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RESPONSE OF SOME EGYPTIAN RICE VARIETIES TO WATER REQUIREMENT COMPONENTS IN NORTH NILE DELTA REGION

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Abstract

Rice is a major consumer of water, so select water requirement component a useful trait for rice production wherever irrigation water is limited. Two micro- paddy lysimeter (tanks) experiment were done at Sakha Agricultural Res., Station, (A.R.C), Egypt, in 2017 and 2018 seasons for estimate and consumptive use components for some Egyptian rice varieties (Oryza sativa L); namely cvs.; Sakha 107, Giza 179 and177 to evaluate the estimated rice crop evapotranspiration (ETc) values computed to assess the best method for estimating the reference evapotranspiration which suitable with Middle North Nile Delta conditions. Data of water components of; evaporation (E), evapotranspiration (ET) and ET+ deep percolation (ET+P) for rice were obtained from three groups of tanks.Results reveled that components; evaporation (E) is the highest part of total water consumption in the seasons with an average of 44.2% (617.1 mm), 44.2% (572.8 mm) and 44.1% (542.3 mm), while, transpiration (T) is the lowest part of total water consumption in the two seasons with average of 12.7% (178.1 mm), 12.7% (164.4 mm) and12.6% (154.9 mm). So, evapotranspiration (ET) has an average of 56.9% (795.2 mm), 59.9% (737.2 mm) and 56.6% (697.2 mm) for Group1.2 and 3 respectively. In addition, for percolation (P), between evaporation and transpiration with an average of 43.1% (602.2mm), 43.1% (559.2mm) and 43.4% (533.9mm) for Group1.2 and 3 respectively. Results showed Penmen-Monteith methods and Hargreaves performed best for North Delta, Egypt because of least percentage deviation between ETa and ETc. and the least amount of error. Results revealed also rice cvs. Giza 179 recorded the highest values of productivity of irrigation water (PIW) and Crop water productivity (CWP)

Key words: *rice consumptive use, Evaporation, evapotranspiration and deep percolation*

Introduction

Whereas the availability of fresh water resources in the world are constant and the population is increasing continually, the per capita share of water will continue to decrease resulting in water scarcity or stress in some areas. One of the most important inputs for the production of crops is water. So, one of the technical options that can help farmers cope with water scarcity at the field level how to maximize water use efficiency by crops to increase crop production in order to narrowing the food gap between consumptions and production. Water influences crop performance not only directly but also indirectly through influencing nutrients availability, and timing of cultural operation….etc

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Agriculture in Egypt is entirely depending upon irrigation. With the exception of some aquifers, the water resources in Egypt are limited and depending upon water comes from River Nile. Egypt water share is 55.5x 109 $m^3 year^{-1}$ and with population increasing tremendously, irrigation water has to be well managed and production has to be increased and how to find a way to save more irrigation water becomes essential. About 80-85% of the Egyptian water supply is used in agricultural sector. So, the necessity to rationalize the use of irrigation water becomes a must. Approximately 3.3 million ha (h=2.38 fed.,) of fertile agricultural soils heavily cultivated with crops including rice, sugarcane and cotton in summer. There is a clear restriction on reducing irrigation water in Egypt based on the imperative to control salinity in the Northern Delta.

The saline aquifer emerging in the Northern Delta will cause soil salinity problems due to increased migration when the hydraulic pressure gradient permits. Periodic flushing with necessary fresh water is essential to reduce this upward movement. There is an indication that rice agronomy has indeed improved some of the moderately saline soils in the North Nile Delta. So, cultivation is vital to maintion soil fertility and reduce the risk of salinity hazard in certain areas such as North Nile Delta (Badawi and Ghanem 2007).

Rice (*Oryza sativa* L.) is not only the main food for approximately half of the world's population, most of whom live in the developing counties, which occupy a third of the world's total area, but is also a major source of income and engagement for the rural people who grow grain and provides 35-60 percent of the calories consumed by 2.7 billion people. (Guera *et al*. 1998). Rice is consumed large quantities of water specifically under the traditional irrigation method, so water saving is becoming a serious factor for agricultural development. Lack of irrigation fresh water and a need to search for current water management strategies together on the farm to increase the efficiency of water use for irrigation of rice.

Doorenbos and Pruitt 1977, determined the Kc of rice and quoted as; 1.0, 1.15 and 0.7 for vegetative, midseason and maturity stages respectively, in FAO-56 irrigation and drainage paper. Crop coefficient (Kc) is necessary in calculating the consumptive water use of selected crops. This is due to the fact that potential evapotranspiration ET_o estimation is purely based on climatic data. The introduction of crop and soil effect into ET_o in order to determine actual or crop water use, Kc is very important. Several methods and models have been adopted to determine crop coefficient for rice in different regions of the world with varying degree of success (Allen *et al*. 1998). The global rice ET estimate ranges from 450 to 700 mm/season, dependent on growing season and climate (Doorenbos and Kassam 1979).

Determination the water requirements of the crop is the first step used in a good design and planning. The process usually includes estimation of evaluate crop evaporation or crop reference evaporation. One of the most important factors determining crop water requirements is a good estimate of crop evapotranspiration. Diverse methods can be used to determine evapotranspiration of crops (ETc), which is a key component of crop water use (Attarod *et al*. 2005). All irrigation projects and the effective use of water are directly and centrally linked to the estimation of evapotranspiration in order to avoid predicting the extent of water availability and its requirements and thus the ease of planning for these projects (Humphrey *et al*. 1994; Pereira *et al*. 1999). Crop water requirements are directly related to crop evapotranspiration (ETc) and differ according to the upon crop grown and its different growth stages (Dunn and Mackay 1995). Koffi Djaman *et al*. (2019) reported that ETo for rice during the hot and dry season in Senegal averaged 6.8 mm d^{-1} in 2014 and 6.6 mm d^{-1} in 2015. The amount of seasonal irrigation water for the cultivated rice was 1110 mm in 2014 and 1095 mm in 2015 daily ETa for rice ranged from 4.7 to 10.5 mm in 2014 and from 4.4 to 10.5 mm in 2015 an average of 8.17 mm in 2014 and 8.14 mm in 2015

