing). Laterals spacing were 0.70 m.
(2) Gated pipes: The slide gate space was 75 cm; the opening diameter was 32 mm with 4 m^3/h discharge, and this gate fixed on PVC pipe of 160 mm diameter.
(3) Flooding irrigation: Control

Irrigation Requirements of Squash: Irrigation water requirements of squash were calculated according to the following equations 1, 2 and 3 that presented in table (2).

Table 2 : Irrigation water requirements of squash for three irrigation systems

	Drip Irrigation (DI)	Gated Pipes (GP)	Flooding Irrigation (FI)
Equations	$IRg = [(ET_o \times Kc \times Kr) / Ei] + LR$ ………. (1)	$IRg = [(ET_o \times Kc) / Ei] + LR$ ………. (2)	$IRg = [(ET_o \times Kc) / Ei] + LR$ ……. (3)
	Ei = 90%	Ei = 55%	Ei = 45%
Where: IRg = Gross irrigation requirements, mm/day; ET_O= Reference evapotranspiration, mm/day, Kc = Crop factor (FAO-56); Kr = Ground cover reduction factor and Ei = Irrigation efficiency, %, LR = Amount of water required for the leaching of salts, mm.			
The seasonal irrigation water, m^3/ha for 2017	1400	2180	2660
The seasonal irrigation water, m^3/ha for 2018	1360	2110	2600

Water Application Efficiency: Application efficiency of irrigation water (AE_{IW}) is the actual storage of water in the root zone to the water applied to the field. The AE_{IW} was calculated using equation 4:

$$AE_{IW} = Ds / Da \quad ...(4)$$

Where AE_{IW} is the application efficiency of irrigation water, %, Ds is the depth of stored water in the root zone, cm by equation 5

$$Ds = (\theta 1 - \theta 2) * d * \rho \quad ...(5)$$

Where: Da is the depth of applied water (mm), d is the soil layer depth (mm), θ1 is the average of soil moisture content after irrigation (g/g) in the root zone, θ2 is the average of soil moisture content before irrigation (g/g) in the root zone as shown in figure (3), ρ = bulk density of soil (g/cm^3).

Vegetative Growth of Squash Plant: After 60 days from planting, five plants from each sub plot were randomly taken for measuring the vegetative growth parameters of squash, i.e., plant height (cm), number of leaves and foliage dry weight (g).

Nutritional Status of Squash Plant: Total concentration of nitrogen, phosphorus and potassium were determined in dry leaves of squash according to the official and modified methods of analysis (A.O.A.C., 1998).

Squash Yield: At the harvesting times, fruits of each plot were harvested by hand every 2–3 days and were classified to marketable fruits (3-4 cm in diameter and 13–16 cm in length) and non-marketable fruits (misshapen large and small fruits) in each harvest, thereafter, marketable and total fruit yield were determined as ton/ha.

Water Productivity of Squash: "WP_{Squash}": The water productivity of squash was calculated according to James (1988) as follows by equation 6:

$$WP_{Squash} = Ey/Ir \quad ...(6)$$

Where WP_{Squash} is water productivity of squash (kg $_{Squash}$ $m^{-3}{}_{water}$), Ey is the economical or marketable yield (kg $_{Squash}$ /ha); Ir is the amount of applied irrigation water ($m^3{}_{water}$/ha/season).

Quality Traits of Squash: Some of quality traits of fruits squash such as, fruit length (cm) fruit weight (g), fruit diameter (cm) were determined. Also, total soluble solid was determined by a refractometer.

Statistical Analysis: The data obtained were subjected to analysis of variance (ANOVA) according to Gomez and Gomez (1984), using Co-Stat Software Program Version 6.303 (2004) and LSD at 0.05 level of significance was used for the comparison between means.

