THE INTERACTION EFFECT BETWEEN WATER REGIMES AND POTASSIUM LEVELS ON GROWTH, GRAIN YIELD AND WATER PRODUCTIVITY IN RICE

ISMAIL S. EL-REFAEE

Rice Research and Training Center, Field Crops Research Institute, Agricultural Research Center, Sakha - Kafr El-Sheikh, Egypt

(Manuscript received 15 March 2006)

Abstract

The interaction between water regimes and potassium levels was studied, using two rice cultivars, i.e., Sakha 104 and Giza 178, at the Experimental Farm of Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt, during 2003 and 2004 rice seasons. Four water regimes, namely, continuous flooding, continuous saturation, irrigation every six and nine days as well as four potassium levels, namely, 0, 57, 86 and 114 kg K_2O/ ha were used. The experiments were laid out in a split split-plot design, with four replications. The water regimes were applied in the main plots and the cultivars were placed in the sub-plots. Besides, the potassium levels occupied the sub-sub plots.

The main results revealed that no significant differences were obtained between continuous saturation and continuous flooding on grain yield and most of its attributes. Prolonging irrigation intervals up to nine days resulted in about 17 % reduction in grain yield. Giza 178 produced a higher dry matter, grain yield and water productivity than Sakha 104. The results, also, showed that increasing K levels up to 86 kg K_2O/ha increased significantly plant height, dry matter and grain yield and its attributes under prolonging irrigation intervals in both seasons.

The present study indicated a reduced water input and an increased water productivity of rice grown under just-saturated soil conditions, compared with continuous flooded rice.

Additionally, continuous saturation gave a similar grain yield as that of continuous flooding with only 3-4% reduction in grain yield. This means that almost 20-25% of irrigation water could be saved, if all farmers followed this practice. As a result, a high water productivity could be obtained and about 1500 million L.E. could be added to the national income.

Key words: Rice, growth and yield, potassium levels, water regimes, water productivity.

INTRODUCTION

Rice (*Oryza sativa L.*) is one of the most important grain crops in the world. It is not only a stable food, but also contributes the major economic activity and a key source of income and employment for the rural population. In 2004 season, the annual area planted with rice in Egypt was about 1.534 million faddans (0.639 million hectares) and the total production of rice was about 6.375 million tons with a national average of 9.97 tons/ha (RRTC, 2005).

Water is critical at any growth stage of the rice plant. It is needed for growth and transport of nutrients from the soil to the different plant parts. Rice, unlike other cereals, has a remarkable adaptation to a wide range of hydrological conditions. Although it can achieve its highest grain yield in waterlogged conditions under irrigation, it is widely grown in rainfed lowland and uplands where soils are kept aerobic for certain period or the entire period of crop growth. Aerobic exposure drastically changes the micro-environment for rice growth and increases environmental constraints that seriously affect crop production.

In Egypt, irrigation water is relatively limited (55.5 mlrd m^3 a year) and insufficient for both reclamation and irrigation purposes for Egyptian soil. So many tedious trials were done by rice breeders and agronomists to maximize rice productivity and rationalize water use. The major and significant change in this respect is the development of short-duration cultivars, which maintain higher and increased productivity, as well as saving irrigation water. The productivity of irrigation water can be increased either by reducing losses of evaporation, seepage and percolation and/or surface runoff, as well as reusing or recycling water. It can, also, be increased by developing improved early maturing varieties, improving agronomic practices, reducing water use for land preparation and reducing crop growth period and, also, water distribution strategies. Generally, there are two different ways for increasing water productivity in irrigated rice areas as follows:(1) Physiologically, by breeding high-yielding cultivars with short growing cycle, and (2) Technically, by applying water-saving irrigation methods, as well as by improving management of available water resources.

El-Wehishy and Abdel-Hafez (1997) found that plant height, number of panicles/hill, panicle length, number of spikelets/panicle, grain and straw yields, as well as harvest index were, generally, decreased as the irrigation intervals increased up to fourteen days, while percentage of unfilled grains/panicle was increased. However, some studies indicated that irrigation at 8-day intervals did not affected grain yield (Nour, 1989 and Awad, 2001). Irrigation every eight days recorded the highest water use efficiency (0.69 kg/m^3) and saved about 13.2% of irrigation water, compared to four days interval (Awad, 2001).

Potassium (K) has been given credit for several important roles in plant nutrition. An important function of potassium is in the plant water relations of, particularly, leaves. Plants with adequate potassium lose less moisture because they have a slower transpiration rate. When exposed to stress conditions, they close their stomata much more quickly than potassium-deficient plants. Janardan *et. al.* (1994) found that K fertilizer increased growth, yield components, dry matter and grain yields, as well as K uptake of rice, compared with no fertilizer application. Kalita *et. al.* (1995) reported that grain yield significantly increased with up to 40 kg K_2O/ha, which was mainly due to an increase in number of panicles/m^2 and number of filled grains/panicle. Mehla (1995) observed that number of panicles/m^2, number of tillers/m^2 and 1000-grain weight increased with increasing K application, but spikelets sterility decreased.

Varietal differences in growth, grain yield and its components under both irrigation and drought conditions were recorded by Abou El-Darag (2000) and El-Refaee *et. al.* (2005).

Therefore, the present study was carried out to study the interaction between water regimes and K-levels on growth, grain yield and water productivity of two rice cultivars, namely, Sakha 104 and Giza 178.

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 2003 and 2004 summer seasons. The meteorological data of the experimental sites are presented in Table (1).

Table 1. Monthly temperature means (^{0}C), relative humidity (RH %) and evaporation (E) (mmd^{-1}) at the study area in 2003 and 2004 seasons.

Month	2003					2004				
	Air temperature (^{0}C)		RH (%)		E (mm/ day)	Air temperature (^{0}C)		RH (%)		E (mm/ day)
	Max.	Min.	7:30 A.M	13:30 P.M		Max.	Min.	7:30 A.M	13:30 P.M	
May	32.2	15.0	84.7	54.2	7.91	28.5	13.0	76.0	40.0	6.65
June	33.5	18.7	86.2	43.7	7.50	32.3	16.2	84.0	46.6	7.65
July	32.6	19.7	84.4	52.6	7.58	33.1	18.5	86.0	48.0	7.55
August	33.7	19.9	91.3	55.0	6.59	32.5	21.0	87.7	47.7	7.01
September	33.0	18.0	88.3	48.9	6.11	32.2	18.0	87.4	48.2	6.21
October	30.0	15.1	81.5	47.3	4.36	29.3	15.8	81.3	47.4	4.26

The experiments were laid out in a split split-plot design, with four replications. Four irrigation treatments, namely, continuous flooding (CF), continuous saturation (CS) and irrigation every six days (6D) and every nine days (9D), were located in the main plots with 5-7 cm water head at the time of water addition. The sub-plots were occupied by the two rice cultivars, Sakha 104 (Japonica) and Giza 178 (Indica-Japonica). The potassium levels (0, 57, 86 and 114 kg K_2O/ha) were assigned to the sub-sub plots. For the best water control and to avoid the lateral movement of water, the main plots were separated each other by 2 m wide ditches. The experiments were preceded by Egyptian clover in both seasons. The soil texture was clay with pH = 8.2 and organic matter content 1.6 %. The total N was 440 ppm and the soluble of P and K were 12.0 and 1.1 ppm, respectively.

