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IRRIGATION REGIME AND POTASSIUM LEVELS EFFECTS ON YIELD OF SOME RICE GENOTYPES, WATER USE EFFICIENCY (WUE) AND ECONOMIC RETURNS

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ABSTRACT

Irrigation intervals and potassium levels were studied using Giza179, GZ7112 and Sakha106 rice genotypes at the experimental Farm of Rice Research and Training Center (RRTC) Sakha, Kafr El-Sheikh, Egypt, during 2012 and 2013 seasons. Four irrigation intervals treatments namely; continuous flooding (W), irrigation every 4 days (4W), irrigation every 8 days (8W) and irrigation every 12 days (12W), as well as five rates of potassium; 0 (K0), 36 (K1), 72 (K2), 108 (K3) and 144 (K4) kg K_2O/ha were used. The field experiments were laid out in a split-spit design with four replications. The irrigation treatments were applied in the main plots, the rice genotypes were placed in the sub- plots and the potassium rates were put in the sub-sub plots. The main obtained results indicated that Giza179 produced higher grain yield and its attributes followed by GZ7112 rice line under continuous flooding (W) without any significant decrease in yield up to 8W and then significantly decreased under12W treatment. The amount of water saved due to increasing irrigation intervals compared to continuous flooding were (10.36 and 8.37 %) for Giza179 and (10.50 and 10.36%) for GZ7112 under 4W treatment and (17.81 and 23.66%) for Gzia179 and (13.33 and 18.44%) for GZ7112 with 8W treatment, while under 12W water saved was about 23.91 and 27.90 % with reduction in grain yield about 22.42 and 24.71 % in 2012 and 2013 seasons respectively. Over both season using Giza179 and GZ7112 rice genotypes which gave higher yield about (9.70 and 9.33 t/ha), water saved (20.73 and 15.88 %) and water use efficiency (0.90 and 0.81 kg/m^3) for both genotypes respectively. It means that the total water input ranged from 11260.88 and 10006.80 m^3/ha (which equal about 4700 m^3/fed) under 8W treatment using Gzia179 rice variety compared with national average which reaches to 1428.57 m^3/ha (which equal about 6500 m^3/fed). The application of potassium up to 108 K_2O/ha (K3) significantly increased rice yield and relatively mitigated the undesirable effect of water stress resulted in increase the WUE and water saved %.

INTRODUCTION

In Egypt, Rice is one of the major water consuming crops and most of Egyptian rice genotypes are grown under continuous flooding with about 5 cm depth of standing water throughout the growing season. Most of Egyptian rice genotypes show better growth and higher productivity under continuous flooding conditions than ones exposed to water deficit at certain growth stages. Rice occupies about 22 % of the total growing area in Egypt during summer season and it consumed about 20% of the total water resources (*Abd Allah, et al, 2009*). Water resources in Egypt are limited to 55.5 x 10^9 m^3/ year, with tremendous increase in the population, production has to be increased and irrigation water has to be well managed and has ways for increasing water use efficiency. Total water requirements for rice crop is a serious problem because of the limited irrigation water available from the River Nile. Some rice planted areas, especially those are located at the end of the terminal irrigation ditales in the northern part of the Nile Delta, suffer from shortage of irrigation water during different growth stages, which are considered to be one of the most serious constraints to rice production in Egypt. So, water input can be reduced by; reducing water depth to soil saturation and using different irrigation interval *Ghanem and Badawi Tantawi, 1999*). The amount of water saved due to increasing irrigation intervals ranged from about 19 to about 39%. Highest saving of irrigation water was found when irrigation intervals increased from continuous to irrigation every 12 days. The rice genotypes differ in requirement of irrigation water according to its growth duration. So, highest saving was found with Giza 177 with prolonged irrigation, while the lowest saving of irrigation water was found with Giza 178 and Giza 176 rice genotypes *(Nour et al, 1997).* Among the nutrients, potassium (K) is a macro-element known to be very dynamic and a major contributor to the organic structure and metabolic functions of the plant. Potassium in rice soils is one of the limiting factors for increasing rice yield (*Yang et al., 2003*). Cultivars with high affinity for K exhibit an increase in root growth and consequently, uptake water in rice, when treated with potassium.

Potassium improves water relations as well as productivity of different crops under water stress conditions (*El- Refaee, 2006)*. Several biochemical pathways, osmotic potential, translocation process, and growth and maintenance of a cell are dependent on potassium ion the cell sap (*Mengel and Kirkby (1987*). This study aimed at 1) Rationalize water use with maintaining high productivity with different rates of potassium and 2) Identify the rice variety which has more tolerant to water deficit.

MATERIALS AND METHODS

Field experiment was conducted at the Experimental Farm of Rice Research and Training Center (RRTC) Sakha, Kafr El-Sheikh, Egypt, during 2012 and 2013 rice growing seasons; to identify the impact of different water intervals i.e. continuous flooding (W), irrigation every 4 days (4W), irrigation every 8 days (8W) and irrigation every 12 days (12W) and potassium levels namely, 0 (K0), 36 (K1), 72 (K2), 108 (K3) and 144 (K4) kg K_2O/ha on yield and its attributes of Giza179, GZ7112 and Sakha106 rice genotypes and the best interaction among studied factors, as well as water productivity and (value of matric potential in soil) and K levels on grain yield and water use efficiency (water productivity) and value of soil matric potential. The experiment was laid out in a split-split plot design with four replications; irrigation intervals were located in the main plots. The three rice genotypes were placed in the sub-plots and the potassium levels were put in the sub-sub plots. Pre-germinated seeds of the three rice genotypes at the rate of 120 Kg/ha, were broadcasted manually in the nursery on 10 th of May in 2012 and 2013 seasons. Nitrogen (urea 46 % N), phosphorus (15.5 % P_2O_5) and Zinc ($ZnSO_4$) and other cultural practices were applied according to recommendation of Rice Research and Training Center (RRTC). The total amount of potassium fertilizer in form of potassium sulphate (K_2SO_4) was applied as a basal application during land preparation. Pump, provided with a calibrated water meter was used for all irrigation measurements a long rice seasons. The quantity of water require for land preparation (nursery and permanent field) were 4350.80 and 4508.40 m^3/ha in 2012 and 2013 seasons respectively.