Results and Discussion

Water Application Efficiency

The results presented in figure (2) came to conform to the logic, where the highest estimation of water application efficiency values was when using drip irrigation system compared to the gated pipe and flooding irrigation systems, and this resulted from the lowest amount of lost irrigation water with occurred under drip irrigation where the transmission source is next to the plant directly but the other systems were more water loss by deep percolation. Attributable to the water is added at a very slow rate, drop by drop, which leads to the ease of exchanging air with added irrigation water within the root zone, and this case creates a healthy environment for the root zone of squash plants, which has led to these conditions increasing the absorption of water and nutrients, contrary to what it just happened with other surface irrigation systems. Moreover, the highest value of water application efficacy by using drips irrigation, which means that the amount of added irrigation did not occur to it by a large loss by deep leakage, which resulted in the failure to wash nutrients from the root-spreading area, as happened with other systems. Water application efficiency values decreased under all systems by increasing the periods between irrigation. The total amount of added irrigation water to the soil after 7 days was less than total amount of added irrigation water after 9 and 11 days which led to that, the total amount of added irrigation water whether after 9 days or 11 days is higher than the ability of the clay soil to retain and a depth leak will occur outside the root zone. The highest value for the water application efficiency for drip irrigation were occurred with 7 days as the period between irrigation, while the lowest value was for flooding irrigation at adding irrigation water every 11 days.

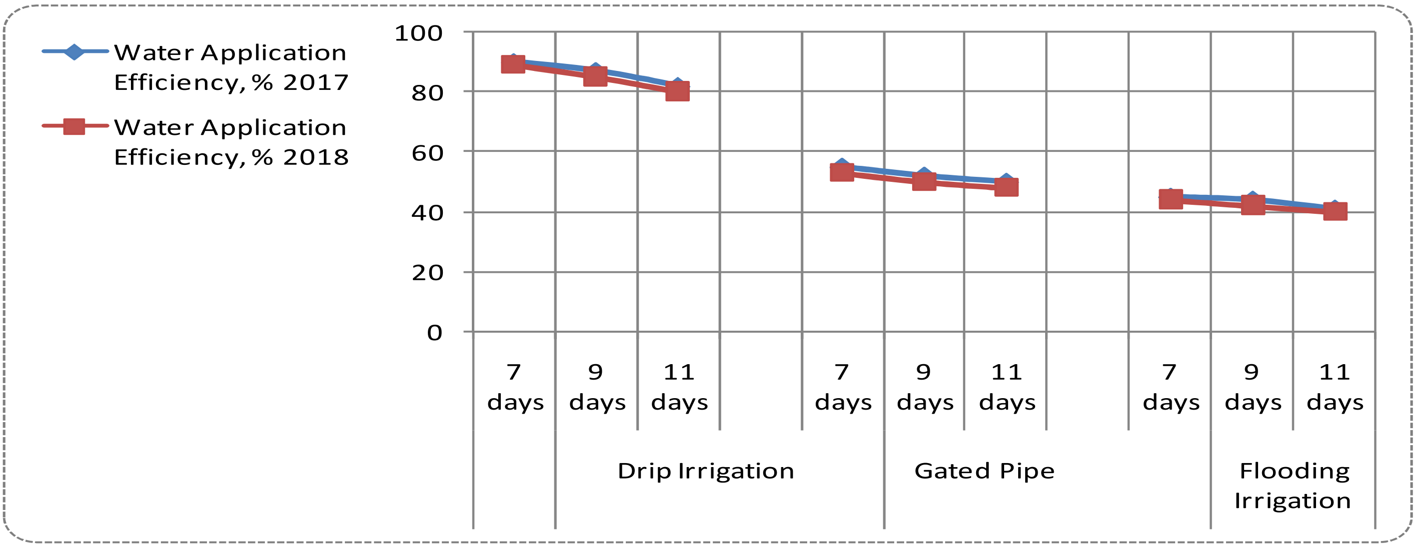

Fig. 2 : Effect of irrigation system and irrigation intervals on the water application efficiency

Vegetative Growth of Squash Plant

Data presented in table 3 showed that significant increases in plant height; number of leaves/plant and foliage dry weight/plant were achieved in both seasons due to irrigated squash plants through drip irrigation system as compared with the other two studied irrigation systems (gate pipe and flooding). The lowest values obtained for the traits were by flooding irrigation system. These results are in harmony with those obtained by El-Gendy *et al.*, 2009.

