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Effect of irrigation interval on water consumption, water use efficiency, growth and yield of rice in two area of Sulaymani governorate

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ABSTRACT

The different of locations (which has different in soil and water quality) and irrigation interval has an important influence on water use efficiency and rice crop yield to determine the effects of different irrigation water management on yield and water use efficiency of rice (Oryza sativa L.) in two different locations soils and water quality, the two-field experiments were conducted on silty clay loam and silty clay soil, in earthen and western Suleimani province of Kurdistan-Iraq The experiment was a complete randomized design with a factorial arrangement of treatments with three replications. The main treatment was Irrigation interval (full irrigation (D_1), one day (D_2), two days (D_3), and three-day irrigation (D_4)) The depth irrigation were 939, 811, 726 and 681 mm, respectively for qaragol, while for chalax the depth irrigation were 980, 821, 749 and 722 mm respectively. The sub- treatment was, Qaragol (L_1) and chalax (L_2) locations respectively, the results showed that the effects of irrigation interval and locations and their interaction on rice grain yield and water use efficiency were significant at 5%. The highest grain yield (6263 Kg ha^{-1}) belonged to the (L_2) location and the lowest grain yield (5823.3 Kg ha^{-1}) belonged to (L_1) in Qaragol location. And the highest water use efficiency 8.547 in Qaragol location belongs to the (D_4) and the lowest water use efficiency 6.387 increasing of water use efficiency (D_1 vs. D_4) caused a 29.5% improvement in water use efficiency. The irrigation schedule can be planned to save water without considerable reduction of crop yield.

تاثير فاصة الري في كفاءة استعمال الماء ونمو وحاصل الرز في منطقتين مختلفتين في محافظة السليمانية

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الخلاصة

إن اختلاف المواقع (والتي تختلف في نوعية التربة والمياه) وفترات الري لها تأثير كبير على كفاءة استخدام المياه وإنتاجية محصول الرز (.Oryza sativa L) لتحديد تأثيرات إدارة مياه الري المختلفة على المحصول وكفاءة استخدام المياه لمحصول للرز في موقعين مختلفين من حيث نوعية التربة و المياه . أجريت تجربة الحقلية على تربة طينية غرينية مزيجية وتربة طينية غرينية ، في المنطقة الغربية والشرقية بمحافظة السليمانية - العراق. كانت صممت التجربة وفق التصميم العشوائي الكامل بالتجارب عاملية للمعاملات بثلاثة مكررات. كانت المعاملة الرئيسية هي فا صلة الري (الري الكامل (D_1) ، يوم واحد(D_2)، يومان(D_3) ، الري لثلاثة أيام (D_4)). كانت المعاملة الفرعية وهي الموقع قرغول (L_1) وجالاغ (L_2) على التوالي ، وأظهرت النتائج أن تأثير فترات الري والمواقع وتداخلهما على محصول حبوب الرز وكفاءة استخدام المياه كانت معنوية عند 5٪. وأعلى محصول حبوب (6263 كغم هكتار$^{-1}$) ظهرت في الموقع (L_2) وأدنى محصول حبوب (5823.3 كغم هكتار $^{-1}$) تعود إلى (L_1) في موقع قركول. وكانت أعلى كفاءة استخدام للمياه 8.547 كغم /م3 في موقع قركول عند فترات الري (D_4) وكانت أدنى كفاءة استخدام المياه 6.387 كغم /م3 (D_1) وادت الى زيادة كفاءة استخدام المياه الرى مقارنة بفترات الري D_4 وادى إلى تحسن بنسبة 29.5٪ في كفاءة استخدام المياه. يمكن تخطيط جدول الري لتوفير المياه دون تقليل كبير في انتاجية المحاصيل .

الكلمات المفتاحية: كفاءة استخدام الماء، محصول الرز، الانتاج المحصول، نسجه التربة، فاصله الري.