Pre-germinated grains of the two rice cultivars, at the rate of 120 kg/ha, were broadcasted in the nursery on 8^{th} and 10^{th} of May in 2003 and 2004 seasons, respectively. Three to four seedlings, thirty days old, were transplanted at 20 x 20 cm distance among hills and rows. Nitrogen (Urea, 46 %N), phosphorus (15.5 % P_2O_5) and zinc (Zn So_4) as well as all other cultural practices were undertaken as recommended. The total K was applied as a basal dose application according to the levels. Plant samples were randomly collected from all treatments at booting stage to estimate the dry matter weight. Number of days to heading was recorded at 50 % of heading of each sub sub-plot. At harvest, plant height was estimated and the total number of tillers and panicles were counted from ten random hills and, then converted into numbers/m^2. Ten random panicles were collected from each sub sub-plot to estimate the panicle length, number of spikelets/panicle, unfilled grains percentage, panicle grain weight, 1000-grain weight and sink capacity (number of spikelets per field unit area). Panicle density was estimated as the number of spikelets per panicle divided by panicle length. Grain yield was measured from 12 m^2 (3 x 4 m) area at the center of each sub-sub plot and adjusted to 14 % moisture content.

Water pump, provided with a calibrated water meter, was used for all water measurements. Water productivity (WP) was calculated as the weight of grains per unit of irrigation water received during crop growth (kg grains/m^3 water).

To evaluate the contribution of irrigation regimes in saving irrigation water, it is necessary to deal with the statistical and economical points of view. Both tools were used to compare between the different irrigation treatments to stat which one is more efficient and much effective in saving irrigation water and how much its contributed in this respect.

Data collected were statistically analyzed, according to Gomez and Gomez (1984), using IRRISTAT computer program.

RESULTS AND DISCUSSION

A- Growth characters:

Irrigation regimes significantly affected the growth characters of rice in both seasons (Table 2). Continuous flooding gave the highest values of dry matter and plant height. However, increasing irrigation intervals up to nine days significantly reduced dry matter and plant height, as well as delayed heading. These results might be attributed to the importance of water in encouraging the cell division, elongation and vegetative growth to produce more leaves and leaf area, which, in turn, resulted in more photosynthetic rate for higher dry matter production. Wopereis *et. al.* (1996) found that flowering and maturity, of stressed plants, were delayed. These results are in agreement with those obtained by Yang and Hsiang (1994) and El-Wehishy and Abdel-Hafez (1997).

Cultivars significantly differed only in dry matter production and plant height (Table 2). Giza 178 rice cultivar produced significantly the highest dry matter in 2004 season. However, Sakha 104 gave the highest values of dry matter in 2003 season and plant height in both seasons. Such difference could be attributed to the genetic variability between the two rice cultivars under study. However, the number of days to 50 % heading did not significantly differ between the two cultivars. These findings are closely related to the findings of Abou El-Darag (2000) and El-Refaee *et al.* (2005). They found significant differences among rice cultivars in some growth characters.

Compared with the control, application of potassium fertilizer significantly increased only the rice dry matter and plant height (Table 2). The results showed that increasing K levels up to 86 and 114 kg K_2O/ha significantly increased dry matter and plant height with no significant differences between each other in both seasons. On the other hand, application of K fertilizer had insignificant effect on number of days to 50 % heading in both seasons. These results agreed with those obtained by Kalita *et. al.* (1995) and Mehla (1995).

Dry matter production and plant height were, in general, highly significantly affected by the two-factor interactions in the two seasons (Tables 3 and 4). The effect of the interaction between irrigation regimes and cultivars was highly significantly with respect to dry matter in both seasons (Table 3 A). In both seasons, dry matter production was the highest for Sakha 104 under continuous flooding (CF). However, the lowest dry matter was obtained from both cultivars under irrigation every nine days (9D).

Table 2. Dry matter production (g/m^2) , number of days to 50 % heading and plant height (cm) of Sakha 104 and Giza 178 rice cultivars as influenced by irrigation regimes and potassium levels in 2003 and 2004 seasons.

Treatments	Dry matter (g/m^2)		No. of days to 50 % heading		Plant height (cm)	
	2003	2004	2003	2004	2003	2004
Irrigation regimes (I):						
Continuous flooding (CF)	1273.6	1153.3	98.91	94.53	110.9	103.7
Continuous saturation (CS)	1245.9	1137.0	98.38	95.34	100.6	99.5
Irrigation every 6 days (6D)	1132.4	1042.2	99.06	97.44	94.7	94.9
Irrigation every 9 days (9D)	1090.0	949.1	99.50	98.41	91.2	84.5
L.S.D (5 %)	27.9	18.1	0.79	1.71	3.2	3.5
Cultivars (C):						
Sakha 104	1194.9	1060.3	99.09	96.70	101.8	97.4
Giza 178	1176.0	1080.5	98.84	96.16	96.9	93.9
L.S.D (5 %)	14.9	11.9	NS	NS	1.9	1.9
K-levels (kg K_2O/ ha) (K):						
0	1114.9	995.3	98.81	96.63	97.1	93.3
57	1139.4	1080.3	99.16	96.75	100.0	96.4
86	1254.9	1100.9	99.31	96.50	100.3	97.3
114	1232.7	1105.2	98.56	95.84	100.0	95.7
L.S.D (5 %)	18.8	22.0	NS	NS	1.4	2.2
Interactions:						
I x C	**	**	NS	NS	**	*
I x K	**	**	NS	NS	*	NS
C x K	**	**	NS	NS	**	NS
I x C x K	NS	NS	NS	NS	NS	NS

NS = Not significant and **, * Highly significant and significant at 0.01 and 0.05 levels, respectively.

Results in Table (3 B) indicated that the application of 86 kg K_2O either under continuous saturation (CS) (in 2003 season) or continuous flooding (CF) (in 2004 season) resulted in the highest dry matter production. However, the zero level of potassium under irrigation every nine days recorded the lowest values in both seasons.

Furthermore, dry matter was highly significantly affected by the interaction between potassium levels and rice cultivars in both seasons (Table 3 C). Dry matter recorded its maximum value (1261 g/m^2) with Sakha 104 when potassium was applied at the rate of 86 kg K_2O/ha in 2003 season. While. Giza 178 recorded the maximum dry matter (1131 g/m^2) with applying 114 kg K_2O/ha in 2004 season.

Table 3. Dry matter production as affected by the interaction between the studied factors in 2003 and 2004 seasons.

(Table 3 A)

Cultivars (C)	2003				2004			
	Irrigation regimes (I)							
	CF	CS	6D	9D	CF	CS	6D	9D
Sakha 104	1307	1248	1138	1086	1170	1126	1008	938
Giza 178	1240	1243	1127	1094	1137	1148	1076	961
L.S.D (5 %)	32				27			

CF = Continuous flooding, CS = Continuous saturation, 6D = Irrigation every 6 days and 9D = Irrigation every 9 days .

