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Irrigation performance and water consumptive use for rice crop grown under moisture stress at different seed rates, Assiut, Egypt

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ABSTRACT

A field experiment in a split-plot design with three replications was conducted on a clay loam soil located at the experimental farm, Faculty of Agric., Al-Azhar Univ., Assuit, Egypt (27° 12⁻ 16.67⁼ N latitude and 31° 09⁻ 36.86⁼ E longitude and at 51 m altitude) during two growing summer seasons of 2013and 2014. The experiment aims to study the effects of different irrigation regimes or seed rates on growth, yield, water consumptive use and water use efficiency (WUS) of Egyptian rice (*Oryza sativa*, L.) Orabi1.Evapotranspiration was estimated using some empirical formulas ($ET_{o)}$ and was compared with the actual measured one ($ET_{a)}$. The main plots were assigned for irrigation regimes (30, 60 and 85% soil moisture depletion from the available water, SMD, donatedas I_1, I_2 and I_3, respectively) The split units were assigned for seed rates (95.2, 119, 142.8, 166.6 kg seed ha^{-1}, donatedas S_1, S_2, S_3 and S_4 respectively).The results showed that the seasonal ET_a values were 1000, 955.20 and 901.30 mm at 30, 60 and 85 % SMD, respectively. It is noticed that the FAO Penman-Montithe equation was suitable to calculated ET_o for rice crop grown under Assiut conditions. The field water use efficiency (FWUE) and crop water use efficiency (CWUE) were higher under irrigation regimes 30% SMD (I_1) then the treatments. The calculated Kc and Ks values at different rice growth stages by various equations were irregular in both seasons. The maximum plant heights (86 and 87 cm) as well as grain yield (8.66 and 9.33 t $ha^{-1)}$ were obtained under irrigation regime at $I_1$with S_1 in 1st and 2nd season, respectively. Also, grain nitrogen % of grain was significantly affected by all treatments especially in the 2nd season.

Key words: Evapotranspiration, Water consumptive use, Water use efficiency, Irrigation regimes, Crop factor, Rice.

Introduction

Water management has become a crucial issue particularly in arid and semi-arid zones, which are characterized by scarce or limited water resources. Conserving water resources is a priority for the Egyptian Government by improving the irrigation systems. Rice is a semi aquatic crop plant that requires high amount of water for proper growth and development. It occupies about 22% of the planted area in Egypt during the summer season. Moreover, rice is an important export crop. The rice area is augmented during the last five years to about one and half million feddans. Therefore, Egyptian scientist succeeded in release new rice varieties suitable for drought conditions with high production to maximize the farmer's income. Nowadays, Nile water is not sufficient to congruent with the incredible population that need more water to irrigation new areas to secure their food and fibers. Therefore, water saving becomes argent demand to fact his problem through either prolonging irrigation intervals without any drastic effect on the grain yield, or growing drought tolerant varieties, which have a capability to grow under shortage of water (Mady, 2004). The amount of irrigation water should match evaporation from the soil and transpiration by the crop (plus any application inefficiency losses). The potential water savings in the field, when rice can be grown good as an upland crop, especially on soils with high seepage and percolation rates (Bouman and Toung 2001). In Asia, ‘‘upland rice’’ is already grown aerobically with minimal inputs in the upland environment, but mostly as a low-yielding subsistence crop to give stable yields under the adverse environmental conditions of the uplands (Lafitte *et al.*, 2002).

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Achieving high yields under irrigated aerobic soil conditions requires new varieties of ''aerobic rice'' that combine the drought-resistant characteristics of upland varieties with the high-yielding characteristics of lowland varieties (Lafitte *et al.*, 2002). It is well established fact that continuous flooding is not necessary for rice to achieve high yields. After seedling establishment phase, even in the absence of standing water in field, rice plant can extract soil water from the below surface soil around root zone (Lampayan*et al.*, 2015). Studies's findings of Bouman and Tuong 2001; Ghosh and Singh 2010; Qin *et al.*, 2010; Peng *et al.*, 2011 suggest that water saving technologies could increase crop water productivity without severe reductions in crop yield. Due to lack of fixed criteria for re-watering the plots under different soil and climatic conditions, AWD often result in over irrigation or under irrigation. It is difficult to decide when the best time to re water the rice crop. The number of days that the soil is left dry varies from 6-8 days for heavy soils and 4–5 days for lighter soils depending on the soil texture, crop stage, variety and weather Bouman *et al.,* and Yang *et al.*, (2007).Water deficit stress (WDS) is one of the main factor limiting rice production globally, as rice is more susceptible to WDS than other cereals. To increase rice productivity and to alleviate food insecurity and poverty it is urgent to develop WDS resistant rice cultivars. Stress response by rice crop is a complex phenomenon including biochemical and osmotic adjustments. WDS decreases plant growth by reducing cell division and cell elongation caused by turgor loss. It is mainly affected by climatic factors and is controlled by physiological functions of rice under submerged conditions (Lawlor andCornic 2002; Kato *et al.,* 2004; Tsubo*et al.*, 2007 and Chaves *et al.,* 2009). Zayed *et al.,* (2012) stated that rice bed planting and furrow irrigation gave high water use efficiency, high values saved water amount with considerable grain yield. Ndiiri*et al.,* (2012) found that the system of rice intensification (SRI) gave the highest values of yield and yield attributing traits as well as the highest values of root dry weight comparing with continues flooding for transplanted rice. Also, they reported that SRI showed 27% of save water versus continues flooding in transplanting rice. Producing high yield under irrigated systems requires large quantities of water. It is estimated that to produce 1 kg of rice grain, 2500 L of water is needed. Globally this equates to one third of the world's available fresh water being used for rice irrigation (Bouman, 2009).