INTRODUCTION

Rice is one of the main crops as the second food in Iraq and some countries of the world, but it is one of the crops that consumes the most irrigation water and is more sensitive to water shortage (Islam MJ, Mowla, G, Parul S.S, Alam MZ, and Islam MS (2004a). The farmers use the flood irrigation method in Iraq, which requires the soil to remain submerged in water throughout the growing season. It is a method that causes a lot of damage to soil in addition to its need for large amount of water (Ayele T, Beyene S, Esayas A (2013). The continuous decrease in irrigation water sources, while continuing to adopt traditional irrigation, cultivation and preparation systems that require large quantities of irrigation water, will lead to a shortage in the quantities of water available for cultivation of this crop, which leads as a result to a decrease in the productivity of the unit area as well as a decrease in the agricultural areas that are cultivating this crop (Mahrup, A., M. Mashum, I. Kusnarta, Sukartono, J. S. Gill. (2005).

Therefore, it is necessary to evaluate and use methods to provide and increase any water production for rice production. Permanent flood irrigation of paddy fields with very low irrigation efficiency resulted in more water consumption than the actual need. To reduce water consumption in rice irrigation, various irrigation methods exist to reduce water ingress into rice fields, including non-flood management during periods of rice growth (Bouman, B.; Tuong, T.P. (2002). Because increasing water consumption too much does not play a role in increasing the yield, savings from using this method in times of drought and water shortage can solve existing problems (Amiri, E., T. Razavipour, A. Farid and M. Bannayan. (2011). The results of research in different parts of the world and Iran showed the appropriateness of the effect of non-flood irrigation management on grain yield and rice water productivity increase (Bouman, B.; Tuong, T.P. (2002); (Tuong TP, Bouman AM, Mortimer M (2004); (Rezaei A, Asadi A, Rezvanfar A, Hassanshahi H (2009).

Plants as the amount of water produced per unit amount of water consumed Molden. D and Frite .C. (2003). The basis of evapotranspiration is 0 kg of grain per cubic meter of evaporation/6-1/ however, the range of water productivity for rice in their research was 6 and transpiration their results showed that the water productivity could increase significantly if the amount of irrigation water was reduced and the irrigation method changed. Among the other widespread varieties, which are characterized by high productivity and a relatively short growth period, as well as aromatic varieties are the jasmine and Euphrates class. This study was based on the following objective: to study the effect of irrigation interval on water use efficiency, growth and yield of rice in two different locations in Sulaiman province

MATERIAL AND METHODS

The response of rice Genotypes (Bazian) to soil moisture stress in the semi-arid environment of Sulaimani regions for the growth period and growth stages was investigated in two field experiments during the summer season of 2021.

Experimental site description

The governorate of Sulaimani is located in the northeast of Iraq, on the border with Iran. The first is Qaragol Located at (Latitude: 35º 21' 34" N; Longitude 45º 37' 42" E at the altitude of approximately 546 m above sea level). In sharazoor desert 20 km east of Sulaimani. The second is chalax located 35º 49' 37" N; Longitude 45º 05' 753" E at the altitude of approximately 546 m above sea level) 25 km northwest of Sulaimani city. (Fig.1) This experiment is carried out in the field for the summer season in 2021. First, the germinated seeds are sown in the treasury in early May and until the sign was maintained and cared for, then in early June to the main land transplanted and transplanted in 1× 1 plots. In order to establish seedlings after transplanting for 7 days all plots are permanently flooded and then at the time of height irrigation treatments 5 cm was applied. From meteorological station, data Agriculture was used at a distance of five kilometer from the test both sites. All cultivation stages are done according to the custom of the region and the rice harvest season has begun in the northeastern regions of the Kurdistan region, and the type of rice produced in the region is consider one of the best types consumed for food. And harvests are also recorded accordingly Crop standards were met. The grain weight, root dry weight, plant high and the amount of water entering the border is measured using a Weir. Measured in cubic meters, this meter is placed at the shoulder of the experimental board. Rice yield with moisture 14% was measured by harvesting 0.5 square meters from the middle of the plot. Venkatesan Q. et, al. 2005 irrigation was given to a depth of 5 cm when the soil moisture depleted to a level of 60% of field capacity and 40% of field capacity respectively, during the corresponding growth stages. During rest of the periods 5 cm depth of water was maintained as usual.

