RATIONALIZE MAIZE IRRIGATION WATER USING MODERN IRRIGATION SYSTEMS AND PLASTIC MULCHING IN CLAYEY SOILS OF FAYOUM

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ABSTRACT

Using the modern irrigation systems lead to water lost decrease, controlling the quantity and increase crop productivity. The current study aims to evaluate the surface, improved surface and drip irrigation systems to rationalize maize irrigation water in soils. Field experiments were conducted in Sanores District, Fayoum Governorate. The treatments include three irrigation systems (surface, improved surface and drip), three deficit irrigation treatments (100%, 80% and 60% of ETc) and three soil plastic mulching treatments (without, white plastic and black plastic). All treatments were combined in the complete randomized blocks design (spilt –spilt plot) with three replicates. Maize **(*Zea mays L,*** variety 321) was planted during two summer seasons (2017 and 2018). Class A Pan was used for estimating the daily ETo values to determine the intervals between irrigation treatments. Disturbed and undisturbed soil samples were collected from the experimental field before conducting such treatments. Measurements of maize growth parameters and yield were carried. Some crop water relations of maize were determined. Statistical analysis for the obtained data was performed.

Results indicated that the highest values of plant height, cobs No. per plant, cob weight, number of rows per cob, weight of 100 grains and grains yield of maize were coincided with improved surface irrigation system, irrigation treatment (80% of ETc) and black plastic mulching. Also, the highest value of forage weight of maize was recorded with surface irrigation system, irrigation treatment (100% of ETc) and soil black plastic mulching. The mean values of the water consumptive use of maize plants were significantly decreased by 31.26 and 12.10% under drip irrigation compared with surface and improved surface irrigation systems. The mean values of water productivity of maize crop significantly increased by 27.13 and 3.88% under drip irrigation compared with surface and improved surface irrigation systems, respectively. It could be concluded that improved surface irrigation system, irrigation treatment (80% of ETc) and black plastic mulching saved about 20% of the applied irrigation water (about 965 m^3 ha^{-1}), as well as, the highest grains yield of maize plants in clayey soils under Fayoum conditions.

Keywords: Water rationalization, improved surface irrigation, drip irrigation, deficit irrigation, soil mulching, maize yield and water productivity.

INTRODUCTION

Agriculture consumes approximately 70% of the available fresh water on the Earth. Maize considered as one of the main cereal crops occupying the second order after wheat in Egypt. The total cultivated area of maize reached about 2.47 million fed. in 2015 and maize grain production in Egypt is approximately 8.059 million ton **(FAO, 2016).** The efficient use and rationalization of the Egyptian irrigation water in agriculture is need to reduce the cultivation of crops with high water consumption, gradually replace crops consuming less water, and installing developed irrigation systems in the old land to maximize the use of the irrigation water **(Ahmed et al., 2013)**.

Gated pipes irrigation gave a water saving 25-28% of water use efficiency compare to conventional basin irrigation **system (Jibin and Faroud, 2007)**. **Abo Soliman et al., (2008)** concluded that the lowest amount of water applied, consumptive use, water losses, and the highest values of water use efficiency and water application efficiency were obtained under gated pipes. **Sonbol et al. (2010), Abdel-Raheem and Elwan (2016)** recommended the application of gated pipes under different soil texture and weather conditions in Egypt.

Under drip irrigation system the mean grain yield of maize increased with increasing water use which resulted in 2.67, 3.62, 3.89, and 4.7 t ha^{-1} grain yield at 60, 40, 20 and 0% irrigation water deficits treatments, respectively **(Silungwe et al., 2010 and Kadasiddappa et al., 2016). D**rip irrigation method was found significantly superior than surface furrow irrigation in terms of growth parameters of maize **(Ramulu et al., 2019)**.

Wang et al. (2011) reported that the using of plastic sheet was capable of promoting deep soil water, improving crop growth, accelerating the soil-plant-atmosphere transport and significantly improve crop water use efficiency. **Abd El-Wahed and Ali (2013)** reported that soil mulching credited to increase water contents in soil due to reduce evaporation. **Memon et al. (2018)** reported that the saving percentages of water were 52.22% and 31.00% at plastic mulch and without mulching, respectively compared with traditional irrigation practice.

Aguilar et al. (2007) found that limited or regulated deficit irrigation is one way of maximizing productivity of total applied water (PAW); thus, the limited irrigation treatment reached a higher PAW value (2.66 kg m^{-3}) than full irrigation (1.90 kg m^{-3}). **Shinde et al. (2009)** showed that irrigation scheduled at 0.80 IW/CPE ratio recorded significantly higher plant height and dry matter of maize.

This study aims to rationalize the irrigation water of maize plants grown in clayey soils using improved surface and drip irrigation systems and soil plastic mulching under Fayoum conditions.

Materials and methods

Field experiment was conducted in Sanores District, Fayoum Governorate, Egypt, as a clayey texture soil during two summer seasons of 2017 and 2018. The main initial soil physical and chemical properties of the experimental soil were presented in Table (1). Three different irrigation systems represented the main plots, i.e., surface (S_1), improved surface (S_2) and drip (S_3). Each main plot was divided into three deficit irrigation treatments, i.e., 100% (I_1), 80% (I_2) and 60% (I_3) of ETc.

Tables (1). Some initial soil physical and chemical properties of the experimental soil (as average of the two seasons)*.