(Table 3 B)

K-levels (K) (kg K_2O/ ha)	2003				2004			
	Irrigation regimes (I)							
	CF	CS	6D	9D	CF	CS	6D	9D
0	1236	1186	1053	986	1123	1105	897	856
57	1253	1185	1076	1043	1151	1131	1059	980
86	1323	1354	1190	1153	1191	1130	1100	983
114	1283	1258	1212	1178	1148	1182	1113	978
L.S.D (5 %)	45				52			

CF =Continuous flooding, CS = Continuous saturation, 6D= Irrigation every 6 days and 9D=Irrigation every 9 days .

(Table 3 C)

Cultivars (C)	2003				2004			
	K-levels (K) (kg K_2O/ ha)							
	0	57	86	114	0	57	86	114
Sakha 104	1135	1159	1261	1224	979	1079	1104	1079
Giza 178	1094	1120	1249	1241	1011	1082	1098	1131
L.S.D (5 %)	28				34			

Data in Table (4 A) indicated that there was a significant interaction between rice cultivars and irrigation regimes for plant height in both seasons. The tallest plants (116.6 and 107.2 cm) were obtained from Sakha 104 under CF treatment (continuous flooding), while, the shortest plants (90.8 and 84.4 cm) were obtained from the same cultivar under irrigation every nine days in 2003 and 2004 seasons, respectively. Plant height of Giza 178 was, generally, less affected by irrigation regimes than Sakha 104.

Table 4. Plant height as affected by the interaction between the studied factors in 2003 and 2004 seasons.

(Table 4 A)

Cultivars (C)	2003				2004			
	Irrigation regimes (I)							
	CF	CS	6D	9D	CF	CS	6D	9D
Sakha 104	116.6	105.4	94.4	90.8	107.2	102.3	95.6	84.4
Giza 178	105.2	95.8	94.9	91.6	100.2	96.7	94.2	84.5
L.S.D (5 %)	4.0				4.0			

CF = Continuous flooding, CS = Continuous saturation, 6D = Irrigation every 6 days and 9D = Irrigation every 9 days.

(Table 4 B)

K-levels (K) ($kg\ K_2O$/ ha)	2003					
	Irrigation regimes (I)				Cultivars (C)	
	CF	CS	6D	9D	Sakha 104	Giza 178
0	108.8	98.7	93.9	87.2	98.3	96.0
57	111.0	102.6	94.9	91.4	103.0	96.9
86	112.6	100.6	95.5	92.4	103.3	97.2
114	111.2	100.5	94.4	93.8	102.7	97.3
L.S.D (5 %)	3.4				2.1	

CF = Continuous flooding, CS = Continuous saturation, 6D = Irrigation every 6 days and 9D = Irrigation every 9 days.

The interaction between irrigation regimes and potassium levels had marked effect on plant height in 2003 season (Table 4 B). Regarding plant height, the tallest plants (112.6 cm) was obtained by continuous flooding (CF) and potassium level of 86 kg K_2O/ha. Meanwhile. the shortest one (87.2 cm) was obtained by irrigation every nine days and zero potassium level. The data observed that increasing potassium level up to 86 kg K_2O/ha could compensate for the undesirable effect of increasing the irrigation intervals.

Data presented in Table (4 B), also, showed that the tallest plants (103.3 cm) was obtained when rice plants of Sakha 104 cultivar was fertilized with 86 kg K_2O/ha. Meanwhile, plants of Giza 178 cultivar, with zero potassium level, were the shortest (96.0 cm).

B- Grain yield and its attributes:

Grain yield and its attributes were significantly affected by the Irrigation regimes in both seasons (Tables 5 and 6). Irrigation every nine days significantly deceased the number of tillers/m^2, number of panicles/m^2, panicle length, number of spikelets/panicle, sink capacity, panicle density, panicle grain weight, 1000-grain weight and grain yield, compared with continuous flooding (CF) treatment. On the other hand, unfilled grain percentage was increased with increasing irrigation intervals up to nine days. The highest values of grain yield were recorded by continuous flooding (10.73 and 10.88 t/ha), followed by continuous saturation (10.39 and 10.47 t/ha) and irrigation every six days (10.13 and 10.26 t/ha). However, the lowest values (8.65 and 8.73 t/ha) were obtained by irrigation every nine days with no significant differences among CF, CS and 6D, in the first season, and between CF and CS in the second season. The increased grain yield with CF could be ascribed to increased grain yield attributes (Table 5). Also, the results might be interpreted by the fact that available water enhanced the production and transportation of the dry matter content to panicles, resulting in more grain filling and weight, as well as higher grain yield. Such results agreed with those obtained by EL-Wehishy and Abdel Hafez (1997) and Awad (2001).

Table 5. Number of tillers/m^2, number of panicles/m^2, panicle length (cm), number of spikelets/panicle and unfilled grains (%) of rice cultivars as influenced by irrigation regimes and potassium levels in 2003 and 2004 seasons.

Treatments	No. of tillers/m^2		No. of panicles/ m^2		Panicle length (cm)		No. of spikelets/ panicle		Unfilled grains (%)	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Irrigation regimes (I):										
Cont. flooding (CF)	612.2	606.5	600.6	597.7	20.73	20.93	130.2	134.8	4.59	5.02
Cont. saturation (CS)	591.3	585.3	585.0	572.5	20.57	20.67	127.4	126.2	5.28	5.09
6 days (6D)	574.8	558.8	564.2	548.5	19.66	20.12	119.3	116.3	6.47	6.34
9 days (9D)	517.6	503.9	509.9	494.4	18.88	19.01	103.4	98.2	6.59	6.56
L.S.D (5 %)	10.9	12.4	10.5	13.9	0.69	0.45	6.99	8.74	0.89	0.21
Cultivars (C):										
Sakha 104	565.1	554.6	555.4	543.8	19.22	19.30	106.1	102.2	5.35	5.71
Giza 178	582.8	572.6	574.5	562.7	20.70	21.07	134.0	135.6	6.12	5.81
L.S.D (5 %)	11.8	9.0	11.6	8.9	0.28	0.36	3.37	4.26	0.57	NS
K-levels(K):										
(kg K_2O/ ha)										
0	554.0	550.5	542.6	537.6	19.41	19.61	114.4	110.4	6.50	6.19
57	569.3	560.0	562.7	550.3	20.26	20.33	119.0	118.1	5.22	5.74
86	586.3	570.3	578.4	565.8	20.14	20.48	122.8	125.7	5.42	5.64
114	586.3	569.7	575.9	559.4	20.04	20.32	124.1	121.3	5.80	5.47
L.S.D (5 %)	10.7	12.9	9.4	12.9	0.56	0.52	6.70	4.85	0.77	0.29
Interactions:										
I x C	NS	NS	NS	NS	NS	NS	NS	NS	**	**
I x K	*	NS	NS	NS	NS	**	NS	NS	**	**
C x K	NS	NS	NS	NS	NS	**	NS	**	**	*
I x C x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant and **, * Highly significant and significant at 0.01 and 0.05 levels, respectively.

