1

Egypt. J. Soil. Sci. Vol. **61**, No. 1, pp. 1-11 (2021)

Egyptian Journal of Soil Science

http://ejss.journals.ekb.eg/

Productivity and Water Use Efficiency of Summer Squash Crop under Two Methods of Irrigation Water Application

Mohamed H. Sheta[1] and Mostafa H. Fayed[2*]

[1]*Soils and Water Department, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt.*

[2]*Water and Irrigation Systems Engineering Department, Faculty of Agricultural Engineering, Al-Azhar University, Nasr City, Cairo, Egypt.*

EGYPT is currently seeking to implement a plan to rationalize water consumption in all sectors. As the agricultural sector consumes about 85% of Egypt's water resources, therefore new irrigation application methods must be searched to rationalize water use by increasing the irrigation efficiency. Field experiment was conducted to compare two water application methods to calculate the requirements of water for squash (*Cucurbita pepo*, L. var. Hybrid Revera) during the summer season of 2019. Two methods of irrigation water application were used and adapted to conditions of drip irrigation system: (i) method A: using estimation of the reference evapotranspiration using the method of weather factors-dependent Penman-Monteith. (ii) method B is the water depletion from the soil, which depends on the water properties of soil. Crop water needs, yield, water use efficiency and the irrigation water amount lost by deep percolation were determined. The results showed that the irrigation method dependent on the soil water properties has positive effects on the squash production compared to method A. Moreover, the highest value of water use efficiency was obtained by method B, which was 5.31 kg m^{-3}, while its value for method A was 4.33 kg m^{-3}. Also, the highest yield was obtained by method B, which was 15970.10 kg ha^{-1}, while the productivity under method A was 15492.69 kg ha^{-1}. In addition, the highest values of lost water through deep percolation (14.82 %) were detected with method A. Generally, method of irrigation soil-based was more accurate in calculating the amount of irrigation water added and had clearly positive effects on growth, yield and water use efficiency of squash compared to a climate-dependent irrigation method.

Keywords: Reference evapotranspiration, Soil water properties, Water depletion-Squash crop

Introduction

Water is one of the most precious natural resources in the world, especially in arid and semi-arid regions and in parts of the world that have inadequate water resources. Innovative irrigation solutions must address the water scarcity problems affecting arid and semi-arid regions. Therefore, irrigation water management is becoming the primary limiting factor for production of a crop (Rafie and El-Boraie, 2017). Because of the water limitation facing Egypt, rationalization of irrigation water became a unique and necessary way to save used water of Egypt. Therefore, researchers must work for the effective rationalization of irrigation at the farm level (El-Henawy and Soltan, 2013).

The process of irrigation scheduling requires answering two questions. The first one is when to irrigate? The second is how much water is needed for irrigation? (James, 1993). scheduling methods of irrigation are categorized as climate, soil, water, plant, or combinations (Martin et al., 1990). Irrigation scheduling has been described as the primary tool to enhance water use efficiency (WUE), increase the water resources availability,

*Corresponding author: E-mail: mostafa.fayed@azhar.edu.eg

DOI: 10.21608/ejss.2020.48343.1404

Received : 31/10/2020 ; Accepted: 1/12/2020

provoke a positive effect on the quality of soil, and increases yields of the crop (El-Nady & Shalaby, 2014 and Peacock, 1996). Scheduling the needed irrigation water for all crops will help in minimizing the loss of water during the growing season and is a clef to beat this problem through the enhancement of water use efficiency. Agriculture has been known to require a large quantity amount of irrigation water, and this quantity will increase in the future as a result of the large increase of population (Ali, 2017 and Ebrahim & Ali, 2018)

In Egypt, the estimation of actual water consumption (ETa) has an effective role in planning and management of water resources. The crop water requirements change via the growth season of crop due to the diversity of crops sunshade, as well as the climatic changes that controls the water consumption of the crop (Benli et al., 2006 and Salama et al., 2015).

Any chosen irrigation water application methods should aim at maximizing the yield of a crop. Consequently, enhancing irrigation water productivity for crops in the agriculture sector, as the major water user, is the critical factor in resolving problems of water shortage (El-Nady and Hadad, 2016). Weather-dependent methods are used in irrigation to estimate crop water requirements during the crop growth season on a large scale (White and Raine, 2008). The reference evapotranspiration and crop coefficient in these methods are used to calculate the crop consumptive use. Irrigation methods that depend on the soil water properties always measure the soil water potential or soil moisture content. Therefore, measuring the soil moisture content has an essential and effective role in calculating the amount of water required to reach the soil to the field capacity in the root zone (Phene et al., 1990). The amount of irrigation water needed to be stored in the root zone, called the net depth of irrigation water, is exactly the amount of irrigation water needed to reach the soil moisture content to field capacity and can be calculated by measuring the water content of soil, directly or indirectly (Salama et al., 2015).

Summer squash is considered one of the most marketable vegetable crops and one of the major vegetables in many countries of the Mediterranean region (Mohammad, 2004). The roots depth of squash is shallow and sensitive to soil moisture content. Too much or shortage of soil water content may damage roots and fruits; thus, good drainage of soils is appropriate for squash. Summer squash grown in northern Egypt is affected significantly by water stress (Amer, 2011 and El-Dewiny, 2011).