Number of tillers/m^2, number of panicles/m^2,panicle length (cm), panicle density, unfilled grain/panicle (%), number of filled grain/panicle, panicle weight (g), 1000- Grain weight (g) and grain yield (t/ha) were estimated according to IRRI STS 1996. Panicle density was estimated as the number of spikelets per panicle divided by panicle length. Some chemical analyses of soil used in this study before and after experiments were presented in Table 1. Total soluble cations and anions in soil paste extract were assessed according to *Richards (1969).* Matric-potential data alone can be used to determine the approximate water content of the soil by tensiometer apparatus. The tensiometer apparatus was used to measure soil matric potential. Means of monthly temperature (C^o), percentage of relative humidity (RH) and evaporation (mmd^{-1}) of study site in both seasons are presented in Table 2. All collected data were subjected to statistical analysis according to procedure describe by *Gomes and Gomes* (1984). Means were compared at p< 0.05 by the reviesed least significant differences (LSD), which adapted by *Waller and Duncan (1969).* Water use efficiency (WUE) was calculated as following equation:

WUE (kg $ha^{-1}mm^{-1}$) = Crop yield (kg ha-1)/Water supply (mm or m^3).

Table 1: Chemical analyses of the experimental soil before planting and after harvest in 2012 and 2013 summer seasons

Soil chemical properties	Before planting		After harvest	
	2012	2013	2012	2013
pH(1:2.5)	8.35	8.44	8.12	8.35
Ec (ds.m^{-1})	3.12	3.34	3.09	2.90
Total N (ppm)	477.00	430.50	588.9	599.70
Available P (ppm)	14.00	12.00	18.20	17.80
Available K (ppm)	189.60	170.00	450.50	460.60
Anions(meq.L^{-1})				
$CO3^{--}$	--	--	--	--
$HCO3^-$	5.30	6.10	6.50	5.77
Cl^-	8.50	9.30	8.80	8.30
$SO4^{--}$	17.40	18.00	15.63	14.90
Cations(meq.L^{-1})				
Ca^{++}	11.70	10.50	6.30	5.80
Mg^{++}	3.50	5.00	4.10	3.70
Na^{++}	1.60	2.00	1.40	1.70
K^+	14.40	15.60	19.13	17.70
Available micronutrients (ppm)				
Fe	5.00	5.80	6.00	6.50
Mn	3.04	3.20	3.70	3.60
Zn	1.00	0.95	1.30	1.22

Table 2: Monthly temperature means (c^o), relative humidity (RH %) and evaporation (mmd^{-1}) at study area in 2012 and 2013 seasons

Months	2012 season					2013 season				
	Air temperature (C^o)		RH %		E (mm/day)	Air temperature (C^o)		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	30.82	20.78	75.70	50.05	572.38	31.43	21.81	75.03	45.78	612.78
June	33.58	23.51	79.60	50.77	649.26	32.44	23.97	74.63	51.27	660.57
July	33.16	25.30	84.05	53.02	605.00	32.32	24.31	79.57	54.70	610.93
August	34.65	25.02	84.90	52.14	578.87	33.79	24.76	83.63	60.52	512.92

RESULTS AND DISCUSSION

- **Effect of irrigation intervals:**

Grain yield and its attributes of the some rice genotypes as affected by the irrigation intervals and potassium levels (Tables 3 and 4) in 2012 and 2013 seasons are presented in Tables 3 and 4. Prolonging irrigation intervals up to 12 days significantly decreased the number of tillers/m^2, number of panicles/m^2, panicle length (cm), panicle density, number of filled grain/panicle, panicle weight (g), 1000- grain weight (g) and grain yield (t/ha) of all rice genotypes compared with the continuous flooding (W) treatment in both studied seasons. The highest mean values of all mentioned traits were recorded by abundance of water with continuous flooding, followed by irrigation every 4 and 8 days in both seasons in both. The inverse was true in unfilled grain percentage, which increased with prolonging irrigation intervals up to 12 days. It could be attributed to the fact that the available water enhances nutrient availability improved nutrients uptake by plants and suited climatic conditions, as well as enhanced the producing and translocation of dry matter content to panicles (sink) producing more grain filling and weight, and consequently higher grain yield. In contrast, water stress leads to a reduction in the efficiency of physiological processes, including protein synthesis, photosynthesis, respiration, and nucleic acid synthesis, causes inhibition the activities of many enzymes and leads to changes in the changes in the ultra structures of plant tissues. These results agreed with those obtained by *Awad et al (2001), El- Refaee (2006) and El- Refaee et al, (2008)*.

- **Rice genotypes performance:**

There were significant differences among three tested rice genotypes for all studied characters (Tables 3 and 4), where Giza179 surpassed the other two rice genotypes in grain yield and its attributes under this study. It can be observed that Giza179 came in the first rank and gave the highest grain yield followed by GZ7112, while Sakha106 reach to the last rank in both seasons. The genotypic differences in grain yield and its attributes are reflected different genetic makeup.

- **Effect of potassium level:**

Data in Tables 3 and 4 show that a significant increase in all studied characters with increasing of potassium level from 0 to 144 kg K_2O/ha without significant difference with 108 kg K_2O/ha except unfilled grain % in both seasons. Meanwhile, the lowest mean values of all studied characters were recorded with untreated treatment in both seasons. It may be attributed to the role of potassium in increasing plant photosynthesis rate because potash is required in the activation of starch synthesis and then conversion of soluble sugars into starch in vital step in the grain filling process and consequently, increased grain and panicle weight. The positive responses of K application on yield attributes have also, been reported by *Tiwari et al., (1998) and Egilla et (2001).*

Table 3: Number of tillers/m2, Number of panicles/m2, Panicle length (cm) and Panicle density of some rice genotypes as affected by irrigation intervals and potassium levels in 2012 and 2013 seasons