However, irrigation intervals showed significant effects on vegetative growth of squash. Irrigation squash plants every 7 days resulted in increasing plant height; number of leaves/plant and foliage dry weight/plant in both seasons. Vice- versa, irrigation every 11 days showed the lowest values of previous vegetative parameters. These results are in a full agreement with those obtained by Farrag and El-Nagar, 2005; Ibrahim and Selim, 2007 on summer squash and Bafeel and Moftah, 2008 and Abd El-Aal *et al.*, 2008 on eggplant.

Concerning the interaction between irrigation systems and irrigation intervals, data in table 3 showed significant effects on vegetative growth of squash in both seasons. The highest plant height, number on leaves/plant and foliage dry weight were achieved as a result of using drip irrigation system combined with watering plants every 7 days in both seasons. These results might be due to creating a healthy root system and enough water requirements which resulted in increasing the required essential nutrients (Ibrahim, 2007) which improve photosynthetic capacity operation which in turn led to enhance growth. While the lowest values were obtained by using flooding in combination with watering plants every 11 days.

Table 3 : Effect of irrigation system and irrigation intervals on some vegetative growth characters of the squash plant

Treatments	Plant height (cm)				No. of leaves/plant				Foliage dry weight/plant (g)			
	Season 2017											
	Irrigation system (IS)											
Irrigation intervals (II)	S1 (DI)	S2 (GP)	S3 (FI)	Mean	S1 (DI)	S2 (GP)	S3 (FI)	Mean	S1 (DI)	S2 (GP)	S3 (FI)	Mean
7 days	80.17	78.60	76.30	78.36	39.30	37.72	36.90	37.97	24.70	24.10	22.32	23.71
9 days	77.30	74.12	74.11	75.18	36.72	35.24	34.42	35.46	22.90	23.07	21.52	22.50
11 days	71.50	69.75	68.71	69.99	34.14	32.12	32.00	32.75	22.12	21.80	20.13	21.35
Mean	76.32	73.16	73.04		36.72	35.03	34.44		23.24	22.99	21.32	
LSD 5%												
II	1.07				0.32				0.24			
IS	1.23				0.78				0.31			
IIXIS	3.21				0.82				0.52			

	Season 2018											
7 days	84.20	81.50	80.90	82.20	37.32	36.22	35.12	36.25	24.12	23.12	22.72	23.32
9 days	80.10	78.30	79.70	79.37	36.13	34.34	32.74	34.40	23.14	22.31	20.00	21.82
11 days	77.30	73.70	74.30	75.77	34.70	33.26	32.15	33.37	21.22	20.73	19.82	20.59
Mean	80.53	78.50	78.30		36.05	34.61	33.34		22.83	22.05	20.85	
LSD 5%												
II	1.13				0.28				0.18			
IS	2.20				0.42				0.23			
IIXIS	3.17				0.56				0.34			

S1: Drip irrigation S2: Gated pipe S3: Flooding irrigation

Nutritional Status of Squash

Table 4 showed the effect of irrigation systems, irrigation intervals and their interaction on leaf macronutrients concentration (N, P and K). It is quite clear that irrigation systems showed significant effects on leaf macronutrients concentration (N and K) while P concentration did not significantly affect. Drip irrigation system showed the highest significant increments of both leaf nitrogen and potassium concentrations as compared with the other two studied systems (gated pipe and flooding). The recorded increments may be due to improving the root growth which allows plants to absorb more nutrients. Increasing the period between irrigation resulted in an increase in the amount of added irrigation water, which resulted in the inability of the root zone to retain the amount of excess irrigation water also, led to the escape of a large amount of irrigation water loaded with nutrients out of the area of root spread and the formation of a non-fertile area for the spread of roots and the roots of cultivated plants exposed to nutritional stress. The same trend was found by Farrag and El-Nagar, 2005 on cucumber.

Irrigation intervals showed also significant effect on leaf N and K concentrations, while P concentration did not significantly affect. Irrigated squash plants every 7 days gave the highest leaf N and K concentrations in both seasons. In this connection, similar trend was reported by Ibrahim and Selim, 2007.

Moreover, the interaction between irrigation system and irrigation intervals had significant effects on leaf N and K concentration in both seasons (table 4). Plants watered every 7 days intervals in combination with drip irrigation gave the highest values for leaf N and K concentrations. In this connection, in contrast, the lowest values were noticed with the treatment of 11 days irrigation interval within flooding irrigation in both summer seasons 2017 and 2018.