The main objective of the present study was to compare two methods of irrigation water application for the yield of squash grown in loamy sandy soil under drip irrigation system to determine the most accurate calculation of the amount of water application for squash. The first method was to calculate the evapotranspiration depending on climatic parameters, and the second method depended on the soil water properties. Also, study the effect of both two methods on yield and water use efficiency.

Materials and Methods

Soil description

The experiment was conducted in the experimental field, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt (30º 03' 17.7" N and 31º 19' 14.1" E). The experiment was designed in a completely randomized in three replicates and was adapted to conditions of the trickle irrigation system. Soil samples were collected before planting from a depth of 0 - 60 cm to perform the necessary analyses to know the physical and chemical properties of the soil. These analyzes were performed according to methods of Klute & Page (1986) and Page et al. (1982).The soil physicochemical properties are presented in Table 1.

Irrigation treatments

Treatments of the experiment were two methods to compute the amount of water required as below:

(i) The first method (A) using the rate of crop evapotranspiration (ET_c) whose calculation depends on reference evapotranspiration (ET_o) and crop coefficient (K_c) which varies according to the different stages of crop growth. The (ET_c) is estimated by Eq. (1); (Savva & Frenken, 2002) as follows:

$$ET_c = ET_o \times K_c \quad \ldots\ldots\ldots (1)$$

where:

ET_c = crop evapotranspiration in mm day^{-1},

ET_o = reference crop evapotranspiration in mm day^{-1}, and

K_c = crop coefficient.

The term ET_o was computed using the Penman-Monteith equation (Savva & Frenken, 2002) as follows in Eq. (2):

$$ET_o = \frac{0.408\,\Delta\,(R_n - G) + \gamma\,\frac{900}{T + 273}\,u_2(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,u_2)} \quad \ldots (2)$$

TABLE 1. Physicochemical properties of experimental initial soil

(a) Physical properties of soil under study

Soil sample depth (cm)	Particle size distribution (%)				Texture Class	OM[a] (g kg^{-1})	Bulk density (Mg m^{-3})	Total porosity (%)	Moisture content (%) at:		
	Coarse sand	Fine sand	Silt	Clay					FC[b]	PWP[c]	AW[d]
0-20	10.12	73.80	7.91	8.17	LS[e]	5.4	1.67	36.98	13.45	4.27	9.18
20-40	10.23	74.08	7.76	7.93	LS	5.3	1.68	36.60	13.48	4.51	8.97
40-60	10.56	74.74	6.89	7.81	LS	5.2	1.69	36.23	12.87	4.85	8.02

(b) Chemicalproperties of soil under study

Soil sample depth (cm)	pH (1:2.5)[f]	EC (dSm^{-1})[g]	Cations (mmolc l^{-1})				Anions (mmolc l^{-1})			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
0-20	8.01	1.69	4.29	2.16	9.74	0.68	0.00	2.47	6.00	8.40
20-40	8.03	1.78	4.47	2.62	10.19	0.47	0.00	2.40	6.61	8.74
40-60	8.10	1.81	3.92	2.39	11.21	0.53	0.00	2.48	7.28	8.29

[a]OM:Organic matter content, [b] FC: Field capacity; [c] PWP: Permanent wilting point, [d] AW: Available water, [e]LS: Loamy Sand, [f]1:2.5 w/v soil water suspension and [g]Soil paste extract.

where:

Δ = slope of saturation vapor pressure curve at temperature T in kPa°C^{-1},

R_n = net radiation of the crop surface in MJm^{-2} day^{-1},

G = density of soil heat flux in MJm^{-2} day^{-1},

γ = constant of psychrometric in kPa°C^{-1},

T =mean daily air temperature at 2 m height in °C,

u_2 = wind speed at 2 m height in ms^{-1},

e_s = saturation vapor pressure in kPa,

e_a = actual vapor pressure in kPa, and

e_s- e_a = deficit of saturation vapor pressure in kPa.

To calculate ET_o by Penman-Monteith equation, the weather parameters at the experimental location were recorded during the growing season by meteorological weather station as shown in Table 2. These data were obtained from the Center Laboratory for Agricultural Climate (CLAC) which belongs to the Agriculture Research Center, Ministry of Agriculture during the various growth periods of summer squash plants.The cumulative ET_o for April, May, June, and July was 3.92, 4.25, 6.11 and 7.32 mm, respectively.

TABLE 2. The mean climatic data at the experimental location during the season of 2019

Months	Average temperature		Relative humidity RH (%)	Wind speed u_2 (km h^{-1})	Rainfall P (mm)	Sunshine n (h)	Reference evapotranspiration ET_o (mm day^{-1})
	T_{max} (°C)	T_{min} (°C)					
April	27.3	13.9	42.2	12.3	0.0	10.64	3.92
May	32.6	20.1	44.3	11.4	0.0	11.76	4.25
June	33.4	22.5	48.1	11.9	0.0	11.84	6.11
July	35.8	24.1	49.9	9.6	0.0	12.24	7.32

(ii) The second method (B) includes measuring the quantity of irrigation water drained (water depletion) from the field capacity of soil in roots zone. The water content of soil before the next irrigation in the root zone should be measured to estimate the amount of irrigation water needed. The amount of irrigation water applied was calculated by Eq. (3) as follows:

$$IWQ =(\theta_{FC}-\theta_{BI})\times D_{rz}\times A\times E_i \quad \dots (3)$$

where:

IWQ = the irrigation water quantity in m^3,

θ_{FC} = the volumetric moisture content of soil at field capacity in %,

θ_{BI} = the volumetric moisture content of soil immediately before the next irrigation in %,

D_{rz} = the effective depth of roots in m,

A = area of the experimental plot in m^2, and

Ei = the irrigation efficiency in %. It was equal to 93% in this study according to Keller & Karmeli (1974) and (1975).

