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BEHAVIOR OF EGYPTIAN HYBRID RICE CULTIVAR (EHRI) UNDER DIFFERENT IRRIGATION REGIMES AND HARVESTING TIMES

Omar, A. M.[1] ; I. S. El-Refaee[2] and Hasnaa A. Ghazy[2]
[1] Agron. Dept., Fac. Agric., Kafr El-Sheikh University, Egypt
[2] Agric. Res. Center, Field Crops Res. Inst., Rice Res. & Train. Center, 33717 Sakha - Kafr El-Sheikh, Egypt

ABSTRACT

These studies were carried out at the Experimental Farm of Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt, during 2007 and 2008 summer seasons. The purpose was to investigate the effect of irrigation intervals, cut-off irrigation and harvesting times on grain yield and its attributes as well as grain quality characters and water relations of Egyptian hybrid rice cultivar (EHR1). A split split–plot design, with four replicates, was used. The main plots were devoted to three irrigation intervals namely: continuous flooding (CF), irrigation every 6 (6D) and 12 days (12D). The sub-plots were assigned to five times for cut-off irrigation, i.e. cut-off irrigation after complete heading (ACH), 1-, 2-, 3- and 4- weeks after complete heading (WACH). However, the sub-sub plots were consisted of three harvesting times, i.e. harvest rice plants at 10-, 15- and 20- days after cut-off irrigation (DACI).

The main results showed that grain yield and its attributes, as well as milling recovery and protein content, were significantly decreased as irrigation intervals increased from CF up to twelve days, but, unfilled grains (%) and amylose content were increased. Irrigation every six days came in between with insignificant difference with CF in most of previously mentions traits. Delayed cut-off irrigation up to 3- and 4-WACH significantly increased grain yield and most of its attributes, as well as grain quality. However, it reduced amylose content in 2007 and unfilled grains (%) in both seasons, as compared with cut-off irrigation ACH. Harvesting rice plants 10 and 15 DACI recorded the highest number of grains/panicle, panicle weight, 1000 grain weight and grain yield. However, the lowest values of milling recovery and protein content were recorded when plants were harvested at 10 DACI.

Continuous flooding consumed the highest amount of irrigation water**,** while increasing irrigation intervals up to six and twelve days tended to decrease the amount of water used. Furthermore, 6D treatment recorded the highest water productivity (0.796 and 0.798 kg/m^3) and minimum grain yield reduction (4.54 and 3.64 %) with water saved about 8.04 and 7.08 %, compared to CF in both seasons, respectively. Delay cut-off irrigation recorded higher water productivity than early cut-off irrigation after complete heading.

Generally, in case of water shortage, it was concluded to use irrigation every six days and cut-off irrigation 3-WACH with harvest plants 10 DACI for the highest water productivity and grain yield, as well as acceptable grain quality characters, of Egyptian hybrid rice cultivar (EHR1).

Keywords: Hybrid rice, irrigation regimes and harvesting times.

INTRODUCTION

Hybrid rice technology is one of the innovative breakthroughs that can further increase rice production and food security in Egypt. Hybrid rice varieties can out-yield conventional modern ones by 19 % even at the same input levels (Lin, 1994). In general, rice hybrid have yield advantage of 1.0 to 1.5 t/ha over inbred high yielding rice varieties, yielding 5 to 6 t/ha in India (Virmani, 2002).

Rice (*Oryza sativa* L.) is a simi-aquatic plant and does not need standing water for a successful rice crop. In Egypt, the dominant practice in rice production is flooded irrigation, which consumes large amounts of water as being approximately 18 % of the total water resources (Badawi *et al.,* 2002). Rice, however, it is a heavy consumer of freshwater and approximately 50 % of the freshwater used in Asian agriculture was used for rice production (Guerra *et al.*, 1998). With limited water resources, a future increases in rice production requires the development of water saving technologies. In Egypt, water resources are not sufficient for both reclaiming and irrigation purposes for the soil. So, saving some of irrigation water is a necessity demand to face this problem, in the future. Several water saving irrigation techniques for rice have been reported previously. The most widely adopted water saving practice in China was alternate wetting and drying (Zhi, 1993). Other way to save water was by increasing irrigation intervals with minimum grain yield reduction. In Egypt, increasing intervals between irrigations, wherever, allowed the rice fields to dry for a few days between irrigations for six to eight days. Awad (2001) found that grain yields were not affected by irrigation intervals, ranging from four to eight days. Belder *et al*., (2005) reported that water productivity was higher, in the alternately submerged and non-submerged regimes, than in the continuous submerged regime.

Scheduling last irrigation (cut-off irrigation) at the correct stage of maturity may influence moisture content in grain at harvest and, then, affect grain yield and quality. Whereas, moisture content in the grain at harvest affects the head rice recovery (Govindaswamy and Ghosh, 1970). Cut-off irrigation on rice fields early may cause moisture stress in grains before they are physiologically mature. Early cut-off irrigation may lead to lower harvest moisture contents associated with lower head rice yield. This practice causes a significant reduction in grain yield and increasing the unfilled, immature and broken, grains. Current recommendations for cutting off irrigation suggest maintaining the flood until 25 to 28 days after 50 % heading to prevent reduction in grain yield and milling quality (Slaton, 2001). This corresponds to physiological maturity for most of the kernels on the panicle. El-Refaee (2007) reported that withholding of irrigation 21 days after heading is considered as the optimum timing of last irrigation to rice field to get high grain yield and quality.