Table 6. Sink capacity, panicle density, panicle grain weight (g), 1000-grain weight (g) and grain yield (t/ha) of Sakha 104 and Giza 178 rice cultivars as influenced by irrigation regimes and potassium levels in 2003 and 2004 seasons

Treatments	Sink capacity x 1000		Panicle density		Panicle grain weight (g)		1000-grain weight (g)		Grain yield (t/ha)	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Irrigation regimes (I):										
Cont. flooding (CF)	78.21	80.53	6.28	6.40	2.85	2.94	25.01	24.74	10.731	10.88
Cont. saturation (CS)	74.68	71.90	6.18	6.13	2.77	2.87	24.61	24.67	0.39	10.47
6 days (6D)	67.47	65.69	6.05	5.76	2.69	2.62	24.82	24.82	10.13	10.26
9 days (9D)	52.98	51.27	5.44	5.16	2.42	2.26	23.74	23.74	8.65	8.73
L.S.D (5 %)	3.89	4.41	0.35	0.18	0.12	0.20	0.19	0.44	0.63	0.51
Cultivars (C):										
Sakha 104	59.28	57.11	5.50	5.28	2.45	2.49	28.05	28.03	9.73	10.27
Giza 178	77.39	77.58	6.47	6.45	2.92	2.83	21.04	20.96	10.22	10.91
L.S.D (5 %)	2.16	2.44	0.15	0.18	0.10	0.15	0.18	0.19	0.26	0.24
K-levels(K):										
(kg K_2O/ ha)										
0	62.56	61.32	5.89	5.61	2.48	2.40	24.08	24.17	9.45	9.69
57	67.51	65.85	5.86	5.82	2.71	2.70	24.58	24.50	9.87	10.06
86	71.32	72.35	6.08	6.08	2.78	2.79	24.85	24.78	10.21	10.29
114	71.96	69.87	6.12	5.93	2.76	2.75	24.67	24.52	10.38	10.31
L.S.D (5 %)	4.10	4.14	0.35	0.27	0.10	0.21	0.22	0.33	0.28	0.20
Interactions:										
I x C	NS	**	*	NS	NS	*	NS	**	NS	NS
I x K	NS	NS	NS	NS	**	*	**	**	NS	**
C x K	NS	**	NS	**	NS	NS	NS	NS	NS	NS
I x C x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant and **, * Highly significant and significant at 0.01 and 0.05 levels, respectively.

Data presented in Tables (5 and 6) further revealed the existence of significant differences between the two rice cultivars in all of studied characters. In both seasons, Giza 178 gave the highest values of grain yield and most of its attributes, except for the 1000-grain weight which recorded its maximum values with Sakha 104. However, the two rice cultivars had no significant effect on the unfilled grain percentage in the second season. Generally, the superiority of Giza 178 in grain yield and most of its component might be attributed to the improved plant type characters, namely, dry matter production, number of panicles/m^2 and number of filled grains, that compensated for its lower 1000-grain weight. These results are in harmony with data obtained by El-Kady and Abd El-Wahab (1999) and Abou El-Darag (2000).

Data in Tables (5 and 6), also, clearly indicated that increasing potassium levels from zero up to 114 kg K_2O/ha had a positive and significant effect on all grain yield attributing characters. In both seasons, grain yield and most of its attributing characters, i.e., number of tillers/m^2, number of panicles/m^2, number of spikelets/panicle, sink capacity, panicle density, panicle grain weight and 1000-grain weight, significantly responded to adding potassium fertilizer up to 86 and 114 kg K_2O/ha. On the other hand, zero potassium gave the lowest values of the above mentioned traits, except for the percentage of unfilled grains, in both seasons, that was the highest in this case. This might be due to role of K in improving utilization of N, which directly played an essential role in cellular metabolism, reflecting improved growth and grain yield attributing characters, which, ultimately, resulted in higher grain yield. The response to potassium application of 86 and 114 kg K_2O/ha increased grain yield of rice over control treatment by 8.04 and 9.84 % (in 2003 season) and 7.35 and 8.9 % (in 2004 season), respectively. In both seasons, the 86 kg K_2O/ha produced a comparable grain yield that was not significant with the higher level of potassium (114 kg K_2O/ha). Generally, increasing potassium level significantly improved rice growth, photosynthetic capacity and all grain yield attributes, as well as decrease the water stress effect. Furthermore, increasing potassium fertilizer obviously increased the number of filled grains/panicle, hence, decreased sterility percentage, which restricted grain yield under increasing irrigation intervals. The results agreed with those obtained by Kalita *et al.* (1995) and Mehla (1995).

The effect of the interactions between the studies factors on grain yield and its attributes were presented in Tables (7 to 15). Number of tillers/m^2, as significantly affected by the interaction between the irrigation regimes and potassium levels in 2003 season, are presented in Table (7). Data showed that the highest number of tillers/m^2 (616.5) was produced when 86 kg K_2O/ha was applied under continuous flooding. However, the lowest value (492.4) was found with no potassium fertilizer application under irrigation every nine days. The results showed that application of K fertilizer had insignificant effect on number of tillers/m^2 under continuous flooding might be attributed to enhance the availability of potassium under available water condition.

Table 7. Number of tillers/m^2 as affected by the interaction between the irrigation regimes and potassium levels in 2003 season.

Irrigation regimes (I)	K-levels (K) (kg K_2O/ ha)			
	0	57	86	114
Continuous flooding	607.4	608.8	616.5	616.1
Continuous saturation	572.0	591.8	601.3	600.3
Irrigation every 6 days	544.4	569.0	589.0	569.9
Irrigation every 9 days	492.4	507.8	538.4	531.8
L.S.D (5 %)	25.5			

The effect of the interaction, between irrigation treatments and K-levels or between rice cultivars and K-levels, was highly significant with respect to panicle length only in 2004 season (Table 8). Panicle length recorded its maximum value (21.88 cm) with continuous saturation treatment and 57 kg K_2O/ ha. while, the lowest value (18.91cm) was obtained from the combination between irrigation every nine days and 86 kg K_2O/ ha. Besides, Giza 178 under continuous flooding gave the highest panicle length (22.19 cm). However, Sakha 104 under irrigation every nine days gave the lowest value of panicle length (18.86 cm), hence, the panicle length of Giza 178 was more affected by irrigation regimes.

Table 8. Panicle length (cm) as affected by the interaction between some studied factors in 2004 season.

Irrigation regimes (I)	K-levels (K) (kg K_2O/ ha)				Cultivars (C)	
	0	57	86	114	Sakha 104	Giza 178
Continuous flooding	20.19	20.50	21.70	21.34	19.70	22.19
Continuous saturation	20.08	21.88	20.81	19.91	19.47	21.19
Irrigation every 6 days	19.33	19.96	20.50	20.70	19.20	21.87
Irrigation every 9 days	18.94	18.99	18.91	19.31	18.86	19.16
L.S.D (5 %)	1.23				0.77	

The interaction between potassium levels and rice cultivars had a positive and a highly significant effect on number of spikelets/panicle only in 2004 season (Table 9). The best combination was Giza 178 rice cultivar with potassium level of 86 kg K_2O/ha. Meanwhile, the worst one was Sakha 104 rice cultivar and zero potassium level.