The depth of irrigation water application varied according to the growth stage of squash crop and this depth was also estimated at each stage. The actual evapotranspiration in the site of experiment was estimated in the root zone by calculation the soil moisture depletion. According to Young and Sisson (2002) tensiometer was used for measuring soil water content every 20 cm from 20 cm soil surface up to depth of 60 cm. Also, the soil moisture content in the soil surface layer from 0 to 20 cm was estimated using the gravimetric sampling method (direct method of measuring the moisture content of soil samples taken from a field) according to Waller and Yitayew (2015). All measures of soil moisture content were determined before the next irrigation directly and after one hour of irrigation. The amount of irrigation water lost by deep percolation was estimated as a difference between the actual evapotranspiration and (applied water-leaching requirements).

Squash crop and trickle irrigation network

Squash (*Cucurbita pepo*, L. var. Hybrid Revera) plants were grown in an experimental field from 16th April to 14th July 2019. The mineral fertilizer was added to the soil of experimental area according to the instruction and recommendations of Ministry of Agricultureand Land Reclamation. Where, phosphorus fertilizer as calcium superphosphate (15.5% P_2O_5) and ammonium nitrate (33.5% N) were added at a rate of 60 and 150 kg ha^{-1} respectively, and potassium sulfate (48% K_2O) was added at a rate of 70 kg K_2O ha^{-1}.

The general lengths of the four distinct growth stages for squash crop in Mediterranean and arid region are presented in Table 3 (Allen et al., 1998). The representative values of squash crop coefficient are shown in Table 3 (Allen et al., 1998).

The experimental plot area was plowed, disked, and leveled. It was 10.5 m^2 (length of 3.5 m and 3 m of width). The trickle irrigation network was designed and installated in the experimental field. The distance between lateral lines was 1 m (one lateral for planting row). The distance between emitters on the lateral line was 0.5 m and equal to distance between plants in the row. Discharge rate of the dripper was 4 Lh^{-1}. The irrigation intervals were three days.

Water use efficiency (WUE) and irrigation water use efficiency (IWUE)

Eq. (5) was used to calculate the WUE, and the IWUE was computed according to Payero et al. (2008) using Eq. (6) as follows:

$$WUE=Y/ET_c \quad \dots (5)$$

$$IWUE=Y/IA \quad \dots (6)$$

where:

WUE =water use efficiency in kg m^{-3},

Y = marketable yield in kg ha^{-1},

ET_c = seasonal crop evapotranspiration in m^3 ha^{-1},

IWUE = irrigation water use efficiency in kg m^{-3}, and

IA = seasonal applied irrigation water in m^3 ha^{-1}.

Statistical analysis

The statistical analysis concerned mainly as a comparison between data of the control and that of the corresponding population using Student's t-Tests (Pearson, 1939). An analysis of variance was performed to determine the effect of method A, method and orthogonal contrast comparisons were carried out using the statistical methods by Cochran and Cox (1957).

TABLE 3. Lengths of development stages of squash and single crop coefficients

Growth stages	Initial	Development	Mid-season	Late season	Total days
Lengths of crop development stages in (days)	20	30	25	15	90
Single crop coefficients (K_c)	$K_{c\ ini}$ 0.5	$K_{c\ mid}$ 0.95		$K_{c\ end}$ 0.75	

Results and Discussion

Estimation of reference evapotranspiration (ETo) and crop evapotranspiration (ETc)

Table 4 shows the reference evapotranspiration (ET_o) and the crop evapotranspiration (ET_c)in the different growth stages of squash under two treatments of irrigation water application. The irrigation water amount used during the initial stage of squash was 40.03 mm, as plants grown until the ground shading area reached to10%. While the crop evapotranspiration reached the maximum in the development stage, it was 98.50 mm where the ground cover reached to 70%. During the mid-stage where full cover area, the maximum water uses was 145.11 mm. While in the late stage, the amount of water applied was 81.44 mm.Such results were confirmed by the findings of Doorenbos and Pruitt (1977), reported that the water consumption increases with the progress in plant growth and reaches a peak through some part of the plant growth stage, depending on the plant kind, growth characteristics of plant and the ambient environmental conditions, and afterward tapers off till harvest stage.

Estimation of irrigation water applied

Figure 1 illustrates the irrigation water applied using the two methods of A and B. The applied amount of seasonal irrigation water for squash plants using the two methods A and B was 405.24 and 317.67 mm season^{-1}, respectively as in Fig. 1. From the values of seasonal added irrigation water, B method was found to be 21.61% more efficient than A method in water-saving.