Soil physical properties		**Depth (cm)**			
		0–20	**20-40**	**40–60**	**Mean**
Particle size distribution	Sand %	27.27	28.50	28.88	28.22
	Silt %	26.80	25.18	23.88	25.29
	Clay %	45.94	46.33	47.25	46.51
	Texture class	Clay	Clay	Clay	Clay
Bulk density (Mg m^{-3})		1.26	1.31	1.37	1.31
Particle density (Mg m^{-3})		2.65	2.66	2.66	2.66
Total porosity, % volume		52.96	50.85	48.50	50.77
Air porosity, % volume		40.72	37.05	33.33	37.03
Void ratio (e)		1.13	1.04	0.95	1.04
Hydraulic conductivity (cm hr^{-1})		0.24	0.17	0.13	0.18
Soil moisture constants, % at:	Field capacity	38.83	37.56	37.00	37.80
	Wilting point	20.31	21.19	22.20	21.23
	Available water	18.52	16.37	14.80	16.56
Soil chemical properties					
pH (1: 2.5 soil-water suspension)		7.27	7.44	7.69	7.47
ECe (dS m^{-1})		1.22	1.06	1.46	1.25
Soluble cations, ($mmol^{+}$ L^{-1})	Ca^{++}	3.35	2.85	4.10	3.43
	Mg^{++}	2.50	1.95	3.00	2.48
	Na^{+}	5.95	5.00	7.35	6.10
	K^{+}	0.55	0.45	0.40	0.47
Soluble anions, ($mmol^{+}$ L^{-1})	$CO_3^{=}$	-	-	-	-
	HCO_3^{-}	2.33	1.48	3.34	2.38
	Cl^{-}	7.03	5.50	7.55	6.69
	$SO_4^{=}$	3.05	3.55	3.85	3.48
$CaCO_3$, g kg^{-1}		55.05	48.50	21.80	41.78
Organic matter, g kg^{-1}		19.30	15.05	11.50	15.28

*Each value in this table is mean of three replicates.

Each sub main plot was divided into three soil mulching, i.e., without (M_0), white plastic mulch (M_1) and black plastic mulch (M_2). All treatments combined in the complete randomized blocks design (spilt - spilt plot) with three replicates.

The crop evapotranspiration (ETc) was calculated from the following equation, according to **Doorenbos and Pruitt (1992)**:

$$\mathbf{ET_c = ET_o \times K_c}$$

$\mathbf{ET_o}$ is the "Reference ET" (the amount of full water used by a well irrigated) and $\mathbf{K_c}$ is the "Crop Coefficient" (A factor that is used to convert ET_o to potential ETc).

K_c values of maize plants were 0.3, 0.8, 1.2 and 0.6 at the four growth stages. Under surface and improved surface, the number of irrigations at all different irrigation treatments are presented in Table (7).

Under improved surface irrigation, PVC pipes (5 inches in diameter) were used and an orifice gated are distributed along the pipes with 3 m spacing. Gated pipes are connected directly with a water pump to convey and distribute the water to the head of the irrigated fields (furrows method). The discharge of tap was 100 L min.$^{-1}$ and the operation time varied with the application of three irrigation treatments.

Under drip irrigation system, the amounts of irrigation water applied (IWA) of each plot were determined using the following equation **(Abd El-Wahed and Ali, 2013)**:

$$\mathbf{IWA} = \frac{\mathbf{A \times ET_c \times L_i}}{\mathbf{E_a \times 1000}}$$

Where: ETc = the crop evapotranspiration (mm day^{-1}).
IWA = the irrigation water application (m^3), A = the area (m^2).
Li = the irrigation intervals (day), E_a = the application efficiency (%).

Under drip irrigation system, the number of working hours at all different irrigation treatments are presented in Table (7). To achieve the intervals between irrigations in surface irrigation system, scheduling crop irrigation water of maize using the daily Class A Pan evaporation values (mm) were recorded. Monthly mean weather data for years 2017 and 2018 were obtained from Etsa meteorological station, Fayoum, Egypt. The daily ET_o was computed according to **(Allen et al., 1998).** The soil moisture constants of the effective root zone (0-60 cm) were estimated (Table, 2).

All treatments were planted with maize (***Zea mays L.***, variety 321**)** in two summer seasons (2017 and 2018). Maize grains were planted manually in the 6th and 4th August in the 1st and 2nd seasons, respectively, in hills 30 cm apart from each other, the distance between rows was 70 cm. Harvesting of the maize plants was after 120 days from planting. Other cultural management practices for the grown maize have been conducted as the recommendations of the Egyptian Ministry of Agriculture. Measurements of maize plant parameters, yield and yield components were carried out during and after the harvesting stage of the maize plants.

Disturbed and undisturbed soil samples were collected from the experimental field at three depths (0-20, 20-40 and 40-60 cm) before proceeding irrigation treatments and mulching. Some initial soil physical properties were determined according to **Klute (1986),** also, some initial soil chemical characteristics were determined according to **Page et al. (1982)** Table (1).

To obtain water consumptive use, the soil moisture percentage was gravimetrically determined on day basis just before and after 48 hour of each irrigation, as well as at harvesting time. The amount of water consumed (C.U) from the root zone between each two successive irrigations as a water depth in cm, was calculated from the following equation: **(Israelsen and Hansen, 1962).**

$$\text{C.U}\ (\text{ET}_c) = \frac{\text{m}}{100} \times \gamma_d \times \text{D}$$

Under surface and improved surface irrigation systems and different irrigation treatments the number of irrigations, date and irrigation intervals (days) according the cumulative Class A Pan evaporation treatments of maize plants were calculated and presented in Table (3) during 2017 and 2018 seasons.

Table (2). Soil moisture constants and soil available water depth (mm) of the effective root zone of the studied soil.

Depth (cm)	Field capacity (%)	Wilting point (%)	Available water (%)	Bulk density (g cm^{-3})	Available water (cm)	Available water (mm)
The first season (2017)						
0 – 20	35.40	21.12	14.28	1.20	3.427	34.27
20 – 40	32.21	21.30	10.91	1.22	2.662	26.62
40 – 60	30.83	21.60	9.23	1.28	2.362	23.62
The total soil available water (0- 60 cm depth)					8.451	84.51
The second season (2018)						
0 – 20	35.25	21.10	14.15	1.20	3.396	33.96
20 – 40	32.40	21.28	11.12	1.23	2.735	27.35
40 – 60	30.66	21.57	9.09	1.29	2.345	23.45
The total soil available water (0- 60 cm depth)					8.476	84.76

Where: m is the soil moisture after and before irrigation treatments.
D is the depth, cm, and γ_d is the dry bulk density, Mg m^{-3}

The water productivity was expressed as kg maize grains m^{-3} of water consumed. It has been used to evaluate the effects of different irrigation treatments in producing the maximum yield per water unit consumed by the crop plants (**Jensen et al., 1990**). The values of water productivity for maize plants were calculated as follows:

$$\text{Water productivity} = \frac{\text{Grains yield of maize crop (kg fed}^{-1})}{\text{Seasonal crop consumptive use (m}^3\text{ fed}^{-1})}$$

The collected data were statistically analyzed using the procedures outlined by **Snedecor and Cochran (1980).**

Table (3). Number of irrigation, dates and irrigation intervals (days) according the cumulative Class A Pan evaporation treatments of corn of the two seasons 2017 and 2018.