Vamadevan and Dastane (1967) mentioned that only 48 cm as used a consumptive use by the crop and lost through deep percolation about 120 cm from water. The percolation loss was significantly reduced n the case of more saturated soil than under continuously submerged soil. Abd El-Hafez (1982) found that the average values for consumptive use of rice ranged between 5.88 and 6.25 mm/day. Abo- Soliman *et al*. (1990) stated that rice water requirements was ranged between 161 to 214 cm in Northern Delta in Egypt under immersion method and the average consumption efficiency values between 47 to 54%. Omara *et al*. 2000 explained that a decline in water consumption, about 1,120 mm, which is low, as it does not exceed 51% of the total consumption of rice of 2,190 mm. this lower level of efficiency requires more capabilities to maintain water management at the farm level.

Zhang-Xiaoping *et al*. (2004) showed that dry-foot paddy irrigation saving 407.9 mm in total consumptive use, that save in transpiration 116.5 mm, evaporation 27.7mm and seepage 245.7mm. The test indicates that the field seepage by 50.8% and interplant evaporation is reduced by 33.8% compared with flooding irrigation. Qureshi *et al*. (2006) found that average amount of applied irrigation water to dry direct rice was 865 mm compared to 1130 mm for old rice indicating a water savings of 23% in the case of direct dry seeding method. For direct dry rice and old-seedling rice about 43 and 56% , respectively of the total water input was lost by percolation losses. The results indicate that dry direct seeding is more efficient in water saving compared to old method. (El- Bably *et al*. 2007) conducted that actual evapotranspiration mean values for rice cv. Giza 177 was decreased with 15.7% than rice cv. Giza 178 because of the shorter growth duration and amount of applied water for rice cv. Giza 177 and Giza 178 were indicated to be 145.86 and165.20 cm, respectively.

Moursi *et al*. (2007) illustrated that increasing irrigation water depth up to 7.5 cm led to increasing water losses by evaporation and percolation so, irrigation depth should be decreased without any drastic effect on yield. Data showed also depth of water more than 5.0 cm considers waste water. Moursi and Abdelkhalek (2015) stated that largest component of total water requirements

(WR) was evaporation (E) during the season rice crop stages. For ETa the mean values for cv. Sakha 104, Giza 178, Sakha 102 and were 6.0, 6.1 and6.0 mm day^{-1}, respectively.

Darwesh *et al.* (2016) concluded that about 1cm depth above soil surface all the season (irrigation with 5cm depth above soil surface every 6 days) and gave the highest grain yield values. They reveled also a positive linear relationship was determined between irrigation water applied and productivity of irrigation water by rice plant was reduced linearly as irrigation water increased. Zhou Qun *et al.* (2017) illustrated that irrigation rice with well-watered gave the highest yield and water productivity comparing with moderate water deficit and severe water deficit. Stanslaus Terengia Materu *et al.* (2018) studied some irrigate ponding for 3 days and for the next 5 days no irrigation took place 80% of the (40 mm ponding) and 50% of (40 mm) and they found that 80% of 40 mm ponding giving high yield and 33 % (345 mm) of water saving comparing with continuously flooded.

The herein research trial objectives are to determine the water consumptive use components for some Egyptian rice varieties and to compare the estimated evapotranspiration (ETc) values of the rice crop computed using some climatic equations to assess the best method for estimating the reference evapotranspiration that is suitable for conditions North of the Nile Delta

Material and Methods

Two tank experiments were conducted at Sakha Agriculture Research Station, during the two successive summer growing seasons of 2017 and 2018 to estimate and analyze water consumptive components for some Egyptian rice varieties (*Oryza sativa* L); namely cvs. Sakha 107, Giza 179, and Giza 177. Also, the study involved evaluating and comparing the estimated rice crop evapotranspiration (ETc) values computed by Hargreaves, Penmen- Monteith and Class A pan methods used for (ETc) with the measured actual rice evapotranspiration (ETa) using micro- paddy lysimeter used for (ETa) to evaluate the best method for estimating the reference evapotranspiration which suitable with North Nile Delta conditions

The site lies at Kafr EL Sheikh Governorate (Middle North of the Nile Delta), which located at (31¯ 07° N Latitude, 30¯ 57° longitude) with an elevation of about 6 meters above mean sea level (MSL). Presented data in Table 1 show the meteorological parameters during the studied period, recorded from Sakha Agrometeorological Station. The meteorological parameters, include; air temperature (T), relative humidity (RH), wind speed (U_2) and evaporation pan (Ep) . The soil texture of the experimental site is heavy clay which is more suitable for rice cultivation since it has a high-water holding capacity.

In the two seasons the plants were broadcasting varieties were Sakha 107, Giza 179 and Giza 177 rice varieties broadcasting process was performed on the 1st June and 3rd June in the first and second seasons respectively. Harvesting process was occurred on 8th and 10th October in the two growing seasons and for Sakha 107 and occurred on 3rd and 5th October for Giza 179 and occurred on 5th and 7th October Giza 177 in the two seasons.

In this study investigation used three common rice varieties representing a wide range diversity of several agronomic and water shortage or drought tolerance characteristics (Table 2).

Components of water consumptive use for rice

Rice consumptive use (CU) components were estimated for the rice varieties Sakha 107, Giza 179 and Giza 177 by tank experiment. Data of water components of; evaporation (E), evapotranspiration (ET) and ET+ deep percolation (ET+P) for rice were obtained from three groups of tanks. Each group consists of three tanks. Area of each tank is 746 cm^2, depth of all tanks is 30.3 cm and its diameter is 95 cm, and the soil for tanks 2 and 3 were taken from the experimental field with its successive layers in order to be similar as possible to natural soil Fig (1).

One group was allocated to Sakha 107, the second group was for Giza 179 and the third group for Giza 177 all groups under broadcasting method.