Factors	Number of tillers/m^2		Number of panicles/m^2		Panicle length (cm)		Panicle density	
	2012	2013	2012	2013	2012	2013	2012	2013
Irrigation Intervals (I)								
Continuous flooding (W)	618.71	606.67	550.07	540.30	21.87	21.58	6.42	6.35
Irrigation every 4 days (4W)	608.93	598.62	537.53	526.10	21.73	21.49	6.39	6.30
Irrigation every 8 days (8W)	601.18	586.38	532.09	510.00	21.89	21.26	6.33	6.16
Irrigation every 12 days (12W)	574.79	556.67	480.00	473.30	20.76	20.98	6.20	5.92
LSD (5 %)	4.85	3.77	4.16	6.10	0.17	0.15	0.06	0.05
Genotypes (G)								
Giza179	617.89	608.60	554.00	537.80	22.37	21.96	7.23	6.43
GZ7112	596.04	588.55	536.25	508.90	21.73	21.41	6.21	6.10
Sakha106	586.22	565.60	484.52	490.60	20.22	20.62	5.69	6.02
LSD (5 %)	3.12	8.09	10.11	7.53	0.11	0.12	0.08	0.03
K levels (K2O kg/ha) (C)								
0 (K0)	522.86	511.53	461.53	451.20	20.39	19.85	5.58	5.56
36 (K1)	597.14	583.53	500.17	484.50	21.17	21.10	6.40	6.22
72 (K2)	623.25	605.89	545.22	531.70	21.70	21.62	6.56	6.45
108 (K3)	639.40	628.64	561.53	552.60	22.16	22.18	6.63	6.40
144 (K4)	621.85	608.33	556.17	542.00	21.77	21.88	6.63	6.23
LSD (5 %)	4.67	4.64	3.33	6.53	0.29	0.16	0.10	0.07
Interactions								
I x G	*	*	*	*	*	*	*	NS
I x C	*	*	NS	NS	*	*	NS	NS
G X C	*	NS	NS	NS	NS	NS	*	*
I x GX C	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Unfilled grain/panicle (%), number of filled grain/panicle, Panicle weight (g), 1000- grain weight (g) and grain yield (t/ha) as affected by irrigation intervals and potassium levels in 2012 and 2013 seasons

Factors	Unfilled grain/panicle (%)		Number of filled grain/panicle	Panicle weight (g)			1000- Grain weight (g)			Grain yield (t/ha)
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Irrigation Intervals (I)										
Continuous flooding (W)	4.95	5.12	140.31	137.50	3.75	3.53	23.84	24.42	9.75	9.51
Irrigation every 4 days (4W)	4.92	5.27	138.69	135.90	3.63	3.47	23.69	24.21	9.70	9.28
Irrigation every 8 days (8W)	5.19	5.43	135.60	131.40	3.51	3.39	23.32	23.77	9.51	9.24
Irrigation every 12 days (12W)	5.52	5.64	129.42	124.67	3.21	3.09	22.62	22.91	7.87	7.16
L.D.S. (5%)	0.09	0.11	0.65	1.13	0.12	0.10	0.21	0.15	0.16	0.18
Genotypes (G)										
Giza179	4.75	5.23	146.48	141.60	3.71	3.56	24.67	24.23	9.67	9.18
GZ.7112	5.15	5.31	134.95	130.84	3.84	3.45	23.30	23.83	9.65	8.68
Sakha106	5.54	5.56	126.58	124.64	3.38	3.11	22.14	23.42	7.91	7.61
L.D.S. (5%)	0.04	0.15	1.82	0.22	0.14	0.08	0.21	0.13	0.28	0.16
K levels (K_2O kg/ha) (C)										
0 (K0)	5.87	6.09	112.89	110.70	2.91	2.72	22.23	23.05	6.56	6.71
36 (K1)	5.23	5.79	135.08	131.41	3.32	3.09	23.16	23.65	9.00	8.77
72 (K2)	5.06	5.30	142.06	139.72	3.66	3.52	23.80	24.91	9.80	9.34
108 (K3)	4.77	4.85	146.58	142.14	3.94	3.85	24.07	24.33	10.22	9.87
144 (K4)	4.72	4.79	143.42	137.85	3.79	3.68	23.59	23.92	10.18	9.69
L.D.S. (5%)	0.11	0.13	0.84	1.09	0.12	0.07	0.25	0.17	0.12	0.20
Interactions										
I x G	**	**	NS	NS	*	*	NS	NS	NS	NS
I x C	**	**	NS	NS	*	*	*	*	**	**
G X C	*	*	*	*	NS	NS	NS	NS	NS	NS
I x G X C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

- **Effect of interaction:**

4.1- Irrigation intervals * Rice genotypes interaction (I x G)

Significant interaction between rice genotypes and irrigation intervals were observed for number of tillers/m^2, number of panicle/m^2, panicle length (cm) and panicle density in 2012 and 2013 seasons are presented in Table 5.

Table 5: Number of tillers/m^{2,} Number of panicle/m^2, panicle length (cm) and panicle density as affected by the interaction between rice genotypes and irrigation intervals in 2012 and 2013 seasons

	Genotypes	2012 season				2013 season			
		W	4W	8W	12W	W	4W	8W	12W
Number of tillers/m^2	Giza179	642.72	629.22	614.39	585.25	630.02	615.13	604.73	584.53
	GZ7112	611.02	600.03	595.99	577.11	602.20	595.00	586.20	570.80
	Sakha106	602.38	597.55	582.95	562.01	587.80	585.73	568.20	520.67
	LSD (5 %)	7.6				8.66			
Number of panicle/m^2	Giza179	589.73	583.5	567.27	498.73	596.50	557.6	545.3	478.8
	GZ7112	555.27	550.2	540.8	475.47	543.30	522.5	496.70	473.10
	Sakha106	505.2	478.87	488.2	465.8	508.00	498.10	488.10	468.10
	LSD (5 %)	10.46				10.68			
panicle length (cm)	Giza179	22.7	22.53	22.38	21.88	22.35	22.27	21.82	21.39
	GZ7112	22.06	21.98	21.86	21.01	21.68	21.87	21.28	21.19
	Sakha106	20.84	20.68	20.22	19.13	20.72	20.72	20.69	20.36
	LSD (5 %)	0.27				0.24			
panicle density	Giza179	7.27	7.22	7.2	7.11	6.63	6.54	6.42	6.12
	GZ7112	6.33	6.24	6.14	6.09	6.28	6.22	6.08	5.83
	Sakha106	5.67	5.71	5.62	5.57	6.14	6.15	5.98	5.82
	LSD (5 %)	0.11				0.08			

The rice variety Giza179 under continues flooding (w) gave the highest values of above mentioned characters followed by GZ7112 rice line, while Sakha106 variety gave the lowest values. The same trend was observed with the other irrigation intervals (4W, 8W and 12W) where, Giza179 produced high values for studied characters compared to the other two genotypes without significant difference between 4W and 8W treatments. It can be concluded that Giza179 showed heights desirable values of all traits under all irrigation intervals While, Sakha106 recorded the lowest values of all studied characters under 12W treatment in 2012 and 2013 seasons respectively.

