Study of Irrigation Intervals and Bio-Fertilizer on Growth, Yield, and Water Use Efficiency of Some Wheat Cultivars

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Abstract

A field experiment in a split - split plot arranged in Randomize Complete Block Design with three replicates was conducted on a silt clay soil located at the experimental farm, at university of Baghdad–college Agriculture in Abu-Ghraib/ Baghdad, Iraq, during growing winter seasons of 2013/2014 to study the effect of irrigation intervals (every 10, 20 and 30 days), bio-fertilizers (inoculation with *Pseudomonas putida*) and wheat cultivars (IPA 99, Abu-Ghraib 3 and Research 22) on wheat plant growth, grain, biological yield and water use efficiency. The irrigation intervals (every 10, 20 and 30 days) were arranged in main plots whereas, other treatments of cultivars in the sub plots and inoculation with *Pseudomonas putida* in sub sub plot. The obtained results could be due to irrigation every 10 and/or 20 days supplied sufficient soil moisture in the root zone which increased the capacity of wheat plant in photosynthesis and consequently increased flag leaf area, number of spikes m^{-2}, plant height (cm) and number of tillers m^{-2}**.** The results also showed that the application of biofertilizers significantly improved the all parameter growth, yield and water use efficiency of wheat**.** Total amount of irrigation water applied varied from 65 mm to 245 mm depending on the irrigation intervals, biofertilizers and cultivar. The total amount of *ETa* was 429, 330 and 278 mm for irrigation every 10, 20 and 30 days, respectively. The highest water use efficiency (WUE_f and WUE_c) were obtained from plants exposed to the lowest of water supply. These result indicted the role of rainfall, increased wetted soil volume inside root zone and this mean increasing in water volume which was stored in root zone

KEYWORDS: irrigation intervals, wheat cultivars, *Pseudomonas putida*, yield, water use efficiency.

Introduction

Wheat (*Triticum aestivum* L.) is considered the most strategic crop for Iraq and some other developing countries. Increasing wheat productivity is a national target in Iraq to fill the gap between wheat consumption and production. Water stress affects physiological processes, growth and yield of wheat plant. Amer (2004) studied the effect of irrigation levels: control treatment (depletion of 50% of available water) and four treatments which represented (75%, 50% and 25% of the mount of the control) on the productivity of some bread and durum wheat cultivars. The results revealed that, the highest number of spikes/m^2, 1000 grain weight and grain yield were obtained from irrigation 75% watering amount treatment, and saved 696 and 490 m^3 of water ha^{-1} for two seasons. Water stress affects physiological processes, growth and yield of wheat plants. Whenever, soil moisture stress increased, the wheat yield decreased (Abbas *et al.,* 2001). Irrigation intervals every 15 days gave the highest

values for number of spikes/ m^2, number of grains/spike, spike weight, grain weight/spike, spike index, 1000 - grain weight, grain and straw yields and grain protein content (Zeidan *et al.*, 2009). Agrochemical fertilizers have been inflicting adverse effect on the environment causing pollution and damaging beneficial soil flora and fauna, causing erosion and no longer able to sustain the productivity. Therefore, in order to make agriculture sustainable, biofertilizer and organic fertilizers have important role to play in improving nutrient supplies and thus yield. Biofertilizers are ecofriendly, cost effective and renewable source of plant nutrients. They can play a vital role in maintaining soil fertility and sustainability, the long term use of biofertilizer is economical, ecofriendly, more efficient, productive and accessible to marginal and small farmers over chemical fertilizers. The role and importance of Biofertilizers in sustainable crop production has been reviewed by several authors (Biswas *et al.*, 1985; Wani and Lee, 1995). Organic compost and bio-fertilizer positively affect wheat yield and its component; the treatment gave the highest values of biological yield, 1000-grain weight as well as grain and straw yields. Interaction of irrigation intervals and fertilizers positively affected wheat yield and its component (Mohamed *et al.*, 2013). Thus, the aim of the present investigation was to study the effect of irrigation intervals and biofertilizers on water use efficiency, yield and yield attributes of some bread wheat cultivars under semi arid conditions in middle of Iraq.

Material and Methods

Field experiments on Wheat was carried out at University of Baghdad, College Agriculture in Abu-Ghraib, Baghdad, Iraq, (33°22'N, 44°24'E; altitude, 34.1 m) during winter season 2013-2014 (November to May). Some soil characteristics (Table 1) were determined as follows: soil particle size distribution by pipette method, soil bulk density was determined by the core method. Soil reaction (pH) and electrical conductivity (EC) were determined at the same soil water suspension 1:1 (W:V) by pH-meter and electrical conductivity-bridge, respectively. Organic matter was determined by method of Walkley and Black (Black, 1965 a,b).

