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Effect of Water Deficit at Critical Physiological Stages of Rice on WUE and Productivity

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ABSTRACT

Water plays a prominent role in crops production. Field experiments were conducted at El-Karada Research Station, Kafr El-Sheikh, Egypt during summer seasons of 2014 and 2015. The experiment investigated the effect of water deficit at different critical physiological stages to inspect the impacts of water withholding on water use efficiency (WUE), plant growth and yield of some rice cultivars. Results revealed that the growth characteristics as well as grain yield and its attributes were decreased by the irrigation withholding treatments at any growth stages in both seasons of the study. Continuous flooding (CF) throughout the grown seasons led to the highest values of growth parameters and grain yield followed by water withholding 12 days at mid-tillering(MT), while the lowest values obtained when the plants were subjected to water stress 12 days at heading (H) and panicle initiation (PI) stages. Water stress at MT stage gave the highest values of WUE (0.810 and 0.819 kgm^{-3}) with the lowest values of yield reduction (5.14 and 4.30 %) and its water save was amounted to be (6.37 and 6.74 %) in both seasons, respectively. The results also revealed that the Egyptian hybrid 1 rice cultivar surpassed the other two studied cultivars which is more tolerant to water stress as well as recorded the highest water use efficiency. It could be concluded that water deficit at both PI and H stages must be avoided to obtain considerable rice grain yield. In case of severe shortage of water resources, water withholding 12 days at MT stage could be applied due to its tolerant of WUE as well as reduction of the yield.
Keywords: Rice, Critical stages, Water saving, Withholding and WUE

INTRODUCTION

In worldwide countries including Egypt, water stress is a limiting factor in agriculture production. This could done by preventing a crop from reaching the genetically determined theoretical maximum yield. In plants, a better understanding of the morphological and physiological basis of changes in water stress resistance could be used to select or create new varieties of crops to obtain a better performance under water stress conditions. Through description of some aspects of drought induced effect of drought stress on morphological, physiological yield and its associated traits in rice (Singh *et al*., 2012). Also, as reported in International Rice Research Institute (IRRI) knowledge bank by 2025; 15-20 million hectares of irrigated rice will suffer from some degree of lack of water. Aware of the precarious state resources of water are facing and concerned about what its impact will be on rice production systems, IRRI continually explores, develops, and promotes strategies and technologies which farmers could adapt to help them improve their water management and productivity. However, Nile River constitutes 98% of Egypt's total resources of limited water. The amount of water allocated to Egypt is 55.5 billion m^3 as agreed in the 1959 treaty. Average annual consumption of fresh water is 601.9 m^3/ capita. Since rice consumes large amount of water being a semi-aquatic plant, the main challenge facing rice development is to find out means to produce more rice with less water. Many attempts and hard efforts has been done by rice breeders and agronomists to maximize productivity with less water consumptive and less reduction in rice yield under less water use. Water withholding at insensitive growth stage during rice life cycle is one way for water saving. Therefore, developing new technologies for water save in paddy fields without yield reduction is needed for ensuring food security. EL-Ekhtyar (2004) found that drought stress at any growth stage of rice and their combination had marked significant effect on dry matter production, leaf area index, chlorophyll content and heading date. Prolonging irrigation interval from three to nine days significantly decreased chlorophyll content, leaf area index, yield attributing traits and rice grain yield. The irrigation intervals of 3 and 6 days produced the highest rice grain yield and most of grain yield components as reported by Zayed *et al*. (2007), El Refaee *et al*. (2008 and 2012), Majied (2012) and EL-Ekhtyar (2014). In pot experiment, water tension of 1500 kPa as considered for permanent wilting point is not suitable for rice. Therefore, plant available water (PAW) cannot be a suitable soil-water criteria for rice plants that are sensitive to water deficit. Furthermore, it is concluded that local variety is very sensitive to mild and severe-drought stress during reproductive stage, (Davatgar N. *et al*., 2009).