No. of irrigations	Irrigation treatments (C.P.E.)					
	I_1		I_2		I_3	
	Date	Interval day	date	Interval day	date	Interval day
planting	August 6th	-	August 6th	-	August 6th	-
1st	20-8-2017	14	24-8-2017	18	1-9-2017	25
2nd	4-9-2017	15	12-9-2017	19	28-9-2017	27
3rd	20-9-2017	16	3-10-2017	21	26-10-2017	28
4th	8-10-2017	18	25-10-2017	22	24-11-2017	29
5th	28-10-2017	20	17-11-2017	23	---	---
6th	20-11-2017	23	---	---	---	---
Harvesting	5-12-2017	--	5-12-2017	--	5-12-2017	--

Results and discussions

1. Effect of irrigation systems, irrigation treatments and soil plastic mulching on growth parameters of maize plants

Data in Table (4) show that the highest values of plant height, cobs number per plant and cob weight of maize plants are 253.56 cm, 1.78 and 345.56 gm and had been coincided with S_2, I_2, M_2 treatment. Irrigation treatments had a clear effect on all growth parameters which significantly decreased at irrigation treatment I_3.

Data in Table (4) show that the improved surface and drip irrigation systems when compared with surface irrigation system lead to significant increase in the mean values of the plant height by 5.35 and 4.84% for M_0, 5.72 and 5.43% for M_1 and 5.72 and 4.81% for M_2 treatment, respectively. The improved surface and drip irrigation systems when compared with surface irrigation system lead to significant increase in the mean values of cobs number per plant by 3.55 and 2.84% for M_0, 7.38 and 2.68% for M_1 and 10.60 and 1.99% for M_2 treatments, respectively. Also, the improved surface and drip irrigation systems when compared with surface irrigation system lead to significant increase in the mean values of cob weight by 3.05 and 0.00% for M_0, 3.14 and 2.67% for M_1 and 7.19 and 3.37% for M_2 treatments, respectively. These results are a good in agreement with those obtained by **Payero et al. (2009)**.

Results in Table (4) indicated also that under improved surface irrigation system, soil black plastic mulching lead to significant increases in the mean values of the maize plant height, stem diameter, cobs number per plant and cob weight values by 7.41, 2.46, 12.57 and 5.43 with without mulches and 2.61%, 1.05%, 4.19% and 4.23% with white mulches, respectively. These results are in agreement with those obtained by **Irmak and Rudnick (2014).**

2. Effect of irrigation systems, irrigation treatments and soil plastic mulching on yield and yield components of maize plants.

Data in Table (5) indicated that the variations of both crop parameters were the highest values of number of rows per cob, weight of 100 grain (gm) and grains yield of maize (t ha^{-1}) were 15.07, 24.6 gm and 9.150 t ha^{-1}, respectively. These values were recorded coincided with S_2 I_2 M_2 treatment. Also, the highest value of forage weight (t ha^{-1}) is 36.6 t ha^{-1} and had been recorded coincided with S_1 I_1 M_2 treatment.

However, Table (5) show that under without mulching treatment, improved surface and drip irrigation systems lead to significant increase in the mean values of the number of rows per cob, weight of 100 grains and grain yield by 5.79 and 2.62%, 5.57 and 3.35% and 12.72 and 4.92% compared with surface irrigation system, respectively. Also, under white plastic mulching treatment, improved surface and drip irrigation systems when compared with improved surface and drip irrigation systems lead to significant increase in the mean values of the number of rows per cob, weight of 100 grain and grains yield by 6.11 and 3.02%, 4.52 and 3.47% and 13.70 and 6.01%, respectively. In addition, under black plastic mulching treatment, improved surface and drip irrigation systems when compared with improved surface and drip irrigation systems lead to significant increase in the mean values of the number of rows per cob, weight of 100 grains and grains yield by 5.85 and 3.38%, 3.55 and 3.03% and 12.09 and 4.16%, respectively. On the other hand, surface irrigation system when compared with improved surface and drip irrigation systems lead to significant increases in the mean values of the forage weight by 1.72 and 4.23%, 1.79 and 3.30% and 2.73 and 4.06% for M_0, M_1 and M_2 treatments, respectively.

Table (4). Some plant growth parameters of maize plants as influenced by irrigation treatments and soil plastic mulching under different irrigation systems (as mean values of two seasons 2017 and 2018)*.

Irrigation system	No of irrig. or work. hr.	Irrig. treatment	Without mulching				White plastic mulching				Black plastic mulching			
			Plant height (cm)	Stem diameter (cm)	Cobs No. per plant	Cob weight (gm)	Plant height (cm)	Stem diameter (cm)	Cobs No. per plant	Cob weight (gm)	Plant height (cm)	Stem diameter (cm)	Cobs No. per plant	Cob weight (gm)
Surface irrigation	7	I_1	214.56	2.72	1.33	291.11	220.67	2.73	1.44	305.56	225.33	2.75	1.46	306.67
	6	I_2	226.00	2.86	1.56	325.56	244.56	2.92	1.68	318.89	250.11	2.93	1.72	320.44
	5	I_3	184.11	2.58	1.33	276.67	189.56	2.60	1.34	278.89	196.89	2.63	1.35	280.44
		Mean	**208.22**	**2.72**	**1.41**	**297.78**	**218.26**	**2.75**	**1.49**	**301.11**	**224.11**	**2.77**	**1.51**	**302.52**
Improved surface irrigation.	7	I_1	227.44	2.77	1.44	310.33	241.89	2.79	1.67	311.67	251.33	2.83	1.67	340.56
	6	I_2	234.89	2.88	1.58	327.44	247.11	2.91	1.69	336.67	253.56	2.92	1.78	345.56
	5	I_3	195.78	2.70	1.35	282.78	203.22	2.76	1.43	283.33	205.89	2.80	1.56	286.67
		Mean	**219.37**	**2.78**	**1.46**	**306.85**	**230.74**	**2.82**	**1.60**	**310.56**	**236.93**	**2.85**	**1.67**	**324.26**
Drip irrigation	31.33	I_1	224.67	2.78	1.44	293.89	227.11	2.80	1.56	311.22	229.11	2.81	1.57	313.89
	25.06	I_2	233.89	2.81	1.57	311.67	240.44	2.84	1.67	328.89	251.00	2.89	1.69	330.33
	18.80	I_3	196.33	2.70	1.34	283.89	222.78	2.74	1.35	287.33	224.56	2.76	1.36	293.89
		Mean	**218.30**	**2.76**	**1.45**	**296.48**	**230.11**	**2.79**	**1.53**	**309.15**	**234.89**	**2.82**	**1.54**	**312.70**