All groups were irrigated till 5 cm above soil surface for the two seasons. The water level in each tank was recorded daily to find out the consumed water in the last 24 hours. Each tank was re-watering every 6 days till the static head of water above soil surface. Irrigation intervals were the same for all tank's groups.

Percolation and evapotranspiration are an among the main components of consumptive for water budget in the rice areas, so estimate these values is very important to measure in order to calculate the actual water requirement in the areas as a source for irrigation scheduling. The rate of evaporation is to be parted from evapotranspiration rate, it can be measured using small cylinder without rice plants inside, but the plants are distributed outside the cylinder as Fig.1 (a). since the water in the cylinder is consumed by evaporation only, its rate can be measured as the decrease in the depth of water inside it.

Table 1: Some agro-meteorological data for Sakha region, (31° 07' N Latitude, 30° 05' E Longitude), during 2017 and 2018 season.

Months		T (c°)*			RH(%)**			U *** 2 km d^{-1}	PanEvap. (mm/day)
		Max.	Min.	Mean	Max.	Min.	Mean		
2017	June	32.50	28.10	30.30	80.10	51.40	65.75	102.60	7.10
	July	34.20	29.00	31.60	84.40	57.60	71.00	80.90	6.44
	Aug.	33.90	28.30	31.10	85.90	55.30	7.60	70.20	6.04
	Sept.	32.50	25.90	29.20	86.30	50.30	68.30	85.70	5.37
	Oct.	28.70	24.00	26.35	81.10	54.70	67.90	73.20	3.26
2018	June	32.60	25.30	28.95	75.50	48.00	61.75	98.6	7.71
	July	34.20	25.40	29.80	82.60	51.00	66.80	89.50	7.37
	Aug.	33.60	25.20	29.40	82.40	51.40	66.90	76.00	6.42
	Sept.	32.80	23.50	28.15	83.10	48.30	65.70	68.70	4.98
	Oct.	29.50	20.60	25.05	82.50	49.60	66.05	57.90	3.24

T*= air temperature, RH**= relative humidity and U_2=*** wind speed

Table 2: Name; origin; type; pedigree and some features of the genotypes.

Genotype	Parentage	Origin	Type	Drought tolerance
Giza 177	(Giza 171 / Yu mji No.1 // piNo.4)	Egypt	Japonica	Drought susceptible
Giza 179	(GZ 1368 -S-5-4 / GZ 6296-12-1-2)	Egypt	Indica / Japonica	Moderately tolerant
Sakha 107	(Giza 177 / BL1)	Egypt	Japonica	Moderately tolerant

Actual evapotranspiration a plot can be calculated using a similar cylinder with the bottom set in the top soil, where some rice plants grown as revealed in Fig.1 (b). Figure.1 show example cylinder scaling with only one plant hill, and each cylinder in this study contains 18 plants for more exact measurements.

The actual percolation rate in a plot can be measured using the bottomless cylinder as revealed in Fig.1 (c). Water consumption through percolation and evapotranspiration can be measured with the rate of decrease the water head inside the cylinder. Therefore, calculated rate of percolation can be estimated by subtracting from it the values of evapotranspiration rate measured with the cylinder Fig.1 (b).

It is easy to find out the role of each component on rice consumptive use, which ultimately affected the ways to rationalize rice irrigation via reducing evaporation or minimizing down deep percolation losses.

All tanks irrigated till 5.0 cm above soil surface, such depth was recommended previously before the present study by Moursi *et al.* (2007) and Moursi and Abdelkhalek (2015)

Water balance in paddy fields

In this study, it was assumed that surface drainage, rainfall, seepage, and runoff are negligible because in Egypt at the time of the study these parameters are not ineffective, so, the consumptive use mainly consists of crop evapotranspiration deep percolation. Watanabe (1999) also described that, in a plot-to-plot irrigation system, water consumption consists of infiltration and evapotranspiration. Hence, the terms of supply terms are irrigation only.