Table 4 : Effect of irrigation system and irrigation intervals on the N, P and K concentrations in squash leaves

Treatments	**N%**				**P%**				**K%**			
	Season 2017											
	Irrigation system (IS)											
Irrigation intervals (II)	S1 (DI)	S2 (GP)	S3 (FI)	Mean	S1 (DI)	S2 (GP)	S3 (FI)	Mean	S1 (DI)	S2 (GP)	S3 (FI)	Mean
7 days	4.11	3.95	3.82	3.96	0.32	0.29	0.25	0.29	3.75	3.62	3.50	3.62
9 days	4.00	3.75	3.60	3.78	0.27	0.26	0.22	0.25	3.61	3.35	3.20	3.39
11 days	3.85	3.68	3.50	3.68	0.25	0.24	0.20	0.23	3.30	3.20	3.05	3.18
Mean	3.99	3.79	3.64		0.28	0.26	0.22		3.55	3.39	3.25	
LSD 5%												
II	0.07				NS				0.06			
IS	0.09				NS				0.11			
IIXIS	0.18				NS				0.15			
	Season 2018											
7 days	4.81	4.00	3.75	4.19	0.33	0.31	0.27	0.30	3.82	3.65	3.40	3.62
9 days	4.00	4.11	3.91	4.01	0.30	0.29	0.24	0.28	3.62	3.42	3.10	3.38
11 days	4.72	3.85	3.62	4.06	0.27	0.27	0.22	0.25	3.40	3.20	3.00	3.20
Mean	4.51	3.99	3.76		0.30	0.29	0.24		3.61	3.42	3.17	
LSD 5%												
II	0.13				NS				0.12			
IS	0.04				NS				0.14			
IIXIS	0.15				NS				0.17			

S1: Drip irrigation S2: Gated pipe S3: Flooding irrigation

Yield and Water Productivity of Squash

The results in table (5) showed the effect of irrigation systems, irrigation interval and their interaction on the yield (total and marketable ton/ha) and water productivity of squash. From table 5 drip irrigation showed positive significant effects on total yield, marketable yield and water productivity of squash in the two growing seasons as compared with the other studied systems. The increments recorded in total yield amounted by 11 and 15 %, marketable yield by 10 and 17 % and water productivity of squash by 109 and 123% as compared with using flooding system in the first and second seasons, respectively. In this regard, the increase in yield might be due to several reasons. The first of them, with the drip irrigation system, the water is added at a very slow rate, drop by drop, which leads to the case of exchanging air with added irrigation water within the root zone, and this case creates a healthy environment for the root zone of squash plants, which has led to these conditions increasing the absorption of water and nutrients, contrary to what it just happened with other surface irrigation systems. The second was the highest value of water application efficiency by using drip irrigation, which means that the amount of added irrigation did not occur to it by a large loss by deep leakage, which resulted in the failure to wash nutrients from the root-spreading area, as happened with other systems. These results are in coinciding with those detected by Noura *et al.*, 2019 a,b; Ospanbayev *et al.* 2017; Elsawy *et al.,* 2019).

Data presented in table (5) revealed that shorting irrigation intervals caused significant increases in fruit yield in both growing seasons. Irrigation every 7 days gave the highest values of fruit yield (total and marketable (ton/ha) and water productivity of squash. While, irrigation every 11 days produced the minimum values of the traits as compared to other intervals in both seasons. These findings agree with those of Al-Omran *et al.* (2005) and Ibrahim and Selim (2007) on summer squash, Farrag and El-Nagar (2005) on cucumber and Sensoy *et al.* (2007), Dogan *et al.* (2008), and Zeng *et al.* (2009) on melon. The same trend was found by Ertek *et al.* (2004) and Ibrahim and Selim (2007) who found that the medium level of irrigation was better than excessive or inadequate irrigation for early squash harvests. Using of 7 days as a period between irrigation led to the small volume of added water compared to the amount of water at 9 and 11 days between irrigation, while increasing the period between irrigation resulted in an increase in the amount of added irrigation water, which results in the inability of the root zone to retain the amount of excess irrigation water as this also led to the escape of a large amount of irrigation water loaded with nutrients out of the area of root spread and the formation of a non-fertile area for the spread of roots and the roots of cultivated plants exposed to nutritional stress and this is already what happened and reflected negatively on the characteristics under study, especially crop productivity.