In sandy soil, irrigated crops require great attention to irrigation timing because delaying the irrigation until the plant stress becomes clear leads to the economic loss of productivity. It also requires a careful amount of irrigation water applied, because applying much amount of irrigation water reduces the efficiency of water use and increases the possibility of salts sedimentation below the root zone and into the groundwater, as well as increased the costs of pumping (Alhammadi & Al-Shrouf, 2013 and Sánchez et al., 2012).

The seasonal irrigation water applied of squash plants under two methods of irrigation water application by drip irrigation system were 345.18 and 290.09 mm season^{-1} for A and B, respectively.

These values represent relatively 14.82 and 8.68% of the amount of water added for treatments A and B, respectively. Whereas the water application efficiency decreases with deep percolation. Therefore, it is necessary to choose the appropriate irrigation method to improve the water use efficiency. So, method Bwas the best for savings irrigation water from lost via deep percolation. Miyazaki (2005) found that water is retained in the rooting zone by interaction between soil particles and irrigation water. Thus, this interaction reduces the potential energy of water in soil.

These results could be supported by those obtained by Scott (2000), it has been found that the relation between the force of attraction of water by soil particles surfaces and moisture content in the soil is an inverse relationship which means that the first layers of water is held with great forces of attraction, the magnitude of the forces of attraction for water reduce as the distance from the partial surface increase. So, the adding a greater irrigation water amount for method A gives the opportunity to irrigation water to evaporate from the soil particles surface compared to the method B.

TABLE 4. Estimating the ET_o and ET_c for different growth stages of the summer squash crop

Evapotranspiration	Growth stages of squash				Total
	Initial	Development	Mid-season	Late season	
ET_o (mm)	80.05	134.94	152.75	108.59	476.33
ET_c (mm)	40.03	98.50	145.11	81.44	365.08

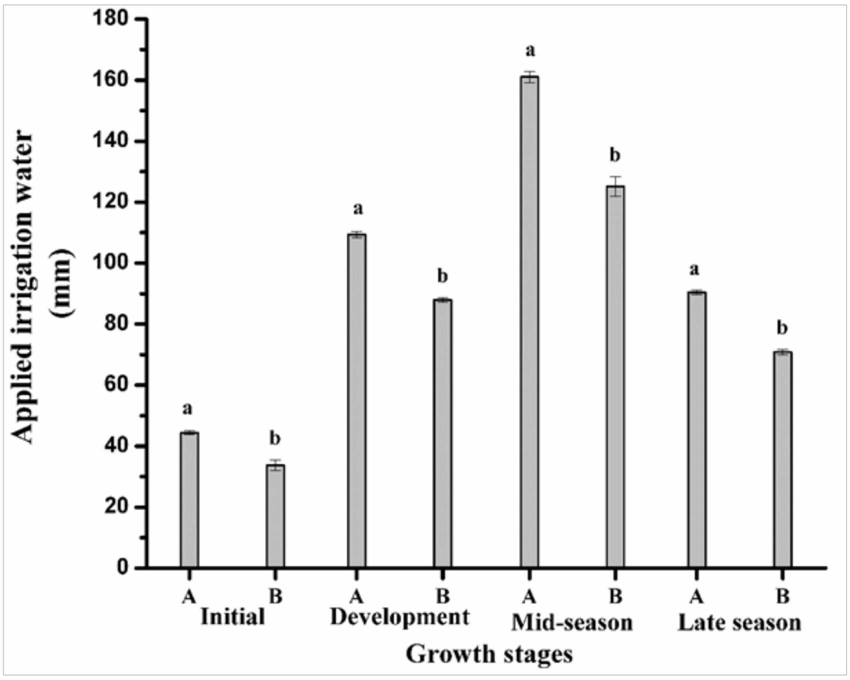

Fig. 1. The amount of irrigation water applied (mm stage^{-1}) in the different growth stages of summer squash crop when using two methods (A and B) of irrigation water application. Data are mean value ± SD. Bars with same letters in each growth stage are not significant at p ≤ 0.05 level.

Previous results agreed with Savva and Frenken (2002); Ali (2010); Todorović (2019). They mentioned that evapotranspiration increases with the development of growing crop and arrives the maximum over a portion of the plant age mainly due to several factors such as surrounding climatic conditions, crop type, soil type, and variations in crop cover, and then gradually decreases in the end of late season stage (harvest time).

Marketable yields (Y)

The marketable yield of squash crop obtained as affected by two application methods of irrigation water was shown in Fig. 2. It was 15492.69 and 15970.10 kg ha^{-1} for A and B, respectively. Thus, the squash fruit yield obtained from treatment B was higher than that obtained from treatment A. This means that, to obtain high productivity; it is not necessary to add a much quantity of irrigation water. It is worth noting that, the decrease in productivity of the treatment A may be due to a loss in the added fertilizers to plants during growth period by leaching (Salama et al., 2015). Dong et al. (2007) and Gao et al. (2015) reported that excessive irrigation might not produce greater yield or optimal economic benefit. therefore, suitable irrigation schedules must be established.

These results agreed with Cabello et al. (2009) and Salama et al. (2015), who decided that applying water of irrigation more than wanted by consumptive use of crop (ET_c) would cause a lower yield due to waterlogging or nutrients leaking below the root zone.