Materials and Methods

The present investigation was carried out at The Experimental Farm, Faculty of Agriculture, Al-Azahar University, Assuit, Egypt (27° 12¯ 16.67˭ N latitude and 31° 09¯ 36.86˭ E longitude and at 51 m altitude) during the two growing seasons of 2013 and 2014. The experiment aims to study the effects of different irrigation regimes and seed rates on growth, yield, water consumptive use and water use efficiency (WUS) of Egyptian rice (*Oryza sativa,* L.) Orabi1. Evapotranspiration was estimated using some empirical formulas ET_o and was compared with the actual measured one ET_a. As well as their effects on plant growth parameters, yields and the crop factor (K_c).The experiment was laid out in stripe block design with three replicates and consisted of 12 treatments. The treatments were three irrigation regimes, with four seeding rates. The stripe blocks were used to express irrigation regimes (30, 60 and 85% soil moisture depletion from the available water, SMD, donated as I_1, I_2 and I_3, respectively) and they were bounded with buffer zone (3 m width) to avoid the horizontal seep age. The split units were assigned for seed rates (95.2, 119, 142.8 and 166.6 kg seed ha^{-1}, donated as S_1, S_2, S_3 and S_4 respectively).

The area of each plot was 20 m^2 (4 m in length and 5 m in width) planted in 1st May of both seasons. Rice plants were Harvested 140 days after planting.
The relevant physical and chemical properties of the investigated area were determined according to Klute (1986) & Page (1982) and they are shown in Table 1.

All the agriculture practices were done as usually as farmers do. Nitrogen application was 165 kg ha^{-1} as Urea 46.5%, Phosphorus at rate of 35 kg ha^{-1} as single super phosphate, and potassium at 54kg K_2O ha^{-1} as potassium sulfate.

Actual consumptive water use (Evapotranspiration):

The amount of water consumed from the root zone between each two successive irrigations as a water depth in cm, was calculated according to the equation of Israelson and Hansen (1962).

$$CU = D * Pb * \frac{Q_2 - Q_1}{100}$$

Where: CU = actual evapotranspiration D = the irrigation soil depth (cm) *P*b = bulk density of soil (gm/cm^3) Q_2 = the percentage of soil moisture at field capacity Q_1 = the percentage of soil moisture before irrigation.

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

a- Chemical properties									
Soil depth (cm)	O.M. (%)	$CaCO_3$ (%)	pH	SP%	ECe (dS/m)	SAR	Available nutrients (ppm)		
							N	P	K
0-30	1.3	3.60	7.80	82	1.10	4.03	77.0	10.5	310
30-60	1.15	3.10	7.82	81	1.15	4.04	68.5	10.1	295

b- Physical properties										
Depth (cm)	Percentage (%)			Texture Class	Moisture content θ v%		A.W. (%)	B_d (g/cm^3)	Inf. rate (cm/h)	H.C (m/day)
	Sand	Silt	Clay		F.C.	W.P.				
0-30	24.50	39.25	35.25	Clay Loam	41.0	21.0	20.0	1.29	0.15	0.058
30-60	25.00	39.00	36.00	Clay Loam	42.0	21.0	21.0	1.30		

O.M. = Organic matter pH= soil reaction SP = Saturation percent ECe = Salinity in soil past extract
SAR= Sodium adsorption ratio F.C. = Field capacity W.P.= Wilting point A.W.= Available water
B_d= Bulk density

To obtain the actual water consumptive use (ET_a), the soil moisture % was determined gravimetrically on dry basis just before and 24 hours after irrigation.

Daily water use values were obtained by dividing the water consumed in one irrigation period by its total days.