Cut-off irrigation and harvesting times are important factors to be considered for an optimum rice harvest and they are keys to high head rice yields. Harvest management preserves rice quality and grain yield that contribute directly to profit. Early harvest may lead to increases the unfilled and immature grains. This prematurely grains may result in partially chalky kernels and milk white kernels and increasing the thickness of the bran and aileron layers (Dewedar, 2004). Harvest, generally, commences in most countries when the average moisture content of the grains on the panicles is in the 20 – 27 % (Elaine *et al*., 2005). Hossain *et al.*, (2009) concluded that the rice harvesting at 30 to 35 days after flowering (DAF) was found to be suitable for higher grain quality, in respect of head rice outturn, and amylose content. However, the highest protein content was obtained from early harvesting (25 DAF).

The present study aimed to find out the best irrigation intervals, as well as irrigation cut-off after complete heading and harvest times, for higher grain yield and acceptable grain quality characteristics of EHR1 hybrid rice cultivar.

MATERIALS AND METHODS

Two field experiments were conducted at the Experimental Farm of Rice Research and Training Center (RRTC), Sakha Kafr El-Sheikh, Egypt, during 2007 and 2008 summer seasons. The purpose was to investigate the effect of irrigation intervals, cut-off irrigation after complete and harvesting times on grain yield and its attributes, as well as grain quality characters and water relations, of Egyptian hybrid rice cultivar (EHR1). The meteorological data of the experiment sites are presented in Table 1 according to Sakha Meteorological Station.

A split-split plot design, with four replicates, was used in this study. The main plots were devoted to three irrigation intervals namely: continuous flooding (CF), irrigation every 6 (6D) and 12 days (12D) with 5-6 cm water head at the time of water addition. The sub plots were assigned to five timing of cut-off irrigation, i.e. cut-off irrigation after complete heading (ACH), 1, 2, 3 and 4 weeks after complete heading (WACH). However, the sub-sub plots were consisted of three harvesting times namely: 10, 15 and 20 days after cut-off irrigation (DACI).

Table 1: Monthly temperature means, relative humidity (RH) and pan evaporation (E) at the study area during the experimental period

Month	2007					2008				
	Air temperature (^{0}C)		RH %		E (mm/ day)	Air temperature (^{0}C)		RH %		E (mm/ day)
	Max.	Mini.	7:30	13:30		Max.	Mini.	7:30	13:30	
May	30.0	12.0	76.3	45.0	6.48	29.0	10.0	70.5	42.5	6.91
June	33.0	16.5	82.4	56.0	7.61	33.0	15.0	82.5	50.0	7.33
July	32.6	17.3	83.0	54.0	6.88	32.0	15.7	80.0	55.7	6.79
August	32.5	17.2	83.0	56.5	6.40	33.0	16.3	83.2	56.0	6.53
September	32.0	13.0	74.5	52.0	5.56	33.5	15.0	77.3	47.7	6.08
Mean	32.02	15.2	79.84	58.7	6.59	32.1	14.4	78.7	50.38	6.73

The experiments were preceded by barley (*Hordeum vulgare L.*) in both seasons. The soil was clay with pH 8.1 and 8.2 and an organic matter content of 1.7 and 1.6 %. The total N was 500 and 515 ppm in both seasons, respectively. Phosphorus fertilizer, at the rate of 35.5 kg P_2O_5/ha, was applied to the soil during land preparation. Potassium fertilizer was added, at rate of 57 kg K_2O/ha, as basal dose and incorporated into dry soil. The recommended dose of Nitrogen fertilizer (165 kg N/ha), in the form of Urea (46 % N), was applied in three equal splits (as basal, top dressing at panicle initiation and late booting). Seeds of EHR1 hybrid rice cultivar, at a rate of 24 kg/ha, were soaked in sufficient water for 24 hours and incubated for another 48 hours to enhance germination. Zinc (Zn So_4), as well as all other cultural practices, was applied as recommended. The experiments were sown on 3^{rd} and 5^{th} of May in the two successive seasons. Two to three, thirty days old, seedlings were transplanted at 20 cm distance between hills and rows in plot size of 30 m^2 (5 x 6 m) each.

To avoid lateral movement and more water control, each main plot was separated by two meter wide ditches. Water pump provided with a calibrated water meter was used for all water measurements. Water productivity (WP) was calculated as weight of grains per unit of water used (kg grain/m^3 water).

At harvest, plant height was estimated and total number of panicles were counted and, then, conformed to numbers/m^2. Ten random panicles were collected from each sub sub-plot to estimate panicle length, total grains/panicle, unfilled grain percentage, panicle weight and 1000-grain weight. Grain and straw yields was measured from 12 m^2 (3 x 4 m) and adjusted to 14 % moisture content and, then, conformed to t/ha. Harvest index was determined according to Yoshida (1981) by subdividing grain yield (economic yield) on the total dry weight of grains and straw (biological yield).

Milling recovery (hulling, milling and head rice %) were measured according to the method described by Juliano (1971). Improved Kjeldahl methods of A.O.A.C. (1970) was used to determine the N content, then, multiplied by the factor of 5.95 to estimate the crude protein in rough grains. Amylose content was estimated according to Williams *et al*. (1958).

The analysis of variance was carried out according to Gomez and Gomez (1984) using GENSTAT 5^{th} Edition Computer Program. Means were compared, using the least significant differences (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Grain yield and its attributes:

Prolonged irrigation intervals caused a remarkable reduction in grain yield and its attributes (Fig. 1 and Table 2). In both seasons, continuous flooding (CF) followed by irrigation every 6 days (6D) gave the highest values of plant height, number of panicles, number of grains/panicle, panicle weight, 1000 grain weight, harvest index, grain and straw yields. However, increased irrigation intervals up to 12 days (12D) significantly reduced all previously mentions traits. While, unfilled grains (%) reached the maximum values. Grain yield was 11.25, 10.74 and 8.08 t/ha, in the first season, and 11.76, 11.33 and 8.73 t/ha, in the second season, for CF, 6D and 12D, respectively. These results indicated that exposed rice plant to drought stress (12D) caused significant reduction in grain yield, this held true since all yield components were affected by such conditions. It is a fact that the unavailability of water inhibits the production of dry matter content in the different plant organs, because of the water imbalance inside the pant, beside number of panicles/m^2, number of filled grain/panicle and grain yield. Similar finding were reported by Awad (2001) and El-Gewaily (2006).