Water use efficiency (WUE) and Irrigation water use efficiency (IWUE)

WUE is one of the factors necessary to define the best practices for irrigation water management. Fig. 3 and 4 illustrates the obtained results for WUE and IWUE. Water use efficiency was 4.33 and 5.31 kg m^{-3} for A and B, respectively. The irrigation water use efficiency was 3.69 and 4.85 kg m^{-3} for A and B, respectively as shown in Fig. 4. It was obvious that, the lower values of WUE and IWUE were found with treatment A and the higher values were in treatment A. These results mean that applying too much of irrigation water amount led to a decrease in yield, water use efficiency, and irrigation water use efficiency. So, suitable scheduling of the irrigation must be established. The same results were found by Salama et al. (2015).

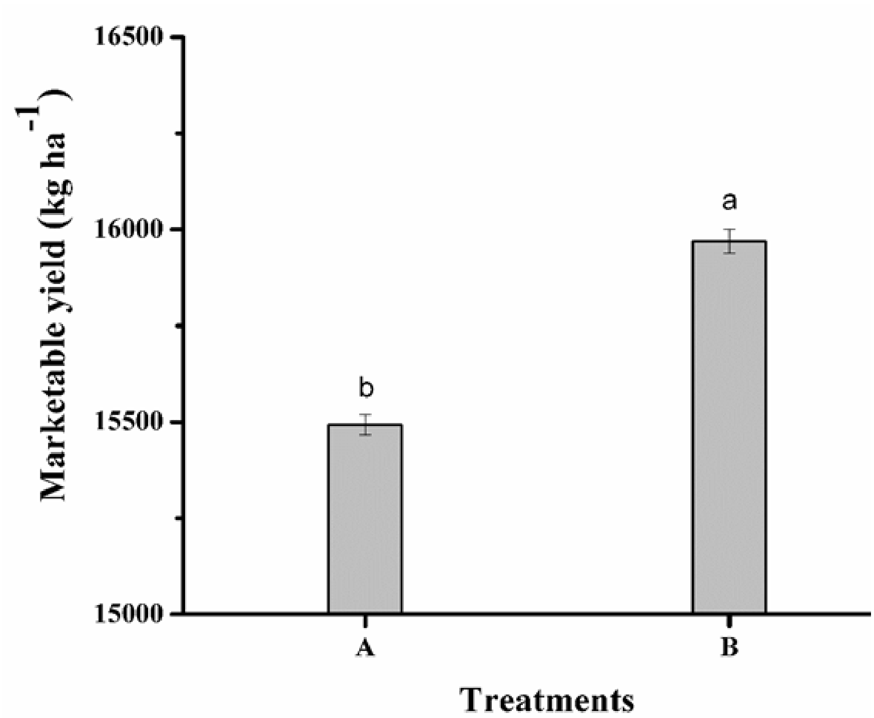

Fig. 2. Marketable yield (kg ha^{-1}) for treatments A and B. Data are mean value ± SD. Bars with same letters are not significant at $p \leq 0.05$ level

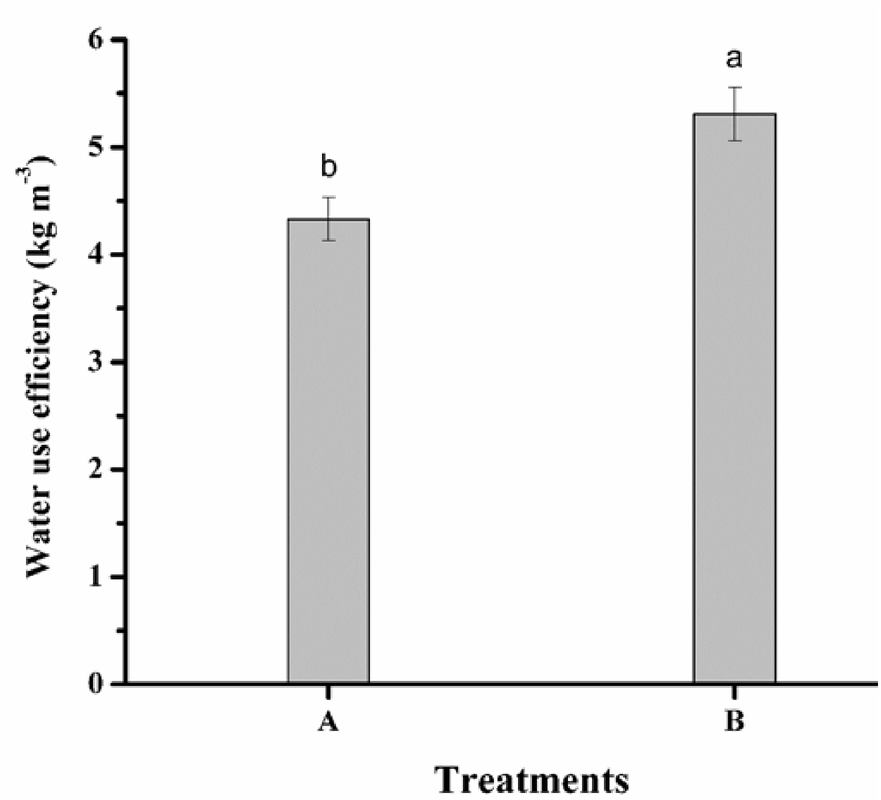

Fig. 3. Water use efficiency (kg m^{-3}) for treatments A and B. Data are mean value ± SD. Bars with same letters are not significant at $p \leq 0.05$ level