Land preparation and soil sampling

Soil sample were taken on based the root depth of plant rice from 0 -30 cm, then the samples were taken to laboratory soil physical of the Natural resources department in college of agriculture engineering science of Sulaimani University. Soil samples air-dried, grounded, passed through a 2 mm sieve thoroughly mixed and continued to be used in plastic bags. And to determine the soil bulk density used a cylindrical core 4.2 cm diameters and 5.1 cm height. Analysis of particle size distribution was carried out by using the pipette and sieving methods (Klute, 1986). Soil bulk density was measured by using core method as described by Blake and

Hartge (1986). The electrical conductivity of the same extract was also measured with EC-meter model D 8120 and adjusted to 25ºC as described in (Van Reeuwijk, 1995). (Table 1)

Experimental design

The experiment was designed to study the effect of irrigation intervals and locations as a split-plot design of two factors with the completely randomized design (CRD). By applying treatments: Irrigation management at 4 intervals as the main factor including: I_1 Full Irrigation: I_2 1-daily irrigation (continuous): I_3 between irrigation and others: I_4 between two days irrigation with different locations as a sub-factor 2 location include: Qaragol and Chalax cultural farm rice crop in three replications. Data with (SSP) software using mean analysis and the LSD or Dunnet (Duncan, B.D. (1955). test is also use to compare the averages. (Fig.2)

Table (1) some selected physical and chemical properties for the soil at the site of the field experiments (Qaragol) and Chalax

Property		Unit	Qaragol Value	Chalax Value
Particle size distribution	Sand	$g.kg^{-1}$	8.45	14.15
	Silt	g.kg-1	54.30	45.73
	Clay	g.kg-1	37.25	40.12
	Texture name	-	Silty Clay Loam	Silty clay
Soil bulk density		$Mg.m^{-3}$	1.38	1.52
Water retention at	-33 kPa	$g.kg^{-1}$	252	24.35
	-1500 kPa	$g.kg^{-1}$	150	14.33
pH		-	7.37	7.25
Ec_e		dSm^{-1}	0.51	0.46
Organic matter		$g.kg^{-1}$	28.13	261
Calcium carbonate equivalent		$g.kg^{-1}$	147	165

Water applied

In the plots designated for control, water depth of 5 cm was provided from transplantation until one week before harvest. In additional plots designated for 40%, 60%, and 80% stress treatments, irrigation was applied to a depth of 5 cm when the soil moisture level reached a level of 80%, 60%, and 40% of field capacity, respectively, throughout the corresponding growth phases. 5 cm of water depth was maintained during the remaining times as usual.

Water use efficiency

Water use efficiency or crop water productivity as reviewed by [Molden, D and Frite, C. (2003)] is generally defined as the ratio of crop yield (Kg) to the volume of water applied (m3) to produce the yield:WUE= Yield/ water applied …………………………… (1)

The relationship between crop yield and water application is called the water production function (WPF). The WPF becomes curvilinear as more applied water goes to drainage or loss. A useful way to express the water production function is on a relative basis, where actual yield (Ya) is divided by maximum yield (Ym) and actual evapotranspiration (ETa) is divided by crop evapotranspiration (ETc). The relationship between evapotranspiration deficit (1 – (ETa/ETc)) and yield depression (1 – (Ya/Ym)) is always linear (Doorenbos J, Kassam AH. (1979).) with a slope called the yield response factor of the crop (KY). This relationship is expressed by the following equation: $(1- (Ya/Ym)) = KY\ (1- (ETa/ETm))$ …………………………… (2)