Table 1. Physic-chemical properties of the soil

Soil depth (cm)	BD gcm^{-3}	FC	WP	AW	Particle size distribution (g/kg)				EC $dS\ m^{-1}$	pH	OM %
		%			clay	Silt	sand	Texture			
0-30	1.43	33.0	15.2	17.8	420	400	180	Silty clay	2.62	7.5	2.14
30-60	1.46	34.5	14.1	18.4	420	470	110	Silty clay	3.11	7.4	1.42

The experimental treatments were split - split plot arranged in Randomize Complete Block Design with three replicates. The main plots were assigned to irrigation intervals, whereas biofertilizer was assigned to the sub plots and biofertilizers inoculation to the sub sub plot**.** NPK mineral fertilizer as urea, calcium super phosphate and potassium sulphate were applied, as they are commonly used for growing wheat plants and recommended by Ministry of Agriculture were applied to all treatment excepted treatments inoculation added half amount of the calcium super phosphate. Sowing was done on November 23th 2013. Harvest was done on 2/May/2014. The treatments were:

1. Irrigation treatment as follows (main plot):

a. Irrigation every 10 days.

b. Irrigation every 20 days.
c. Irrigation every 30 days.

2. Cultivars *Triticum asetivum* (sub plot):

a. IPA 99 (V_1)
b. Abu-Ghraib 3 (V_2)
c. Research 22 (V_3)

3. Biofertilizers inoculation treatment (sub sub plot): (Bacteria solvent phosphate – *Pseudomonas putida*). Bacterial strains were used as seed treatments. Seeds of wheat were surface-sterilized with 0.02% sodium hypochlorite for 2 min, and rinsed thoroughly in sterile distilled water. For inoculation seeds were coated with 40% Arabic gum as an adhesive and rolled into the suspension of bacteria until uniformly coated density of bacteria in suspension were 1.025 CFU (×109 /ml) for *Pseudomonas putida*.

a. Inoculation (C_1)
b. Non Inoculation (C_0)

The area of each plot was 15 m^2 (3×5). Grains of wheat were sown at a rate of 120 kg. ha^{-1}, All agriculture practices for growing wheat were applied as recommended. During the cultivation seasons; the mean relative humidity was 41% and mean rainfall was 205 mm during wheat growing season.

The amounts of applied irrigation water (m^3/ha) correspond to each interval. Irrigation was applied according to the irrigation intervals. Irrigation system was surface flow irrigation through line pipe provided with meter gages for measuring water applied. Irrigation were scheduled when soil water content in the root zone was depleted by the crop to specific fraction of available water (irrigation was imposed at 50% depletion of available water). The amount of water consumed from the root zone between two successive irrigations as a water depth in cm, was calculated from the following equation (Israelson and Hansen, 1962):

$$d = D \times P_b \times (Q_2 - Q_1)/100 \qquad (1)$$

Where:
d = Depth of water added
D = irrigation root zone depth (cm)
P_b= Bulk density of soil (g. cm^{-3})
Q_2= Percentage of soil moisture at field capacity
Q_1= Percentage of soil moisture before irrigation

The amount of water consumed in each irrigation interval was obtained from the difference between soil content before the following irrigation and field capacity. Actual evapotranspiration was estimated according to the Allen *et al.* (1998):

$$\mathbf{ETa = R + I - D \pm \Delta W} \qquad (2)$$

Where:
ETa= Evapotranspiration (mm), R = Rainfall (mm), I = Depth of irrigation (mm), D = Depth of drainage (mm), and ΔW = the change of soil water storage in the measured soil depth.

Since the amount of irrigation water was only sufficient to bring the water deficit to field capacity, deep percolation was ignored. Water use efficiency (crop and field) were calculated according to the following equations (3 and 4):

$$WUE_c = \frac{Yield}{ET_a} \ldots\ldots(3) \qquad WUE_f = \frac{Yield}{Water\ applied} \ldots\ldots\ldots(4)$$

Plant samples of one square meter from each plot were harvested and ten plants were taken randomly to determine yield attributes (flag leaf area, plant height, tillers.m^{-2}, spike. m^{-2}, grain weight, grain yields and biological yield). Analysis of variance (ANOVA) was conducted to evaluate the effects of the treatments on the yield and water use efficiency. Least significant differences method (L.S.D) was used to differentiate means at the 0.05 level (SAS, 2010).