Reference evapotranspiration (ET_o) values were computed from weather data by using some of the empirical equations as it follows: The reference evapotranspiration ET_o of individual agroecological units are calculated by FAO Penman-Monteith method, using decision support software–CROPWAT 8.0 developed by FAO (2009), based on FAO Irrigation and Drainage Paper 56 (FAO 1998).

Hargreaves Method: According to Jensen *et al.* (1990) and Allen *et al.* (1998), the Hargeaves formula for estimating ET_o was as follows:

$ET_0 = 0.0023\, R_A TD^{0.5}(T+17.8)$ mmd^{-1}

where: R_A = extraterrestrial radiation in the equivalent evaporation units, from Table presented by Allen *et al.* (1998).

TD = the difference between mean monthly maximum and mean monthly minimum temperatures, (°C);

T = mean air temperature, (°C).

Turc Method: According to Jensen *el al.* (1990), Turc equation was presented as follows: For RH > 50%: $ET_0 = 0.013\left(\frac{T}{(T+15)}\right)(R_s + 50)$

For RH < 50%: $ET_0 = 0.013\left(\frac{T}{(T+15)}\right)(R_s + 50)\left(1 + \frac{50-RH}{70}\right)$

Where: T is the average temperature (°C) and R_s is solar radiation ($cal\ cm^{-2}d^{-1}$), RH is mean relative humidity (%)

Crop coefficient (Kc) is calculated as the dimensionless ratio of crop ET and the potential ET (ET_a and ET_o).

$$K_c = \frac{ET_a}{ET_0}$$

Where: ET_a= actual evapotranspiration measured for the grown crop in mm/day of each month, ET_o = potential evapotranspiration in mm/day for each month.

Water stress coefficient (Ks) was estimated as:

$$K_s = \frac{ET_{adj}}{ET_0}$$

Where: ET_{adj} = actual evapotranspiration measured for the grown crop(under soil moisture depletion SMD 60 and 85% treatments) (mm/day), ET_o = potential evapotranspiration(mm/day).
Crop Water utilization efficiency (WUE)The values of WUE for rice were calculated according to Vites (1965) as follows:

$$\mathrm{WUE} = \frac{\text{Seed yield (Kg/ha)}}{\text{Seasonal crop consumptive use (m3/ha)}}$$

Field Water utilization efficiency (FWUE):Water utilization efficiency is expressed as Kg seeds/m^3 of water applied.

Yield and yield components:

At harvest, ten randomly tillers were taken from each sub plot as a sample to determine plant height (cm), Panicle weight (g) and Number of grain/panicle. Panicles number/m^2 was numbered in the field. All sub plots were harvested individually to determine1000-grain weight(g), straw yield and grain yield(t/ha) and harvest index (%). After that, the grains content of nitrogen percentage was determined by using recommend by A. O. A. C. (1990).
Data were subjected to analysis of variance (ANOVA) using SPSS Statistics, Version 21(combine analysis was doing for ET_a and daily consumptive water use parameters)and means were compared by using $LSD_{at0.05}$.

Results and Discussion

Rice water relations:

Actual evapotranspiration (ET_a):

Data as shown in Table 2, indicate that ET_a at the different growth stages slightly increased in summer season of 2014 compared to that of 2013. This may be associated to some factors affecting evapotranspiration such as differences in climatic factors between the two seasons or the evaporative power of air. The high temperature would automatically have resulted in higher water consumptive use. Also, the highest Monthly values of ET_a were recorded in the mid growth stage (25 Jul. to 18 Aug.) followed by development (26May to 24 Jul.) and end stages (19 Aug. to 17 Sep.); the lowest values were recorded in the initial stage (1May to 25 May).

Table 2: Actual evapotranspiration (mm) as affected by soil moisture regime atdifferent rice growth stages during summer season of 2013 and 2014.

Treatments	Growth stage				Gross season (140 day)
Irrigation regimes	Initial (25 day)	Development (60 day)	Mid (25 day)	End (30 day)	
I_1	143.00	455.53	208.39	193.08	1000.00
I_2	153.87	432.31	189.07	181.69	956.94
I_3	141.79	399.70	181.51	179.42	902.42
F test	**	**	**	**	**
$LSD_{at0.05}$	1.32	3.66	1.56	1.05	4.08
F test for years	**	**	**	**	**

It is clear from the results in Table 2 that, ET_a values were decreased significantly by increasing irrigation intervals through all growth stages except, initial stage where increased with 60%soil moisture depletion (I_2) then decreased with 85%soil moisture depletion (I_3) compared to 30%soil moisture depletion (I_1).The seasonal ET_a values decreased significantly as the percentage of soil moisture depletion increased. The highest values of ET_a were obtained at 30%soil moisture depletion (I_1) and the lowest values were achieved at 85%soil moisture depletion (I_3)in almost all stages of growth as well as gross season. These results may be attributed to the high availability of water which in turn increases transpiration from vegetative growth of existed plants and evaporation from the soil surface by more water capillary movement. These results may be due to prevailing agronomic and climatic conditions (El-Bably *et al.*, 2007 and Abdullahi *et al.*, 2013).