LSD at 5%	S	I	M	I×S	M×S	M×I	M× I ×S
Plant height (cm)	1.026	0.849	0.617	1.410	1.190	1.174	2.007
Stem diameter (cm)	0.018	0.023	0.012	0.035	0.022	0.028	0.044
Cobs No. per plant	0.032	0.027	0.016	0.044	0.034	0.034	0.057
Cob weight (gm)	17.47	13.33	6.12	22.77	NS	15.38	NS

Where: *Each value in this table is an average of 3 replicate, S is irrigation system, M is mulching and I is irrigation treatment (I_1, I_2 and I_3 are 100%, 80% and 60% of crop evapotranspiration, respectively).

Table (5). Yield and yield component of maize plants as influenced by irrigation treatments and soil plastic mulching under different irrigation systems (as mean values of two seasons 2017 and 2018)*.

Irrigation system	No of irrig. or work. hr.	Irrig. treat.	Without mulch				White plastic mulching				Black plastic mulching			
			No. of rows per cob	Weight of 100 grains (gm)	Forage weight (t ha^{-1})	Grains yield (t ha^{-1})	No. of rows per cob	Weight of 100 grains (gm)	Forage weight (t ha^{-1})	Grains yield (t ha^{-1})	No. of rows per cob	Weight of 100 grains (gm)	Forage weight (t ha^{-1})	Grains yield (t ha^{-1})
Surface irrigation	7	I_1	13.00	20.08	34.8	6.891	13.41	20.99	35.5	7.038	13.44	21.23	36.6	7.353
	6	I_2	13.56	21.49	34.5	8.089	13.78	22.37	34.9	8.219	13.87	22.86	35.1	8.330
	5	I_3	12.33	19.33	22.9	6.487	12.56	19.75	26.8	6.605	12.67	20.16	27.2	6.842
		Mean	**12.96**	**20.30**	**30.73**	**7.156**	**13.25**	**21.04**	**32.40**	**7.287**	**13.33**	**21.42**	**32.97**	**7.508**
Improved surface irrigation	7	I_1	13.36	20.92	33.8	8.464	13.67	21.42	34.6	8.758	13.70	21.81	35.1	8.867
	6	I_2	14.67	23.36	34.0	8.816	15.00	24.03	34.2	9.004	15.07	24.06	34.3	9.150
	5	I_3	13.11	20.00	22.8	6.920	13.50	20.51	26.7	7.094	13.56	20.67	26.8	7.232
		Mean	**13.71**	**21.43**	**30.20**	**8.066**	**14.06**	**21.99**	**31.83**	**8.285**	**14.11**	**22.18**	**32.07**	**8.416**
Drip irrigation	31.33	I_1	13.33	20.26	32.9	7.338	13.52	21.14	34.3	7.554	13.67	21.65	34.9	7.645
	25.06	I_2	13.67	22.51	33.6	8.153	14.40	23.38	33.9	8.354	14.56	23.73	34.1	8.464
	18.80	I_3	12.89	20.18	21.8	7.034	13.03	20.79	25.8	7.266	13.11	20.84	25.9	7.350
		Mean	**13.30**	**20.98**	**29.43**	**7.508**	**13.65**	**21.77**	**31.33**	**7.725**	**13.78**	**22.07**	**31.63**	**7.820**

Where: *Each value in this table is an average of 3 replicate, S is irrigation system, M is mulching and I is irrigation treatment (I_1, I_2 and I_3 are 100%, 80% and 60% of crop evapotranspiration, respectively).

Results in Table (5) indicated that under improved surface irrigation system, soil black plastic mulching lead to significant increase in the mean values of the maize number of rows per cob, weight of 100 grains, forage weight and grains yield values by 2.83 and 0.35%, 3.38 and 0.86%, 5.83 and 0.75% and 4.16 and 1.56% compared with the without mulching and white plastic mulching, respectively. However, under drip irrigation system, soil black plastic mulching lead to significant increase in the mean values of the maize number of rows per cob, weight of 100 grains, forage weight and grains yield values by 3.48 and 0.94%, 4.94 and 1.36%, 6.96 and 0.95% and 3.99 and 1.22% compared with the without mulching and white plastic mulching, respectively. However, soil plastic mulching influence on maize grains yield more than deficit irrigation treatments. This results are in agreement with those obtained by **Wang et al. (2016)** who found that in semi-arid areas of China, plastic-film mulched ridge–furrow cropping has been extensively used for maize production.

3. Effect of irrigation systems, irrigation treatments and soil plastic mulching on water consumptive use (m^3 $fed.^{-1}$) of maize plants.