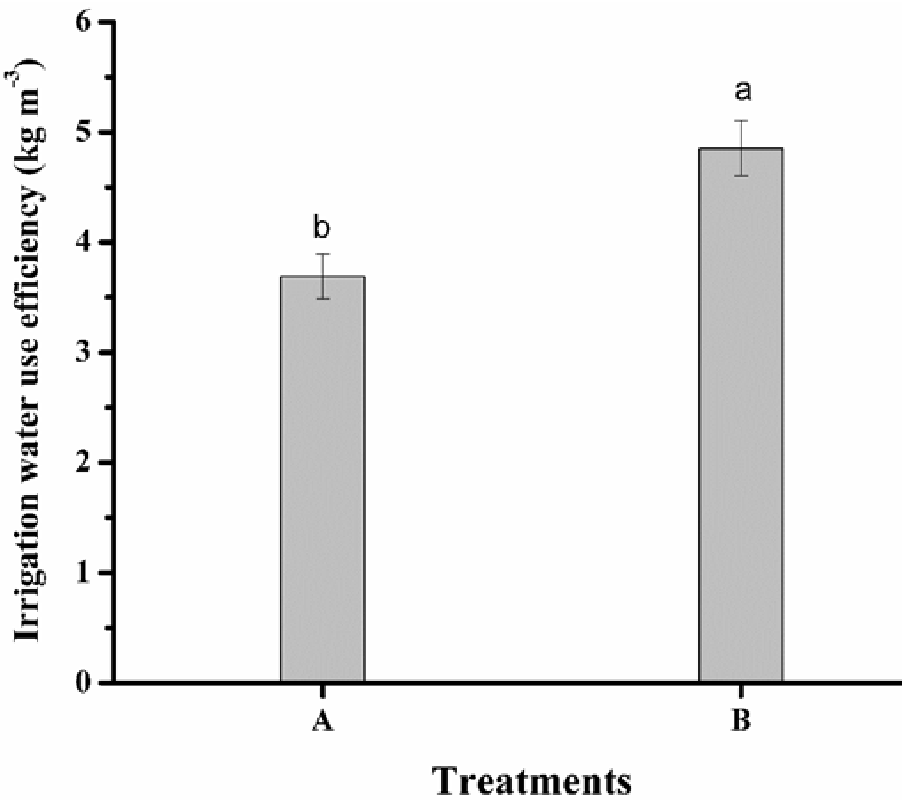

Fig. 4. Irrigation water use efficiency (kg m^{-3}) for treatments A and B. Data are mean value ± SD. Bars with same letters are not significant at $p \leq 0.05$ level

Conclusion

Generally, good irrigation application method requires consideration of all conditions that affect irrigation times throughout the growing season. Taking the right and appropriate timing for irrigation leads to obtaining the highest yield, thus the highest profit and rationalizes the using of irrigation water. Therefore, irrigationwater application method is one of the main factors of good water management methods to prevent excessive addition of irrigation water, subsequently wastage of water. In this work, an experiment was carried to compare between two irrigation application methods with drip irrigation system in loamy sand soil. The first one depends on climatic data (Penman-Monteith method) and the second depends on depletion from the field capacity of soil (soil-based method). It can be concluded that the irrigation method B which depends on the soil water properties, had a clear positive effect on growth throughout the season and marketable yield and WUE of summer squash (*Cucurbita pepo*, L. *var.* Hybrid Revera). Furthermore, it could be used and is more efficient in irrigation water-saving (21.61%) compared to method A. The highest value of lost irrigation water by deep percolation was 60.06 mm with the water application method A and this caused a decrease in WUE. Therefore, it is necessary to choose the adequate method of water application to ameliorate irrigation efficiency.Therefore, it is recommended to irrigate zucchini squash by method B because this method is more accurate in calculating the amount of irrigation water added. Also, it not only gives high production and high-water use efficiency, but also reduces the deep percolation of irrigation water and thus saves the irrigation water amount compared to method A.

Declaration of Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors would like to thank all staff members at Soils and Water Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt, to support and access laboratory facilities. Also, the authors gratefully acknowledge Prof. Dr. Alaa El-Din A. Elmesery for his scientific support.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not for profit sectors.

References

Alhammadi, M. S., & Al-Shrouf, A. M. (2013) Irrigation of sandy soils, basics and scheduling. In Crop Production. Intech Open.

Ali, A. A. (2017) Effect of deficit irrigation during growth stages on water use efficiency of carrot under El-Ismailia conditions. *Egyptian Journal of Soil Science*, **57** (4), 393-406. https://doi.org/10.21608/ejss.2017.612.1076

Ali, M. H. (2010) Fundamentals of irrigation and On-farm water management: Volume 1. In *Fundamentals of Irrigation and On-farm Water Management*: Volume 1. Springer New York. https://doi.org/10.1007/978-1-4419-6335-2

Allen, R. G., Pereira, L. S., Raes, D., Smith, M., & others. (1998) Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. Fao, Rome, 300 (9), D05109.