Daily consumptive water use (mm)

Results in Table 3 shows that the daily water consumed decreased significantly by increasing irrigation intervals through all growth stages except, initial stage where increased with 60%soil moisture depletion (I_2) then decreased with 85%soil moisture depletion (I_3) compared to 30%soil moisture depletion (I_1).The seasonal daily water consumed values decreased significantly as the percentage of soil moisture depletion increased. The highest values of the daily water consumed were obtained at 30%soil moisture depletion (I_1) and the lowest values were achieved at 85%soil moisture depletion (I_3) in almost all stages of growth as well as gross season. The highest values of daily consumptive use were obtained under irrigation regime30% SMD (I_1)during almost growth stages and gross season, while the lowest values were obtained during all growth stages for irrigation regime85 % SMD (I_3). Results clearly show that daily consumptive water use started with low value during May. Thereafter, the daily ET_a rate increased to maximum value at August. During late August, the daily ET_a rate decreased and reached its minimum values at September. These results were found to be true in both seasons. The obtained results can be ascribed as that at May, the vegetation has not been established yet and most of the water loss was due to evaporation from the bare soil. Thereafter, as the vegetation growth increased during late May and June the rate of ET_a increased and reached its maximum rate during flowering and early Grain filling. During late July and August, the ET_a rate decreased when the leaves of the plants dried, and the rate reached its minimum values on September (harvesting time). These results may be due to prevailing agronomic and climatic conditions (El-Bably*et al.*, 2007 and Abdullahi, *et al.* 2013).

Table 3: Daily consumptive water use (mm) as affected by soil moisture regime at different rice growth stages during summer season of 2013 and 2014.

Treatments	Growth stage				Gross season (140 day)
Irrigation regimes	Initial (25 day)	Development (60 day)	Mid (25 day)	End (30 day)	
I_1	5.72	7.60	8.34	6.44	7.02
I_2	6.03	7.16	7.57	6.21	6.74
I_3	5.67	6.66	7.22	5.98	6.39
F test	**	**	**	**	**
$LSD_{at0.05}$	0.12	0.07	0.09	0.21	0.07
F test for years	NS	NS	**	**	**

Reference evapotranspiration (ET_o):

The values of ET_o (Table 4) were calculated using different empirical equations. The results show that the estimated seasonal ET_o values in both growing seasons followed the descending order of FAO Penman-Montithe >Turc> Hargreaves. The estimated ET_o value by FAO Penman-Montithe equation were estimated of the actual evapotranspiration (ET_a) by 3.9 and 1.4% in the first and second season, respectively under I_1(no water stress). The ET_o value estimated by Turc equation was less than that of the ET_a value by 18.40 and 18% in the first and second season, respectively under I_1. While, the estimated ET_o value by Hargreaves equation was less than that of ET_a by 20.70% and 22.2% in the first and second season, respectively under I_1.

Data of ET_o values estimated by different empirical equations in both seasons revealed that the ET_o values started small according to the small plant cover in the early stage. Then, they increased to reach their maximum values in mid-season (August) due to the maximum temperature and plant canopy, and then tended to decline again until the crop maturity due to crop canopy changes.

The above results clearly suggested that the FAO Penman-Montithe equation calculated ET_o efficiently and it could be used secure to grow rice crop under Assiut circumstances. Same results were reported earlier by Nasir *et al.* (2002), Hussain *et al*. (2003) and Abd El-Lattef (2013).

Table 4: Calculated reference evapotranspiration (mm) during rice growth stages using different empirical equations through the growing season of 2013 and 2014

Equation	Growth stage				Gross season (140 day)
	Initial (25 day)	Development (60 day)	Mid (25 day)	End (30 day)	
2013					
Corrected Penman	7.86	7.99	6.80	6.08	1028.34
Hargreaves	6.04	5.80	5.41	5.01	784.83
Turc	6.13	5.94	5.70	5.16	807.63
2014					
Corrected Penman	6.64	7.49	7.66	7.22	1024.06
Hargreaves	5.56	5.85	*5.63*	*5.14*	*785.38*
Turc	5.70	3.13	5.96	5.61	828.12

Water applied irrigation and water consumptive use

Amount of seasonal irrigation water applied (m^3/ha)for different treatments are shown in Figure1. In general, the applied amount of irrigation water decreased as the percentage of soil moisture depletion increased in both seasons. Irrigation at I_1 consumed the highest amounts of water applied (12693 and 12949 m^3/ha in the 1st and 2nd season, respectively). On the other hand, irrigation at I_3 consumed the lowest amount of water applied (11968 and 12067 m^3/ha in the 1st and 2nd season, respectively).