Results in Table (6) showed that the highest values of water consumptive use of maize plants were 2975.25 and 2915.35 m^3 fed^{-1} at the 1^{st} and 2^{nd} seasons, respectively, and were which coincided with surface irrigation system, irrigation treatment I_1 (100% of ETc) and without soil mulching treatments. On the other hand, the lowest values of water consumptive use of maize plants were 1595.63 and 1569.44 m^3 fed^{-1} at the 1^{st} and 2^{nd} seasons respectively, which were coupled drip irrigation system, irrigation treatment I_3 (60% of ETc) and soil black plastic mulching. These results reflect the high values of maize plants growth parameter which were obtained at irrigation treatments I_1 (100% of ETc) and I_2 (80% of ETc). These results are in a good agreement with those obtained by **Basal et al. (2009)**

who found that using drip irrigation is able to reduce the irrigation water and increase the yield of different crops compared to conventional methods**.**

The mean values of water consumptive use of maize plants at soil black plastic mulching significantly decreased compared with the without mulching and white plastic mulching treatments under the different used irrigation systems.

The results in Table (6) showed that under drip irrigation system, the mean values of water consumptive use of maize plants significantly decreased by 31.40 and 12.66% at the 1st season and by 31.11 and 11.54% at the 2nd season compared with surface and improved surface irrigation systems, respectively. However, the mean values of water consumptive use of maize plants at irrigation treatment I_1 (100% of ETc) were significantly increased when compared with irrigation treatments I_2 (80% of ETc) and I_3 (60% of ETc) under the different used irrigation systems.

Table (6). Effect of irrigation treatments and soil plastic mulching on water consumptive use of maize plants (m^3 fed^{-1}) under different irrigation systems (as mean values of two seasons 2017 and 2018)*.

Irrig. system	No of irrig. or work. hr.	Irrig. treat.	1st season (2017)				2nd season (2018)			
			M_0	M_1	M_2	mean	M_0	M_1	M_2	mean
Surface irrigation	7	I_1*	2975.25	2910.35	2870.24	**2918.61**	2915.35	2860.53	2810.45	**2862.11**
	6	I_2	2560.54	2454.65	2396.75	**2470.65**	2492.64	2396.74	2324.83	**2404.74**
	5	I_3	2145.26	2058.85	1982.45	**2062.19**	2139.96	2052.35	1968.43	**2053.58**
		mean	**2560.35**	**2474.62**	**2416.48**	**2483.82**	**2515.98**	**2436.54**	**2367.90**	**2440.14**
Improved surface irrigation.	7	I_1	2664.56	2576.54	2490.45	**2577.18**	2614.42	2535.47	2400.72	**2516.87**
	6	I_2	2131.20	2063.45	1982.63	**2059.09**	2115.20	2024.23	1940.43	**2026.62**
	5	I_3	1798.40	1755.60	1704.24	**1752.75**	1736.40	1665.43	1650.66	**1684.16**
		mean	**2198.05**	**2131.86**	**2059.11**	**2129.67**	**2155.34**	**2075.04**	**1997.27**	**2075.88**
Drip irrigation	31.33	I_1	2268.24	2175.00	2050.45	**2164.56**	2196.65	2124.14	1998.47	**2106.42**
	25.06	I_2	1914.59	1825.87	1754.58	**1831.68**	1895.32	1805.33	1747.52	**1816.06**
	18.80	I_3	1760.94	1667.65	1595.63	**1674.74**	1740.99	1672.54	1569.44	**1660.99**
		mean	**1981.26**	**1889.51**	**1800.22**	**1890.33**	**1944.32**	**1867.34**	**1771.81**	**1861.16**

LSD at 5%	S	I	M	I× S	M×S	M×I	M× I ×S
1st season	3.44	1.63	1.54	3.62	3.59	2.64	5.02
2nd season	2.10	2.38	1.62	3.65	2.79	3.18	5.23

Where: *Each value in this table is an average of 3 replicate, M_0, M_1 and M_2 are without, white plastic and black plastic mulching, respectively. I_1, I_2 and I_3 are 100%, 80% and 60% of crop evapotranspiration, respectively**.**

Also, the mean values of water consumptive use of maize plants at surface irrigation system were significantly increased when compared with improved and drip irrigation systems, under the different irrigation treatments 100, 80 and 60% of ETc (I_1, I_2 and I_3). The obtained results were in agreement with those obtained by **Kadasiddappa and Praveen (2018)**.

4. Effect of irrigation systems, irrigation treatments and soil plastic mulching on water productivity of maize plants.

Data in Table (7) and Figure (1) indicated that the highest values of water productivity of maize plants are 2.023 and 2.039 kg m^{-3} at the 1st and at 2nd seasons which were coincided with drip irrigation system, irrigation treatment I_2 (80% of ETc) and with soil black plastic mulching. On the other hand, the lowest values of water productivity of maize plants are 0.963 and 1.003 kg m^{-3} at the 1st and 2nd seasons which were coincided with surface irrigation system, irrigation treatment I_1 (100% of ETc) and with the without mulching. These results may reflect the lowest values of maize grains yield which coupled with irrigation treatments I_3 (60% of ETc) and I_1 (100% of ETc) treatments, while the highest ones were observed with irrigation treatments I_2 (80% of ETc). However, Table (7) showed that, the mean values of water productivity of maize plants at soil black plastic mulching were significantly increased when compared with the without mulching and white plastic mulching treatments under the different used irrigation systems. The obtained results were in agreement with those obtained by **Wu et al. (2017).**