Result and Discussion

1. Yield Attributes

1.1. Flag leaf area (cm^2) and Number of spikes (m^{-2})

Results presented in Table 2 and 3 show that, irrigation of wheat plants at short intervals every 10 days (9 irrigations till harvest) led to significant increase and gave the highest values of flag leaf area (cm^2) and number of spikes m^{-2}, IPA 99 wheat cultivar surpassed in flag leaf area (cm^2) the other two cultivars (Abu-Ghraib 3 and Research 22) while IPA 99 and Abu-Ghraib 3 wheat cultivar surpassed in number of spikes m^{-2} compare to Research 22 cultivars. The results also showed that the application of biofertilizers significantly improved the wheat flag leaf area and number of spikes, raising biofertilizer inoculation (with addition of *Pseudomonas putida*) from 42.22 to 48.48 cm^2 and from 181.77 to 208.10 m^{-2} for flag leaf area and number of spikes, respectively. As shown in the combined analysis**,** the interaction effects between irrigation intervals, wheat cultivars and biofertilizer on flag leaf area and number of spikes in Tables 1 and 2 were significant. As for interaction, the tallest flag leaf area 57.8 cm^2 and number of spikes 258 m^{-2} were recorded for wheat plants treated with addition of *Pseudomonas putida* and irrigated every 10 days for IPA 99 cultivars.

Table 2. Flag leaf area (cm^2) of wheat as affected by the irrigation intervals, bio-fertilizers and cultivars

I	V_1		V_2		V_3		Mean
	C_0	C_1	C_0	C_1	C_0	C_1	
10	46.5	57.8	40.6	53.5	47.5	53.6	49.92
20	47.3	50.4	35.4	46.4	38.4	43.5	43.56
30	45.8	47.4	42.5	43.6	36.1	40.2	42.60
Mean	46.53	51.86	39.50	47.83	40.66	45.8	
Mean	49.19		43.66		43.23		
LSD	I	V	C	IV	IC	VC	IVC
0.05	1.35	1.63	0.96	1.96	1.63	2.31	3.26

Table 3. Number of spikes m^{-2} of wheat as affected by the irrigation intervals, bio-fertilizers and cultivars

I	V_1		V_2		V_3		Mean
	C_0	C_1	C_0	C_1	C_0	C_1	
10	198	258	200	244	134	202	206
20	202	232	170	196	196	172	195

30	160	178	196	206	180	185	184
Mean	186.7	222.7	188.7	215.3	170	186.3	
Mean	204.7		202		178.2		
LSD	I	V	C	IV	IC	VC	IVC
0.05	6.29	9.87	5.35	12.91	13.64	16.63	19.01

1.2. Plant height (cm) and Number of tillers m^{-2}

Data presented in Table 4 and 5 showed the effect of the irrigation interval, different cultivars and biofertilizer on the wheat plant height (cm) and number of tillers m^{-2}. Irrigation interval 10, 20 and 30 day are not significant in plant height. Wheat plant irrigated every 10 days (9 irrigations till harvest) and 20 days (5 irrigations till harvest) are not significant between them but led to increase and gave the highest values of number of tillers m^{-2}, showed the maximum number of tillers 236.7 and 242.6 for irrigation interval every 10 and 20 days, respectively. While, wheat plants irrigated every 30 days (3 irrigations from planting date till harvest date) produced the lowest number of tillers 200.7 m^{-2}. Abu-Ghraib 3 wheat cultivar surpassed in number of tillers m^{-2} to other two cultivars (IPA 99 and Research 22) while IPA 99 wheat cultivar surpassed in plant height compare to Abu-Ghraib 3 and Research 22 cultivars. The results also showed that the application of biofertilizers significantly improved the wheat plant height and number of tillers, rising biofertilizer inoculation (with addition of *Pseudomonas putida*) from 98.7 to 106.9 cm and from 210 to 243 m^{-2} for plant height and number of tillers, respectively.

Table 4. Plant height (cm) of wheat as affected by the irrigation intervals, bio-fertilizers and cultivars

I	V_1		V_2		V_3		Mean
	C_0	C_1	C_0	C_1	C_0	C_1	
10	82	122	106	103	90	101	100.66
20	110	111	88	100	104	105	103
30	103	110	99	100	106	110	104.66
Mean	98.33	114.33	97.66	101	100	105.33	
Mean	106.33		99.33		102.66		
LSD	I	V	C	IV	IC	VC	IVC
0.05	N.S	1.07	1.80	2.13	1.97	2.16	3.71

Table 5. Number of tillers m^{-2} of wheat as affected by the irrigation intervals, bio-fertilizers and cultivars

I	V_1		V_2		V_3		Mean
	C_0	C_1	C_0	C_1	C_0	C_1	
10	224	304	250	296	150	196	236.7
20	212	274	262	270	216	222	242.7
30	174	190	206	214	196	224	200.7
Mean	203	256	239	260	187	214	
Mean	230		250		201		
LSD	I	V	C	IV	IC	VC	IVC
0.05	6.89	7.97	5.52	10.62	8.81	13.64	11.79

The obtained results could be due to irrigation every 10 and/or 20 days supplied sufficient soil moisture in the root zone which increased the capacity of wheat plant in photosynthesis and consequently increased flag leaf area, number of spikes m^{-2}, plant height (cm) and number of tillers m^{-2}. The previous results are in full agreement with those reported by Kamel *et al*. (2007) and Zeidan *et al.* (2009). Plant growth parameter promoting bacteria improved photosynthesis may be by increasing water and nutrients absorption leading to produce more assimilation and improve plant growth. Rainfall in this season was enough to bear plants to irrigation every 20 days.