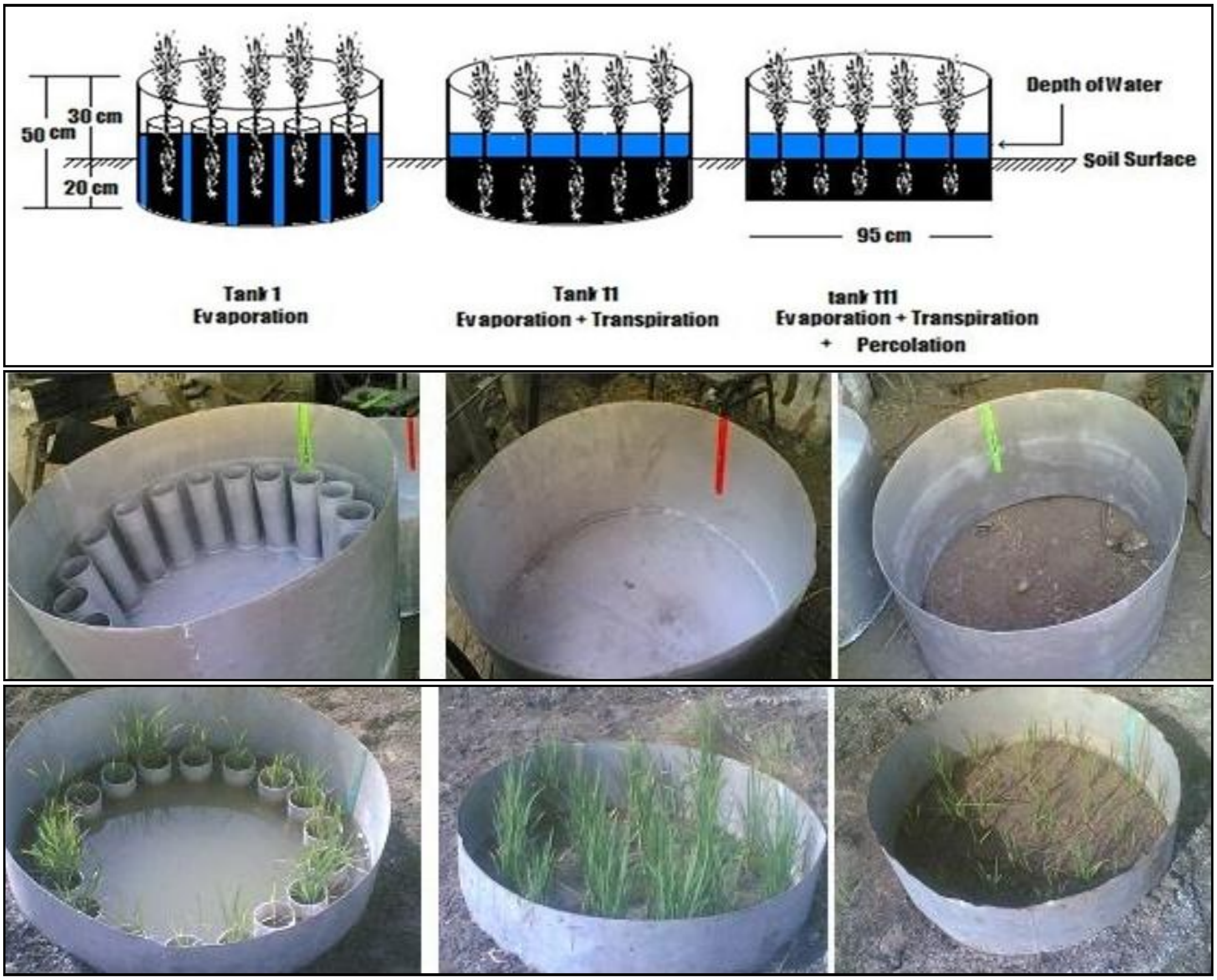
In rice fields, the water balance was measured by field storage and volume of water leaving and entering the field. Field storage consists of soil moisture (W) and ponded water (D). The inflow to the field consisted of irrigation (IR) , seepage inflow(Sin), precipitation (P), and surface inflow (Rin), while the outflow was composed of crop evapotranspiration (ETc), infiltration (I), seepage outflow (Sout) and surface outflow (Rout). Therefore, the equation of water balance was;

$$\Delta (D + W) = (IR + Sin + P + Rin) - (ETc + I + Sout + Rout)$$

Where, Δ (D + W) it is the field storage changes and all terms are measured either in mm or in m^3. Rice fields water balance was calculated for the whole varieties in both seasons.

Estimating Reference evapotranspiration (ETo) using climatological data

ETo is a measure of the evaporative demand of the atmosphere regardless of crop development and crop type and management practices. Climatic factors only affect (ETo). Therefore, ETo is a climatic parameter and can be calculated from meteorological data (Allen *et al*. 1998). The elements of agro-climatological through both growing seasons 2017 and 2018 were collected from the on-site agro-meteorological station. ETo values were estimated for the different months using of the following three methods:



a) E **b) E+T** **c) E+T+P**

Fig. 1: Tank experiment system.

1. according to Hargreaves et al; equation (1985):

$$ET_o = 0.0023Ra.\ TD0.5\ (Ta + 17.8)$$

Where:

Ra = the absolute radiation, cal. cm^{-2}-day^{-1}

TD = the difference between max. and min., air temperature, ^oC

Ta = average of air temperature, ^oC

Ra values were calculated for the area depending on local environmental features **(Ibrahim 1995)**.

2.According to FAO Penman-Monteith method: As described by Allen *et al*. (1998) was used to calculate ET_o. The equation is given as:

$$ETo = \frac{0.408\ \Delta\ (Rn - G) + \gamma\ [900/(T + 273)]\ U_2\ (es - ea)}{\Delta + \gamma\ (1 + 0.34\ U_2)}$$

Where:

ET_o = the reference evapotranspiration, mm.day^{-1}

Rn = net radiation (MJ $m^{-2}d^{-1}$)

G = soil heat flux (MJ $m^{-2}d^{-1}$)

Δ= slope of vapor pressure and temperature curve (kPa $^oC^{-1}$)

γ = psychrometric constant (kPa °C^{-1})

U2 = wind speed at 2 m height (ms^{-1})

es-ea = vapor pressure deficit (kPa)

T= mean daily air temperature at 2 m height (°C)

3. According to Class A pan evaporation method:

$$ET_o = K_p * E_p$$

As:

Kp = pan coefficient, Kp values are affected by the surrounding area, where the pan is located and taken the average value of 0.85.

Ep = daily rate of evaporation, mm.

Computation of crop evapotranspiration (ETc)

$$ET_c = K_c * ET_o$$

Dimension less crop coefficient, Kc is the ratio between the water consumed by a given crop to values of ET_o. K_c values are taken from FAO No. 56, 1998.

The three-method performance measures included the component of estimated (ET_c) and measured (ET_a) components values of mean absolute error (MAE), and root mean square error (RMSE) (Meyer *et al.* 1993).

Some water relations

1.Productivity of irrigation water (PIW)

Productivity irrigation water is commonly studied according to Ali *et al.* (2007) as fellow:

$$PIW = \frac{GY}{IW}$$

Where:

PIW = productivity of irrigation water (kg m^{-3}),

Gy = grain yield kg/m^{-2} area and

IW = Applied water (m^3/ /m^{-2} area.).

2.Water productivity (WP)

Generally defined the water productivity as the ratio of yield (Y), Kg m^{-2}, to the amount of water the crop has depleted in the process of evapotranspiration (ETa), m^3 m^{-2} $season^{-1}$. WP calculated according to Ali *et al.* (2007) as fellow:

$$WP = \frac{GY}{ET}$$

Where:

WP = water productivity (kg m^{-3}),

GY = grain yield (kg /m^{-2} area) and

Statistical analysis

All data were analyzed statistically according to the technique of analysis of variance (ANOVA) as published by Gomez and Gomez (1984). Treatment modalities were compared with the lowest significant difference (LSD) at 5% level and 1 % significance level developed by Waller and Duncan (1979).