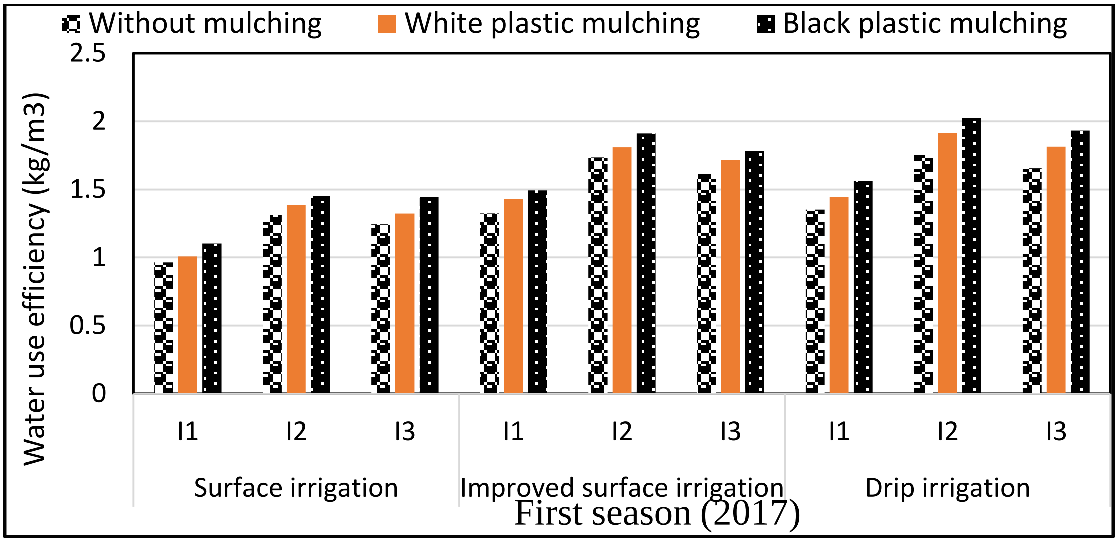
The results in Table (7) showed that under drip irrigation system, the mean values of water productivity of maize plants significantly increased by 27.27 and 4.08% at the 1st season and by 26.98 and 3.68% at the 2nd season compared with surface and improved surface irrigation systems, respectively. Also**, t**he mean values of water productivity of maize plants at irrigation treatment I_1 (100% of ETc) significantly decreased compared with irrigation treatments I_2 (80% of ETc) and I_3 (60% of ETc) under the different used irrigation systems. The obtained results were in agreement with those obtained by also, **Ali and Mohammed (2015)** revealed that use of gated pipes system as compared to surface irrigation reduced water application.

Table (7). Effect of irrigation treatments and soil plastic mulching on water productivity (kg m^{-3}) under different irrigation systems in clayey soils (as mean values of two seasons 2017 and 2018)*.

Irrig. system	No of irrig. or work. hr.	Irrig. treat.	1st season (2017)				2nd season (2018)			
			M_0	**M_1**	**M_2**	**mean**	**M_0**	**M_1**	**M_2**	**mean**
Surface Irrigation	7	I_1	0.963	1.008	1.103	**1.025**	1.003	1.042	1.072	**1.039**
	6	I_2	1.312	1.387	1.453	**1.384**	1.379	1.461	1.513	**1.451**
	5	I_3	1.244	1.322	1.443	**1.336**	1.300	1.378	1.468	**1.382**
		mean	**1.173**	**1.239**	**1.333**	**1.248**	**1.228**	**1.294**	**1.351**	**1.291**
Improved surface irrigation.	7	I_1	1.323	1.432	1.492	**1.416**	1.372	1.448	1.556	**1.459**
	6	I_2	1.735	1.810	1.911	**1.819**	1.754	1.892	2.010	**1.886**
	5	I_3	1.613	1.715	1.782	**1.703**	1.678	1.771	1.842	**1.764**
		mean	**1.557**	**1.652**	**1.728**	**1.646**	**1.602**	**1.704**	**1.803**	**1.703**
Drip irrigation	31.33	I_1	1.351	1.442	1.562	**1.452**	1.412	1.512	1.612	**1.512**
	25.06	I_2	1.752	1.913	2.023	**1.896**	1.845	1.954	2.039	**1.946**
	18.80	I_3	1.654	1.814	1.931	**1.800**	1.722	1.842	1.972	**1.845**
		mean	**1.586**	**1.723**	**1.839**	**1.716**	**1.660**	**1.769**	**1.874**	**1.768**
LSD at 5 %			**S**	**I**	**M**	**S × I**	**S × M**	**I × M**	**S × I × M**	
1st season			0.0026	0.0018	0.0017	0.0032	0.0031	0.0029	0.0050	
2nd season			0.0013	0.0022	0.0017	0.0032	0.0026	0.0031	0.0051	

Where: *Each value in this table is an average of 3 replicate, M_0, M_1 and M_2 are without, white plastic and black plastic mulching, respectively, I_1, I_2 and I_3 are 100%, 80% and 60% of crop evapotranspiration, respectively.

The mean values of water productivity of maize plants at surface irrigation system were significantly decreased when compared with improved surface and drip irrigation systems under the different used irrigation treatments I_1 (100%), I_2 (80%) and I_3 (60%) of ETc. The obtained results were in agreement with those obtained by **Li et al. (2017)** who found that the Ridge–furrow with plastic film mulching practice increased WUE by 29.2% and 70.5%, compared to the traditional flat planting and well irrigation planting practices, respectively, for the summer–maize season.



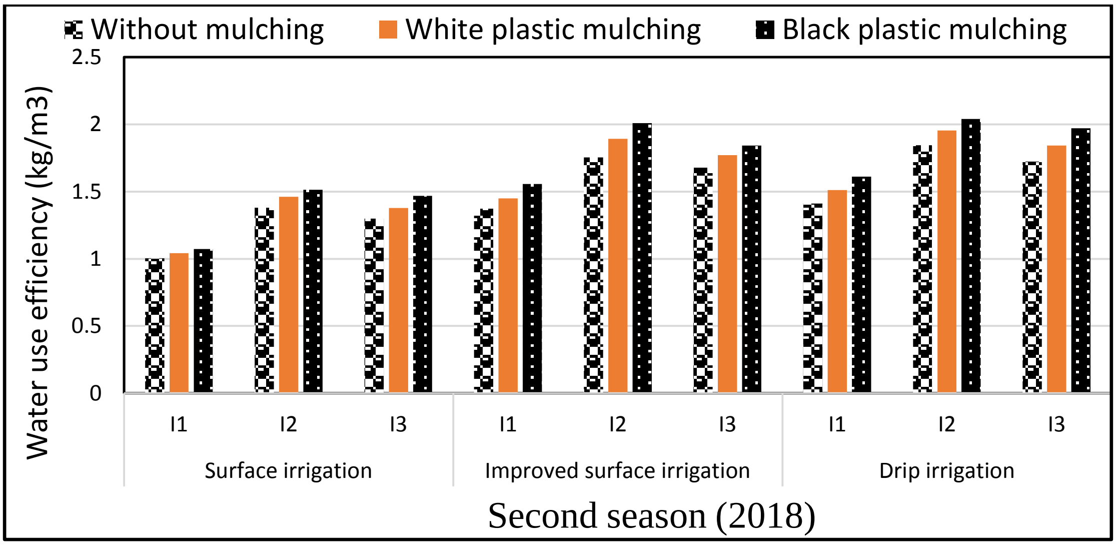


Figure (1). Effect of irrigation treatments and soil plastic mulching on water productivity (kg/m^3) under different irrigation systems in seasons (2017 and 2018).