4.2- Rice genotypes *potassium levels interaction (G x C)

Number of tillers/m^2 and one thousand grain weight (g) significantly affected by the interaction between rice genotypes and potassium levels in 2012 and 2013 seasons (Table 6). Giza179 with K3 treatment recorded the highest values of number of tillers/m^2 (658.90 and 651.43) and thousand grain weight (25.27 and 24.80 g) during the both seasons respectively. In contrast, Sakha106 with K0 gave the lowest values of number of tillers/m^2 (516.74 and 499.42) and thousand grain weights (20.67 and 22.62 g) in 2012 and 2013 seasons respectively. It could be attributed to response differences of the tested rice genotypes to K and genetic difference of these verities to K requirements. These results are harmony with those obtained by Wang et al, 2011) who found that there was significant genotypic difference of rice for K response in soil having slight K deficiency. As shown from soil chemical analysis (Table1) the concentration of available K in soil was low than critical limits (200 ppm) this means that soil suffer from potassium deficiency. It can be concluded that Giza179 may be more response to application of potassium compared with Sakha106 and GZ7112 rice genotypes. It may be due to the difference among rice verities in K nutrition depends on the system of irrigation (Quampah *et al*, 2011).

Table 6: Number of tillers/m^2 and one thousand grain weights (g) as affected by the interaction between some rice genotypes and potassium levels in 2012 and 2013 seasons

	Genotypes	2012 season					2013 season				
		K0	K1	K2	K3	K4	K0	K1	K2	K3	K4
Number of tillers/m^2	Giza179	533.74	621.63	646.75	658.9	628.45	526.67	610.00	629.17	651.43	625.75
	GZ7112	518.1	586.63	616.65	637.72	621.08	508.50	582.50	604.75	630.50	616.5
	Sakha106	516.74	583.18	606.35	616.33	608.51	499.42	558.08	583.75	604.00	582.75
	LSD (5%)	7.6					9.06				
One thousand grain weight (g)	Giza179	23.8	24.49	25.12	25.27	24.67	23.43	24.06	24.59	24.80	24.30
	GZ.7112	22.22	23.13	23.65	23.97	23.52	23.10	23.71	24.22	24.25	23.87
	Sakha106	20.67	21.85	22.63	22.95	22.58	22.62	23.16	23.75	23.93	23.61
	LSD (5%)	0.41					0.28				

4.3- The interaction between irrigation interval* potassium levels (I x C)

Number of tillers/m^2 of some rice genotypes as affected by the interaction between irrigation interval and potassium levels are presented in Table 7. Data indicated that there were significant differences among the values of number of tillers/m^2 under interaction between irrigation interval and K levels. The highest number of tillers (654.63) was obtained with K3 under continuous flooding (W) followed by K3 with 4W treatment (646.22), while the lowest value (498.99) was recorded when rice irrigated every 12 days (12W) without application K (K0). These results were hold true in 2012 and 2013 seasons. It could be attributed to flooding enhances the release of exchangeable K into the soil solution by stimulating the reduction of Fe^{3+} to Fe^{2+} and Mn^{4+} to Mn^{2+} which displaces K from cation exchange capacity (CEC) sites (Patrick et al, 1985). Data in Table 8 shows that panicle length and grain yield significantly affected by the interaction between rice genotypes and potassium levels, where the highest values of panicle length (22.58 and 22.45 cm) and grain yield (10.76 and 10.74 t/ha) were obtained from the combination between continuous flooding (W) and K3 potassium level. However, the integration between 12W treatment under K0 application of potassium gave the lowest values of panicle length (19.61 and 19.25 cm) and grain yield (5.70 and 5.53 t/ha) in 2012 and 2013 seasons respectively. It is clear from the data also, applying different potassium levels improved significantly grain yield under all irrigation intervals during the two seasons (2012 and 2013). There was no significant difference between continuous flooding (W) and 4W treatment in grain yield with the same level of potassium K3 (10.77 and 10.26 t/ha) and K4 (10.50 and 10.60 t/ha) in both seasons respectively. These results indicated that water stress significantly reduced grain yield but potassium application whether, K3 or K4 treatment maintain and improve grain yield due to improving in grain filling as a result to increase viability of flag leaf. As well as, potassium increase the translocation of carbohydrate to grain. When water stress imposed during grain filling usually results in the reduction in grain weight. This reduction is mainly attributed to the decline number of endosperm cells, thereby decreased sink size per kernel (Michihiro et al 1994). These results are harmony with those obtained by E-Refaee *et al*, (2012) who found that flooding irrigation gave the highest grain yield, also he indicated that six days an irrigation interval was statistically placed in the same level with flooded method. Potassium fertilizer is much needed to compensate the water stress effect with increasing water regime up to 12 days when potassium application extends the root system of rice to reach the deep water in the soil an increase its ability for nutrients uptake (Jia et al., 2008). Therefore, higher K concentration in plant tissues plays a vital role for increasing water-stress resistance and crop yield stabilization (Umar, 2006). According to Tiwari et al. (1998), K fertilization alleviates the negative effects of water stress in rice. It infers that potassium has an important role in resistance of rice to water-deficit stress. It can be noted that Giza179 rice variety is tolerant to water deficit and more response to application of potassium than GZ7112 and sakha106 rice genotypes. It may be due to positive relationship between stress protein accumulations in leaves of rice genotypes, which tolerant to water stress. Some protein specific to desiccation also, have a major role in cellular protection and recovery in vascular plants (Farrant *et al.,* 1993).