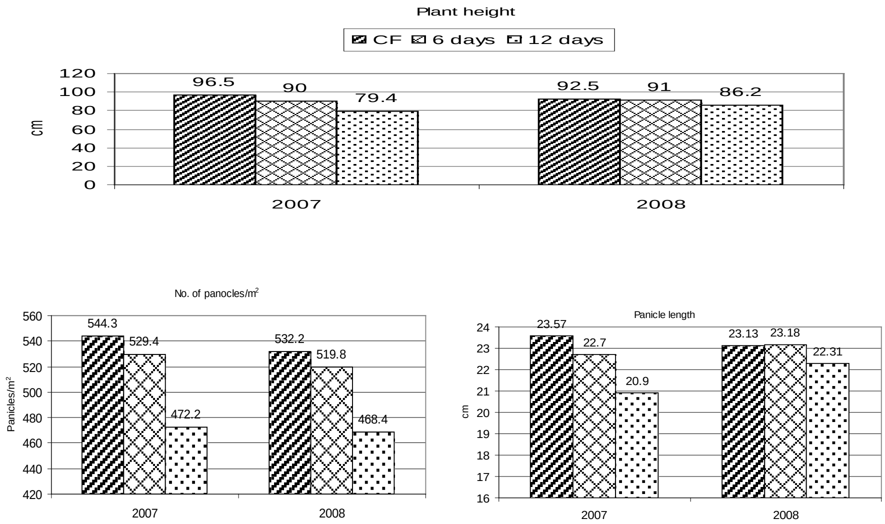

Fig. 1: Plant height, No. of panicles and panicle length of Egyptian hybrid rice cultivar (EHR1) as influenced by irrigation intervals

The effect of cut-off irrigation times on grain yield and its attributes were significant, except straw yield in both seasons (Table 2). Delayed irrigation termination up to 3- and 4-WACH significantly increased grain yield and most of its attributes. However, it reduced unfilled grains (%) as compared with cut-off irrigation after complete heading. The increased grain yield attributes were the reason for increasing grain yield with cut-off irrigation at 21 days (3 weeks) after complete heading. Continuing irrigation up to 3-WACH might be improved the translocation of photosynthates and thereby increased the grain yield. However, under early cut-off irrigation the carbohydrates tended to decrease due to the shortage of water required to photosynthetic processes and the restriction of translocation of insufficient metabolite form source to sink owing to plant-water deficit, which, led to decrease the grain yields. These results are in conformity with the findings of Uppal and Bali (1994) and El-Refaee (2007).

Grain yield and some of its attributes were significantly affected by harvesting times (Table 2). Harvesting plants 10 DACI recorded the highest number of grains/panicle, panicle weight and 1000 grain weight, followed by 15 DACI, in both seasons. However, the lowest values of all previous characters were obtained when plants were harvested 20 DACI as compared with the other harvest time. The highest grain yields (10.23 and 10.70 t/ha) were obtained when plants harvested 10 DACI and (10.02 and 10.77 t/ha) 15 DACI, with no significant difference between each other. While, the lowest values (9.82 and 10.35 t/ha) were recorded when plants harvested 20 DACI in the two respective seasons. It is means that harvested rice plants after 10 or 15 DACI were the optimum, because of the complete filling, resulted in produces the heaviest panicles and grains. These results are in agreement with those of Asano *et al.* (2000) and Dewedar (2004).

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Data in Table 3 showed that the highest number of grains/panicle, in 2007, was obtained when cut-off irrigation 1-WACH with harvest plants 10-DACI were combined. Continuous flooding with 2-WACH recorded that the highest number of grains/panicle in 2008. The lowest value of unfilled grains (%) was obtained by either cut-off irrigation 3- and 4-WACH or harvesting plants 20 DACI under CF treatment in the first season, however, the lowest values (9.1 and 7 %) of unfilled grains (%) were obtained when cut-off irrigation 3- and 4-WACH with harvest plants 20-DACI in both seasons, respectively. The highest values of panicle weight (3.89 g) was recorded when irrigation terminated 4-WACH and harvest plants 10-DACI in 2007. Continuous flooding with cut-off irrigation 3-WACH recorded the highest grain yield (12.43 and 12.60 t/ha) in both seasons, respectively (Table 3). The highest values of straw yield were obtained when irrigation terminated after complete heading with harvest plants 10-DACI in 2007. Irrigation every 6 days with cut-off irrigation 4- and 3- WACH recorded the highest values of harvest index in both seasons, respectively (Table 3).

Grain quality:

Data in Table 4 revealed that milling recovery (hulling, milling and head rice %) and both amylose and protein contents were significantly affected by irrigation intervals in both seasons, except hulling (%) in 2008. Continuous flooding caused an increase in milling recovery and protein content. However, 12D decreases all previous traits, under study, but, gave the highest amylose content. Irrigation every 6 days comes in between with insignificant difference with CF in the most of the studied characters. These results could be attributed to the decrease in moisture content of the grains leading to the reduction in milling recovery percentage. The same trend was found by Nour *et al.* (1994) and El-Refaee (1997).