Table 9. Number of spikelets/panicle as affected by the interaction between rice cultivars and potassium levels in 2004 season.

Cultivars (C)	K-levels (K) (kg K_2O/ ha)			
	0	57	86	114
Sakha 104	98.19	104.35	104.96	101.16
Giza 178	122.63	131.87	146.41	141.44
L.S.D (5 %)	6.84			

The effect of the two-factor interaction between the studies traits had a highly significant effect on the unfilled grains (%) in 2003 and 2004 seasons (Table 10). Sakha 104 cultivar, under continuous flooding, produced the lowest unfilled grain percentage values of 3.98 and 4.51 % (Table 10 A). On the other hand Giza 178 cultivar, under no potassium application, gave the highest percentage of unfilled grains of 7.78 and 6.43 (Table 10 C) in 2003 and 2004 seasons, respectively. Data in Table (10 B) indicated that the lowest value of unfilled grains percentage (3.59) was obtained with the combination of continuous flooding and potassium level of 57 kg K_2O/ha in the first season. However, the combination of continuous saturation and high potassium level of 114 kg K_2O/ha gave the lowest value (4.51 %) in the second season.

Table 10. Unfilled grains (%) as affected by the interaction between the studied factors in 2003 and 2004 seasons.

(Table 10 A)

Cultivars (C)	2003				2004			
	Irrigation regimes (I)							
	CF	CS	6D	9D	CF	CS	6D	9D
Sakha 104	3.98	6.15	5.23	6.03	4.51	5.25	6.28	6.79
Giza 178	5.19	4.41	7.72	7.15	5.53	4.93	6.45	6.33
L.S.D (5 %)	1.25				0.38			

CF = Continuous flooding, CS = Continuous saturation, 6D = Irrigation every 6 days and 9D = Irrigation every 9 days.

(Table 10 B)

K-levels (K) (kg K_2O/ ha)	2003				2004			
	Irrigation regimes (I)							
	CF	CS	6D	9D	CF	CS	6D	9D
0	5.65	6.41	7.96	5.98	5.01	5.99	6.79	6.98
57	3.59	5.13	4.61	7.53	4.74	5.11	6.13	6.98
86	4.63	4.49	4.91	7.63	5.19	4.74	6.25	6.38
114	4.48	5.09	8.41	5.22	5.15	4.51	6.30	5.91
L.S.D (5 %)	1.83				0.62			

CF = Continuous flooding, CS = Continuous saturation, 6D = Irrigation every 6 days and 9D = Irrigation every 9 days.

(Table 10 C)

Cultivars (C)	2003				2004			
	K-levels (K) (kg K_2O/ ha)							
	0	57	86	114	0	57	86	114
Sakha 104	5.22	5.25	5.62	5.30	5.96	5.88	5.66	5.34
Giza 178	7.78	5.18	5.21	6.30	6.43	5.59	5.62	5.60
L.S.D (5 %)	1.15				0.44			

Regarding sink capacity (Table 11), the rice cultivars highly significantly varied in their sink capacity under the same irrigation treatment or the same level of potassium only in 2004 season. Under continuous flooding, Giza 178 produced the highest value (93.32), while, Sakha 104 produced the lowest value (44.64) when irrigated every nine days. Furthermore, applying 86 kg K_2O/ ha to Giza 178 rice cultivar gave higher value of sink capacity (85.72) than that of no potassium application to Sakha 104 rice cultivar (54.13).

Table 11. Sink capacity x 1000 as affected by the interaction between some studied factors in 2004 season.

Cultivars (C)	Irrigation regimes (I)				K-levels (K) (kg K_2O/ ha)			
	CF	CS	6D	9D	0	57	86	114
Sakha 104	67.74	60.52	55.55	44.64	54.13	57.43	58.99	57.91
Giza 178	93.32	83.29	75.83	57.90	68.51	74.27	85.72	81.84
L.S.D (5 %)	5.30				6.20			

CF = Continuous flooding, CS = Continuous saturation, 6D = Irrigation every 6 days and 9D = Irrigation every 9 days.

The interaction between rice cultivars and irrigation treatments, as well as rice cultivars and potassium levels, had either a significant (in 2003 season) or highly significant (in 2004 season) effect on panicle density (Table 12). Generally, the highest panicle density of 6.71 and 6.86 were obtained from Giza 178 rice cultivar under continuous saturation (in 2003 season) and 86 kg K_2O/ha (in 2004 season), respectively.

Table 12. Panicle density as affected by the interaction between some studied factors in 2003 and 2004 seasons.

Cultivars (C)	Irrigation regimes (I) 2003				K-levels (K) (kg K_2O/ ha) 2004			
	CF	CS	6D	9D	0	57	86	114
Sakha 104	5.94	5.66	5.40	5.01	5.19	5.45	5.30	5.17
Giza 178	6.62	6.71	6.69	5.86	6.02	6.22	6.86	6.69
L.S.D (5 %)	0.53				0.40			

CF = Continuous flooding, CS = Continuous saturation, 6D = Irrigation every 6 days and 9D = Irrigation every 9 days.

Table (13) shows that the maximum values of panicle grain weight (2.90 and 3.26 g) were obtained by the combination of continuous flooding and high potassium level of 114 kg K_2O/ha. Meanwhile, the combination irrigation every nine days and zero potassium gave the minimum values of this trait (2.22 and 2.16 g) in both respective seasons. On the other hand, in 2003 season, Giza 178 cultivar, under continuous flooding, recorded the maximum value (3.29 g), while, the minimum value (2.16 g) was recorded by Sakha 104 with nine days irrigation interval.

Table 13. Panicle grain weight (g) as affected by the interaction between some studied factors in 2003 and 2004 seasons.

Irrigation regimes (I)	2003				2004				2003	
	K-levels (K) (kg K_2O/ ha)								Cultivars (C)	
	0	57	86	114	0	57	86	114	Sakha 102	Giza 178
Cont. flooding (CF)	2.82	2.84	2.84	2.90	2.62	2.84	3.04	3.26	2.58	3.29
Cont. saturation (CS)	2.52	2.81	2.87	2.86	2.49	3.2	3.08	2.73	2.75	3.00
6 days (6D)	2.34	2.85	2.80	2.78	2.34	2.58	2.81	2.74	2.47	2.77
9 days (9D)	2.22	2.34	2.60	2.51	2.16	2.19	2.22	2.30	2.16	2.27
L.S.D (5 %)	0.24				0.50				0.33	

One-thousand grain weight was highly significantly affected by the interaction between certain studied factors in 2003 and 2004 seasons (Table 14). Data showed that the maximum value (24.97 g) was obtained with the application of 57 kg K_2O/ha and 6D treatment (in 2003 season) and the application of 114 kg K_2O/ha and CF treatment (25.25 g) (in 2004 season). Sakha 104 gave significantly a higher value of this trait than Giza 178 under all irrigation treatments. Generally, Sakha 104, under CF treatment, produced the maximum value (28.95 g), while Giza 178, under 9D treatment gave the minimum value (20.38 g).

Table 14. 1000-grain weight (g) as affected by the interaction between some studied factors in 2003 and 2004 seasons.