Furthermore, rice normally requires a water application of about 1900 mm, an amount much higher than other crops. Cotton, for example, requires an application of about 1380 mm and maize requires about 1000 mm. The cultivation of rice in the summer season has expanded significantly from about 420×10^3ha in 1987 to about 654.4×10^3ha in 1999 to about 756×10^3 ha in 2014 (RRTC, 2015). Water for rice irrigation in summer season is provided to farmers through irrigation canals on the basis of a rotation, which consists of 4 days "on" and 6 days "off" (4/6 rotation). The normal duration of the rice water rotation is from May 1 to October 15. The irrigation rotation for non–rice planting areas (winter crops) is 5 days "on" and 10 days "off" (5/10 rotation). The normal duration for the non–rice rotation is from mid-October to end of April. Less amount of irrigation water was used when an irrigation interval of every 12-days was practiced for rice. Regarding water use efficiency, it decreased significantly as irrigation periods increased and varied among different varieties (Abou El-Hassan, 1997). Abou El-Hassan *et al*., (2006) recommended that the optimum irrigation interval for paddy rice is 6 days. Through irrigation every 6 days, significant amounts of water can be saved (8.6% for Sakha 101 and 13.7% for Giza 177). However, 50% of the amount of water diverted to rice fields is consumed through evapotranspiration and the rest is lost due to percolation (EWUP, 1983). Nevertheless, efforts had been initiated in Egypt to control soil salinity level from 1960 through implementation of subsurface drainage in Egypt. However, the modified drainage to reduce rice water percolation are tested and reported (Wahba *et al*., 2008). Analogously, the scope of this research was to investigate the impacts of water stress at different critical physiological stages of rice growth, taking into consideration the productivity and water use efficiency. The study also addresses the possibilities of water saving scenarios which have the lowest impacts on rice yield.

MATERIALS AND METHODS

Two field trails were tested during the summer season of 2014 and 2015 at Kafr El-Sheikh, El-Karada Experimental Research Station, which is located in northern Nile Delta, Egypt, as shown in Figure 1. .

The meteorological data for the studied location is presented in Figure 1. The experiments were arranged in strip plot design with four replicates. The data were statistically analyzed using Stat-View software (SAS, 2002). The treatment means were compared using Duncan's multiple range test, Duncan (1955). The main treatments are devoted into three water withholding for 12 days at various growth stages mid-tillering(MT), panicle initiating (PI) and heading (H)) as well as continuous flooding (CF) treatment namely; W-MT, W-PI, W-H and CF, respectively. Three rice crop varieties (short duration) namely: Egyptian Hybrid 1(135 days), Giza 179 (125 days) and Giza 178 (135 days) were selected as a sub treatment.

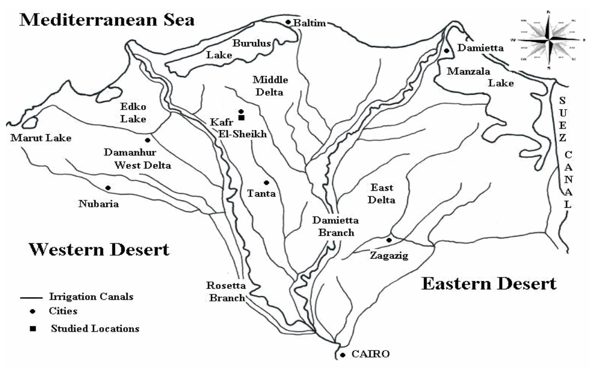

Figure 1. Map of Egypt showing the location of the experimental field

Table 1. Monthly meteorological data during summer seasons at Kafr El-Sheikh (2014-2015)

Month	Air temperature (°C)			Relative humidity (%)			Wind velocity (km d^{-1})	Pan Evaporation (mm)
	Max.	Min.	Mean	Max.	Min.	Mean		
Summer 2014								
May	30.5	19.6	25.0	77.2	48.6	62.9	98.9	587.1
June	32.7	20.6	26.7	52.3	86.2	69.3	82.3	655.5
July	33.2	23.6	28.4	83.2	55.1	69.2	97.9	772.9
Aug.	34.1	21.8	28.0	92.4	53.5	73.0	99.0	813.5
Sept.	32.5	20.8	26.7	87.6	52.2	69.9	89.2	664.5
Summer 2015								
May	30.2	18.8	24.5	77.3	46.1	61.7	114.6	715.0
June	30.9	21.4	26.2	78.8	51.2	65.0	105.3	695.3
July	33.0	22.4	27.7	85.2	54.3	69.8	97.3	686.4
Aug.	35.1	25.0	30.1	83.8	51.7	67.8	91.2	814.7
Sept.	34.6	23.8	29.2	82.7	46.5	64.6	98.3	663.7