5. Economic income of the maize crop as affected by different irrigation systems, irrigation treatments and soil plastic mulching.

The obtained data in Table (8) indicated that using improved surface irrigation system resulted in the highest value of maize economic income (9522.82 L.E.) compared with surface (8450.65 L.E.) and drip (8548.46 L.E.) irrigation systems. The economic income of maize crop under improved surface and drip irrigation systems increased by 12.69 and 1.16% compared with surface irrigation system, respectively. On the other hand, under three different irrigation systems, the highest values of maize crop economic income recorded at irrigation treatment I_2 (80% of ETc) compared with irrigation treatments I_1 (100% of ETc) and I_3 (60% of ETc). The highest values of maize crop economic income under irrigation treatment I_2 (80% of ETc) application are 10004.65, 10832.38 and 9734.40 L.E. at surface, improved surface and drip irrigation systems, respectively. The obtained results were in agreement with those obtained by **Zhang et al. (2017)** who showed the optimizing water productivity and economic return of high yield spring maize coincided with drip irrigation and plastic mulching in arid areas of China.

The results in Table (8) showed that, the economic income of maize crop at irrigation treatment I_2 (80% of ETc) were exceeded with 16.84 and 29.76% for surface irrigation system, 4.80 and 31.47% for improved surface irrigation system and 15.06 and 21.49% for drip irrigation system when compared with irrigation treatments I_1 (100% of ETc) and I_3 (60% of ETc), respectively. These results are fallen in the same line of those stated by **Zairi et al. (2003)**.

Data recorded in Table (8) showed that the values of maize crop economic income were increased at soil without mulching treatments under different irrigation systems and irrigation treatments compared with soil white and black plastic mulching treatments. These results may reflect the costs of soil mulching treatments compared with the soil without mulching treatment. It could be concluded that the improved surface irrigation system, irrigation treatment I_2 (80% of ETc) and black plastic mulching produced the high values of growth parameters, grains yield and yield component of maize plants, as well as, it saved @ 20% of the applied irrigation water @ 965 m^3 ha^{-1} in clayey soils under Fayoum conditions.

Table (8). Maize crop economic income as influenced by irrigation treatments and soil plastic mulching under different irrigation systems (average values of the two seasons 2017 and 2018).*

irrigation system	Irrig. treat.	Soil mulch.	No. of irrig.	Price of applied irrig. treat. (L.E.)	Price of soil mulch. (L.E.)	Constant costs (L.E.)	Total costs (L.E.)	Maize yield t fed^{-1})	Maize forage yield (t fed^{-1})	Price of maize yield (L.E.)	Price of forage maize yield (L.E.)	Total price of Maize yield (L.E.)	Profit net (L.E.)	Mean Profit net of irrig. treat. (L.E.)	Mean profit net of irrig. syst. (L.E.)
Surface irrigation	I_1 (100% of ETc)	M_0	7	350	0	2600	2950	2.894	14.616	10419.19	2484.72	12903.91	9953.91		
		M_1	7	350	2500	2600	5450	2.956	14.910	10641.46	2534.70	13176.16	7726.16	8320.35	
		M_2	7	350	2500	2600	5450	3.088	15.372	11117.74	2613.24	13730.98	8280.98		
	I_2 (80% of ETc)	M_0	6	300	0	2600	2900	3.397	14.490	12230.57	2463.30	14693.87	11793.87		
		M_1	6	300	2500	2600	5400	3.452	14.658	12427.13	2491.86	14918.99	9518.99	10004.65	8450.65
		M_2	6	300	2500	2600	5400	3.499	14.742	12594.96	2506.14	15101.1	9701.10		
	I_3 (60% of ETc)	M_0	5	250	0	2600	2850	2.725	9.618	9808.34	1635.06	11443.4	8593.40		
		M_1	5	250	2500	2600	5350	2.774	11.256	9986.76	1913.52	11900.28	6550.28	7026.95	
		M_2	5	250	2500	2600	5350	2.874	11.424	10345.10	1942.08	12287.18	6937.18		
Improved surface irrigation	I_1 (100% of ETc)	M_0	7	700	0	2600	3300	3.555	14.196	12797.57	2413.32	15210.89	11910.89		
		M_1	7	700	2500	2600	5800	3.678	14.532	13242.10	2470.44	15712.54	9912.54	10312.16	
		M_2	7	700	2500	2600	5800	3.724	14.742	13406.90	2506.14	15913.04	10113.04		
	I_2 (80% of ETc)	M_0	6	600	0	2600	3200	3.703	14.280	13329.79	2427.60	15757.39	12557.39		
		M_1	6	600	2500	2600	5700	3.782	14.364	13614.05	2441.88	16055.93	10355.93	10832.38	9522.82
		M_2	6	600	2500	2600	5700	3.843	14.406	13834.80	2449.02	16283.82	10583.82		
	I_3 (60% of ETc)	M_0	5	500	0	2600	3100	2.906	9.576	10463.04	1627.92	12090.96	8990.96		
		M_1	5	500	2500	2600	5600	2.979	11.214	10726.13	1906.38	12632.51	7032.51	7423.92	
		M_2	5	500	2500	2600	5600	3.037	11.256	10934.78	1913.52	12848.3	7248.30		

Table (8). Continue*.