Amer, K. H. (2011) Effect of irrigation method and quantity on squash yield and quality. *Agricultural Water Management,* **98** (8), 1197-1206. https://doi.org/10.1016/j.agwat. 2011.03.003

Benli, B., Kodal, S., Ilbeyi, A., & Ustun, H. (2006) Determination of evapotranspiration and basal crop coefficient of alfalfa with a weighing lysimeter. *Agricultural Water Management,* **81** (3), 358–370. https://doi.org/10.1016/j.agwat.2005.05.003

Cabello, M. J., Castellanos, M. T., Romojaro, F., Martínez-Madrid, C., & Ribas, F. (2009) Yield and quality of melon grown under different irrigation and nitrogen rates. *Agricultural Water Management,* **96** (5), 866-874. https://doi.org/10.1016/j.agwat.2008.11.006

Cochran, W. G., & Cox, G. M. (1957) Statistical analysis when residual effects are present. *Experimental Designs*. 2nd ed. John Wiley & Sons, Inc., New York, NY, 135.

Dong, B. D., Zhang, Z. B., Liu, M. Y., Zhang, Y. Z., Li, Q., Shi, L., & Zhou, Y. T. (2007) Water use characteristics of different wheat varieties and their responses to different irrigation schedulings. *Transactions of the CSAE*, **23** (9), 27-33.

Doorenbos, J., Pruitt, W.O. (1977) Crop water requirements. FAO Irrigation and drainage paper No. 24. FAO, Rome 34-37.

Ebrahim, A. S., & Ali, A. A. (2018) Yield response of squash (Cucurbita pepo L.) to water deficit under East Owainat conditions. *Egyptian Journal of Soil Science*, **58** (2), 161-175.

El-Dewiny, C. (2011) Water and fertilizer use efficiency by squash grown under stress on sandy soil treated with acrylamide hydrogels. *Journal of Applied Sciences Research*, **7** (12), 1828-1833.

El-Henawy, A. S., & Soltan, E. M. K. E. (2013)Irrigation water management for sunflower production at North Nile Delta Soils. *Egypt J Soil Sci,* **53** (1), 1-8.

El-Nady, M. A., & Hadad, W. M. (2016) Water Use Efficiency of Soybean under Different Tillage and Irrigation Methods. *Egyptian Journal of Soil Science*, **56** (2), 295–312. https://doi.org/10.21608/ejss.2016.2371.

El-Nady, M. A., & Shalaby, A. A. (2014) Impact of Irrigation Intervals and Fertilization on Actual Evapotranspiration and Wheat Production. *Egyptian Journal of Soil Science*, **54** (4), 305–318. https://doi.org/10.21608/ejss.2014.180.

Gao, Y., Shen, X., Li, X., Meng, Z., Sun, J., & Duan, A. (2015) Effects of pre-Sowing Irrigation on Crop Water Consumption, Grain Yield and Water Productivity of Winter Wheat in the North China Plain. *Irrigation and Drainage*, **64** (4), 566-574. https://doi.org/10.1002/ird.1927.

James, L. (1993) *Principles of Farm Irrigation System Design.* John Wiley and Sons Limited. http://css.wsu.edu/people/faculty/james-e-durfey/.

Keller, J., & Karmeli, D. (1974) Trickle Irrigation Design Parameters. *Transactions of the American Society of Agricultural Engineers*, **17** (4), 678-684. https://doi.org/10.13031/2013.36936.

Keller, J., & Karmeli, D. (1975) Tickle Irrigation Design Parameters. Rain Bird Sprinkler Manufacturing Corporation. Glendora, California, USA, 133.

Klute, A., & Page, A. L. (1986) Methods of soil analysis. Part 1. Physical and mineralogical methods; Part 2. Chemical and microbiological properties. In American Society of Agronomy, Inc. (Issue BOOK). American Society of Agronomy, Inc.

Martin, D. L., Stegman, E. C., & Fereres, E. (1990) Irrigation scheduling principles. *Management of Farm Irrigation Systems*, 153-203.

Miyazaki, T. (2005) Water Flow In Soils. In *Water Flow In Soils*. CRC Press. https://doi.org/10.1201/9781420030136.

Mohammad, M. J. (2004) Squash yield, nutrient content and soil fertility parameters in response to methods of fertilizer application and rates of nitrogen fertigation. *Nutrient Cycling in Agroecosystems,* **68** (2), 99-108. https://doi.org/10.1023/B:FRES.0000019036.64212.9c.

Page, A. L., Miller, R. H., & Keeney, D. R. (1982) Methods of soil analysis. Part 2. Chemical and Microbiological Properties. 2nd. ed. Am. Soc. Agron. Inc. Soil Sci. Soc. Am. Inc. Madison, Wisconsin, USA.

Payero, J. O., Tarkalson, D. D., Irmak, S., Davison, D., & Petersen, J. L. (2008) Effect of irrigation amounts applied with subsurface drip irrigation on corn evapotranspiration, yield, water use efficiency, and dry matter production in a semiarid climate. *Agricultural Water Management*, **95** (8), 895-908.