The soil of the experiment sites is clayey in texture. Soil samples were taken from soil layers of 0-20, 20-40 and 40-60 cm, respectively, and analyzed to obtain soluble cations and anions, and electric conductivity (*EC*). *EC* was determined in the field using portable EC-meter. The soil chemical properties before planting and after harvesting are presented in Table 2. All agricultural operations followed were the same for all treatments as recommended by the Agric. Res. Center (ARC) and Rice Research and Training Center (RRTC, 2015) Egypt. Each plot field experiment size was 4×5m with precise land leveling carried out prior to pre-germinated seeds were broadcasted in the nursery on 2ndand 5thof May in 2014 and 2015 seasons, respectively. Seeds at the rate of 124 kg /ha were soaked in excess of water for 24 hours and further incubated for another 36 hours to enhance germination. Two seedlings 25 days old were transplanting at 20x20cm distance between hills and rows. Each irrigation treatment was tightly separated by ditches with 2-m wide and 1-m depth to isolate each other. Plant samples of five hills were randomly collected from each plot at the end of drought stress treatments to estimate chlorophyll content (SPAD value) and leaf area index (LAI) according to Yoshida *et al*. (1976).LAI is the ratio between the leaf-area (cm^2) of the plant divided by ground area occupied by the plant (cm^2). Chlorophyll content was estimated by chlorophyll meter (Model Li3000L). At harvest, panicles of five random hills from each plot were counted, then converted to number of panicles m^{-2} and plant height (cm) was measured. Ten main panicles from each plot were randomly packed to determine number of total grains panicle^{-1}, number of filled grains panicle^{-1}and 1000-grain weight. Area of 2m^2 from the central in each plot were harvested, dried, threshed, then grain yields were determined at 14 % moisture content and converted into t.ha^{-1}.

The following water parameters were also studied:

- Amounts of water applied (mm ha^{-1}) were measured and recorded using calibrated water meter attached to the irrigation pump unit. The electrical conductivity (*EC*) of irrigation water was 0.39dS m^{-1}, while the measured sodium adsorption ratio (*SAR*) was 2.99.
- Water use efficiency (g m^{-3}) is the weight of marketable crops produced (g) per volume unit of applied water (m^3) (Michael, 1978).
- A tank with 60 cm diameter and 110 cm length was used to determine rice water consumption. The tank had been placed in an experimental field in each site in

order to be surrounded by buffer area of paddy, representing the actual microclimate. Three tanks were used for the measurement of consumptive use of water for each variety of rice crop. The first tank has a bottom wall, and rice plants were grown on soils in the tank to measure evapotranspiration. The second tank also has a bottom wall but no plants were grown on soils in the tank to measure evaporation from water surface. The third one has no bottom and rice plants were grown in it to measure both evapotranspiration and percolation. At the beginning of observation, water level in each tank was set at 10 cm deep above the soil surface. Water level in each tank was measured daily to determine water losses, which was being compensated to maintain the desired level. Rice plants were transplanted from the nursery bed to the two tanks on the same day of transplanting in the experimental field.

Table 2. Chemical characteristics of the soil before planting and after harvesting for various treatments in the experimental site

Treatment	Soil depth (cm)	$EC_{1:5}$ (dS m-1)	Cation (meq L^{-1})				Anion (meq L^{-1})			$SAR_{1:5}$
			Na^+	K^+	Ca^{+2}	Mg^{+2}	HCO^{-1}	Cl^-	SO_4^{-2}	
Before Planting	0-20	2.71	13.5	0.5	3.6	7.7	6.95	5.35	13	6.038
	20-40	2.92	15.7	0.6	4.7	7.1	7.0	8.8	12.3	6.464
	40-60	3.40	18.9	0.6	5.4	7.4	7.4	9.5	14.2	7.470
CF	0-20	2.9	15.9	0.6	4.9	7.2	7.3	7.2	14.1	6.463
	20-40	3.2	17.1	0.6	5.3	7.4	7.2	9.2	14.0	6.786
	40-60	3.6	18.9	0.65	4.4	7.0	8.05	9.8	14.2	7.560
W-MT	0-20	3.0	17.8	0.65	5.9	9.2	10.0	9.0	14.6	6.473
	20-40	3.2	17.5	0.6	5.3	7.9	8.6	8.7	14.0	6.809
	40-60	3.6	16,9	0.6	4.4	7.0	8.0	7.4	13.5	7.071
W-PI	0-20	3.1	16.9	0.6	4.6	7.5	7.3	7.0	15.3	6.870
	20-40	3.2	17.4	0.6	5.3	7.9	8.6	9.45	13.2	6.770
	40-60	3.4	18.5	0.65	5.7	8.2	9.0	9.2	14.9	7.008
W-H	0-20	3.0	16.3	0.6	4.5	7.2	7.1	7.3	14.2	6.736
	20-40	3.1	17.1	0.6	5.1	7.7	8.4	9.2	12.9	6.759
	40-60	3.3	18.2	0.65	5.6	8.2	9.4	10.0	13.3	6.920