Irrigation system	Irrig. treat.	Soil mulch.	No. of hours work	Price of applied irrig. treat. (L.E.)	Price of soil mulching (L.E.)	Constant costs (L.E.)	Total costs (L.E.)	Maize yield t fed^{-1})	Maize forage yield (t fed^{-1})	Price of maize yield (L.E.)	Price of forage maize yield (L.E.)	Total price of maize yield (L.E.)	Profit net (L.E.)	Mean Profit net of irrig. treat. (L.E.)	Mean profit net of irrig. systems (L.E.)
Drip irrigation	I_1 (100% of ETc)	M_0	31.33	1253.2	0	2600	3300	3.082	13.818	11095.06	2349.06	13444.12	9590.92		
		M_1	31.33	1253.2	2500	2600	5800	3.173	14.406	11421.65	2449.02	13870.67	7517.47	8268.76	
		M_2	31.33	1253.2	2500	2600	5800	3.211	14.658	11559.24	2491.86	14051.1	7697.90		
	I_2 (80% of ETc)	M_0	25.06	1002.4	0	2600	3200	3.424	14.112	12327.34	2399.04	14726.38	11123.98		
		M_1	25.06	1002.4	2500	2600	5700	3.509	14.238	12631.25	2420.46	15051.71	8949.31	9734.40	8548.46
		M_2	25.06	1002.4	2500	2600	5700	3.555	14.322	12797.57	2434.74	15232.31	9129.91		
	I_3 (60% of ETc)	M_0	18.80	752.0	0	2600	3100	2.954	9.156	10635.41	1556.52	12191.93	8839.93		
		M_1	18.80	752.0	2500	2600	5600	3.052	10.836	10986.19	1842.12	12828.31	6976.31	7642.23	
		M_2	18.80	752.0	2500	2600	5600	3.087	10.878	11113.20	1849.26	12962.46	7110.46		

*** One irrigation in surface irrigation system = 50 L.E., one irrigation in improved surface irrigation system = 100 L.E., one hour irrigation in drip irrigation system = 40 L.E. one m^2 of white or black plastic mulch = 1 L.E. (M_0 is without mulch, M_1 is white plastic mulch and M_2 is black plastic mulch), Constant costs = 2600 L.E. (700 L.E. plowing and leveling + 100 L.E. ridges + 250 L.E. planting + 800 L.E. chemical fertilizers + 350 L.E. hoeing + 400 L.E. harvesting), 1 kg of maize yield = 3.6 L.E and 1 ton of forage maize yield = 170 L.E.**

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ترشيد مياه الري للذرة الشامية باستخدام نظم الري الحديثة وتغطية سطح التربة بالبلاستيك في الأراضي الطينية بالفيوم

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استخدام نظم الري الحديثة يساعد على التغلب على نقص مياه الري والتحكم في استهلاكها، ويؤدي أيضا الى التحكم في كمية مياه الري والوقت المناسب لإجراء عملية الري وزيادة في إنتاجية المحاصيل. تهدف هذه الدراسة الى تقييم نظم الري السطحي والري السطحي المطور والري بالتنقيط وتغطية سطح التربة بالبلاستيك لترشيد مياه الري لنباتات الذرة الشامية النامية في التربة الطينية بالفيوم.

أقيمت تجربة حقلية بمركز سنورس بمحافظة الفيوم ، شملت هذه التجربة ثلاثة نظم ري مختلفة (الري السطحي – الري السطحي المطور – الري بالتنقيط)، وتحت كل نظام ري تم تطبيق ثلاثة معاملات للري المتناقص وهي الري عند ١٠٠٪ ، ٨٠٪ ، ٦٠٪ من البخرنتح للمحصول ET_c، وتم تقسيم كل معاملة ري متناقص الى ثلاثة معاملات لتغطية سطح التربة وهي (بدون تغطية - التغطية بالبلاستيك الأبيض - التغطية بالبلاستيك الأسود)، تم توزيع جميع المعاملات في نظام القطاعات الكاملة العشوائية تحت نظام احصائي القطع المنشقة مرتان مع وجود ثلاثة مكررات. وتم زراعة نباتات الذرة الشامية خلال صيف موسمين متتاليين لعامي ٢٠١٧ ، ٢٠١٨، أستخدم وعاء البخر القياسي لتقدير قيم البخرنتح القياسي اليومي ET_o وحساب قيم البخرنتح للمحصول ET_c بمعلومية قيم معامل المحصول K_c للتعرف على الفترة بين الريات تحت ظروف معاملات الري المختلفة.

توضح النتائج أن أعلى قيم لكل من طول النبات وعدد الكيزان في النبات الواحد ووزن الكوز وعدد الصفوف في الكوز ووزن ال ١٠٠ حبة ومحصول الحبوب لنباتات الذرة الشامية توافقت مع نظام الري السطحي المطور ومعاملة الري ٨٠٪ من ET_c ومعاملة تغطية سطح التربة بالبلاستيك الأسود، وعلى الجانب الآخر وجد أن أعلى قيم لمحصول العلف (المجموع الخضري) لنباتات الذرة الشامية كان موجودا تحت نظام الري السطحي ومعاملة الري ١٠٠٪ من ET_c ومعاملة تغطية سطح التربة بالبلاستيك الأسود.

وأظهرت نتائج التحليل الاحصائي أن متوسط قيم الاستهلاك المائي لنباتات الذرة الشامية حدث بها نقص معنوي بمقدار ٣١.٢٦ و١٢.١٠٪ (متوسط لقيم الموسمين) بينما حدثت زيادة معنوية بمقدار ٢٧.١٣ و ٣.٨٨٪ (متوسط لقيم الموسمين) في قيم كفاءة استخدام المياه لنباتات الذرة الشامية تحت نظام الري بالتنقيط مقارنة بنظامي الري السطحي والري السطحي المطور على الترتيب. ويمكن التوصية باستخدام معاملة الري عند ٨٠٪ من قيم ال ET_c ومعاملة تغطية سطح التربة بالبلاستيك الأسود تحت نظام الري السطحي المطور لانهم يؤدوا الى توفير حوالي ٢٠٪ من مياه الري المضافة (حوالي ٩٦٥ م^{٣} للهكتار) مع الحصول على أعلى قيم للمحصول من نباتات الذرة الشامية المنزرعة في الأراضي الطينية تحت ظروف محافظة الفيوم.

الكلمات الدالة: ترشيد مياه الري، الري السطحي المطور، الري بالتنقيط، الري المتناقص، تغطية سطح التربة، الذرة الشامية، انتاجية المياه.