Results and Discussion

Components of rice consumptive use for Giza 177

In Table (3) data show the values of evaporation (E), transpiration (T) and deep percolation (P) for Giza 177 under broadcasting method. Evaporation (E) is the maximum of total water consumption in the growing season with an average 44.1% (542.3 mm) including; 56.6% (306.5 mm) at vegetative stage, 15.8 % (85.8 mm) at reproductive stage and 27.6% (149.9 mm) at ripening stage.

While, for transpiration (T) is the lowest of total water consumption by rice plant in the season with average of 12.6% (154.9 mm) include; 33.1% (51.3 mm) at vegetative stage, 24.2% (37.4 mm) at reproductive stage and 42.7 % (66.2 mm) at ripening stage. So, evapotranspiration (ET) for Giza 177 under broadcasting represent an average of 56.6 % (697.2 mm). Concerning percolation (P) in between evaporation and transpiration with an average of 43.4 % (533.9 mm) including; 76.0 % (405.8 mm) at vegetative stage, 9.8 % (52.5 mm) at reproductive stage and 14.2 % (75.7 mm) at ripening stage. This result is agreements with Koffi Djaman *et al*. 2019.

Table 3: Water consumed (mm) for evaporation (E), evapotranspiration (ET) and evapotranspiration (ET) + percolation (P) at different stages of rice cultivar Giza 177 in the two growing seasons.

water consumed	Components of rice consumptive use									
	2017					2018				
	E*	T**	ET***	P****	ET+P	E*	T**	ET***	P****	ET+P
Vegetative, mm (≈71 days)	295.5	47.5	343.0	429.5	772.5	317.5	55.2	372.7	382.0	754.7
Means in two seasons	E		T		ET		P		ET+P	
	306.5		51.3		357.8		405.8		763.6	
Reproductive, mm (≈18days)	84.0	37.9	121.9	51.4	173.3	87.6	36.9	124.5	53.6	178.1
Means in two seasons	E		T		ET		P		ET+P	
	85.8		37.4		123.2		52.5		175.7	
Ripening, mm (≈35days)	145.0	65.8	210.8	76.5	287.3	154.9	66.5	221.4	74.9	296.3
Means in two seasons	E		T		ET		P		ET+P	
	149.9		66.2		216.1		75.7		291.8	
Seasonal water consumed, mm (≈124 days)	524.5	151.2	675.7	557.4	1233.1	560.0	158.6	718.6	510.5	1229.1
Means in two seasons	E		T		ET		P		ET+P	
	542.3		154.9		697.2		533.9		1231.1	

E* = evaporation, T** =transpiration, ET*** = evapotranspiration and P**** = percolation

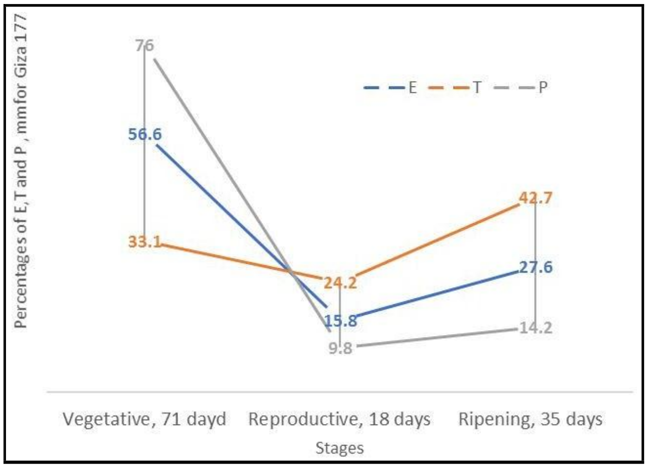


Fig. 2: Percentages of rice consumptive use components; E (evaporation), T (transpiration) and P (percolation) for Giza 177.

As shown in Table 3 and Fig. 2, more evaporation was occurred during vegetative stage (≈71 days from sowing) with average of 56.6 % followed by ripening stage (≈35 days) with 27.6 % and the least percentage was for reproductive stage (≈18 days) with 15.8 %.

Regarding transpiration (T), more of T was happened during ripening stage (42.7 %) followed by vegetative stage (37.4 %) and the least at reproductive stage (24.2 %).

In addition, most of percolation is during the vegetative stage (76.0 %) then at ripening stage (14.2%) and the least at reproductive stage (9.8%).

As shown in Table 4 some of percentages of component of rice consumptive use for rice cultivar Giza 177 under broadcasting in the two seasons and the mentioned percentages are cleared in the following figure (5).

Table 4: Percentages of consumptive use components at different stages for rice cultivar Giza 177 in the two growing seasons.

Growth Stages	Percentages of rice consumptive use components (%)							
	2017				2018			
	E/ ET	T/ ET	ET/ ET+P	P/ ET+P	E/ ET	T/ ET	ET/ ET+P	P/ ET+P
Vegetative	86.2	13.8	44.4	55.6	85.2	14.8	49.4	50.6
Reproductive	68.9	31.1	70.3	29.7	70.4	29.6	69.9	30.1
Ripening	68.8	31.2	73.4	26.6	70.0	30.0	74.7	25.3

E* = evaporation, T** = transpiration, ET*** = evapotranspiration and P**** = percolation.

Components of rice consumptive use for Giza179

In Table (5) data show the values of evaporation (E), transpiration (T) and deep percolation (P) for Giza 179. Evaporation (E) is the maximum consumption of total applied water with an average 44.2% (572.8 mm) include; 57.2% (327.5 mm) at vegetative stage, 15.7 % (89.5 mm) at reproductive stage and 27.1% (155.0 mm) at ripening stage. These results are harmony with Moursi *et al.* (2007).