RESULTS AND DISCUSSION

Growth Parameters

Data listed in Table 3 revealed that the water withholding at various growth stages significantly influenced the studied growth parameters under such condition in both seasons. Prolonging irrigation intervals up to 12 days declined growth of the tested rice cultivars in 2014 and 2015 seasons. Continuous flooding gave the highest means of tested rice growth characteristics, plant height (cm), leaf are index (LAI) and chlorophyll content in both seasons. While, the W-MT stage treatments slightly affected rice growth traits. Analogously, water withholding 12 days at PI and H stages provide the lowest values of growth parameters in 2014 and 2015 seasons. This is due to water stress increased osmotic pressure resulted in high water potential inside plant cells, low water content, low photosynthesis rate and low metabolism process. Furthermore, the water stress might affect cell division and elongation resulted short plants, narrow leaves leading to small leaf area index. Low water content of leaf induced by water stress might destroy chlorophyll pigments resulted in low chlorophyll content led to low photosynthesis and dry matter production. Water stress might increase antioxidants releasing in plant cell which damaged the cell membranes and the protein shrinking as a result of water imbalance. Under water stress, the respiration rate might be increased resulted in more water and energy losses against anabolism and ultimately induced starvation and very low growth rate. Similar analysis had been reported by *Nour et al. (1994 b), El-Ekhtyar (2004), El-Saka (2013) and Nada, A.M. (2016).*

Data listed in Table 3 showed that the three tested rice cultivars significantly influenced the growth; plant height, LAI and chlorophyll content. Egyptian hybrid 1 rice cultivar gave the highest values of the studied growth characters followed by Giza178 rice cultivar. While, the lowest values obtained from Giza 179 rice cultivar except LAI the lowest values obtained from Giza 178 rice cultivar regarding the above mentioned traits during 2014 and 2015 seasons. Water stress might also affect rice roots growth and its capability of nutrient and water absorption. The water stress affected plant phenology because the recovery period after each cycle of stress and watering resulted in delaying or accelerating heading date based the intensity of water stress and rice variety. *El-Ekhtyar (2004)* reported that under drill-seeded rice, three tested rice cultivars, namely, Sakha 101, Giza 178 and Giza182, significantly varied in their dry matter production, LAI, chlorophyll content and heading date. However, Giza 178 rice cultivar performed better concerning the above mentioned criteria, followed by Sakha 101.

The interaction between water withholding and rice cultivars had significant effect on plant height, LAI and chlorophyll content in both seasons of study as presented in Table 4. Generally, the best combinations in this study were obtained by CF and Egyptian hybrid 1 rice cultivar. This combination gave the highest values of the previous mentioned traits. While, the lowest values of plant height and chlorophyll content recorded between water withholding at PI stage and Giza179 rice cultivar.

The water withholding at H stage and Giza 178 rice cultivar gave the lowest values of LAI in 2014 and 2015 seasons. In this concern, it was clear that Egyptian hybrid 1 rice cultivar is considered as more drought tolerant because it less affected by water withholding at various growth stages, while, Giza 179 and Giza 178 rice cultivar are intermediated.

Table 3. Growth patterns of some rice cultivars as influenced by water withholding treatments during 2014 and 2015 seasons.