Concerning the interaction between irrigation system and irrigation interval on fruit yield (total and marketable (ton/ha) and water productivity of squash in both seasons, data in table 5 showed that irrigation with drip irrigation significantly increased and recorded the highest total yield, marketable yield when irrigation every 7 days was applied compared with the other treatments. In contrast, irrigation with flooding irrigation gave the lowest values of the traits when irrigation every 11 days was applied compared with the other treatments in the first and second seasons. Figures (3, 4) to clarify more and know the direction of the influence of the factors under study on the yield and water productivity of squash

Table 5: Effect of irrigation system and irrigation intervals on the yield and water productivity of squash.

Treatment	Total yield (ton/ha)				Marketable yield (ton/ha)				Water productivity kg/m^3			
	Season 2017											
	Irrigation system (IS)											
Irrigation intervals (II)	S1 (DI)	S2 (GP)	S3 (FI)	Mean	S1 (DI)	S2 (GP)	S3 (FI)	Mean	S1 (DI)	S2 (GP)	S3 (FI)	Mean
7 days	28.60	27.21	26.31	27.37	27.49	26.41	25.03	26.31	19.64	12.11	9.41	13.72
9 days	28.11	27.00	26.00	27.04	26.76	26.29	25.40	26.15	19.11	12.06	9.55	13.57
11 days	25.67	23.21	22.10	23.66	24.37	22.40	20.90	22.56	17.41	10.28	7.86	11.85
Mean	27.46	25.81	24.80		26.05	25.03	23.78		18.72	11.48	8..94	
LSD 5%												
II	0.91				0.72							
IS	1.14				1.22							
II X IS	1.52				1.36							
	Season 2018											
7 days	26.70	25.60	23.50	25.27	26.12	24.51	22.30	24.31	19.21	11.62	8.58	13.14
9 days	27.18	25.20	23.70	25.36	25.90	24.37	22.80	24.36	19.04	11.55	8.77	13.12
11 days	24.58	22.23	21.20	22.67	24.28	20.63	20.17	21.69	17.85	9.78	7.76	11.80
Mean	26.15	24.34	22.80		25.43	23.17	21.76		18.70	10.98	8.37	
LSD5%												
II	0.87				0.65							
IS	1.12				1.20							
II X IS	1.41				1.72							