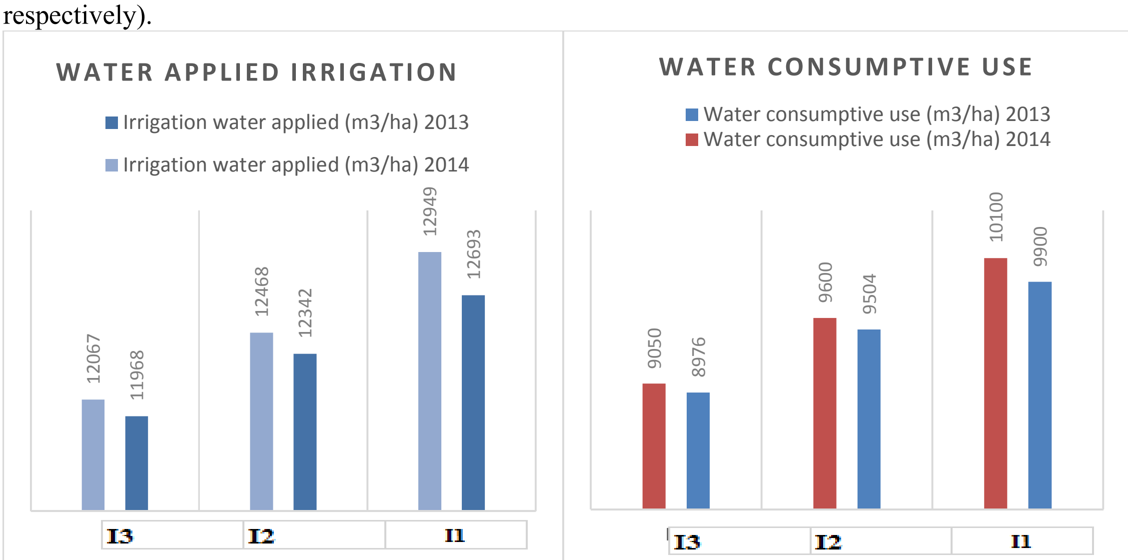

Fig. 1: Rice irrigation water applied and water consumptive use under various irrigation regimes in 2013 and 2014 season.

Field water use efficiency (FWUE) and Crop water use efficiency (CWUE):

The results in Table5 show that the irrigation regimes were significantly affected the field water use efficiency and Crop water use efficiency in both growing seasons. The obtained results indicated that the FWUE was higher under I_1. It is obvious that increasing the amount of applied irrigation water accompanied with increasing in total yield/ha but the seasonal ET_a was high enough to reduce the FWUE as the percentage of SMD increased. These values are comparable well with those reported for flooded rice in the Philippines (Bouman and Tuong 2001 and Tabbal *et al.* 2002). CWUE values were significantly affected by irrigation regimes based on different water deficit at both seasons where, it decreased by irrigation intervals increasing. The increase in crop water use efficiency was mainly due to the increase of available water resulted in an increase in total grain yield more than the increase of actual water consumptive use. It might be stated that decreasing the water consumptive use by increasing water stress caused a reduction in the attained grain yield that consequently decreased the value of CWUE. Water-deficit may occur early in the growing season or any time from flowering to grain filling, and the intensity of the stress depends on the duration and frequency of water-deficit (Wade *et al.* 1999).These results were in harmony with those obtained by Yasin *et al.* (2003) Mady, (2004).

Seed rates and the interactions between irrigation regime and seed rate did not exhibit any significant effect on FWUE and CWUE in both seasons.

Table 5: Field water use efficiency and crop water use efficiency under various irrigation regimes and seed rates for rice during 2013 and 2014 season.

Parameters	Field water use efficiency (kg/m^3)				Crop water use efficiency (kg/m^3)			
Season	2013				2013			
Treatments	Irrigation regime			Mean	Irrigation regime			Mean
Seed rate	I_1	I_2	I_3		I_1	I_2	I_3	
S_1	0.68	0.30	0.27	0.42	0.87	0.39	0.35	0.54
S_2	0.67	0.34	0.21	0.41	0.86	0.44	0.29	0.53
S_3	0.35	0.26	0.21	0.27	0.68	0.34	0.27	0.43
S_4	0.64	0.26	0.24	0.38	0.82	0.34	0.31	0.49
Mean	0.59	0.29	0.23	0.37	0.81	0.38	0.31	0.50
F test	I	S: NS	IxS: NS		I	S: NS	IxS: NS	
$LSD_{at0.05}$	0.02	--	--		0.03	--	--	
Season	2014				2014			
S_1	0.72	0.32	0.28	0.44	0.92	0.42	0.38	0.57
S_2	0.67	0.36	0.23	0.42	0.85	0.46	0.31	0.54
S_3	0.58	0.30	0.23	0.37	0.75	0.39	0.30	0.48
S_4	0.64	0.30	0.25	0.40	0.82	0.39	0.33	0.51
Mean	0.65	0.32	0.25	0.41	0.84	0.42	0.33	0.53
F test	I	S: NS	IxS: NS		I	S: NS	IxS: NS	
$LSD_{at0.05}$	0.03	--	--		0.04	--	--	