Treatments	Plant height (cm)		Leaf area index (LAI)		Chlorophyll content (SPAD value)	
	2014	2015	2014	2015	2014	2015
water withholding (I):						
CF	98.93a	99.13a	6.89a	7.01a	40.47a	41.26a
W- MT	97.53b	96.53b	6.30b	6.55b	34.73b	36.00b
W- PI	92.1d	93.07d	4.88d	5.04d	28.13d	30.48d
W- H	95.07c	94.43c	5.18c	5.28c	31.30c	3356c
F. Test	**	**	**	**	**	**
Rice cultivars (CV):						
Egyptian Hybrid 1	102.70a	102.80a	6.55a	6.82a	38.11a	39.40a
Giza 179	91.68c	91.88c	5.72b	5.73b	28.23c	30.46c
Giza 178	93.34b	92.70b	5.17c	5.36c	34.63b	36.11b
F. Test	**	**	**	**	**	**
I x K Interaction:	*	**	**	**	**	**

Means: followed by the same litter (s) are not significantly different, according to DMRT.
*** and** And N.S.: Significant at 0.05 and 0.01 levels and not significant, respectively.**
CF: continuous flooding, W-MT: withholding 12 days at mid- tillering, W-PI: 12 days at panicle initiation and W-H: 12 days at heading.

Table 4. Water withholding treatments and rice cultivars interaction on plant height (cm), LAI and chlorophyll content (SPAD value) during 2014 and 2015 seasons

water withholding		Rice cultivars (cv)					
		2014			2015		
		Hybrid 1	Giza 179	Giza178	Hybrid 1	Giza 179	Giza 178
Plant height (cm)	CF	105.40a	95.30de	96.10d	106.20a	95.40e	95.80e
	W- MT	104.60a	93.10f	94.88e	103.80b	92.60f	93.20f
	W- PI	98.40c	87.60i	90.30h	99.70d	88.30h	91.20g
	W- H	102.40b	90.70h	92.10g	101.50c	91.20g	90.60g
F. Test		*	**	**	*	**	*
LAI	CF	7.48a	6.85b	6.34c	7.60a	6.80c	6.63cd
	W- MT	6.85b	6.19c	5.86d	7.29b	6.36e	6.00f
	W- PI	5.62e	5.03f	4.00i	5.90f	5.00g	4.21i
	W- H	6.26c	4.80g	4.47h	6.48	4.77h	4.60h
F. Test		**	**	**	*	**	**
Chlorophyll content (SPAD value)	CF	44.75a	33.46f	43.20b	45.10a	35.18f	43.50b
	W- MT	38.92c	29.40i	35.86e	40.25c	30.58h	37.16e
	W- PI	31.88g	24.45l	28.06j	33.80g	27.74i	29.90h
	W- H	36.88d	25.60k	31.41h	38.46d	28.35i	33.88g
F. Test		**	**	**	**	**	**

Means: followed by the same litter (s) are not significantly different, according to DMRT.
**** And N.S.: Significant at 0.05 and 0.01 levels and not significant, respectively.**

Yield and yield attributing characteristics

Results of variation analysis show that the measured properties of panicles number/m^2, number of filled grains per panicle, 1 thousand grain weight (g) and grain yield t/ha had a significant difference in water withholding treatments as shown in Table 5. Water stress12 days at any growth stage significantly reduced the yield attributes.

CF gave the highest values of panicles number/m^2; 1000-grain weight (g) and grain yield (t/ha)followed by W-MT stage treatment, while, the lowest values were produced by W-PI stage treatment. Regarding number of filled grains /panicle, the lowest values were obtained when rice plants subjected to water stress at W-H stage followed by water stress at W-PI stage in both seasons of study.

Table 5showed that the three tested rice cultivars significantly influenced the yield and yield attributing characteristics; number of panicles/m^2, number of filled grain/panicle,1000-garin weight (g) and grain yield (t/ha). Egyptian hybrid 1 rice cultivar gave the highest values of number of filled grain/panicle followed by Giza 179 rice cultivar while, the lowest values recorded by Giza 178 rice cultivar. Egyptian hybrid1 rice cultivar indicate the highest values of grain yield (t/ha) followed by Giza 179 rice cultivar while the lowest values were obtained by Giza 178 rice cultivar. Giza 179 rice cultivar gave the highest values of 1000-garin weight (g) followed by Egyptian hybrid 1 rice cultivar while the lowest values were obtained by Giza178 rice cultivar. Regarding, number of panicles/m^2, the highest values obtained from Egyptian hybrid1 rice cultivar followed by Giza179 rice cultivar during 2014 and 2015 seasons. The varietal differences might be due to the genetic background. Prolongation of irrigation intervals have a significant effect on yield and its components of rice as reported by Nour *et al*.(1996), Halil, S. and N. Beser (1997), Khafaga,E.E.E.; *et al*. (2006) and Farooq, M.; *et al* (2009).