Table 7: Number of tillers/m^2 as affected by the interaction between the irrigation intervals and potassium levels in 2012 seasons

Irrigation intervals	K0	K1	K2	K3	K4
W	542.33	620.20	636.30	654.63	640.07
4W	531.97	602.80	632.80	646.22	630.87
8W	518.16	602.63	622.70	640.37	622.20
12W	498.99	562.94	601.20	616.37	594.43
LSD (5%)	9.52				

Table 8: panicle length (cm) and grain yield (t/ha) and of rice genotypes as affected by the interaction between the irrigation intervals and potassium levels in 2012 and 2013 seasons

Irrigation Intervals		2012 season					2013 season				
		K0	K1	K2	K3	K4	K0	K1	K2	K3	K4
panicle length (cm)	W	20.83	21.53	22.03	22.58	22.36	20.2	21.28	21.77	22.45	22.2
	4W	20.6	21.33	22.16	22.46	22.09	20.34	21.21	21.73	22.22	21.95
	8W	20.53	21.3	21.86	22.07	21.67	19.63	21.17	21.65	22.11	21.74
	12W	19.61	20.53	20.74	21.52	20.96	19.25	20.72	21.34	21.92	21.66
LSD (5 %)		0.54					0.32				
Grain yield (t/ha)	W	7.12	9.83	10.33	10.76	10.73	7.07	9.62	10.24	10.74	10.89
	4W	6.88	9.74	10.28	10.77	10.83	7.03	9.50	9.94	10.26	9.63
	8W	6.83	9.35	10.28	10.62	10.49	7.19	9.14	9.71	10.37	9.81
	12W	5.7	7.43	8.57	8.99	8.67	5.53	6.80	7.45	8.11	8.28
LSD (5 %)		0.26					0.40				

Water relations

Grain yield of some rice genotypes, grain yield reduction %, total water inputs (m^3/ha), water use efficiency kg/m^3 (WUE) and soil matric potential are presented in Table 10. Data revealed that Giza179 and GZ7112 rice genotypes gave the highest grain yield under continuous flooding (10.39 and 10.26 t/ha) in 2012 season. However, Sakha106 gave the greatest reduction % in grain yield than Giza179 and Gz7112 rice genotypes under all irrigation intervals in both seasons. In the same time total water input was so high and reach to (13700.90 a, 14156.88 and 15202.89 m^3/ha) for Giza179, GZ7112 and Sakha106 rice genotypes respectively under continuous flooding, While WUE was very low (0.753, 0.724 and 0.556 kg/m^3) for tested genotypes. Data also, indicated the grain yield of Giza179 and GZ7112 had slightly decrease (10.25 and 10.11 t/ha) with the grain yield reduction about 1.34 and 1.50 % in season 2012 respectively compared with continuous flooding with lower water input (12280 and 12670 m^3/ha) and saved water 10.36 and 10.50 % as well as water use efficiency was 0.834 and 0.797 kg/m^3. Regarding to, irrigation every 8 days there were slight decrease in grain yield of Giza179 and GZ7112 genotypes (9.90 and 9.77 t/ha) equal about 4.15 and 4.10 t/fed with yield reduction about 4.71 and 4.78 % compared with continuous flooding and lower water input (11260.88 and 12269.90 m^3/ha) than W and 4W treatments with water saving about 17.81 and 13.33 %. As well as high water use efficiency 0.879 and 0.796 kg/m^3. These results were hold true in first season and the same trend was observed in second season. Data in the same table showed that irrigation every 12 days caused strongly decrease in grain yield of all tested rice genotypes with low WUE.

Table 9: Grain yield reduction (%), total water input (m^3/ha), water saved (%) water use efficiency and soil matric potential as affected by irrigation intervals in 2012 and 2013 seasons

Seasons	Irrigation Intervals	Rice Genotypes	Grain yield (t/ha)	Grain yield Reduction (%)	Total water input (m^3/ha)	Water saved (%)	water use efficiency (WUE)		Soil matric potential at 20 cm depth (kPa)
							kg/m^3	Trad %	
2012	Continuous flooding (W)	Giza179	10.39	-	13700.90	-	0.753	100	0
		GZ7112	10.26	-	14156.88	-	0.724	100	0
		Sakha106	8.46	-	15202.89	-	0.556	100	0
		Mean	9.70	-	14353.56	-	0.680	100	0
	Irrigation every 4 days (4W)	Giza179	10.25	1.34	12280.90	10.36	0.834	110.76	-1.00
		GZ7112	10.11	1.50	12670.80	10.50	0.797	110.08	-2.00
		Sakha106	8.52	4.72	12807.30	15.75	0.665	119.60	-2.00
		Mean	9.66	2.52	12586.33	12.21	0.766	113.48	-1.66
	Irrigation every 8 days (8W)	Giza179	9.90	4.71	11260.88	17.81	0.879	119.12	-10.00
		GZ7112	9.77	4.78	12269.90	13.33	0.796	109.94	-10.00
		Sakha106	8.06	4.72	13438.90	11.61	0.599	100.54	-9.00
		Mean	9.24	4.73	12323.23	14.25	0.760	109.86	-9.66
	Irrigation every 12 days (12W)	Giza179	8.32	19.92	10502.66	23.34	0.792	104.92	-16.00
		GZ7112	7.78	24.17	10650.90	24.76	0.730	100.82	-15.00
		Sakha106	6.60	23.16	11612.40	23.62	0.570	102.52	-14.00
		Mean	7.57	22.42	10921.99	23.91	0.697	102.75	-15.00
2013	Continuous flooding (W)	Giza179	10.12	-	13107.80	-	0.772	100	0
		GZ7112	9.68	-	13509.10	-	0.716	100	0
		Sakha106	8.35	-	13920.77	-	0.599	100	0
		Mean	9.38	-	13512.55	-	0.695	100	0
	Irrigation every 4 days (4W)	Giza179	10.07	0.49	12010.90	8.37	0.834	114.51	-2.00
		GZ7112	9.18	5.16	12150.60	10.06	0.731	102.10	-3.00
		Sakha106	7.88	5.62	12910.40	7.26	0.610	111.86	-3.00
		Mean	9.02	3.75	12357.30	8.56	0.725	109.50	-2.60
	Irrigation every 8 days (8W)	Giza179	9.50	5.13	10006.80	23.66	0.940	121.76	-12.00
		GZ7112	8.90	8.05	11018.50	18.44	0.807	112.71	-10.00
		Sakha106	7.60	8.98	12082.88	13.20	0.630	105.17	-10.00
		Mean	8.66	7.38	11036.06	18.43	0.792	113.21	-10.66
	Irrigation every 12 days (12W)	Giza179	7.52	25.69	9120.60	30.42	0.825	116.80	-16.00
		GZ7112	7.25	25.10	9750.77	27.82	0.744	101.77	-15.00
		Sakha106	6.41	23.35	10376.77	25.46	0.620	103.50	-13.00
		Mean	7.06	24.71	9749.38	27.90	0.730	107.40	-14.66

According to the previous data in Table 9, using Giza179 or GZ7112 genotypes which appear reasonable tolerance to water stress without significant reduction in grain yield (9.99 and 9.77 t/ha which equal about 4.15 and 4.10 t/fed) and total water input about 11260.90 and 12269.90 m^3/ha with water saving 17.81 and 13.33 % in both seasons respectively. It means that Giza179 variety under irrigation every 8 days should be used, followed by GZ7112 rice line under water shortage.