Crop coefficient (Kc):

The crop factor reflects all the crop characteristics, (sowing date, development rate and growing season duration) under certain climatic conditions. The crop coefficient was calculated by divided the ET_a value at I_1 treatment (with almost no water stress) by the obtained ET_o at various equations (Table 6) under different seed rate. Due to the variations in the crop characteristics throughout its growing season, Kc values for a given crop changes from sowing till harvesting. For rice crop under nearly non-stress conditions (I_1) the values of Kc were small under all seed rate. The Kc started to increase from the initial Kc value at the beginning and reached a maximum value (Kc mid) at the time of maximum or near maximum plant devolvement. During the late season period, as plants began to be mature, the Kc started again to decrease until it reached a lower value at the end of the growing period equal to Kc end. This tendency was observed for both growing seasons.

Table 6: Rice crop coefficient (kc) for different ETo equations during growth stages without water stress under various seed rates through two seasons

I_1						
Equation	Growing seeson	Growth stage				Seasonal
		Initial	Development	Mid	End	
FAO Penman-Monteith	2013	0.72	0.94	1.22	1.05	0.98
	2014	0.88	1.03	1.1	0.9	0.98
Hargreaves	2013	0.93	1.29	1.53	1.28	1.26
	2014	1.04	1.31	1.49	1.26	1.28
Turc	2013	0.92	1.26	1.45	1.24	1.22
	2014	1.02	1.25	1.41	1.15	1.21

At mid stage, the crop coefficient values indicated that the highest Kc mid was obtained when using the ET_o calculated by Hargreaves equation in both seasons. While the lowest value of Kc mid was obtained from ET_o calculated by FAO Penman in both seasons.

In general, the calculated Kc values at different rice growth stages by various equations were not always identical in both seasons. This may be due to that the differences of the hypothetical reference crop that calculated by FAO Penman equation relative to the crop canopy and aerodynamic resistance were more constant in both growing seasons than hypothetical reference crop that calculated by other equation. Same results were reported earlier by Lal *et al*. (2012) and Linquist*et al.* (2015).

Coefficient of water stress (Ks):

Soil water shortage may reduce soil water uptake and limit crop evapotranspiration. At field capacity, the depletion of water content from root zone is minimized. When soil water is extracted by evapotranspiration, the depletion increases, and the soil water stress will be induced. Stresses at different growth stages affected the obtained Ks values (estimated from ET_a at I_2& I_3 and ET_o data) that greatly lowered with the prolonged stress (Table 7). Seasonal averages of rice Ks values were almost similar under all seed rates. The obtained results indicated that the Ks values followed the same trend of Kc value either through the growth stages or under various seed rates (Table 7). The obtained results of Ks values for both seasons indicated that the FAO Penman equation was the best one to calculate ET_o for the two growing seasons. This may be due to that the differences of the hypothetical reference crop that calculated by FAO Penman equation relative to the crop canopy and aerodynamic resistance were more constant in both growing seasons than hypothetical reference crop that calculated by other equation.

Table 7: Rice crop coefficient (Ks) for different ETo equations during growth stages with water stress under various seed rates through two seasons.

I_2						
Equation	Growing seeson	Growth stage				Seasonal
		Initial	Development	Mid	End	
FAO Penman-Monteith	2013	0.76	0.89	1.11	1.01	0.94
	2014	0.91	0.96	0.99	0.86	0.93
Hargreaves	2013	0.99	1.23	1.39	1.23	1.21
	2014	1.09	1.23	1.35	1.21	1.22
Turc	2013	0.98	1.2	1.32	1.2	1.18
	2014	1.06	1.17	1.28	1.11	1.16
I_3						
FAO Penman-Monteith	2013	0.72	0.84	1.05	0.95	0.89
	2014	0.86	0.88	0.95	0.85	0.89
Hargreaves	2013	0.93	1.16	1.32	1.16	1.14
	2014	1.03	1.12	1.29	1.20	1.16
Turc	2013	0.92	1.13	1.25	1.12	1.11
	2014	1.00	1.07	1.22	1.10	1.10

Rice yield and yield attributes.