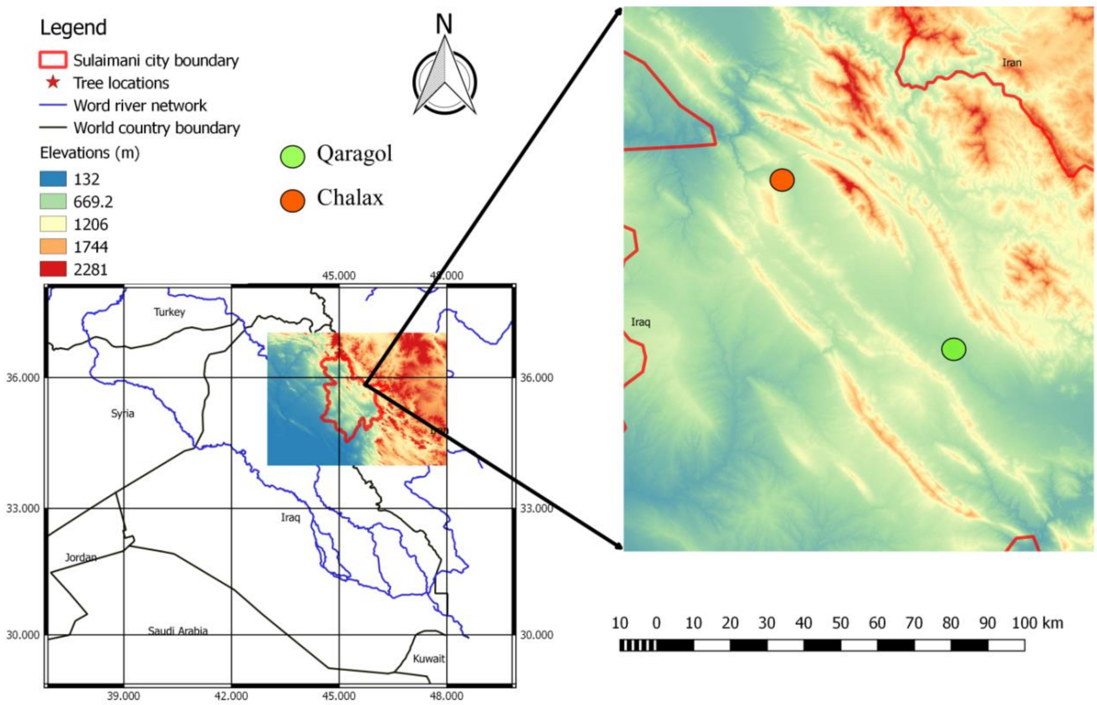


Fig. (1) Map of the study site in sulaimani -Kurdistan Region-Iraq

Assessment of Agronomic Parameters

Plant Height

Measurements for plant height were recorded at panicle initiation and heading stage. Twenty (25) hills were randomly selected from throughout the diagonals and median for evaluation of plant height. Plant height was measured from the base to the tip of the highest leaf and was individually counted.

Root Parameters

Five hills from each replicate were randomly selected for root assessment at panicle initiation. This was done using an auger 10 cm diameter to remove soil of 30 cm depth from selected hills. A uniform soil volume of 1570 cm^3 was excavated to collect root samples for all treatment. Roots were washed and removed from uprooted plants. Root volume was measured by the water displacement method by putting all the roots in a measuring cylinder and getting the displaced water volume (Tuong TP, Bouman AM, Mortimer M (2004). Root depth was obtained by direct manual measurements of top root using a ruler against a millimeter paper. Roots dry biomass per hill was obtained after oven drying at 70 ◦C for 24 h.

Yield Components

At harvest (June 7), yield components were determined from 20 sample hillsides. Panicle length and number of grains per panicle were measured according to method Kima, A.S.; Chung,W.G.;Wang, Y.-M.; Traoré, S. (2014). All remaining stubble in 6 m^2 of each plot was harvested to obtain grain yield per unit area (t/ha-1). Three samples of harvested grains were taken randomly from each replicate and their dry weight was determined after oven dry at 70 ◦C for 24 hours. The grain yield was then adjusted to 14% seed moisture. It was calculated as grain yield divided by total water supplied in the plot and was expressed in kg/m3 (Bouman, B.; Tuong, T.P. (2002). Water saving was obtained regarding the irrigation water and calculated as the difference in irrigation under the two irrigation regimes divided by the irrigation water applied under the CF regime.