The interaction between water withholding and rice cultivars had significant effect on number of panicles/m^2, number of filled grain/panicle,1000-garin weight (g) and grain yield (t/ha) in both seasons of study (Table 6).

Generally, the best combinations between CF and Egyptian hybrid 1 rice cultivar produce the highest values of the previous mentioned traits except 1000-garin weight (g) which recorded by the combinations between Giza 179 rice cultivar and CF treatment. The combinations between W-PI stage treatment and Giza179 rice cultivar gave the lowest values of number of panicles/m^{2}and number of filled grain/panicle. While, the W-H stage and Giza 178 rice cultivar gave the lowest values of 1000-garin weight (g) in both seasons of study. In addition, W-PI stage treatment was more affected on the above mentioned treats than others. In this concern, it was clear that Egyptian hybrid 1 rice cultivar is considered as more drought tolerant because it less affected by water withholding at various growth stages, while, Giza 179 and Giza 178 rice cultivar are intermediated.

Table 5. Grain yield and yield components of some rice cultivar as influenced by water withholding treatments during 2014 and 2015 seasons

Treatments	Number of panicles.m^{-2}		Number of filled grains/panicle		1000-grain weight (g)		Grain yield (t.ha^{-1})	
	2014	2015	2014	2015	2014	2015	2014	2015
water withholding (I):								
CF	521.70a	530.33a	141.93a	14498a	25.06a	25.31a	11.68a	11.85a
W- MT	476.00b	492.70b	138.63b	140.70b	23.99b	24.58b	11.08b	11.34b
W- PI	381.30d	428.33d	134.70c	133.17c	23.01d	23.46d	1035d	10.38d
W- H	431.30c	445.67c	120.90d	126.87d	23.27c	23.71c	10.61c	10.84c
F. Test	**	**	**	**	**	**	**	**
Rice cultivars (CV):								
Egyptian Hybrid 1	489.75a	510.25a	149.05a	152.54a	25.09b	25.43b	12.24a	12.51a
Giza 179	409.50c	433.00c	130.30b	131.75b	26.14a	26.33a	10.46b	11.00b
Giza 178	458.50b	479.50b	122.78c	125.00c	20.27c	21.04c	10.10c	9.80c
F. Test	**	**	**	**	**	**	**	**
I x (CV) Interaction:	**	**	**	**	**	**	**	**

Means: followed by the same litter (s) are not significantly different, according to DMRT.
***, ** and N.S.: Significant at 0.05 and 0.01 levels and not significant, respectively.**

Table 6. Water withholding treatments and rice cultivars interaction on number of panicles.m^{-2}, No. of filled grains/panicle, 1000-grain weight (g) and grain yield (t.ha^{-1}) during 2014 and 2015 seasons

water withholding (I):		Rice cultivars (cv) 2014 Hybrid 1	2014 Giza 179	2014 Giza178	2015 Hybrid 1	2015 Giza 179	2015 Giza 178
No. of panicles.m^{-2}	CF	560^a	467e	538b	568a	482d	541b
	W- MT	511c	431f	486d	536b	440e	502c
	W- PI	420f	344i	380h	449e	410g	426f
	W- H	468e	396g	430f	488d	400h	449e
No, of filled grains/panicle	CF	157.8a	138.40	129.6g	160.8a	140.8e	133.4g
	W- MT	153.7b	134.8e	127.4h	156.8b	135.6f	129.7h
	W- PI	149.6c	131.3f	123.2i	148.4c	129.8h	121.3i
	W- H	135.1e	116.7j	110.9k	144.2d	120.8i	115.6j
1000-grain weight (g)	CF	26.08b	27.46a	21.63g	26.13c	27.69a	22.10g
	W- MT	25.61c	26.14b	20.23h	25.70d	26.38b	21.66h
	W- PI	24.18f	25.60c	19.24j	24.77f	25.61d	20.00j
	W- H	24.49e	25.36d	19.96i	25.10e	25.62d	20.41i
Grain yield (t.ha^{-1})	CF	13.18a	11.15e	10.71f	13.27a	11.80d	10.47g
	W- MT	12.53b	10.42g	10.28h	12.72b	11.17e	10.14i
	W- PI	11.41d	10.21h	9.43j	11.82d	10.66f	8.65k
	W- H	11.83c	10.06i	9.95i	12.24c	10.37h	9.91j