Table 5: Water consumed (mm) for evaporation (E), evapotranspiration (ET), and evapotranspiration (ET) + percolation (P) at different stages of rice cultivar Giza 179 in the two growing seasons.

water consumed	Components of rice consumptive use									
	2017					2018				
	E*	T**	ET***	P****	ET+P	E*	T**	ET***	P****	ET+P
Vegetative, mm (≈72 days)	311.0	50.1	361.1	451.0	812.1	344.5	64.5	409.0	402.0	811.0
Means in two seasons	E		T		ET		P		ET+P	
	327.5		57.3		384.8		426.5		811.3	
Reproductive, mm (≈17days)	87.0	39.5	126.5	53.5	180.0	92.0	39.1	131.1	55.0	186.1
Means in two seasons	E		T		ET		P		ET+P	
	89.5		39.3		128.8		54.3		183.1	
Ripening, mm (≈33days)	151.0	68.5	219.5	79.5	299.0	160.1	67.5	227.6	77.5	305.1
Means in two seasons	E		T		ET		P		ET+P	
	155.5		68.0		223.5		78.5		302.0	
Seasonal water consumed, mm (≈122 days)	549.0	158.1	707.1	584.0	1291.1	596.6	171.1	767.7	534.5	1302.2
Means in two seasons	E		T		ET		P		ET+P	
	572.8		164.4		737.2		559.2		1296.4	

E*= evaporation, T**=transpiration, ET***= evapotranspiration and P****= percolation.

While, for transpiration (T) is the lowest of total water consumption in the season with average 12.7% (164.4 mm) include; 34.8% (57.3 mm) at vegetative stage, 23.8% (39.3 mm) at reproductive stage and 41.4 % (68.0 mm) at ripening stage. So, evapotranspiration (ET) for Giza 179 under broadcasting is an average of 56.9% (737.2 mm). Concerning percolation (P) in between transpiration and transpiration with an average of 43.1 % (559.2 mm) include; 76.3 % (426.5 mm) at vegetative stage, 9.7% (54.3 mm) at reproductive stage and 14.0 % (78.5 mm) at ripening stage.

As shown in Table 5 and Fig. 3, more evaporation occurred during vegetative stage (≈72 days) with 57.5 % followed by ripening stage (≈33 days) with 27.1 % and the least percentage of reproductive stage (≈17 days) with 15.7%. Regarding transpiration (T), more of T is during ripening stage 41.4% followed by vegetative stage 34.8 % and the least at reproductive stage 23.8 %. In addition, most of percolation is during the vegetative stage 76.3% then at ripening stage 14.0% and the least at reproductive 9.7 %.

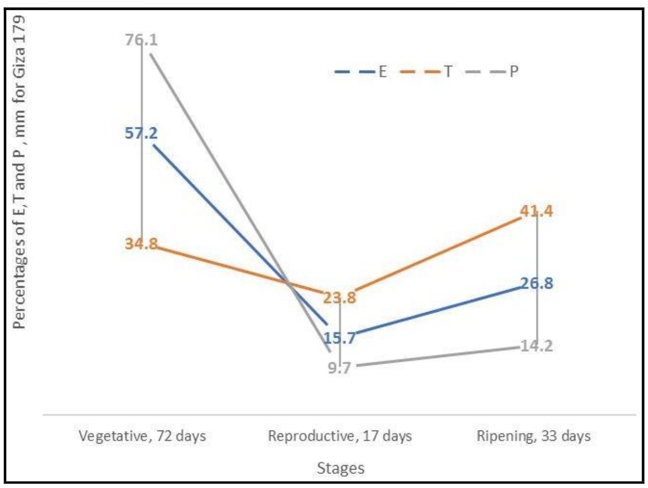


Fig. 3: Percentages of rice consumptive use components; E (evaporation), T (transpiration) and P (percolation) for Giza 179.

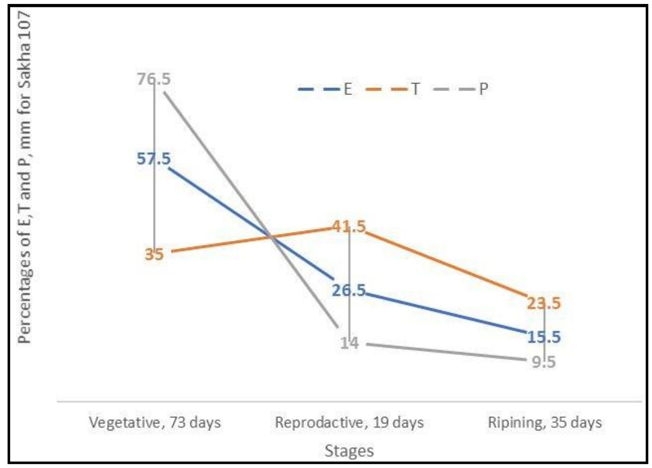


Fig. 4: Percentages of rice consumptive use components; E (evaporation), T (transpiration) and P (percolation) for Sakha 107.

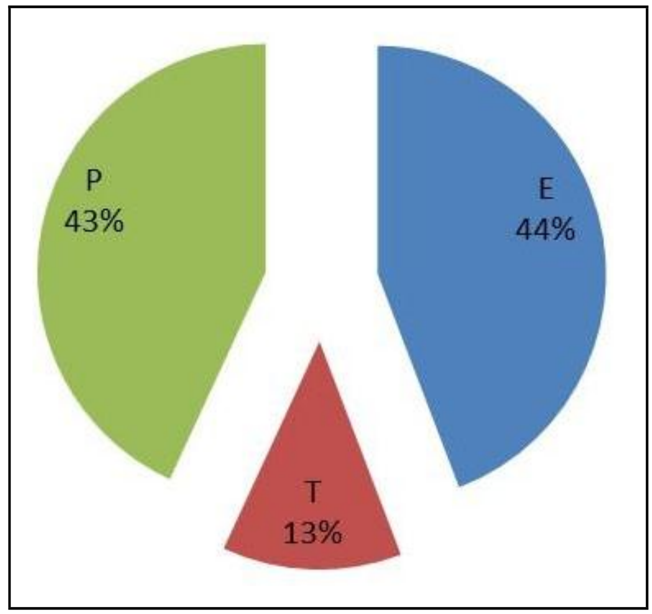


Fig. 5: Mean percentage of evaporation (E), transpiration (T) and percolation (P) for Sakha 107 and Giza 179, 177 under broadcasting in the two growing seasons.