Early cut-off irrigation after heading significantly decreased milling recovery and protein content as compared with other treatments in both seasons (Table 4). However, cut-off irrigation early after complete heading, in 2007, and 4-WACH, in 2008, significantly decreased amylose content. The milling recovery in the last two treatments (3- and 4-WACH) was high due to the corresponding increase in the moisture content of the grain. The lowest milling recovery in the treatment received last irrigation ACH and 1-WACH might be due to early drying of the grains before the completion of ripening. Besides, delay in harvesting along with the other treatments may result in low moisture content in grain during day and in night some amount of moisture is re-absorbed by the deposition of dew. Such alternate drying and wetting cycles cause mechanical stress which may result in the development of fissures and ultimately higher percentage of broken rice. The results are in agreement with those obtained by Uppal and Bali (1994) and El–Refaee (2007).

Table 3: Grain yield and some of its attributes of Egyptian hybrid rice cultivar (EHR1) as influenced by the interaction between the studied factors.

No. of grains/panicle	Cut-off irrigation	Harvest date 2007			Irrigation treatment 2008		
		10-DACI	15-DACI	20-DACI	CF	6 days	12 days
	ACH	166.7	177.3	167.5	165.3	185.8	185.5
	1-WACH	188.4	167.1	169.6	157.6	182.4	194.9
	2-WACH	175.5	176.1	169.1	172.0	182.7	201.7
	3-WACH	165.6	173.6	166.0	174.4	186.3	193.6
	4- WACH	158.7	164.0	148.7	144.4	180.5	186.7
	L.S.D 5%	9.8			12.3		

Unfilled grains (%)	Irrigation treatment	Cut-off irrigation 2007					Harvest date 2007		
		ACH	1-WACH	2-WACH	3-WACH	4-WACH	10-DACI	15-DACI	20-DACI
	CF	13.0	11.1	8.6	6.3	6.3	9.3	9.8	8.0
	6 days	16.3	13.5	12.7	12.2	11.5	14.6	12.4	12.8
	12 days	21.5	13.9	12.8	12.9	11.5	14.3	17.0	13.0
	L.S.D 5%	2.1					1.7		

Unfilled grains (%)	Cut-off irrigation	Harvest date					
		2007			2008		
		10-DACI	15-DACI	20-DACI	10-DACI	15-DACI	20-DACI
	ACH	15.8	20.6	20.6	24.3	24.6	17.0
	1-WACH	13.7	13.1	13.1	22.0	12.8	12.1
	2-WACH	11.8	11.0	11.0	11.5	10.4	9.9
	3-WACH	11.4	10.9	10.9	8.5	7.7	8.3
	4- WACH	11.1	9.9	9.9	9.0	8.0	7.0
	L.S.D 5%	2.1			3.0		

Panicle weight (g)	Cut-off irrigation	Harvest date 2007		
		10-DACI	15-DACI	20-DACI
	ACH	3.22	2.88	2.96
	1-WACH	3.35	3.15	3.22
	2-WACH	3.65	3.62	3.36
	3-WACH	3.50	3.67	3.03
	4- WACH	3.89	3.75	3.21
	L.S.D 5%	0.32		

Grain yield (t/ha)	Cut-off irrigation	Irrigation treatment					
		2007			2008		
		CF	6 days	12 days	CF	6 days	12 days
	ACH	9.68	9.55	7.69	10.16	9.81	7.89
	1-WACH	10.53	9.92	7.87	11.46	11.18	8.83
	2-WACH	11.62	10.89	8.42	12.20	11.65	8.68
	3-WACH	12.43	11.66	8.39	12.60	11.96	9.78
	4- WACH	12.00	11.68	8.03	12.39	12.06	8.45
	L.S.D 5%	0.74			0.57		

Straw yield (t/ha)	Cut-off irrigation	Irrigation treatment 2007		
		CF	6 days	12 days
	ACH	15.61	12.92	11.35
	1-WACH	14.87	13.90	12.18
	2-WACH	14.51	14.22	12.49
	3-WACH	15.42	14.26	12.62
	4- WACH	15.47	13.22	13.30
	L.S.D 5%	1.08		

Harvest index	Cut-off irrigation	Irrigation treatment					
		2007			2008		
		CF	6 days	12 days	CF	6 days	12 days
	ACH	0.383	0.424	0.403	0.416	0.416	0.393
	1-WACH	0.416	0.418	0.392	0.443	0.453	0.416
	2-WACH	0.444	0.434	0.402	0.458	0.461	0.405
	3-WACH	0.437	0.449	0.399	0.446	0.473	0.422
	4- WACH	0.438	0.468	0.376	0.464	0.468	0.404
	L.S.D 5%	0.025			0.016		

CF=continuous flooding, ACH= After complete heading, WACH= Week after complete heading and DACI = Days after cut-off irrigation.

Milling recovery and protein content were significantly responded to different harvest times in both seasons (Table 4). The lowest values were recorded when plants were harvested 10-DACI as compared with harvesting times at 15- and 20-DACI with insignificant differences between each other for most of traits in both seasons. The relatively lower milling recovery at first harvest times is probably due to the presence of unripe, light and deformed grains. The results are in agreement with those reported by Ntanos *et al.* (1998) and Surek *et al.* (1998).

Data in Table 5 indicated that CF with irrigation termination 3-WACH recorded the highest percentage of hulling, milling and head rice in 2007.

Table 4: Grain quality characters of Egyptian hybrid rice cultivar (EHR1) as influenced by irrigation intervals, cut-off irrigation and harvest times.