The obtained results in Table 8 show that plant height, panicle weight, number of grain/panicle and number of Panicle /m^2were significantly affected by irrigation regime in both seasons where, the highest values of this traits were recorded when the irrigation was applied at I_1. This may be due mainly to the availability of soil moisture at the soil irrigation at 30% soil moisture depletion from the available water. The obtained results agreed with those previously observed by Khakwani*et al.* (2005) and Azarpour*et al.* (2011).

Seed rates exhibited significantly effect on panicle weight and number of grain/panicle on the other hand, plant height and No. Panicle /m^2 did not exhibited any significant affect by seed rates in both seasons. The heaviest panicles (2.82 g for the two seasons) were obtained from seed rate 119 kg/ha (S_2) as well as the largest numbers of grain/panicle(128.81 and 125.88 grain/panicle for the first and second season, respectively)were obtained from the same seed rate. This is likely to be due to the optimal growth of vegetation under plant density of 119 kg / ha, resulting in increased photosynthesis, which reaches the ears and grains. This result is in consistent with those pointed by Harris and Vijayaragavan (2015).

Table 8: Plant height (cm), Panicle weight (g), Number of grain/panicle and No. Panicle /m2as affected by irrigation regimes and seed rates in 2013 and 2014 season.

Parameters / Treatments	Plant height (cm)		Panicle weight (g)		No. of grain/panicle		No. Panicle /m^2	
	2013	2014	2013	2014	2013	2014	2013	2014
I_1	82.04	83.92	2.96	3.00	135.82	133.03	271.70	282.77
I_1	70.84	72.42	2.49	2.49	117.58	114.90	145.60	160.76
I_1	72.75	74.92	2.58	2.61	110.21	110.96	107.01	115.15
F test	*	*	**	**	**	*	*	*
$LSD_{at.0.05}$	4.41	3.51	0.16	0.23	9.06	10.16	21.69	26.11
S_1	77.56	79.11	2.63	2.69	118.72	116.91	194.36	205.92
S_2	74.56	75.89	2.82	2.82	128.81	125.88	171.66	180.01
S_3	74.39	77.44	2.58	2.61	116.97	115.53	159.05	176.82
S_4	74.33	75.89	2.66	2.68	120.30	120.19	174.01	182.14
F test	NS	NS	**	**	**	*	NS	NS
$LSD_{at.0.05}$	--	--	0.10	0.12	6.172	7.80	--	--
I_1S_1	86.00	87.33	2.77	2.83	123.98	118.37	311.87	329.32
I_1S_2	78.67	81.00	3.47	3.47	155.48	151.92	244.58	248.92
I_1S_3	80.83	82.67	2.74	2.80	129.95	127.26	246.36	269.31
I_1S_4	82.67	84.67	2.85	2.91	133.86	134.57	283.99	283.52
I_2S_1	72.67	74.33	2.40	2.44	114.98	113.54	154.55	165.79
I_2S_2	70.67	72.00	2.53	2.53	123.39	119.95	166.56	176.54
I_2S_3	70.00	72.33	2.42	2.42	112.10	109.37	135.13	156.36
I_2S_4	70.00	71.00	2.59	2.58	119.84	116.75	126.16	144.34
I_3S_1	74.00	75.67	2.73	2.81	117.19	118.83	116.66	122.65
I_3S_2	74.33	74.67	2.47	2.45	107.57	105.78	103.83	114.57
I_3S_3	72.33	77.33	2.58	2.61	108.86	109.95	95.67	104.80
I_3S_4	70.33	72.00	2.53	2.56	107.21	109.26	111.88	118.56
F test	NS	NS	*	*	*	*	NS	NS
$LSD_{at:0.05}$	--	--	0.18	0.21	10.69	13.51	--	--

The interaction effect between irrigation regime and seed rates was significant for panicle weight and number of grain/panicle traits in 1st and 2nd season. The highest values of panicle weight 3.47g were obtained under I_1S_2 in the two seasons and the highest values similarly of no. of grain/panicle155.48and 151.92grain/panicle were obtained from the same treatment in 1st and 2nd season, respectively. Otherwise, plant height and No. Panicle /m^2 did not exhibited any significant effect in both seasons.

Results in Table 9 reveal that 1000-grain weight, rice straw and grain yields/ha and harvest index as well as nitrogen percentage in grain were significantly affected by irrigation regimes in both seasons.1000-grain weight and grain nitrogen content increased by increasing soil moisture depletion in both season where, the highest values of 1000-grain weight23.39 & 23.50 g and the highest values of grain nitrogen content 2.24 & 2.23% were obtained from irrigation treatment I_3(85%soil moisture depletion from available water) for the first and second season, respectively. It makes sense that, the shortage of grain number/plant increases the weight of grain and its components as a result of increasing its abundance. On the contrary, straw and grain yields as well as harvest index decreased by increasing soil moisture depletion in both season where, the highest values of this traits were obtained when irrigation regime was applied at I_1(30%soil moisture depletion from available water).It could be concluded that rice grain increased by increasing available soil moisture level. The negative effect of drought on grain yield concurs with the results of previous studies (Efisue 2006 ; Ndjiondjop *et al.* 2010).