S1: Drip irrigation S2: Gated pipe S3: Flooding irrigation

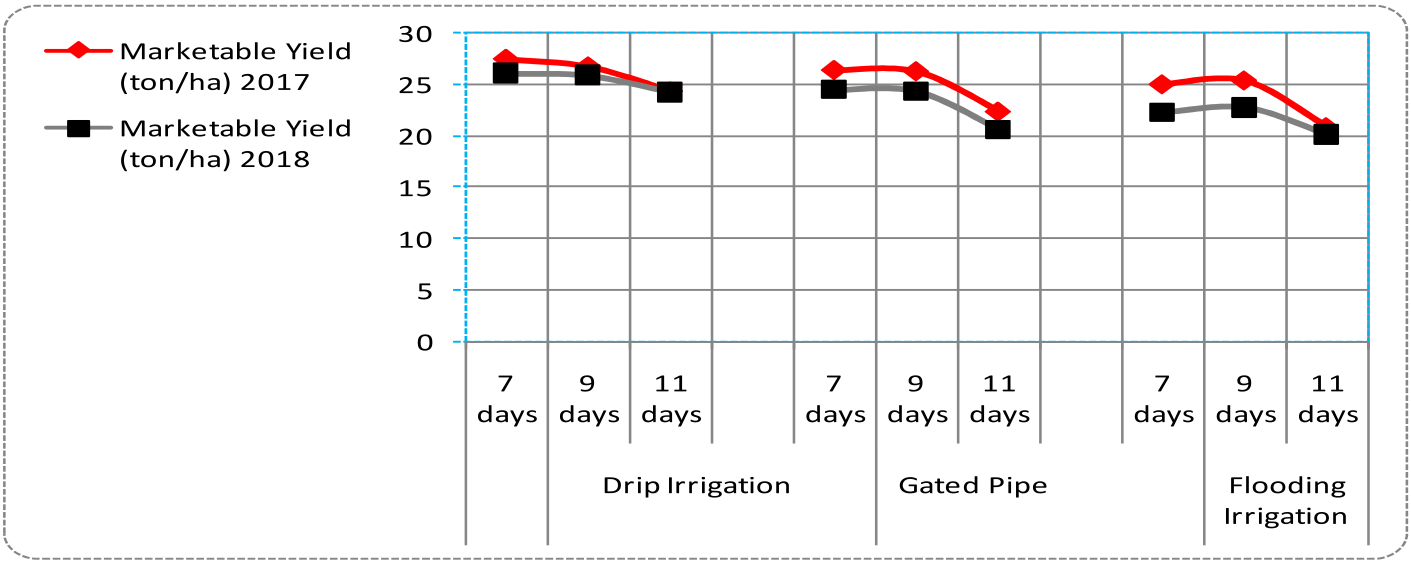

Fig. 3 : Effect of irrigation system and irrigation intervals on the marketable yield of squash

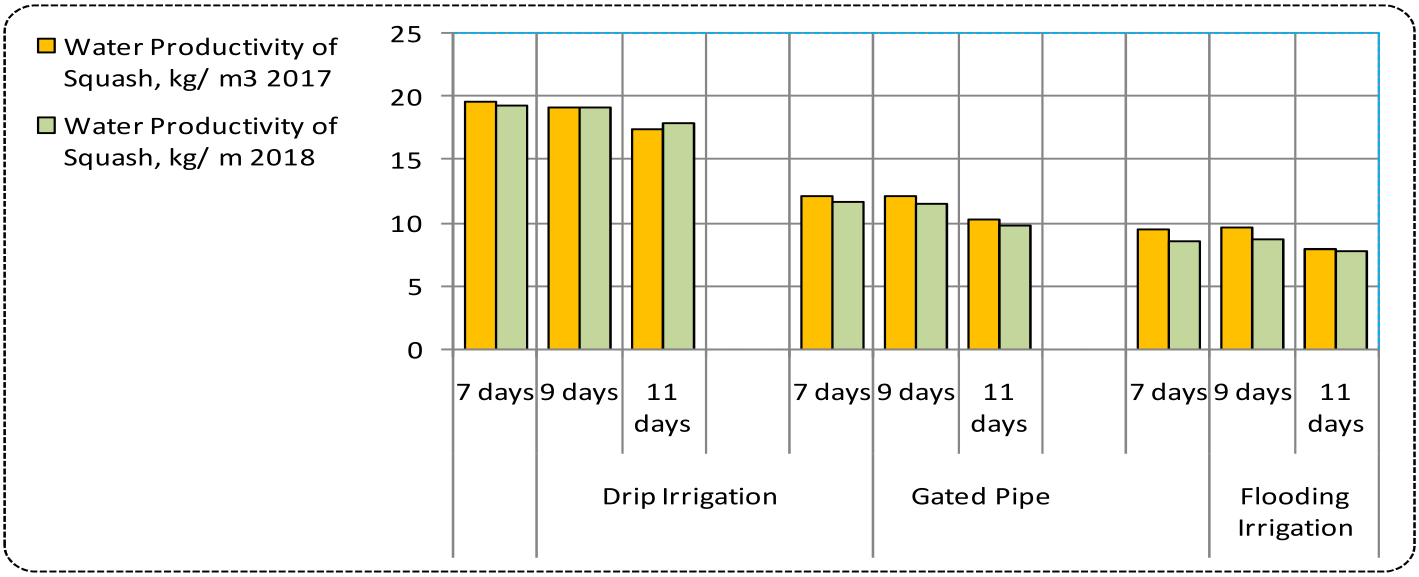

Fig. 4 : Effect of irrigation system and irrigation intervals on the water productivity of squash

Quality Traits of Fruits Squash

The results in tables (6 and 7) showed the effect of three irrigation methods, three irrigation intervals and their interaction on some quality traits of fruits squash. The results presented in tables 6and 7 revealed that irrigation systems had significant effects on fruit length, fruit diameter, fruit weight and TSS % of squash. The highest values of the previous traits were recorded when squash plants irrigated through drip irrigation system as compared with the other used systems, followed by gated pipe system.