Source	DF	Root dry weight (gm) Ms	Shoot dry weight (gm) MS	Plant height (mm) MS
Location	1	3.45042 *	12.0417	20.1667 *
Treatment	3	14.5982 *	136.375 *	188.889 *
Location *treatment	3	1.23153 *	4.15278 *	1.5 n.s
Replication [location] random	4	0.15083 n.s	4.08333 *	0.33333
Error	12	0.18694	0.9722	1.11111

RESULTS AND DISCUSSION

Analysis of variance and mean separation, using the Least Square Deviation LSD presented in Table (2-3), and these analyses were done on the data for yield, root dry weight, shoot dry weight and plant height for both locations there was a significantly higher rice yield (p-0.05) under full irrigation than obtained by all irrigation interval treatments in both locations. This may be due to the frequent application of large quantities of water without cutting irrigation. While there was a notice from table (2) a significantly higher rice crop yield in (L2) location than (L1) this belongs to the quality of flower buds was watch in (L1) irrigation as contrast to (L2) irrigation.

Table (2) Mean squares of variance analysis for some growth characters at both locations and their average

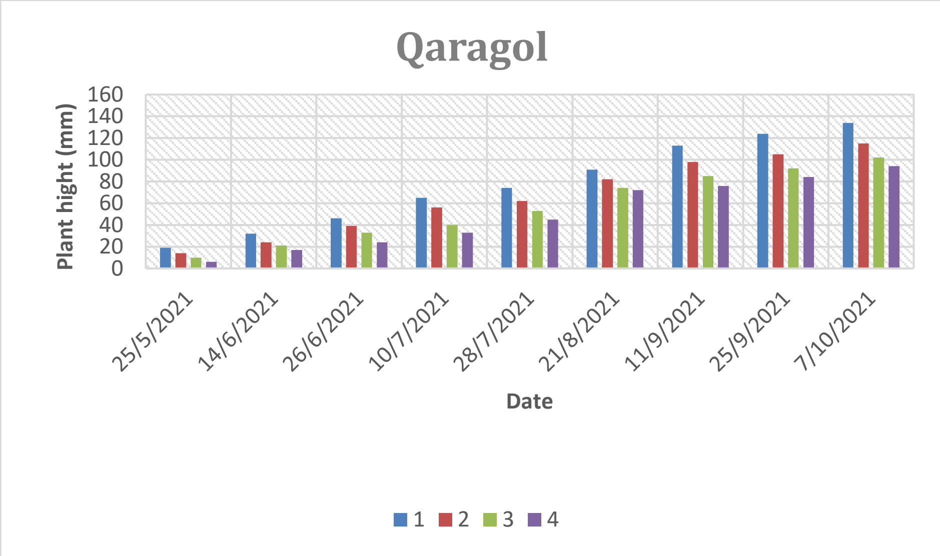
Table (3) shows the effect of the interaction between irrigation treatments and location on rice crop characters on both locations. At the locations (Qaragol and chalax) the effect was significant for the all-rice crop characters plant height, shoot dry weight and root dry weight except plant high in interaction between irrigation treatments and location.

Table (3) some growth characters at both locations and their average

Irrigation treatment	Locations	Root dry weight (gm)	Shoot dry weight (gm)	Plant height (mm)
Full irrigation	Qaragol	9.3 b	18.6 b	134.00 b
	Chalax	11.3 a	22.3 a	154.67 a
1 days	Qaragol	8.3 c	15.3 c	115.33 d
	Chalax	8.27 c	15.6 c	134.00 b
2 days	Qaragol	7.3 d	12.0 d	102.33 f
	Chalax	7.6 cd	12.0 d	119.67 c
3 days	Qaragol	6.3 e	8.6 e	94.00 g
	Chalax	7.06 de	10.3 de	111.00 e

Table.3 and figure (2) show the effect of irrigation interval and location of experiment on plant height is significant at a 5% level with treatment and location. The effect of all the treatment and the interaction effect of treatment and depth of irrigation water on plant height are significant. The comparison of the mean values of plant height shows that the lowest and the highest plant height has belonged to irrigation interval and location treatments, respectively (Table 3). The range of plant high between 94.00 mm to 154.67mm, and the highest was 154.67 in full irrigation at (L2) location and the lowest value were 94.00 mm in 3 days interval irrigation at (L1) location. On the other hand, (Bassiouni, S. M. (2018) reported the shortest plants were observed when rice plants were watered every 9 days at 3 cm depth .as well as the current data are in agreement with those reported by Sarvestani, Z.T.; H. Pirdashti; S.A. Sanavy and H. Balouchi (2008). (Wan, M. Z. (2009). ([Hafez, E. M.; W. H. Abou El Hassan; I. A. Gaafar and M. F. Seleiman (2015). and [Refaie, K.M.; H.M. El Sharkawi; A.A. Khalil; T.F. Metwally; S.M. Abolmaty; B.A. Ali and M.K. Hassanein (2017)