Regarding to WUE of three rice genotypes as affected by the interaction between irrigation intervals and different levels of potassium are illustrated in Fig 1 and 2. Data revealed that WUE significantly affected by the interaction between different potassium levels and irrigation intervals. Under all irrigation intervals application of potassium recorded higher WUE compared with the control treatment in both seasons. These results are harmony with those obtained by Bouman and Tuong (2001) and *El-Refaee* (2006) who reported that there was a significant and positive effect for potassium application on WUE under irrigation regime. As well as, the WUE was higher in the alternately submerged and no submerged regimes than in the continuous submerged regime. The Water use efficiency (WUE) increased up to maximum value (0.894 and 0.921 kg/m^3) under irrigation every 8 days with K3 treatment and about (0.821 and 0.836 kg/ m^3) under irrigation every 4 days with applied K3 treatment also, in both seasons respectively. It is clear that application of potassium (K3) under both 4W and 8W water treatments gave the highest values of WUE. These results agreed *with Quampah et al (2011)* who found that potassium fertilizers application slightly increased WUE under water deficit.

Fig.1: WUE for three rice genotypes as affected by irrigation intervals and different levels of potassium in 2012 season

Fig. 2: WUE for three rice genotypes as affected by irrigation intervals and different levels of potassium in 2013 season

Soil matric potential at 20 cm depth (kpa)

The objective of measure soil matric potential was determining the soil moisture content and consequently, knows the amount of water should application to the soil under irrigation intervals compared with the traditional method. Irrespective of soil type and climatic demand resulting in over-irrigation or under-irrigation under different soil and weather situations, Soil matric potential may be an ideal criterion for irrigation, cultural practices and water management affect rice irrigation water requirements. The mean values of soil matric potential ranged from 0 to -15 kpa at 20 cm depth and 0 to -14.66 kpa under continuous flooding (W) and 12W water treatments in both seasons respectively.

There was no significant decrease in grain yield of rice up to soil matric potential approximately -9.66 and –10.66 kPa under 8W water treatment compared with continuous flooding (W) in both seasons respectively (Table 9). While, decreasing soil matric potential up to -15 and -14.66 kPa decreases rice grain yield significantly about 22.42 and 24.71% in both seasons respectively. The results indicated that under this study rice did not need to be continuously during cropping period; a rice field can be safely irrigated at -9.66 and -10.66 kpa matric suction without significant decline in grain yield. The procedure saved about 14.25 and 18.43 % of the water used in both seasons respectively. These results agreed with obtained (IRRI, 1997) who found that a soil-matric potential approximately -10 kPa at 0.2 m soil depth might be the most economical level to maintain a rice crop.

Economic return of water

Table 10 shows that the quantity of water input to producing one kg grains of rice decreased under irrigation every 4 days, every 8 days (8W) and every 12 (12W) days compared with continuous flooding and. Over both seasons under irrigation every 4 days one kg of rice grains needs 1.11, 1.24 and 1.57 m^3 of water (84.94, 89.35 and 90.95 % of continuous flooding requirement) compared to 1.12, 1.27 and 1.64 m^3 of water under irrigation every 8 days (85.70, 91.45 and 94.85 % of continuous flooding requirement), however irrigation every 12 days to obtained one kg rice needed 1.24, 1.36 and 1.68 m^3 of water (94.71, 97.81 and 97.50 % of continuous flooding requirement) for Giza179, GZ7112 and Sakha106 respectively. These results are harmony with those obtained by *El-Refaee, (2006)*. This means that the quantity of water saved for producing 100 kg rice grains was 196, 147 and 161 m^3 under irrigation every 4 days, compared with 187, 118 and 93 m^3 of water under irrigation every 8 days, however irrigation every 12 days, it was 69, 30.50 and 43 m^3 for Giza179, GZ7112 and Sakha106 respectively. The total quantities of saved irrigation water on the overall national level, by multiplying the national production of the rice crop by average quantity of saved water. It showed that irrigation every 4 days saved 1213.62 and 640.10 million m^3. Irrigation every 8 days saved 823.60 and 643.56 million m^3, while irrigation every 12 days saved 198.80 and 311.4 million m^3 for both seasons respectively. This means that irrigation every 4 days and irrigation every 8 days could save about 900 million m^3 and 733.55 to the national agricultural production respectively. Translated the quantities of water saved into monetary units (Egyptian pounds), it means more national income. Data in Table 10 showed that the irrigation every 4 days treatment could contribute in adding about 1817.60 and 1764.84 million L.E, while irrigation every 8 days could contribute in adding in adding about 1187.00 and 1217.44 84 million L.E for both seasons respectively.

CONCLUSIONS

It can be concluded that using Giza179 rice variety followed by GZ7112 rice line which they fertilized by potassium at rate of 108 kg K_2O/ha which equal 45.30 kg K_2O /fed and irrigated every 8 days produced high grain yield (9.90 and 9.77 t/ha) for Giza179 which equal about 4.10 t/fed and save water about 17.81 and 23.66 % with WUE 0.879 and 0.940 kg/m^3 for Giza179 in 2012 and 2013 seasons respectively. Also, the water inputs were 11260.88 and 10006.80 m^3/ha which equal about 4.70 thousand m^3/fed compared with the national average 6.50 thousand m^3/fed (El- Refaee., 2011)

REFERENCES

Abd Allah, A. A.; **A.A.A. Mohamed and *M. M. Gab-Allah. 2009. Genetic studies of some physiological and shoot characters in relation to drought tolerance in rice. J. Agric. Res. Kafr-El Sheikh Univ., 35 (4).

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.

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

Çelik, H., B.B. Aşik, S. Gürel and A.V. Katkat,. 2010. Potassium as an intensifying factor for iron chlorosis. Int. J. Agric. Biol ., 12: 359–364.