Seed rates didn't exhibit any significantly effect on all parameters in Table 9 except, grain nitrogen content in both season. Where, the highest percent 2.20 and 2.19 % were obtained when seed rate at119 kg/ha (S_2) were applied in the first and second season, respectively.

1000-grain weight was significantly affected by the interaction between irrigation regime and seed rates in the two seasons whereas, grain nitrogen content was significantly affected by the interaction between irrigation regime and seed rates in second season only. The highest 1000-grain weight 23.70 and 24.00 g were recorded from I_3S_3 in the first season andI_1S_1 in the second season, respectively. The highest percent of grain nitrogen content was measured whenI_3S_3 was applied. Otherwise, the interaction between irrigation regime and seed rates hadn't any significant effect on straw& grain yields/ha and harvest index in both season.

Table 9: 1000-grain weight(g), Straw yield (t/ha),Grain yield (t/ha), Harvest index (%) and Grain Nitrogen content %as affected by irrigation regimes and seed rates in 2013 and 2014 season.

Parameters / Treatments	1000-grain weight(g)		Straw yield (t/ha)		Grain yield (t/ha)		Harvest index (%)		Grain Nitrogen content %	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
I_1	21.78	22.63	11.71	11.28	8.00	8.44	40.52	42.78	2.07	2.09
I_2	21.14	21.74	9.87	9.60	3.61	3.99	26.69	29.36	2.14	2.16
I_3	23.39	23.50	8.35	8.15	2.76	3.00	24.85	26.92	2.24	2.23
F test	**	**	*	*	*	*	**	**	**	**
$LSD_{at.0.05}$	0.57	0.66	0.94	0.89	0.31	0.39	1.71	2.00	0.07	0.05
S_1	22.18	23.05	10.08	9.72	5.18	5.60	32.22	34.73	2.13	2.15
S_2	21.93	22.41	10.36	10.18	5.09	5.29	31.00	32.45	2.20	2.19
S_3	22.12	22.65	9.59	9.39	4.16	4.68	28.89	31.79	2.17	2.18
S_4	22.17	22.38	9.87	9.41	4.73	4.99	30.64	33.10	2.09	2.11
F test	NS	NS	NS	NS	NS	NS	NS	NS	**	**
$LSD_{at.0.05}$	--	--	--	--	--	--	--	--	0.04	0.03
I_1S_1	22.33	24.00	11.83	11.50	8.66	9.33	42.26	44.80	2.05	2.10
I_1S_2	22.37	22.90	12.33	12.17	8.49	8.63	40.77	41.50	2.13	2.14
I_1S_3	21.10	22.00	10.57	10.16	6.74	7.53	38.96	42.58	2.08	2.10
I_1S_4	21.30	21.63	12.10	11.29	8.10	8.25	40.09	42.23	2.00	2.01
I_2S_1	20.87	21.53	9.87	9.53	3.70	4.04	27.25	29.76	2.14	2.18
I_2S_2	20.50	21.17	9.83	9.53	4.20	4.45	29.91	31.82	2.20	2.19
I_2S_3	21.57	22.17	9.83	9.72	3.27	3.78	24.94	28.02	2.15	2.16
I_2S_4	21.60	22.07	9.93	9.60	3.25	3.70	24.67	27.82	2.06	2.11
I_3S_1	23.33	23.63	8.53	8.13	3.18	3.43	27.15	29.64	2.20	2.18
I_3S_2	22.93	23.17	8.93	8.85	2.57	2.80	22.32	24.03	2.27	2.25
I_3S_3	23.70	23.77	8.37	8.30	2.47	2.73	22.77	24.77	2.27	2.27
I_3S_4	23.60	23.43	7.58	7.33	2.83	3.03	27.15	29.24	2.20	2.21
F test	*	*	NS	NS	NS	NS	NS	NS	NS	*
$LSD_{at:0.05}$	1.10	1.10	--	--	--	--	--	--	--	0.06

It can be concluded that:

1- Varieties of rice tolerant to droughtcan be grown successful under Assiut governorate condition.
2- FAO Penman-Monteith equation calculated reference evapotranspiration (ET_o) for rice crop efficiently and it can be used secure to grow it under Assiut circumstances.
3- The seasonal actual evapotranspiration (ET_a) for grown rice crop is 1000mm (140 day).

4- Expose rice crop for irrigation stress negatively affected its yield.
5- Seed rates of rice crop does not affect its yield.
6- The seasonal crop coefficient (k_c) was 0.98 as calculated by FAO Penman-Monteith equation (2014).

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