Table (2, 3) the deficit irrigation at vegetative growth stage affected the shoot and dry weight and reduces it significantly in comparison with the full irrigation treatment and deficit irrigation treatments as shown in figure (2 and 3) the reduction in shoot and dry weight for the deficit irrigation at vegetative growth stage in relation to other full and deficit irrigation treatments were 17.74, 35.48, 53.76 % for 1 day, two days and three days at (L1) location and were (16.13, 35.48, and 44.62%) for Di,D2, D3) for L2 location. For full irrigation treatment, the reason beyond the high reduction in plant high under deficit irrigation during the vegetative growth stage is related to cells development and division which sensitive to water stress (Hsiao, T.C. 1973). This finding (reduction in plant high) is in agreement with work of others researches (Huang, H., Zhong, L. and Gallichand, J. (2002). who found that the deficit irrigation influence d plant high of crop especially when applied during vegetative growth stage and influenced stopped at the flowering stage.



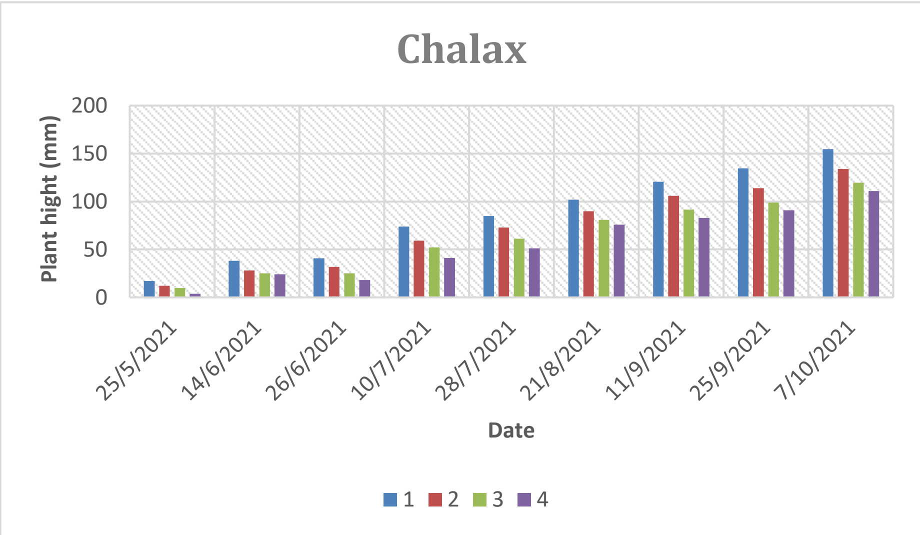


Figure (3 and 4) Effect of irrigation interval on plant high at [L1 and (L2) Qaragol and Chalax location

Table (4and 5) shows the total water applied for the full irrigation (I_1) at (L2) location was 980.7 mm/ha^{-1} and 939.3 mm/ha^{-1} at (L1) location for rice crop. Under deficit irrigation treatments, (I_2, $I_3$and I_4) applied water was 821.6, 749.0 and722.3 mm/ha-1 respectively at (L2) location. However, at (L1) location, the amount of water applied was 811.3, 726.3 and 681.3 mm/ha-1recpectivily.