As shown in Table 6 some of percentages of component of rice consumptive use for rice cultivar Giza 179 in the two seasons and the mentioned percentages are cleared in the following figure (5).

Table 6: Percentages of consumptive use components at different stages for rice cultivar Giza 179 in the two growing seasons.

Growth Stages	Percentages of rice consumptive use components (%)							
	2017				2018			
	E/ ET	T/ ET	ET/ ET+P	P/ ET+P	E/ ET	T/ ET	ET/ ET+P	P/ ET+P
Vegetative	86.2	13.8	44.5	55.5	84.2	15.8	50.4	49.6
Reproductive	68.8	31.2	70.2	29.8	70.2	29.8	70.4	29.6
Ripening	68.8	31.2	73.4	26.6	70.2	29.8	74.6	25.4

E* = evaporation, T** = transpiration, ET*** = evapotranspiration and P**** = percolation.

Components of rice consumptive use for Sakha 107

Data of Table (7) represent values of evaporation (E), transpiration (T), evapotranspiration (ET) and deep percolation (P) and ET+P. Evaporation (E) is the highest component of total water consumption on the season with an average 44.2% (617.1 mm) partially include;

57.5% (354.7 mm) in vegetative stage, 15.7% (96.9 mm) in reproductive stage and 26.8 % (165.5 mm) in ripening stage.

While, for transpiration (T) is the lowest part of total water consumption in the season with average 12.7% (178.1 mm) partially include; 34.8% (62.1 mm) in vegetative stage, 23.8% (42.4 mm) in reproductive and41.4 % (73.7 mm) in ripening stage. These results are agreement with Moursi and Abdelkhalek (2015). So, evapotranspiration (ET) for Sakha 107 under broadcasting is averaged 56.9% (795.2 mm). For percolation (P) is nearly equal evaporation with an average of 43.1% (602.2 mm) include; 76.1% (458.0 mm) in vegetative stage, 9.7% (58.7 mm) in reproductive stage and 14.2% (85.6 mm) in ripening stage.

As shown in Table 7 and Fig. 4, more evaporation was occurred during vegetative stage (≈73 days) with 57.5% followed by ripening stage (≈35 days) with 26.8 % and the least percentage of reproductive stage (≈19 days) with 15.7%. Regarding transpiration (T), more of T is during ripening stage (41.4%) followed by vegetative stage 34.8 % and the least was at reproductive stage (23.8%). In addition, most of percolation is during the vegetative stage (76.1%) then at ripening stage (14.2%) and the least at reproductive (9.7%).

As shown in Table 8 some of percentages of component of rice consumptive use for rice cultivar Sakha 107 in the two growing seasons and the mentioned percentages are cleared in the following figure (5).

Results of Sakha 107 and Giza 179, 177 under broadcasting showed that a value of percolation was higher than those obtained in case of evaporation and transpiration at vegetative growth. Was this finding could be ascribed to the higher amount of water which needed at this plant growth stage. On the other hand, at reproductive and ripening stages the evapotranspiration was higher than percolation. It could be due to much water needed at growth and tilling stages. This result was in agreement with those obtained by Doorenbos and Pruitt (1977); Kukal and Aggarwal (2002); Tripathi (2004); Moursi *et al*. (2007).

Actual Evapotranspiration (ETa)

Data in Table 9 concluded actual evapotranspiration mean valued for Sakha 107 and Giza 179, 177 was 6.1, 5.9 and 5.6 mm. day^{-1}, respectively and they're nearly agreement with Tabbal, et al. (2002) showed that typical ETc rates for baddy fields are 4 - 5 mm/day in the rainy season and 6 - 7 mm/day in the dry season, but can reach 10–11 mm/day in subtropical regions.

Data in Table 9 showed also that ETa values for the rice cv. Sakha 107 were 5.3, 5.3, 6.5 and 6.4 mm day^{-1} and 5.6, 5.6, 6.6 and 6.5 mm day^{-1} for rice cv. Giza 179 and 5.0, 5.1, 6.2, and 6.1 mm day^{-1} for cv. Giza 177 in June, July, August and September months respectively. It can be seen that Eta was increased until August and then decreased gradually until harvest. These results may be due to climatic conditions and prevailing agriculture (Sugimoto, 1976; Wickham, 1978; Tomar and Toole, 1980; Abd El-Hafez *et al*. 1982; El-Bably *et al*. 2007, Abdullahi *et al*. 2013 ; Koffi Djaman *et al*. 2019).

Table 7: Water consumed (mm) for evaporation (E), evapotranspiration (ET), and evapotranspiration (ET) + percolation (P) at different stages of rice cultivar Sakha107 in the two seasons.

water consumed	Components of rice consumptive use									
	2017					2018				
	E^{*}	T^{**}	ET^{***}	P^{****}	ET+P	E^{*}	T^{**}	ET^{***}	P^{****}	ET+P
Vegetative, mm (≈73 days)	338.2	53.7	391.9	489.5	881.4	371.3	70.4	441.7	426.4	868.1
Means in two seasons	E		T		ET		P		ET+P	
	354.7		62.1		416.8		458.0		874.6	
Reproductive, mm (≈19days)	94.8	42.4	137.2	58.0	195.2	99.0	42.4	141.0	59.4	200.4
Means in two seasons	E		T		ET		P		ET+P	
	96.9		42.4		139.3		58.7		198.0	
Ripening, mm (≈35days)	155.9	73.7	229.6	86.8	316.1	175.0	73.7	248.7	84.4	333.1
Means in two seasons	E		T		ET		P		ET+P	
	165.5		73.7		239.2		85.6		324.8	
Seasonal water consumed, mm (≈127 days)	588.9	169.8	758.7	634.3	1392.7	645.3	186.5	831.4	570.2	1401.6
Means seasonal in two seasons	E		T		ET		P		ET+P	
	617.1		178.1		795.2		602.2		1397.4	

E^{*} = evaporation, T^{**} = transpiration, ET^{***} = evapotranspiration and P^{****} = percolation.