Egilla, J.N.; Davies, F.T. Jr. and Drew, M.C. 2001. Effect of potassium on drought resistance of Hibiscus rosa-sinensis cv. Leprechaun: Plant growth, leaf macro and micronutrient content and root longevity. Plant and Soil. 229 (2): 213-224.

El- Refaee. I. S, A.M. Al-Khtyar and A.A. El-Gohary. 2008. Improving rice productivity under irrigation intervals and nitrogen fertilizer. Proceedings (the second field crops conference), FCRI, ARC, Giza, Egypt, 14-16.Oct.

El- Refaee. I. S. 2006. The interaction effect between water regimes and potassium levels on growth, grain yield and water productivity in rice. Egyptian Journal of Agriculture Research. 85 (4): 1399.

El- Refaee. I. S. E.E. Gewaily, E. S. Naeem and B. A. Zayed. 2011. Water balance and economic evaluation of some Egyptian rice cultivars. J. Agric. Res. Kafer El-Sheikh Univ., 37 (1).

El- Refaee. I. S., R.N. Gorgy and T. F. Metwally. 2012. Response of some rice cultivars to plant spacing for improving grain yield and water productivity under different irrigation intervals. Alex. J. Agric. Res. 57. (1): 1-14.

Farrant J.M, Pammenter N.W, Berjak. 1993. Seed development in relation to desiccation tolerance: a comparison between desiccation – sensitive recalcitrant seeds of Avicennia marina and desiccation tolerance types. Seed Sci Res. 3: 1-13.

Ghanem S.A and Tantawi Badawi A. 1999. Water use efficiency in rice culture. In: Chataigner J. (ed.). Future of water management for rice in Mediterranean climate areas: Proceedings of the Workshops. Montpellier: CIHEAM, 39-45 (Cahiers Options Méditerranéennes; n. 40).

Gomes, A.K and A.A Gomes. 1984. Statistical procedures of Agricultural Research.2 and ed. Jahn Wiley Sons, New York.

IRRI (International Rice Research Institute). 1996. International Rice Research Notes. Volume 22. Number 3. .http:// Google. Books. Com.

Jia, Y., X.E. Yang, Y. Feng and G. Jilani. 2008. Differential response of root morphology to potassium deficient stress among rice genotype varying in potassium deficiency. J. Zhejiang Univ. Sci. B, 9: 427-434.

Mengel, K. and E. A. Kirkby, H. Kosogarten and T. Appel. 2002. Principles of Plant Nutrition. 5. th. Edition.

Michihiro.W, J.Lui and G.C.Garvalho.1994. Cultivars difference in leaf photosynthesis and grain yield of wheat under soil water deficit conditions. JPn. J. crop Sci. 63: 339-344.

Mohamed A.M., Ibrahim and S.A. El-Gohary. 1995. Irrigation interval effects on rice production in the Nile Delta. Irrig Sci. 16: 29-33.

Nour M.A.; A.E. Abd El- Wahab; A.A. El-Kady; and R.A. Ebaid. 1997. Productivity of some rice varieties under different irriga-tion intervals and Potassium level. In : Egypt. J. Appl. Sci. 12(6): 137-154.

Patrick, W.H., Jr. D.S. MIkkelesn., B.R. Wells. 1985. Plant nutrient behavior in a flooded soil. In O.P. Engelstad (ed) Fertilizers technology and use. 3 rd ed. Soil science Society of American, Madison, WI. 197-228.

Premachandra, G.S, H. Saneoka and S. Ogata. 1991. Cell membrane stability and leaf water relations as affected by potassium nutrition of water- stressed maize. J. Exp. Bot. 42: 739-745.

Quampah. A. Wang. R. N, I. H. Sjilani, Q. Zhang , S. Hu and A Xu. 2011. Improving Water Productivity by Potassium Application in Various Rice Genotypes. International Journal of Agriculture & Biology. ISSN Print: 1560–8530; ISSN Online: 1814–9596. 10–251/MFA/2011/13–1–9–17. http://www.fspublishers.org.

Richards, L.A.1969. Diagnosis and improvement of saline and alkali soils.

Tiwari, H.S.; Agarwal, R.M. and Bhatt, R.K. 1998. Photosynthesis, stomatal resistance and related characters as influenced by potassium under normal water supply and water stress conditions in rice (Oryza sativa L.). Indian Journal of Plant Physiology 3 (4): 314-316.

Umar, S., 2006. Alleviating adverse effects of water stress on yield of sorghum, mustard and groundnut by potassium application. Pakistan J. Bot., 38: 1373–1380.

Waller, R.A. and D.B. Ducan, 1969. Bayes rule for the Symmetric Malliple Comason problem. J. Am. Stat, Assoc., 64: 1484-1499.

Wang. M, Z. Qingson, S. Qirong and G. Shiwei. 2011. The critical role of potassium in plant stress. Int. J. Mol. Sci. 14: 7370-7390.

Yang, X.E., H. Li, G.J.D. Krik and A. Dobbermann. 2005. Room –induced changes of potassium in the rhizosphere of lowland rice. Commun. Soil Sci. plant Anal., 36: 1947-1963.

Yang, X.E., J.X. Liu, W.M. Wang, H. Li, A.C. Luo, Z.Q. Ye and Y. Yang. 2003. Genotypic differences and some associated plant traits in potassium internal use efficiency of lowland rice (Oryza sativa L.). Nutr. Cyc. Agroecosys., 67: 273–282.