The effect of irrigation interval, locations, and their interaction on water use efficiency is significant at a 5% level (Table 4). The comparison of the mean values of water use efficiencies shows that the highest and the lowest water use efficiency has belonged to L4L2 and l1 L1 treatments, respectively (Table 4). (Pirmoradian, N.; A.L. Sepaskhah and M. Mafton (2004) reported the same results and [Mojtaba, R.; H.S. Vahed; M.K. Motamed and E. Azarpour (2009). The interaction effect of Locations and depth of irrigation water on water use efficiency were shown in (Fig. 3) This table (Bouman, B.; Tuong, T.P. (2002) shows that for replication (location), water use efficiency and total water applied treatments; there is no significant difference between treatments. Therefore, to save water, it is better to use 4 days irrigation (Molden. D and Frite .C. (2003). treatment instead of full irrigation treatment, because 4 days irrigation consumes less water as compared to full irrigation The reduction of depth of ponding (full irrigation vs. 4 days irrigation interval) caused a 22.82% and 21.72% improvement in water use efficiency (Table 4). At present, the farmers apply flooding irrigation to the paddy fields with low irrigation efficiency. Based on the results of this research, paddy fields could be irrigated with much less water than the amount that farmers are using traditionally. (Du, C., Sun, F. Yu, J., Liu, X and Chen, Y. (2016) Reported that mean yield and ET in continuous submergence regime were the same for the two irrigation depths of 50 and 75mm, thereby leading to the same values of ET-based water productivity. Bouman BAM, Yang XG, Wang HQ (2002) Reported that the main cause of reduction of water use efficiency a great reduction in seepage, percolation and evaporation, this technology allows for greater WUE and high water saving compared with traditional flooded irrigation. In cracking clay soils, as the irrigation time increases, the irrigation water loss increases too. To increase the water use efficiency of the soils it is necessary to reduce deep percolation and lateral water losses. The study by Kukal, S.S., Aggarwal, G.C., (2002) showed that reduction in the depth of ponded water decreases the deep percolation substantially.

Table (4) the comparison of the mean values of Water use efficiencies and grain yield

Irrigation treatment	**Locations**	**Total applied water (mm/ha)**	**Grain Yield (Kg/ha $^{-1}$)**	**Water use efficiency**	**Water use efficiency (%)**
Full irrigation	L1	939.3 b	6196.7 b	6.597 e	---
	L2	980.7 a	6263 a	6.387 f	----
1 days	L1	811.3 d	6080 d	7.494 d	11.97%
	L2	821.6 c	6106.6 c	7.432 d.	!4.06%
2 days	L1	726.3 f	5923.3 f	8.155 b	19.1%
	L2	749.0 e	5973 e	7.975 c.	19.91%
3 days	L1	681.3 g	5823.3 h	8.547 a	22.82%
	L2	722.3 f	5893 g	8.159 b	21.72%

Table (5) the effect of irrigation interval, locations, and their interaction on water use efficiency and grain yield

		Grain yield (kg/ha-1)	**Water use efficiency (Kg/m3)**	**Total water Applied (m3)**
Source	DF	Ms	Ms	MS
Location	1	17066.7 *	0.26453 *	4988.17 *
Treatment	3	160250 *	4.0604 *	78660.8 *
Location *treatment	3	588.889	0.02738 *	342.278 *
Replication [location] random	4	920.833 *	0.00363 n.s	5.83333 n.s
Error	12	215.3	0.00232	9.8

Figure (4) shows in (L1) and (L2) locations an attempt was made to establish a relationship between water consumed and yield Figure (5,6). A linear relationship was observed between water applied and yield (Y) with the equation for the relationship as Y = 1.4274 x +4878.9 with r2 =0.9601. A polynomial relationship was determined between (Y) and (AW) Fig, (5, 6). Using the crop water production function (CWPF) equation to predict maximum yield for all the experiments, in addition, in the figure (5) the relationship between water applied and yields Figure (5, 6). A linear relationship was also observed between water applied and yield (Y) with the equation for the relationship as Y = 1.3686x + 4939 .2 with r2 =0.9566