Means: followed by the same litter (s) are not significantly different, according to DMRT

Water relations and soil-salinity

Data presented in Table 2 showed that there is no effect of water withholding treatments on soil salinity. While data listed in Table 7 refers that irrigation intervals had marked variation in total applied water, water save%, yield reduction and water use efficiency in both seasons. CF treatment received the highest values of total applied water (14611 and 14842m^3/ha), while the W-PI treatment recorded the lowest values of total applied water. The water W-PI treatment gave the maximum amount of water save (7.82 and 8.13 %) while, the W-H stage treatment gave the lowest amount of water save (4.48 and 4.72%) in both seasons of study. The highest yield reduction recoded (9.16 and 8.52%) using W-H stage, while, the lowest yield reduction (5.14 and 4.30%) obtained from W-MT stage treatment. However, the highest mean of WUE (0.810 and 0.819 kg/m^3) was obviously recorded by the water W-MT stage. While, the lowest values of WUE (0.760 and 0.767 kg/m^3) were obtained from W-H stage treatment. Therefore, water W-MT stage treatment could be recommended based on WUE and other water relations (Table 8 and Table 9*)*.

Table 7. Water applied for 25-days before starting water withholding treatments, water applied through irrigation treatments and total water applied ($m^3.ha^{-1}$)

Treatments	Water applied before treatments($m^3.ha^{-1}$)		Water applied trough treatments ($m^3.ha^{-1}$)		Total water applied ($m^3.ha^{-1}$)	
	2014	2015	2014	2015	2014	2015
water withholding (I):						
CF			10809	10873	14611	14842
W- MT	3802	3969	9884	9872	13686	13841
W- PI			9667	9667	13469	13636
W- H			10154	10172	13956	14141

Table 8. Water relations of some rice cultivar as affected by water withholding treatments during 2014 and 2015 seasons

Treatments	Total water ($m^3.ha^{-1}$)		Grain yield ($t.ha^{-1}$)		Yield reduction (%)		Water saved (%)		WUE ($kg.m^{-3}$)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
water withholding (I):										
CF	14611	14842	11.68 a	11.85 a	--	--	--	--	0.799	0.798
W- MT	13686	13841	11.08 b	11.34 b	5.14	4.30	6.33	6.74	0.810	0.819
W- PI	13469	13636	10.35 d	10.38 d	11.39	12.41	7.82	8.13	0.768	0.761
W- H	13956	14141	10.61 c	10.84 c	9.16	8.52	4.48	4.72	0.760	0.767

Table 9. The interaction of water withholding treatments and rice cultivars on WUE ($kg.m^{-3}$) during 2014 and 2015 seasons

Treatments	Rice cultivars (cv)					
	2014			2015		
	Hybrid rice	Giza 179	Giza 178	Hybrid rice	Giza 179	Giza 178
water withholding (I):						
CF	0.902	0.763	0.733	0.894	0.795	0.705
W- MT	0.916	0.761	0.751	0.919	0.807	0.733
W- PI	0.847	0.758	0.700	0.867	0.782	0.634
W- H	0.848	0.721	0.713	0.866	0.733	0.701

CONCLUSIONS

It could be concluded that water withholding at both Panicle Initiation and Heading stages must be avoided to obtain considerable grain yield. Water stress at Mid-telling stage could be practiced without a significant reduction in grain yield. Egyptian hybrid 1 rice cultivar could be recommended under drought stress condition, since it proved to be more tolerant to water withholding treatment. Water withholding at Mid-telling stage saved amount of applied water with about 6.64% with a non-significant yield reduction (4.72%) of rice productivity. Using new hybrid varieties which produce high yield should be wider to face food security and increase country water use efficiency.