تـاثير نقـص الميـاه ومسـتويات البوتـاسيوم علـى محصـول بعـض اصـنـاف الارز وكفـاءه استخدام المياه والعـائد الاقتصادى

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مركز البحوث الزراعيه- معهد بحوث المحاصيل الحقيله- مركز البحوث والتدريب فى الارز ـــسخا -كفر الشيخ

تم دراسه التفاعل بين نظم الرى ومستويات البوتاسيوم على اصناف الارز جيزة١٧٩ -GZ7112 -سخا 106فى تجربه حقليه اجريت بالمزرعه البحثيه لمركز البحوث التدريب فى الارز بسخا– كفر الشيخ خلال موسمى ٢٠١٢ و٢٠١٣ .استخدمت اربع معاملات لنظم الرى وهى الغمر المستمر – الرى كل اربعه ايام – الرى كل ثمانية ايام و الرى كل اثنى عشرا يوما واستخدم خمسة مستويات من البوتاسيوم وهى: صفر K2O 144- 108-72 - 36 -كجم/هكتار استخدم تصميم القطع المنشقة مرتين فى اربع مكرارت حيث احتوت القطع الرئيسيه على معاملات الرى والقطع الرئيسيه على معاملات الرى و الشقيه الاولى على اصناف الارز والقطع الشقيه الثانيه على مستويات البوتاسيوم .اوضحت اهم النتائج ان الصنف جيزه١٧٩ اعطى اعلى محصول ومكوناته ثم جاءت بعده السلالة GZ7112 تحت ظروف الغمر المستمر بدون اى اختلاف معنوى مع نقص الرى حتى معامله الرى كل ثمانية ايام بينما انخفض المحصول ومكوناته معنويا تحت ظروف الرى كل ١٢يوم مع كل اصناف الارز .ايضا اوضحت النتائج ان نسبه الاحتفاظ بالمياه زادت مع زياده فترات الرى بالمقارنه بالرى المستمر وكانت 10,36) و ٨ % 37, (بالنسبه للصنف جيزة١٧٩ و 10,50) و (% 10,36 بالنسبه للسلاله GZ7112 تحت معامله الرى كل اربعة ايام و كانت 17,81) و (% 23,66بالنسبه للصنف جيزة١٧٩ و (١٣,٣٣ و ١٨,٤٤ (%تحت معامله الرى كل ثمانية ايام بالنسبه للسلاله GZ7112 بينما تحت معامله الرى كل ١٢ يوم كانت نسبة الاحتفاظ بالمياه و (٢٣ 91,و (% 27,90 مع نسبه انخفاض فى المحصول تقريبا 22,42) و ٢ 4,71 (%خلال موسمى ٢٠١٢و ٢٠١٣ على التوالى .على مدى الموسين استخدم الصنف جيزة١٧٩ و السلالة GZ7112 اعطت اعلى محصول حبوب (٩ 70,و 9,33 طن/هكتار (واعلى نسبه احتفاظ فى المياة (٢٠,٧٣ و ١٥,٨٨ %) واعلى كفاءة فى استخدام المياة 0,90) و ٠,٨١ كجم/م (3لكلا الصنفين على التوالى) .هذا يعنى ان كميه المياة الكليه المضافة تساوى حوالى 4700 م/3فدان مع استخدام الصنف جيزة١٧٩ بالمقارنه بالمتوسط القومى 6500 م/3فدان تحت معامله الرى كل ثمانيه ايام .(اوضحت الدراسة ايضا ان اضافه البوتاسيوم حتى المستوى K2O 108 (K3) كجم/هكتار ادى الى زياده معنويه فى المحصول مع التخفيف النسبى للتاثير الضار الذى يتعرض له نبات الارز نتيجه لنقص المياة مما ادى الى زياده كفاءة استخدام المياة وزياده نسبه المياة المحفوظه.

بتحكيم البحث

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Table 10: Economic return of water as affected by the irrigation intervals and rice genotypes under this study in 2012 and 2013 seasons

Seasons	Irrigation Intervals	Genotypes	*Average requirements m^3/kg	Trad =100	Quantity saved (m^3/kg)	**Total national producing million kg)	Total quantity of water available (million m^3)	Yield added million kg)	***Farm price (L.E/kg)	Total values
			1	2	3	4	5 (3 x 4)	6 (5/1)	7	8 (6 x 7)
2012	Continuous flooding (W)	Giza179	1.318	100	0		0	0		0
		GZ7112	1.379	100	0		0	0		0
		Sakha106	1.797	100	0		0	0		0
		Mean	1.498	100	0		0	0		0
	Irrigation every 4 days (4W)	Giza179	1.130	85.73	0.188		1067.84	944.99		1842.73
		GZ7112	1.220	88.46	0.159		903.12	740.26		1443.51
		Sakha106	1.503	83.64	0.294		1669.92	1111.06		2166.57
		Mean	1.284	85.88	0.214	5680	1213.62	932.10	1.95	1817.60
	Irrigation every 8 days (8W) Mean	Giza179	1.137	86.27	0.181		1028.08	904.20		1763.19
		GZ7112	1.255	91.01	0.124		704.32	561.21		1094.36
		Sakha106	1.667	92.77	0.130		738.40	442.95		863.75
		Mean	1.353	90.32	0.145		823.60	608.72		1187.00
	Irrigation every 12 days (12W)	Giza179	1.262	95.75	0.056		318.08	252.04		491.48
		GZ7112	1.369	99.27	0.010		56.80	41.49		80.91
		Sakha106	1.759	97.89	0.038		215.84	122.71		239.28
		Mean	1.463	97.66	0.035		198.80	135.89		264.99
2013	Continuous flooding (W)	Giza179	1.295	100	0		0	0		0
		GZ7112	1.396	100	0		0	0		0
		Sakha106	1.667	100	0		0	0		0
		Mean	1.441	100	0		0	0		0
	Irrigation every 4 days (4W)	Giza179	1.090	84.16	0.205		1063.95	976.10		1952.20
		GZ7112	1.260	90.25	0.136		705.84	560.19		1120.20
		Sakha106	1.638	98.26	0.029	5190	150.51	91.89	2.00	2222.12
		Mean	1.329	90.89	0.123		640.10	542.72		1764.84
	Irrigation every 8 days (8W)	Giza179	1.05	81.08	0.245		1271.55	1211.00		2422.00
		GZ7112	1.23	88.10	0.166		861.54	700.44		1400.88
		Sakha106	1.58	94.78	0.087		451.53	285.77		571.54
		Mean	1.28	87.98	0.166		487.21	732.40		1464.80
	Irrigation every 12 days (12W)	Giza179	1.213	93.67	0.082		425.58	350.85		504.08
		GZ7112	1.345	96.35	0.051		264.69	196.80		82.98
		Sakha106	1.619	97.12	0.048		249.12	153.87		245.42
		Mean	1.381	95.84	0.06		311.4	225.49		271.78

***Average Requirement = Grain yield (kg/ha) ÷ Total water input (m^3/ha).**

****Source: yearly bulletin of statistics crop areas and plant production, Central Agency for public Mobilization and Statistics**

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