Peacock, T. (1996) Guidelines for planning irrigation and drainage investment projects (Vol. 11). Food & Agriculture Organization of the UN (FAO).

Pearson, E. S. (1939) "Student" as Statistician.Biometrika, 30(3/4), 210-250. https://doi.org/10.2307/2332648.

Phene, C. J., Itier, B., & Reginato, R. J. (1990) *Sensing irrigation needs*. ASAE Publication, 4-90, 429-443.

Rafie, R. M., & El-Boraie, F. M. (2017) Effect of Drip Irrigation System on Moisture and Salt Distribution Patterns under North Sinai Conditions. *Egyptian Journal of Soil Science*, **57** (3), 247–260. https://doi.org/10.21608/ejss.2017.4158.

Salama, M. A., Yousef, K. M., & Mostafa, A. Z. (2015) Simple equation for estimating actual evapotranspiration using heat units for wheat inarid regions. *Journal of Radiation Research and Applied Sciences*, **8** (3), 418–427. https://doi.org/10.1016/j.jrras.2015.03.002.

Sánchez, N., Martínez-Fernández, J., González-Piqueras, J., González-Dugo, M. P., Baroncini-Turrichia, G., Torres, E., Calera, A., & Pérez-Gutiérrez, C. (2012) Water balance at plot scale for soil moisture estimation using vegetation parameters. *Agricultural and Forest Meteorology*, 166-167, 1-9. https://doi.org/10.1016/j.agrformet.2012.07.005.

Savva, A.P., & Frenken, K. (2002) Crop water requirements and irrigation scheduling (p. 132). Harare: FAO Sub-Regional Office for East and Southern Africa.

Scott, H. Don. (2000) *Soil physics: agricultural and environmental applications*. Ames: Iowa State University Press.

Todorović, M. (2019) Crop Water Requirements and Irrigation Scheduling. In: *Encyclopedia of Water*. FAO Sub-Regional Office for East and Southern Africa Harare. https://doi.org/10.1002/9781119300762.wsts0204.

Waller, P., & Yitayew, M. (2015) Irrigation and drainage engineering. In: *Irrigation and Drainage Engineering*. Springer. https://doi.org/10.1007/978-3-319-05699-9.

White, S. C., & Raine, S. R. (2008) A grower guide to plant based sensing for irrigation scheduling. *Agriculture*, **57**. http://eprints.usq.edu.au/23521.

Young, M. H., & Sisson, J. B. (2002) 3.2. 2 Tensiometry. Methods of Soil Analysis: Part 4 Physical Methods, **5**, 575-608.

الإنتاجية وكفاءة إستخدام المياه لمحصول الكوسة الصيفى تحت طريقتين لإضافة مياه الرى

محمد حامد شتا[1] و مصطفى حسن فايد[2]
[1] قسم الأراضى والمياه- كلية الزراعة -جامعة الأزهر- مدينة نصر- القاهرة- مصر.
[2] قسم هندسة نظم المياه والرى- كلية الهندسة الزراعية- جامعة الأزهر- مدينة نصر- القاهرة- مصر.

أجريت تجربة حقلية فى موسم صيف ٢٠١٩م بمزرعة كلية الزراعة ،جامعة الأزهر، مدينة نصر،القاهرة، مصر ،للمقارنة بين طريقتين تستخدمان للتقدير الدقيق للإحتياجات المائية لنباتات الكوسة صنف ريفيرا (*Cucurbita pepo*, L. var. Hybrid Revera) تحت نظام الرى بالتنقيط. الطريقة الأولى: تعتمد على بيانات المناخ والتى تم تجميعها لمنطقة الدراسة وفى هذه الطريقة تم حساب البخرنتح المرجعى ET_0 بإستخدام معادلة بنمان - مونتيث، والطريقة الثانية: تعتمد على خواص التربة المائية وهى طريقةالإستنفاذ الرطوبى.

تم تقدير الإحتياجات المائية لمحصول الكوسة، الإنتاجية، كفاءة إستخدام المياه وكمية المياه المفقودة بواسطة التسرب العميق. وقد أظهرت النتائج أن طريقة الرى المعتمدة على خصائص التربة (الطريقة الثانية) كان لها تأثير إيجابى واضح على الإنتاجية مقارنة بالطريقة الأولى التى تعتمد على بيانات المناخ. علاوة على ذلك،تم الحصول على أعلى قيمة لكفاءة إستخدام المياه ٥.٣١كجم/م٣ بإستخدام الطريقة الثانية. من ناحية أخرى،تم الحصول على أعلى إنتاجية لنباتات الكوسة (١٥٩٧٠.١٠ كجم/هكتار) بإستخدام الطريقة الثانية بينما تم الحصول على أعلى قيمة للمياه المفقودة بواسطةالرشح(١٤.٨٢٪) بإستخدام الطريقة الأولى. وعموما ،كانت طريقة الرى التى تعتمد على التربة أكثر دقة في حساب كمية مياه الري المضافة وكان لها آثار إيجابية واضحة على النمو و الإنتاجية وكفاءة إستخدام المياه لمحصول الكوسة مقارنة بطريقة الرى المعتمدة على بيانات المناخ.