Treatment	Hulling (%)		Milling (%)		Head rice (%)		Amylose content (%)		Protein content (%)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Irrigation intervals (I):										
CF	76.61	77.61	70.84	71.17	62.12	61.47	18.67	19.47	7.23	7.31
6 days	75.85	77.30	70.50	70.35	61.91	61.04	19.60	19.78	7.19	7.20
12 days	74.99	76.78	68.32	69.77	59.66	59.31	19.81	20.15	6.76	6.91
L.S.D 5%	0.55	NS	1.03	0.62	1.44	1.25	0.63	0.60	0.08	0.26
Cut-off irrigation (C):										
ACH	74.06	76.21	66.92	69.38	56.26	59.10	18.74	20.03	6.87	6.87
1-WACH	75.93	75.98	70.08	70.37	61.91	59.49	19.99	20.31	7.04	6.90
2-WACH	75.98	77.44	70.81	71.14	62.84	61.68	19.25	19.86	7.02	7.08
3-WACH	76.58	78.26	70.53	70.48	62.77	61.94	19.66	19.20	7.16	7.44
4- WACH	76.52	78.26	71.09	70.78	61.31	60.82	19.06	19.61	7.22	7.42
L.S.D 5%	0.86	0.97	0.99	1.09	1.73	1.13	0.80	0.71	0.19	0.23
Harvest times (H):										
10-DACI	75.07	76.64	68.45	69.75	59.67	59.08	19.37	19.62	6.97	7.08
15 DACI	75.86	77.51	70.21	70.93	60.65	61.37	19.48	19.89	7.05	7.18
20-DACI	76.52	77.54	70.99	70.61	62.72	61.37	19.22	19.90	7.17	7.17
L.S.D 5%	0.65	0.76	0.87	0.76	1.62	0.80	NS	NS	0.13	NS
Interaction										
I x C	*	NS	*	NS	**	**	*	**	**	**
I x H	NS	NS	NS	NS	**	NS	NS	NS	**	*
C x H	**	NS	*	**	**	**	NS	NS	**	**
I x C x H	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

CF=continuous flooding, ACH= After complete heading, WACH= Week after complete heading and DACI = Days after cut-off irrigation. NS = Not significant, * and ** = Significant at 5 and 1 % levels, respectively.

Table (5): Milling recovery of Egyptian hybrid rice cultivar (EHR1) as influenced by the interaction among the studied factors.

	Cut-off irrigation	Irrigation treatment (2007)			Harvest time (2007)		
		CF	6 days	12 days	10-DACI	15-DACI	20-DACI
Hulling (%)	ACH	75.58	74.41	72.20	71.56	74.82	75.82
	1-WACH	75.95	75.84	76.02	75.31	76.01	76.49
	2-WACH	76.92	75.90	75.12	75.43	75.57	76.94
	3-WACH	77.94	76.64	75.17	76.32	76.56	76.87
	4- WACH	76.66	76.45	76.43	76.73	76.35	76.47
	L.S.D 5%	1.40			1.45		

	Cut-off irrigation	Irrigation interval			Harvest time					
		2007			2007			2008		
		CF	6 days	12 days	10-DACI	15-DACI	20-DACI	10-DACI	15-DACI	20-DACI
Milling (%)	ACH	68.85	67.26	64.64	63.47	68.04	69.23	68.62	68.84	70.68
	1-WACH	70.13	70.40	69.70	69.05	70.18	71.00	69.01	71.50	70.58
	2-WACH	71.51	71.63	69.27	69.68	71.36	71.37	71.79	71.58	70.05
	3-WACH	72.31	71.43	67.86	69.04	70.88	71.68	69.05	71.72	70.66
	4- WACH	71.37	71.79	70.11	71.01	70.57	71.69	70.30	71.00	70.05
	L.S.D 5%	1.75			1.86			1.74		

	Cut-off irrigation	Irrigation interval						Harvest time					
		2007			2008			2007			2008		
		CF	6D	12 D	CF	6D	12 D	10-DACI	15-DACI	20-DACI	10-DACI	15-DACI	20-DACI
Head rice (%)	ACH	60.65	57.21	50.91	61.33	58.22	57.75	54.62	54.16	59.99	58.64	59.07	59.59
	1-WACH	59.30	62.35	64.08	60.37	60.37	57.73	61.75	61.83	62.14	58.96	59.89	59.61
	2-WACH	60.17	64.06	64.29	62.14	61.55	61.35	61.02	64.24	63.26	60.89	61.76	62.38
	3-WACH	66.34	62.73	59.23	61.68	62.46	61.68	59.99	63.00	65.31	59.91	62.83	63.10
	4- WACH	64.13	59.98	59.82	61.84	62.57	58.07	60.98	60.02	62.93	57.00	63.30	62.18
	L.S.D 5%	2.93			3.02			2.71			1.82		

	Irrigation treatment	Harvest time (2007)		
		10-DACI	15-DACI	20-DACI
Head rice (%)	CF	61.53	62.77	62.05
	6 days	59.96	59.76	64.07
	12 days	57.52	59.42	62.05
	L.S.D 5%	2.05		

CF=continuous flooding, ACH= After complete heading, WACH= Week after complete heading and DACI = Days after cut-off irrigation.

However, 6D treatment gave the highest head rice percentage with harvest time 20-DACI in 2007 and with terminates irrigation 4-WACH in 2008. Cut-off irrigation 2-WACH recorded the highest hulling and milling (%) when plants were harvested 20- and 10-DACI in 2008, respectively. On the other hand, cut-off irrigation 3-WACH with harvesting plants 20-DACI recorded the highest milling (%) in 2007 and head rice (%) in both seasons.

Results in Table 6 revealed that the highest values of amylose content were given by 6D with cut-off irrigation 1- and 2-WACH in 2007 and with cut-off irrigation after complete heading in 2008. However, the highest protein content was given by CF with cut-off irrigation 2- and 4-WACH in both seasons, respectively. Continuous flooding with harvest plants 15- and 20-DACI recorded the highest protein content in 2007 and 2008, respectively. The highest protein content was obtained when cut-off irrigation 3- and 4-WACH with harvest plants 20-DACI in both seasons.

Table 6: Amylose and protein contents of Egyptian hybrid rice cultivar (EHR1) as influenced by the interaction between the studied factors.