Irrigation regimes (I)	2003				2004				2003	
	K-levels (K) (kg K_2O/ ha)								Cultivars (C)	
	0	57	86	114	0	57	86	114	Sakha 102	Giza 178
CF	24.65	24.63	24.85	24.81	24.86	24.89	25.19	25.25	28.95	21.14
CS	24.72	24.60	24.84	24.54	24.34	24.69	24.79	25.18	28.75	20.74
6D	24.43	24.97	25.17	24.71	23.28	23.43	24.53	24.83	27.39	20.64
9D	22.88	23.81	24.26	24.00	23.61	23.71	23.59	23.70	26.93	20.38
L.S.D (5 %)	0.52				0.78				0.41	

CF = Continuous flooding, CS = Continuous saturation, 6D = Irrigation every 6 days and 9D = Irrigation every 9 days.

The interaction between irrigation treatments and potassium levels had a highly significant effect on grain yield only in 2004 season (Table 15). The best combination to produce the maximum grain yields (10.95 and 10.96 t/ha) was continuous flooding and applied potassium fertilizer at the level of 86 and 114 kg K_2O/ha., respectively. However, nine-day irrigation interval, under zero potassium application, gave the lowest grain yield (7.90 t/ha). In fact, potassium fertilizer is much needed to compensated the water stress effect under increasing irrigation intervals up to nine days.

Table 15. Grain yield (t/ha) as affected by the interaction between the irrigation regimes and potassium levels in 2004 season.

K-levels (K) (kg K_2O/ ha)	Irrigation regimes (I)			
	Cont. flooding	Cont. saturation	6-day	9-day
0	10.74	10.29	9.83	7.90
57	10.89	10.48	10.20	8.69
86	10.95	10.55	10.53	9.13
114	10.96	10.57	10.50	9.20
L.S.D (5 %)	0.47			

C- Water input and productivity:

Data in Table (16) showed that the amounts of water input, before staring irrigation treatments, for land preparation of both nursery and permanent field, raising nursery for thirty days and through ten days after transplanting and before treatments application, were 4276.9 and 4411.0 m^3/ha, in 2003 and 2004 seasons, respectively. The previous period (forty days) was considered a blank for all treatments. Comparing the different treatments of irrigation (Table 16), it was observed that continuous flooding received the highest amounts of water throughout the season (15131.5 and 14922.5 m^3/ha), as expected, while, the lowest amounts were received by irrigation every nine days treatment (11705.8 and 11591.0 m^3/ha) in 2003 and 2004 seasons, respectively. Over both seasons, the results showed that the total amount of irrigation input ranged between 15171.0 and 11691.0 m^3/ha for Sakha 104 cultivar, however, it ranged between 14883.0 and 11605.8 m^3/ha for Giza 178 cultivar for CF and 9D treatments, respectively. There were no large variations in the amounts of irrigation water input due to the stable conditions, namely, temperature, relative humidity and evaporation rates in both seasons as previously shown in Table (1).

Table 16. Grain yield reduction (%), total water input (m^3/ha), water saved (%) and water productivity (kg/m^3), as well as relative contribution of water in producing rice cultivars by irrigation regimes in 2003 and 2004 seasons.

Season	Irrigation regimes	Cultivars	Grain yield (t/ha)	Grain yield reduction (%)	Total water input (m^3/ha)	Water saved (%)	Water productivity (kg/m^3)		Increasing productivity	
							kg/m^3	Trad %	kg/m^3	kg/100 m^3
2003	Cont. flooding	Sakha 104	10.536	-	15332.5	-	0.687	100.0	-	-
		Giza 178	10.923	-	14930.5	-	0.732	100.0	-	-
		Mean	10.730	-	15131.5	-	0.709	100.0	-	-
	Cont. saturation	Sakha 104	10.164	3.531	11967.1	21.95	0.849	123.6	0.162	16.2
		Giza 178	10.609	2.875	11855.0	20.60	0.895	122.3	0.163	16.3
		Mean	10.387	3.203	11911.1	21.28	0.872	123.0	0.163	16.3
	6 days	Sakha 104	9.886	6.169	13990.2	8.74	0.707	102.9	0.020	2.0
		Giza 178	10.379	4.980	13520.2	9.45	0.768	111.8	0.036	3.6
		Mean	10.133	5.575	13755.2	9.10	0.737	103.9	0.028	2.8
	9 days	Sakha 104	8.346	20.786	11721.8	23.55	0.712	103.6	0.025	2.5
		Giza 178	8.959	17.980	11689.7	21.71	0.767	104.8	0.035	3.5
		Mean	8.653	19.383	11705.8	22.63	0.739	104.2	0.030	3.0
2004	Cont. flooding	Sakha 104	10.686	-	15009.5	-	0.712	100.0	-	-
		Giza 178	11.081	-	14835.4	-	0.747	100.0	-	-
		Mean	10.884		14922.45	-	0.729	100.0	-	-
	Cont. saturation	Sakha 104	10.343	3.238	11839.2	21.12	0.874	122.8	0.162	16.2
		Giza 178	10.600	4.341	11617.1	21.69	0.912	122.1	0.165	16.5
		Mean	10.472	3.789	11728.15	21.41	0.893	122.5	0.164	16.4
	6 days	Sakha 104	10.013	6.298	13560.0	9.66	0.738	103.7	0.026	2.6
		Giza 178	10.513	5.126	13390.0	9.74	0.785	105.1	0.038	3.8
		Mean	10.263	5.712	13475.00	9.70	0.762	104.5	0.033	3.3
	9 days	Sakha 104	8.593	19.586	11660.1	22.32	0.737	103.5	0.025	2.5
		Giza 178	8.866	19.989	11521.8	22.33	0.769	102.9	0.022	2.2
		Mean	8.730	19.788	11590.95	22.33	0.753	103.3	0.024	2.4

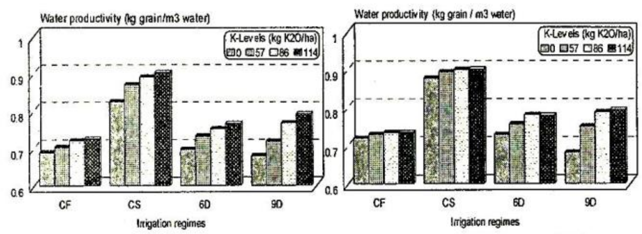
Water inputs before treatments application were 4276.9 and 4411.0 m^3/ha in 2003 and 2004 seasons, respectively.

Water saved, due to increasing the intervals, compared to continuous flooding, ranged from 8.74 to 23.55 %, in the first season, and from 9.66 to 22.32 %, in the second season, for Sakha 104. However, it ranged from 9.45 to 21.71 % (in first season) and from 9.74 to 22.33 % (in second season) for Giza 178. Irrigation every nine days may considerably reduce irrigation water input, compared with continuous flooding. But, at the same time, grain yield significantly decreased. Grain yield reduction of Sakha 104 was higher than that of Giza 178, in most cases. This means that Giza 178 was more tolerant to water deficit than Sakha 104. Nour and Mahrous (1994) found that continuous saturation recorded the highest water saved flowed by irrigation every eight days, as compare to the continuous submergence.