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تأثير نقص المياه في المراحل الفسيولوجية الحرجة علي كفاءة استخدام المياه والنمو والإنتاجية

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أقيمت تجربتان حقليتان بمحطة بحوث المقننات المائية بالقرضا – كفرالشيخ (شمال الدلتا) – مصر خلال موسمي 2014 -2015. و و تهدف هذه التجار ب إلىدراسه تأثير النقص المائي خلال المراحل الفسيولوجية الحرجة لتحديد تأثير العجز المائي علي كفاءة استخدام المياه و النمو و المحصول و مكوناته. و ذلك لبعض أصناف الأرز. و تشمل معاملات الحرمان من المياه الحرمان لمده 12 يوم في مراحل: 1) التفريع المتوسط ، 2) بداية تكوين السنبلة ، 3) مرحله طرد السنابل ، 4) الغمر المستمر طوال موسم النمو (كنترول). و في هذه الدراسة تم استخدام ثلاث أصناف من الأرز و هي: 1) هجين مصري 1، 2) جيزة 179 ، 3) جيزة 178. وقد أستخدم في هذه الدراسة تصميم الشرائح المتعامدة إحصائيا حيث وزعت معاملات الحرمان من مياه الري في القطع الافقيه في حين تم توزيع أصناف الأرز في القطع الرأسية. و يمكن تلخيص أهم النتائج كما يلي: تأثرت صفات النمو و محصول الحبوب و مكونات المحصول تأثيرا عالي المعنوية بمعاملات الحرمان من المياه خلال موسمي الدرسه حيث تناقصت كل من صفات طول النبات ، محتوي الكلوروفيل ، دليل مساحه الأوراق ، عدد السنابل/ م2 ، عدد الحبوب الممتلئة بالسنبلة ، ووزن الألف حبه و كذلك محصول الحبوب نتيجة الحرمان من المياه لمده 12 يوم في أي مرحله من مراحل النمو السابقة في كلا موسمي الدراسة. حيث أعطت معامله الغمر المستمر طوال الموسم أعلي القيم لكل الصفات سابقه الذكر يليها معامله الحرمان لمده 12 يوم في مرحله التفريع المتوسط. بينما أعطت معامله الحرمان من مياه الري لمده 12 يوم في مرحله بداية تكوين السنبلة و كذلك مرحله طرد السنابل أقل القيم في كلا الموسمين. و قد تبين أيضا من الدراسة أن الحرمان لمده 12 يوم في مرحله التفريع المتوسط هي الأقل تأثيرا علي كل الصفات سالفة الذكر مقارنه بمعامله الغمر المستمر طوال الموسم. و سجلت معامله الغمر المستمر طوال الموسم أعلي كميه مياه مضافة حيث بلغت 14611 و 14842 م3/ هكتار. و حصلت الترتيب الثاني في كفاءة استخدام المياه و هي 0.699 و 0.798 كجم /م^3. و أعطت معامله الحرمان من مياه الري في مرحله التفريع المتوسط أعلي قيمه لكفاءة استخدام المياه و هي 0.810 و 0.819 كجم /م^3 و أقل قيمه للنقص في المحصول و هي5.14 و 4.30% . ووفرت هذه المعاملة كميه مياه بلغت 6.37 و 6.74 %. و قد سجلت معامله الحرمان من مياه الري في مرحله بداية تكوين السنبلة علي أعلي قيمه في النقص في المحصول و هي 11.39 و 12.41%. و كذلك أعلي القيم في توفير المياه و هي 7.82 و 8.13%. و كانت كفاءة استخدام المياه لهذه المعاملة هي 0.768 و 0.761 كجم /م^3. و أوضحت النتائج أن الأرز الهجين مصري 1 تفوق معنويا علي باقي الأصناف تحت الدراسة في كل الصفات السابقة و قد أظهر أعلي كفاءة لتحمل الجفاف. و جاء الصنف جيزة 179 في المرتبة الثانية يليه الصنف جيزة 178. وعلية يمكن التوصية بالتالي: تجنب حرمان محصول الأرز من المياه في مرحلتي بداية تكوين السنبلة و كذلك طرد السنابل. في حاله النقص الحاد في الموارد المائية يمكن حرمان الأرز في مرحله التفريع المتوسط حيث أنها الأقل نقصا في الانتاجيه و الاعلي في كفاءة استخدام المياه مقارنه بالغمر المستمر طوال الموسم. يوصي باستخدام صنف هجين مصري 1 حيث انه أظهر كفاءة عاليه في تحمل نقص المياه و الأقل تأثرا بنقص المحصول و الاعلي في كفاءة في استخدام المياه.