	Cut-off irrigation	Irrigation interval					
		2007			2008		
		CF	6 days	12 days	CF	6 days	12 days
Amylose content	ACH	16.98	19.45	19.78	19.73	21.04	19.33
	1-WACH	19.09	20.58	20.31	20.02	20.51	20.41
	2-WACH	18.83	20.58	20.34	19.19	19.98	20.41
	3-WACH	19.05	19.61	20.30	19.13	18.25	20.23
	4- WACH	19.38	19.46	18.31	19.30	19.14	20.39
	L.S.D 5%	1.34			1.20		
Protein content	Cut-off irrigation	Irrigation interval					
		2007			2008		
		CF	6 days	12 days	CF	6 days	12 days
	ACH	7.15	6.86	6.60	6.69	7.15	6.78
	1-WACH	6.98	7.46	6.67	7.44	6.41	6.85
	2-WACH	7.64	6.70	6.71	7.06	7.21	6.99
	3-WACH	7.36	7.47	6.66	7.60	7.70	7.01
	4- WACH	7.01	7.48	7.16	7.79	7.54	6.93
	L.S.D 5%	0.30			0.42		
	Irrigation treatment	Harvest time					
		2007			2008		
		20-DACI	15-DACI	10-DACI	20-DACI	15-DACI	10-DACI
	CF	7.01	7.35	7.33	7.23	7.24	7.47
	6 days	7.27	6.99	7.33	7.14	7.18	7.29
	12 days	6.63	6.80	6.84	6.87	7.13	6.73
	L.S.D 5%	0.19			0.33		
	Cut-off irrigation	20-DACI	15-DACI	10-DACI	20-DACI	15-DACI	10-DACI
	ACH	6.81	6.80	7.00	7.21	6.45	6.95
	1-WACH	7.28	6.94	6.89	6.61	7.24	6.85
	2-WACH	6.86	7.32	6.86	6.87	7.16	7.22
	3-WACH	6.83	7.15	7.52	7.60	7.31	7.40
	4- WACH	7.07	7.02	7.52	7.11	7.75	7.41
	L.S.D 5%	0.30			0.39		

CF=continuous flooding, ACH= After complete heading, WACH= Week after complete heading and DACI = Days after cut-off irrigation.

Water relations:

The amounts of water input, before starting irrigation treatments, were 4270 and 4410 m^3/ha, in 2007 and 2008 seasons, respectively, (Table 9). Nour and Mahrours (1994) indicated that the amount of water used in land preparation for transplanting rice was 4525.5 m^3/ha. Comparing the different treatments of irrigation (Table 9), it was observed that CF received the highest amounts of water throughout the season, while, the lowest amounts were received by 12D treatment. Data showed, also, that increasing irrigation intervals from CF up to six and twelve days tended to decrease the amount of water used from 14656 and 15324 m^3/ha to 13476 and 14183 m^3/ha and 13476 and 14183 m^3/ha in both seasons, respectively. There were no large variations in the amounts of irrigation water input due to the stable conditions (temperature, relative humidity and evaporation rates) in both studied seasons as previously shown in Table (1). El-Refaee *et al*. (2007) found that under continuous flooding rice field received the highest amounts of water throughout the season while, the lowest amount was received by irrigation every 8 days.

Under CF, delayed the time for cut-off irrigation from complete heading to 4-WACH increased water used from 13380 and 14032 m^3/ha to 16011 and 16477 m^3/ha, however, it increased from 12382 and 13077 m^3/ha to 14750 and 15004 m^3/ha with 6D and from 9658 and 10332 m^3/ha to 11083 and 11856 m^3/ha with 12D in the both seasons, respectively. These mainly due to continuous applied of water for more than four weeks with delayed the time of cut-off irrigation.

Data in Table 9 demonstrated that, over cut-off irrigation treatments, water saved due to increasing irrigation intervals compared to CF were (8.04 and 7.08 %) and (29.27 and 27.30 %) with corresponding grain yield reduction of (4.54 and 3.64 %) and (28.2 and 25.8 %) for 6 and 12D in the two successive seasons. Ebaid and El-Refaee (2007) pointed out that water saved due to increasing irrigation interval 8 and 12 days, compared to continuous flooding, were 11.2 and 20.5 % with corresponding grain yield reduction of 11.0 and 24.9 %, respectively. Results showed, also, that cut-off irrigation saved some of irrigation water with different values of reduction in grain yield under both of irrigation every 6 and 12 days as compared with the same treatments under CF in both seasons. Delay in cut-off irrigation significantly increased the grain yield % (Table 7). Compared to cut-off irrigation after complete heading, cut-off irrigation 3-WAH gave the highest percentage of increasing grain yield of 28.47 and 24.00 % under CF, however, cut-off irrigation 4-WAH increased grain yield by 22.33 and 22.99 % under 6D in both season, respectively. Under 12D the highest value of increasing grain yield was recorded with cut-off irrigation 2-WACH (9.46 5) in the first season and 3-WACH (23.98 %) in the second season.

Regarding water productivity (WP), 6D was considered the best water productivity (0.796 and 0.798 kg/m^3) followed by 12D (0.784 and 0.784 kg/m^3). However, CF recorded the lowest values (0.767 and 0.767 kg/m^3) in the first and second seasons, respectively (Table 9). Bouman and Tuong (2001) reported that WP was higher in alternate submerged and non-submerged regimes than in the continuous submerged regime. The WP values were relatively high in irrigation every 6 days compared with the other irrigation intervals. The extremely high values of WP, in this treatment, were caused by the extremely high grain yield and low water inputs in this treatment

Under all irrigation intervals delayed cut-off irrigation recorded higher WP than cut-off irrigation ACH. High WP, with delayed cut-off irrigation, was associated with high grain yield. The productivity of irrigation water could be increased to reach it maximum value of 0.798 and 0.881 kg/m^3 in first season and 0.794 and 0.795 kg/m^3 in second season under CF, and about 0.820 and 0.826 kg/m^3 in first season and 0.817 and 0.810 kg/m^3 in second season when irrigation intervals increased up to six days with cut-off irrigation 2- and 3- WACH, respectively. However, the highest WP under 12D was obtained when irrigation terminated 2-WACH (0.822 kg/m^3) in first season and 3-WACH (0.851 kg/m^3) in second season.