Regarding water productivity, the CS treatment (continuous saturation) was considered the best water productivity for Sakha 104 (about 0.85 and 0.87 kg/m^3) and Giza 178 (about 0.89 and 0.91 kg/m^3) in the first and second seasons, respectively . Because of their higher grain yields, WP was higher for Giza 178 than for Sakha 104 cultivars in all water treatments. This means that higher WP could be obtained even under continuous saturated conditions. Tabbal *et. al.* (2002) reported reduced water input and increased water productivity of rice grown under just-saturated soil conditions, compared with traditional flooded rice.

Considering continuous flooding, equaled to one-hundred percent (Table 16), consequently, continuous saturation gave the highest relative productivity (123.0 and 122.5 %) in 2003 and 2004 seasons, respectively. While, the other two treatments gave the lowest and similar results (about 104 %). In other words, continuous saturation and irrigation every six and nine days achieved an increase in WP. For example, continuous saturation increased the contribution of 100 m^3 of water by 16.4 kg of rice, compared to 3.0 and 3.9 kg of rice in case of using irrigation every six and nine days, respectively. The relative productivity of Giza 178 rice cultivar was slightly higher than that of Sakha 104 in most irrigation regimes in both seasons.

Water productivity (WP), over both rice cultivars, ranged from 0.68 to 0.90 kg/m^3 in both seasons (Fig. 1). The WP values were relatively high in CS, compared with the other irrigation regimes. The extremely high values of WP, in CS, were caused by the extremely high grain yield and low water inputs in this treatment (Table 16). Among the four irrigation regimes, CS had the highest WP and CF had the lowest one. The differences among CF, 6D and 9D were not significant in both seasons. Bouman and Tuong (2001) and Belder *et. al.*(2002) reported that WP was higher in the alternately submerged and non-submerged regimes than in the continuous submerged regime. Data in Fig. (1) showed significant and positive effect was induced by K-levels on WP in both seasons. Under all irrigation regimes application of potassium recorded higher WP than the control treatment. High WP, with potassium application, was associated with high grain yield. The productivity of irrigation water could be increased to reach it maximum value of 0.90 kg/m^3, under CS, and about 0.77 kg/m^3 when irrigation intervals increased up to nine days with applied 86 and 114 kg K_2O/ha.



2003 2004

Fig. 1. Water productivity (kg grain/m^3 water) over both rice cultivars as influenced by irrigation regimes and potassium levels in 2003 and 2004 seasons.

CF = Continuous flooding
CS = Continuous saturation
6D = Irrigation every 6 days
9D = Irrigation every 9 days

D- Economic return of water:

Table (17) shows that the quantity of water input to produce one kg grains of rice decreased in case of continuous saturation and irrigation every six and nine days, relative to continuous flooding treatment. Over both seasons, in case of continuous saturation, one kg of rice grains needs 1.161 and 1.107 m^3 of water (80.0 and 81.8 % of continuous flooding requirement), as compared to1.385 and 1.289 m^3 of water, in case of irrigation every six days (94.8 and 95.2 % of continuous flooding requirement). While, in case of irrigation every nine days, one kg of rice grains needed 1.381 and 1.303 m^3 of water (96.6 and 96.3 % of continuous flooding requirement) for Sakha 104 and Giza 178 rice cultivars, respectively. In other words, the quantity of water saved for producing 100 kg of rice grains was 269 and 247 m^3 in case of continuous saturation, as compared to 46 and 65 m^3 of water in case of irrigation every six days. While, in case of irrigation every nine days, it was 50 and 51 m^3 of water for Sakha 104 and Giza 178 rice cultivars, respectively. Data in Tale (17), also, showed that the total quantities of saved irrigation water on the overall national level, by multiplying the national production of the rice crop by the average quantity of saved water. It indicated that continuous saturation saved 1628.3 and 1599.8 million m^3 and irrigation every six days saved 320.7 and 369.7 million m^3, while, irrigation every nine days saved 351.6 and 274.1 million m^3 in the first and second seasons, respectively. This means that applying continuous saturation could save about 1600 million m^3 to the national agricultural production.

Table 17. Economic return of water as affected by irrigation regimes and rice cultivars in 2003 and 2004 seasons

Season	Irrigation regimes	Cultivars	Average requirements		Quantity saved (m^3/kg)	Total national production (million kg)*	Total quantity of water available (million m^3)	Yield added (million kg)	Farm price* (L.E /kg)	Total values of rice added (Million L.E.)
			m^3/kg	Trad =100						
			1	2	3	4	5 (3 x 4)	6 (5/1)	7	8(6 x 7)
2003	Cont flooding	Sakha 104	1.455	100.0	0	6167.72	0	0	1.050	0
		Giza 178	1.367	100.0	0		0	0		0
		Mean	1.411	100.0	0		0	0		0
	Cont saturation	Sakha 104	1.177	80.9	0.278		1714.6	1456.8		1529.6
		Giza 178	1.117	81.7	0.250		1541.9	1380.4		1449.4
		Mean	1.147	81.3	0.264		1628.3	1418.6		1489.5
	6 days	Sakha 104	1.415	93.1	0.040		246.7	174.3		183.0
		Giza 178	1.303	95.3	0.064		394.7	302.9		318.0
		Mean	1.359	94.1	0.052		320.7	236.0		247.8
	9 days	Sakha 104	1.404	96.5	0.051		314.6	224.1		235.3
		Giza 178	1.305	95.5	0.062		382.4	293.0		307.7
		Mean	1.354	96.0	0.057		351.6	259.7		272.7
2004	Cont flooding	Sakha 104	1.405	100.0	0	6373.77	0	0	1.077	0
		Giza 178	1.339	100.0	0		0	0		0
		Mean	1.371	100.0	0		0	0		0
	Cont saturation	Sakha 104	1.145	79.0	0.260		1657.2	1447.3		1558.7
		Giza 178	1.096	81.8	0.243		1548.8	1413.1		1521.9
		Mean	1.120	81.7	0.251		1599.8	1428.4		1538.4
	6 days	Sakha 104	1.354	96.4	0.051		325.1	240.1		258.6
		Giza 178	1.274	95.1	0.065		414.3	325.2		350.2
		Mean	1.313	95.8	0.058		369.7	281.6		303.3
	9 days	Sakha 104	1.357	96.6	0.048		305.9	225.4		242.8
		Giza 178	1.300	97.1	0.039		248.6	191.2		205.9
		Mean	1.328	96.9	0.043		274.1	206.4		222.3

* Source : Rice Research & Training Center (RRTC), Field Crops Research Institute, Agricultural Research Center, Ministry of Agriculture and Land Reclamation.

Translated the quantities of water saved into monetary units (Egyptian pounds), it means more national income. Data in Table (17) observed that continuous saturation treatment could contribute in adding about 1490 and 1538 million L.E. However, irrigation every six days could contributed in adding about 250 and 300 million L.E. over both cultivars in 2003 and 2004 seasons, respectively.

Generally, continuous saturation gave a grain yield similar to that of continuous flooding with only 3-4% reduction. This means that almost 20-25% of irrigation water could be saved if all farmers followed this practice and about 1500 million L.E. could be add to the national income.