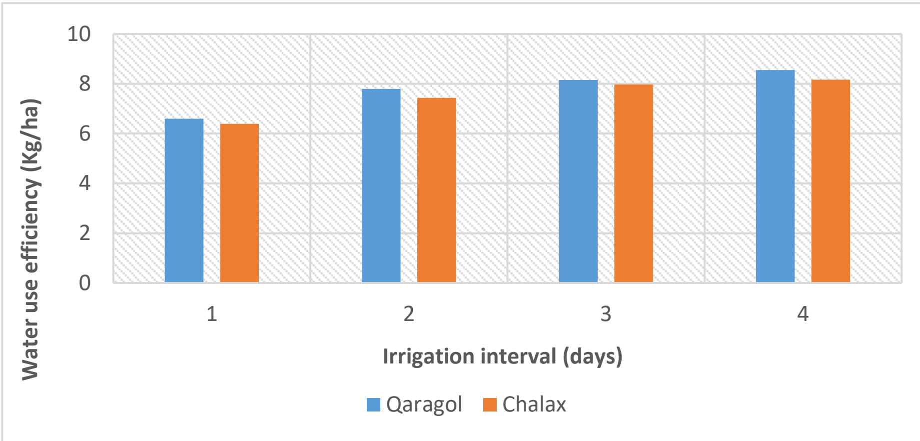
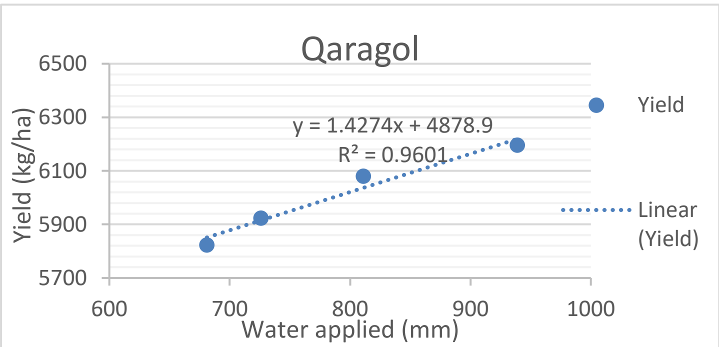


Figure (4) Effect of irrigation treatments on water use efficiency for crop rice at both



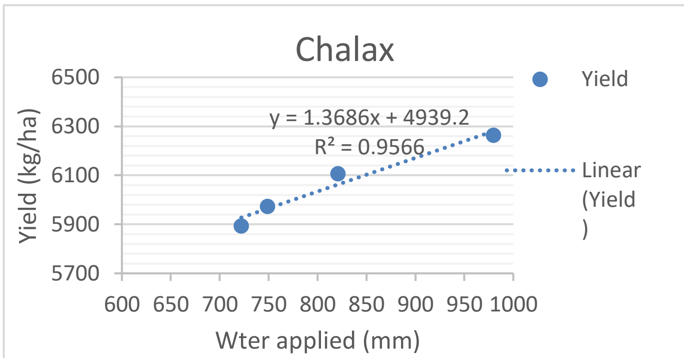


Fig. (5) Relationship between yield and water applied Fig. (6) Relationship between yield and water through the seasons of crop rice at (L_1) location applied through the seasons of crop rice at (L_2)

CONCLUSIONS

The study highlights the effect of different locations with different soil and water quality on rice yield and water use efficiency. The significant effect of location (Qaragol and Chalax) indicates that local environmental conditions play a decisive role in the success of rice cultivation. The study highlights the importance of irrigation interval management for both rice grain production and water use efficiency. Variable irrigation intervals (full irrigation, one-day, two-day, and three-day irrigation) have significant effects on crop performance, indicating that a well-planned irrigation schedule is critical to optimizing results. The study identifies a significant interaction between irrigation interval and location, highlighting the need for a tailored approach to irrigation management based on the specific characteristics of each location. This interactive effect means that the effect of irrigation strategies can vary depending on the soil and water quality of a particular location. The results show significant differences in grain yield between the Qaragol (L_1) and Chalax (L_2) sites. The higher grain yield in Chalax indicates that certain conditions at that location are more favorable for rice cultivation than in Qaragol. Understanding such site-specific variations is critical to optimizing agricultural practices. The study finds significant differences in water use efficiency between different irrigation intervals and locations. The highest water use efficiency is observed in the Qaragol region with a three-day irrigation interval (D4). This suggests that careful irrigation planning can significantly improve water use efficiency without compromising yield.

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