Table 7: Grain yield, yield reduction, grain yield increased, total water used, water saved and water productivity (WP) of EHR1rice cultivar as influenced by irrigation treatments.

Irrigation treatment	Cut-off irrigation	Grain yield (t/ha)	Grain yield reduction (%)	Grain yield increased (%)	Total water used (m^3/ha)	Water saved (%)	WP (kg/m^3)
2007							
CF	ACH	9.677	-	-	13380	-	0.723
	1-WACH	10.527	-	8.78	14013	-	0.751
	2-WACH	11.617	-	20.05	14555	-	0.798
	3-WACH	12.432	-	28.47	15320	-	0.811
	4-WACH	12.002	-	24.03	16011	-	0.750
Average		11.251	-	20.33	14656	-	0.767
6 days	ACH	9.546	1.35	-	12382	7.46	0.771
	1-WACH	9.919	5.78	3.91	12847	8.32	0.772
	2-WACH	10.892	6.24	14.10	13290	8.69	0.820
	3-WACH	11.664	6.18	22.19	14113	7.88	0.826
	4-WACH	11.678	2.70	22.33	14750	7.87	0.792
Average		10.740	4.54	15.63		8.04	0.796
12 days	ACH	7.688	20.55	-	9658	27.82	0.796
	1-WACH	7.868	25.26	1.00	9939	26.92	0.792
	2-WACH	8.415	27.56	9.46	10241	29.64	0.822
	3-WACH	8.385	32.55	9.07	10540	31.20	0.786
	4-WACH	8.025	33.14	4.38	11083	30.78	0.724
Average		8.076	28.22	5.98	10292	29.27	0.784
2008							
CF	ACH	10.159	-	-	14032	-	0.724
	1-WACH	11.459	-	12.80	14901	-	0.769
	2-WACH	12.199	-	20.08	15364	-	0.794
	3-WACH	12.597	-	24.00	15846	-	0.795
	4-WACH	12.387	-	21.93	16477	-	0.752
Average		11.760	-	19.70	15324	-	0.767
6 days	ACH	9.808	3.46	-	13077	6.81	0.750
	1-WACH	11.183	2.41	14.02	13820	7.25	0.809
	2-WACH	11.646	4.53	18.55	14249	7.26	0.817
	3-WACH	11.958	5.07	21.92	14763	6.24	0.810
	4-WACH	12.063	2.62	22.99	15004	7.82	0.804
Average		11.332	3.64	19.37	14183	7.08	0.798
12 days	ACH	7.889	22.34	-	10332	26.37	0.764
	1-WACH	8.834	22.91	11.98	10812	27.44	0.817
	2-WACH	8.680	28.85	10.03	11191	27.16	0.776
	3-WACH	9.781	22.35	23.98	11494	27.46	0.851
	4-WACH	8.453	31.76	7.15	11856	28.05	0.713
Average		8.727	25.79	13.29	11137	27.30	0.784

CF=continuous flooding, ACH= After complete heading, WACH= Week after complete heading and DACI = Days after cut-off irrigation.

Generally, in case of water shortage, it could be concluded to use irrigation every six days and cut-off irrigation 3-WACH with harvest plants 10 DACI for the highest water productivity and grain yield as well as acceptable grain quality characters of Egyptian hybrid rice cultivar (EHR1).

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سلوك صنف الأرز الهجين "هجين مصرى واحد" تحت نظم رى و مواعيد حصاد مختلفة

عبد الحميد محمد عمر[1] ، اسماعيل سعد الرفاعى[2] و حسناء عبد الحميد غازى[2]
[1] قسم المحاصيل – كلية الزراعة – جامعة كفر الشيخ
[2] مركز البحوث و التدريب في الأرز - معهد بحوث المحاصيل الحقلية - مركز البحوث الزراعية- سخا– كفر الشيخ - مصر

أجريت هذه الدراسة فى المزرعة البحثية لمركز البحوث و التدريب في الأرز – سخا – كفر الشيخ – مصر - خلال موسمي صيف 2007 و 2008 م بهدف دراسة تأثير زيادة فترات الرى و مواعيد توقف الرى و الحصاد على محصول الحبوب و مكوناتة و على جودة الحبوب و بعض العلاقات المائية لصنف الأرز الهجين "هجين مصرى واحد". إستخدم تصميم القطع المنشقة مرتين ذو أربع مكررات بحيث إحتوت القطع الرئيسية على ثلاث معاملات للري هي الغمر المستمر و الري كل ستة أيام و اثنى عشر يوماً و إحتوت القطع الشقية الأولى على خمسة مواعيد لتوقف الرى و هى توقف الرى بعد تمام الطرد و 1 و 2 و 3 و 4 أسابيع من تمام الطرد. فى حين إحتوت القطع الشقية الثانية على ثلاثة مواعيد للحصاد وهى: الحصاد بعد10 و 15 و 20 يوماً من ميعاد توقف الرى.

و توضح أهم النتائج أن محصول الحبوب و مكوناتة بالإضافة الى صفات التبيض و محتوى البروتين قد نقصت معنويا بزيادة فترات الرى من الغمر المستمر حتى الرى كل 12 يوماَ، بينما أعطت معاملة الرى كل 12 يوماَ أعلى القيم لنسبة الحبوب الفارغة و محتوى الأميلوز. فى حين سجلت معاملة الرى كل ستة أيام قيما وسطاً مع عدم وجود فروق معنوية بينها و بين معملة الغمر المستمر فى معظم الصفات السابقة، فى كلا الموسمين.