REFERENCES

1. Abou El-Darag, I. H. O. 2000. Effect of time and methods of nitrogen application with transplanting and broadcasting rice on yield and quality characteristics. M.Sc. Thesis, Fac. of Agric., Moshtohor, Zagazig Univ., Egypt.

2. Awad, H. A. 2001. Rice production at the north of Delta Region in Egypt as affected by irrigation intervals and nitrogen fertilizer levels. J. Agric. Sci. 26: 1151-1159. Mansoura Univ., Egypt.

3. Belder, B. A. M., J. H. J. Spiertz, L. Guoan and E. J. P. Quilang. 2002. Water use of alternately submerged and non-submerged irrigated lowland rice. In: Water-Wise Rice Production. Proceedings of the International Workshop on Water-Wise Rice Production. IRRI. Los Banos, Philippines. pp 51-61.

4. Bouman B. A. M. and T. P. Tuong. 2001. Field water management to save water and increase its productivity in irrigated rice. Agric. Water Manamge. 49:11-30.

5. El-Kady, A. A. and A.A. Abd El-Wahab. 1999. Nitrogen fertilizer management and its effect on growth, yield and grain quality of some Egyptian rice yield. Egypt. J. of Appl. Sci. 14(7): 24-35.

6. El-Refaee, I.S., R.N. Gorgy, S. El-Gewaily and W.H. El-Kallawy. 2005. Physiological aspects of grain yield variation in short and medium duration cultivars of rice grown under water stress conditions. The 11^{th} Conference of Agronomy, Agron. Dept., Fac. Agric., Assiut Univ., Nov. 15-16. p: 281-291.

7. El-Wehishy, M.M and A.G. Abdel Hafez. 1997. Response of flooded rice to water deficit. J. Agric. Res., 23, 273-288. Tanta Univ., Egypt.

8. Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedures for Agricultural Uses. 2^{nd} ed., John Wiley & Sons. U.S.A.

9. Janardan S., H. L. Sharma and C. M. Singh. 1994. Direct, residual and cumulative effect of potassium fertilization in rice (*Oryza sativa L.*)–wheat (*Triticum aestivum L.*) cropping system. Indian J. of Agron. 39(3): 345-355.

10. Kalita, U., N.J. Ojha and M.C. Talukdar. 1995. Effect of levels and time of application of potassium on yield and yield attributes of upland rice. J. of Potassium Res. 11: 203-206.

11. Mehla, S. 1995. Potassium fertilizer for higher yields in scented rice. Int. Rice Res. Newsletter. 20: 21-22.

12. Nour, M.A. 1989. Studies on fertilization and irrigation on rice. Ph.D. Thesis, Fac. of Agric., Kafr El-Sheikh, Tanta Univ., Egypt.

13. Nour, M.A. and F. N. Mahrous. 1994. Effect of varying irrigation intervals during tillering, reproductive and ripening stages on rice yield and its components. Egypt J. Appl. Sci. 9(7): 86879.

14. RRTC (Rice Research and Training Center). 2005. Technical Bulletin of Rice Cultivation of 2005. Rice Research Program, Field Crops Research Institute, Agricultural Research Center, Ministry of Agriculture and Land Reclamation (In Arabic).

15. Tabbal D.F., B.A.M. Bouman, S.I. Bhuiyan, E.B. Sibayan and M.A. Sattar. 2002. On-farm strategies for reducing water input in irrigated rice: Case studies in the Philippines. Agric. Water Manage. 56(2):93-112.

16. Wopereis, M.C., M.J. Kropff, A.R. Maligaya and T.P. Tuong. 1996. Drought stress responses of two lowland rice cultivars to soil water status. Field Crops Res. 46:21-39.

17. Yang, C. and W. Hsiang. 1994. Growth and yield of rice as affected by soil water deficits. Chinese J. of Agrometeorology 1(4): 143-150. (C.F. Field Crop Abst., 49(5):403, 1996).

تأثير التفاعل بين نظم الري و مستويات البوتاسيوم على النمو و محصول الحبوب وإنتاجية المياه في الأرز

إسماعيل سـعـد الرفاعــي

مركز البحوث الزراعية– معهد بحوث المحاصيل الحقلية– مركز البحوث و التدريب في الأرز– سخا– كفر الشيخ

درس التفاعل بين نظم الري و مستويات البوتاسيوم على صنفي الأرز "سخا ١٠٤ و جيزة ١٧٨ " في تجربتين حقليتين أقيمتا بالمزرعة البحثية لمركز البحوث و التدريب في الأرز – سخا – كفر الشيخ خلال موسمي ٢٠٠٣ و ٢٠٠٤م. استخدمت أربعة معاملات لنظم الري وهى: الغمر المستمر طوال الموسم و التشبع المستمر طوال الموسم و الري كل ستة و تسعة أيام، و استخدم أربعة مستويات من البوتاسيوم وهى: ٠ و ٥٧ و٨٦ و ١١٤ كجم بو٢أ / هكتار. استخدم تصميم القطع المنشقة مرتين في أربع مكررات حيث احتوت القطع الرئيسية على معاملات الري و القطع الشقية الأولى على صنفي الأرز أما القطع الشقية الثانية فاحتوت على مستويات البوتاسيوم.

و توضح أهم النتائج انه لا توجد فروق معنوية بين معاملتي التشبع و الغمر المستمر طوال الموسم في محصول الحبوب ومعظم مكوناته، و أن زيادة فترات الري إلى تسعة أيام أدت إلى نقص محصول الحبوب بحوالى ١٧ % بالمقارنة مع الغمر المستمر. كما تفوق الصنف " جيزة ١٧٨" في إنتاج المادة الجافة و في صفات محصول الحبوب و مكوناته، و كذلك في إنتاجية وحدة المياه بالمقارنة بالصنف "سخا ١٠٤". و توضح النتائج أيضا أن زيادة مستويات البوتاسيوم حتى ٨٦ كجم بو ٢ أ /هكتار أدت إلى زيادة معنوية في صفات ارتفاع النبات وإنتاج المادة الجافة بالاضافه إلى محصول الحبوب و مكوناته و ذلك تحت زيادة فترات الري في موسمي الزراعة.

و تشير الدراسة أن مجرد الحفاظ على تشبع الأرض طوال الموسم أدى إلى تقليل كميات مياه الري المستخدمة مع زيادة إنتاجيه وحده المياه و ذلك بالمقارنة بالغمر المستمر طوال الموسم.

عموما ، معاملة تشبع التربة المستمر طوال الموسم أنتج محصول حبوب يوازى محصول الحبوب الناتج من معاملة الغمر المستمر طوال الموسم مع نقص غير معنوي في محصول الحبوب قدر بحوالي ٣–٤ % فقط ، مما يعنى أن حوالي ٢٠– ٢٥ % من مياه الري المستخدمة يمكن توفيرها إذا ما التزم جميع المزارعين باستخدام تلك المعاملة و نتيجة لذلك يمكن إضافة حوالي ١٥٠٠ مليون جنيه مصري إلى الدخل القومي