Evaluation of the methods

Actual evapotranspiration reducing by using Sakha 107 by 1.14, 1.31 and 7.37% for Hargreaves method, Penman-Monteith and Class A pan methods, respectively (Table 9). In general, based on MAE, RMES criteria and the percentage deviation from ETa, Hargreaves and Penman-Monteith methods that performed best in Middle Northern Delta, Egypt due to the least amount of error (MAE = -1.198 and -2.79, RMES = 1.086 and 1.437 for both of Hargreaves and Penman-Monteith methods, respectively) and the lowest deviation percentage (1.14 and 1.31) between ET_a and ET_c. Therefore, the values of MAE, RMSE and percentage deviation from ET_a indicated close agreement between crop evapotranspiration (ET_c) and actual evapotranspiration (ET_a) when we using Penman-Monteith or Hargreaves compared to the Class A pan method. These results are harmony with those found by El-Bably *et al*. 2007.

Yield-water relations

The main values of two seasons of productivity of irrigation water (PIW) of rice in kg grain per cubic meter of applied water (Table 10) for Sakha 107, Giza 179, and Giza 177 were 0.795, 0.804 and 0.785 Kg m^{-3} respectively. The results showed that rice productivity of irrigation water for Giza 179 > Sakha 107> Giza 177. Effectively that m^3 of applied water yileds 0.795, 0.804 and 0.785 Kg m^{-3} Kg grain for Sakha 107, Giza 179 and Giza 177, respectively. The data in table 10 also showed that water productivity (WP) values in kg grain per m^3 of water depleted by rice crop through the evapotranspiration (ETa) process for cvs., Sakha 107, Giza 179 and Giza 177were 1.40, 1.42 and 1.38 Kg m^{-3} respectively. The results revealed that the productivity of irrigation water and water productivity for rice for Giza 179 > Sakha 107> Giza 177. This increase of PIW and WP for Giza179 may be due an increase in the yield of this Variety compared to Giza 177 variety with approximate consummation and lower applied water comparing with Sakha 107 variety who a longer growth period, so uses higher applied water. In general, increasing the productivity of irrigation water for rice crop is the main target of study due to the high consumption of rive in three parameters of irrigation water component. These results are consistent with those found by Ibrahim *et al*. 2005.

Table 10: Irrigation water applied, grain yield and crop water productivity of some rice varieties, over both growing seasons.

Varieties	Applied water, mm /season	Grain yield, Kg m^{-2}	PIW, Kg m^{-3}	WP, Kg m^{-3}
Giza 177	1229.10	0.965 b	0.785 b	1.38 a
Giza 179	1296.40	1.042ab	0.804 a	1.42 a
Sakha 107	1397.40	1.111a	0.795 ab	1.40 a
Mean	1307.63	1.039	0.795	1.40
$LSD_{0.05}$	----	0.338	0.055	0.296
F test	----	NS	NS	NS

*, **, *** and NS: significant at p ≤ 0.05, 0.01, 0.001or not significant, respectively. Means separated at P ≤ 0.05, LSD test.

Table 8: Percentages of consumptive use components at different stages for rice cultivar Sakha 107 in the two growing seasons.

Growth Stages	Percentages of rice consumptive use components (%)							
	2017				2018			
	E/ET	T/ET	ET/ET+P	P/ET+P	E/ET	T/ET	ET/ET+P	P/ET+P
Vegetative	86.3	13.7	44.5	55.5	84.1	15.9	50.9	49.1
Reproductive	69.1	30.9	70.2	29.8	70.2	29.8	70.4	29.6
Ripening	67.9	32.1	72.6	27.4	70.4	29.6	74.7	25.3

E^{*} = evaporation, T^{**} = transpiration, ET^{***} = evapotranspiration and P^{****} = percolation.

Table 9: Monthly references evapotranspiration (ETo mm day-1), crop coefficient (Kc), measured actual evapotranspiration (ETa mm day-1) and calculated crop evapotranspiration (ETc) of rice (average of both growing seasons).

Months	Reference evapotranspiration, ETomm day-1			FAO rice coefficient (Kc)	Actual evapotranspiration(ETa), mm day-1 of rice varieties					
	Harg-reaves	Penman Monteith	Class A Pan		Sakha 107	Giza 179	Giza 177	Hargr-eaves	Penman Monteith	Class A Pan
June	6.19	5.90	7.40	1.07	5.6	5.3	5.0	6.62	6.31	7.92
July	5.66	6.20	6.02	1.16	5.6	5.3	5.0	6.57	7.19	6.98
Aug.	5.37	5.50	5.51	1.19	6.6	6.4	6.1	6.39	6.55	6.55
Sep.	4.90	4.50	4.55	1.04	6.5	6.4	6.2	5.09	4.68	4.73
Average					6.1	5.9	5.6	6.17	6.18	6.55
MAE								-1.198	-2.790	-1.956
RMES								1.086	1.437	1.673
Percentage deviation form ET_a values of Sakha 107								1.14	1.31	7.37

Conclusions

It could be concluded that evaporation ≈ 44 % and deep percolation ≈ 43% the highest parts of water requirement components, Penmen-Monteith and Hargreaves methods performed best for middle North Delta, Egypt. Rice cvs. Giza 179 recorded the highest values of productivity of irrigation water (PIW) and Crop water productivity (CWP). This means that there is a great potential scope for the future rice production while minimizing losses of deep percolation and evaporation. This will not only improve food security but also water security. More studies are still necessary to improved understanding the reaction of rice to water requirement components.

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