أدى التأخير في توقف الري حتى 3 و 4 أسابيع من تمام الطرد إلى الزيادة المعنوية فى محصول الحبوب و معظم مكوناتة و كذلك صفات الجودة، في حين أدى تأخير توقف الري إلى النقص المعنوي في محتوى الاميلوز فى موسم 2007 و نسبة الحبوب الفارغة فى الموسمين و ذلك بالمقارنة بتوقف الري مبكرا بعد تمام الطرد. كما سجل ميعادي الحصاد بعد 10 و 15 من توقف الري زيادة معنوية فى عدد السنيبلات/دالية، وزن الدالية ، وزن 1000 حبة، السعة المحصولية، كثافة الدالية و محصول الحبوب في الموسمين. بينما سُجلت أقل القيم لصفات التبيض و محتوى البروتين عند الحصاد بعد 10 أيام من توقف الري بالمقارنة بباقى مواعيد الحصاد الأخرى.

استهلكت معاملة الغمر المستمر طوال الموسم أكبر كميه مياه رى فى حين قلت كميات مياه الرى المستهلكة بزيادة فترات الرى إلى 6 و 12 يوماَ. علاوة على ذلك سجلت معاملة الرى كل 6 أيام أعلى إنتاجية لوحدة المياه (0.796 و 0.798 كجم/م^3) و أقل نقص فى محصول الحبوب (4.54 و 3.64 %) و وفرت كمية من مياه الرى تعادل 8.04 و 7.08 % و ذلك بالمقارنة بمعاملة الغمر المستمر فى كلا الموسمين، على التوالى. كما أدى التأخير فى توقف الرى الى زيادة إنتاجية وحدة المياه و ذلك بالمقارنة بتوقف الرى بعد تمام الطرد.

و بصفة عامة، بناء على النقص فى مياه الرى، يمكن الإستنتاج بأن إستخدام معاملة الرى كل ستة أيام مع توقف الرى بعد ثلاثة أسابيع من الطرد و الحصاد بعد عشرة أيام من توقف الرى، أدى الى الحصول على أعلى إنتاجية لمحصول الحبوب و وحدة المياه بالإضافة إلى صفات جودة مقبولة للحبوب لصنف الأرز الهجين "هجين مصرى واحد".

قام بتحكيم البحث

أ.د / عبد الرحيم عبد الرحيم ليله	**كلية الزراعة – جامعة المنصورة**
أ.د / احمد عزت عبد الوهلب	**مركز البحوث الزراعية**

Table 2: Grain yield and some of its attributes of Egyptian hybrid rice cultivar (EHR1) as influenced by irrigation intervals, cut-off irrigation and harvest times.

Treatment	No. of grains/ panicle		Unfilled grains (%)		Panicle weight (g)		1000 grain weigh (g)		Grain yield (t/ha)		Straw yield (t/ha)		Harvest index	
	2007	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**			**2007**	**2008**	**2007**	**2008**
Irrigation intervals (I):														
CF	191.9	192.5	9.1	10.8	4.00	3.91	24.52	24.18	11.25	11.76	15.18	14.51	0.425	0.447
6 days	175.3	183.5	13.3	12.6	3.62	3.60	24.68	23.80	10.74	11.33	13.71	13.62	0.439	0.454
12 days	139.6	162.5	14.8	15.3	2.52	3.27	22.58	22.78	8.08	8.73	12.39	12.62	0.394	0.408
L.S.D 5%	6.8	6.8	1.3	1.5	0.20	0.40	0.54	0.73	0.44	0.38	0.59	0.65	0.016	0.008
Cut-off irrigation (C):														
ACH	170.5	178.9	17.0	22.0	3.02	2.88	23.12	22.71	8.97	9.29	13.29	13.36	0.404	0.408
1-WACH	175.0	178.3	12.8	15.6	3.24	3.19	23.77	23.19	9.44	10.49	13.65	13.46	0.409	0.437
2-WACH	173.6	185.7	11.4	10.6	3.55	4.00	24.13	23.98	10.31	10.84	13.74	13.60	0.427	0.441
3-WACH	168.4	184.7	10.5	8.2	3.49	4.14	24.40	24.40	10.83	11.45	14.10	13.96	0.431	0.450
4- WACH	157.1	170.6	10.2	8.0	3.61	3.75	24.39	23.66	10.57	10.97	14.00	13.54	0.427	0.446
L.S.D 5%	5.3	7.5	1.2	1.7	0.21	0.25	0.49	0.74	0.42	0.31	NS	NS	0.014	0.009
Harvest date (H):														
10-DACI	171.0	184.9	12.8	15.1	3.52	3.69	24.24	23.88	10.23	10.70	13.98	13.72	0.420	0.437
15 DACI	171.6	181.0	13.1	12.7	3.41	3.62	23.90	23.50	10.02	10.77	13.79	13.58	0.419	0.440
20-DACI	164.2	173.0	11.3	10.9	3.21	3.47	23.74	23.38	9.82	10.35	13.51	13.46	0.419	0.432
L.S.D 5%	0.46	6.2	0.9	1.4	0.14	0.18	0.39	0.45	0.28	0.31	NS	NS	NS	NS
Interaction														
I x C	NS	**	**	NS	NS	NS	NS	NS	**	**	**	NS	**	**
I x H	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x H	**	NS	**	**	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x C x H	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

CF= Continuous flooding, ACH= After complete heading, WACH= Week after complete heading and DACI = Days after cut-off irrigation. NS = Not significant, * and ** = Significant at 5 and 1 % levels, respectively.