Moreover, irrigating squash plants every 7 days gave the highest significant increments in all studied quality parameters. While the lowest values were recorded when the plants irrigated every 11 days.

These findings agree with those of Al-Omran *et al.* (2005) on summer squash and Dogan *et al.* (2008), and Zeng *et al.* (2009) on melon. On the other hand, increasing irrigation intervals from 9 to 11 days caused insignificant decrements in the two summer seasons. The same trend was found by Ertek *et al.* (2004) who found that the medium level of irrigation was better than excessive or inadequate irrigation for early squash harvests.

Data in tables (6 and 7) showed that there were significant effects due to the interaction between irrigation system and irrigation interval on fruit length, fruit diameter and fruit weight in both seasons. While, the interaction did not significantly affect TSS (%). In contrast, irrigation with flooding irrigation gave the lowest values of the fruit length, fruit diameter, fruit weight and TSS % when irrigation every 11 days was applied compared with the other treatments in the first and second seasons 2017 and 2018.

Table 6 : Effect of irrigation system and irrigation intervals on some physical characters of squash fruits

Treatments	Fruit length (cm)				Fruit diameter (cm)				Fruit weight (g)			
	Season 2017											
	Irrigation system (IS)											
Irrigation intervals (II)	S1 (DI)	S2 (GP)	S3 (FI)	Mean	S1 (DI)	S2 (GP)	S3 (FI)	Mean	S1 (DI)	S2 (GP)	S3 (FI)	Mean
7 days	15.44	15.10	14.50	15.01	4.20	4.15	4.00	4.12	145.2	141.0	136.2	140.80
9 days	15.14	14.87	14.40	14.80	4.11	4.00	3.70	3.94	132.1	129.0	125.2	128.77
11 days	14.55	14.02	14.00	14.19	3.70	3.65	3.50	3.62	122.1	120.1	119.3	120.50
Mean	15.04	14.66	14.20		4.00	3.93	3.73		133.1	130.3	126.9	
LSD 5%												
II	0.15				0.18				1.15			
IS	0.23				0.27				2.36			
IIXIS	0.34				0.39				4.12			
	Season 2018											
7 days	16.82	15.90	15.70	16.14	4.30	4.12	3.90	4.11	143.2	139.2	130.7	137.70
9 days	14.92	15.50	14.95	15.12	4.15	3.85	3.70	3.90	129.7	127.5	121.2	126.13
11 days	14.89	14.52	14.00	14.47	4.00	3.70	3.40	3.70	120.2	118.7	117.3	118.73
Mean	15.54	15.13	14.88		4.15	3.89	3.67		131.03	128.47	123.07	
LSD 5%												
II	0.14				0.21				2.11			
IS	0.26				0.25				3.52			
IIXIS	0.37				0.32				5.13			

S1: Drip irrigation S2: Gated pipe S3: Flooding irrigation

Table 7 : Effect of irrigation system and irrigation intervals on the TSS of squash fruits

Treatments	Total soluble solid (TSS %)			
	Season 2017			
Irrigation intervals (II)	S1, (DI)	S2, (GP)	S3, (FI)	Mean
7 days	7.3	7.0	6.6	6.97
9 days	6.5	6.3	6.0	6.27
11 days	5.7	5.4	5.2	5.43
Mean	6.50	6.23	5.93	
LSD 5%				
II	0.21			
IS	0.18			
IIXIS	NS			
	Season 2018			
7 days	7.6	7.2	7.4	7.40
9 days	6.7	6.4	6.7	6.60
11 days	5.8	5.6	5.4	5.60
Mean	6.70	6.40	6.50	
LSD 5%				
II	0.19			
IS	0.17			
IIXIS	NS			

S1: Drip irrigation S2: Gated pipe S3: Flooding irrigation

Conclusion

The aim from the beginning was to improve the yield, water productivity and quality of the squash crop by defining the best irrigation system and determining the best period between irrigation. It could be concluded that under the conditions of this experiment, drip irrigation system was the best system to be used. Irrigation the squash every 7 days was the best irrigation interval and the interaction between them was recommended (drip irrigation system X irrigation 7 days interval).

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