1.3. Grains weight (g) and Grain yield (Ton ha^{-1})

Data illustrated in Table 6 and 7 showed the effect of irrigation interval, different cultivars and biofertilizer on the wheat grain weight (gm) and grain yield (Ton ha^{-1}). The treatment irrigation every 10 days produced highest average grain yield 2.83 Ton ha^{-1} didn't differ significantly from treatment irrigation every 20 days 2.70 Ton ha^{-1}, while the percentage reduced grain yield for the treatment irrigation every 30 days by 26.15% and 22.59%, as compared to irrigation every 10 and 20 days respectively. But this not significant decrease if we calculated the actual amount of water added during the growing season, rainfall an average of 205 mm was enough to give the protection of yield and this good production. Research 22 wheat cultivar surpassed in grain yield compare to Abu-Ghraib 3 and IPA 99 cultivars. The results also showed that the application of biofertilizers significantly improved the wheat plant height and number of tillers, raising biofertilizer inoculation (with addition of *Pseudomonas putida*).

Inoculation of wheat crop with *Pseudomonas putida* improved biological yield (Table 8) and grains yield (Table 7) of wheat and plants nutrients accumulations. Infection rates in wheat roots and spores concentrations in soil were also increased with the inoculation of *Pseudomonas putida* biofertilizers. *Pseudomonas putida* bacteria is important in terms of production of plant growth regulators, particularly auxin (Patten and Glick, 1996) (auxin increases plant growth by elongation of plant cells, stimulate of cell division and differentiation of plant cells), iron chelating compounds, organic acids (succinic acid and lactic) and solving phosphorus by secretion of organic acids and phosphates' (Kim *et al.*, 1998) and increase plant growth (Afsaneh and Shamshiri, 2014). In the water stress condition, mycorrhizae increases macro (especially phosphorus) and micro nutrient uptake than plants without mycorrhizae. As a result, mycorrhizae increases tolerance to water stress by improving plants nutritional status (Osonubi *et al.*, 1992). Thus, increase of phosphorus uptake by mycorrhizae considering the role of phosphorus in molecular structures such as nucleic acids, stomatal conductance and photosynthesis increases the tolerance of plants against water stress (Sawwan *et al.*, 2000).

Table 6. Grains weight (g) of wheat as affected by the irrigation intervals, bio-fertilizers and cultivars

I	V_1		V_2		V_3		Mean
	C_0	C_1	C_0	C_1	C_0	C_1	
10	27.39	30.74	32.04	32.26	31.28	32.50	31.03
20	29.02	30.69	30.27	31.33	34.82	36.47	32.10
30	30.85	35.27	28.73	30.53	30.76	35.48	31.93
Mean	29.08	32.33	30.34	31.37	32.28	34.81	
Mean	30.65		30.85		33.54		
LSD	I	V	C	IV	IC	VC	IVC

0.05	NS	NS	0.91	NS	1.11	2.23	4.52

Table 7. Grain yield (Ton ha^{-1}) of wheat as affected by the irrigation intervals, bio-fertilizers and cultivars

I	V_1		V_2		V_3		Mean
	C_0	C_1	C_0	C_1	C_0	C_1	
10	2.33	3.09	2.04	2.76	3.27	3.48	2.83
20	2.36	3.00	2.33	2.53	2.84	3.13	2.70
30	1.82	2.59	1.98	2.37	1.78	2.01	2.09
Mean	2.17	2.89	2.12	2.55	2.63	2.87	
Mean	2.53		2.34		2.75		
LSD	I	V	C	IV	IC	VC	IVC
0.05	0.43	NS	0.37	0.91	1.20	0.87	1.31

Table 8. Biological yield (Ton ha^{-1}) of wheat as affected by the irrigation intervals, bio-fertilizers and cultivars

I	V_1		V_2		V_3		Mean
	C_0	C_1	C_0	C_1	C_0	C_1	
10	10.96	11.0	10.04	10.84	11.52	11.80	11.03
20	9.00	9.96	9.36	10.56	10.24	10.76	9.98
30	7.64	9.88	9.16	9.64	8.84	9.68	9.14
Mean	9.20	10.28	9.52	10.34	10.20	10.74	
Mean	9.74		9.93		10.47		
LSD	I	V	C	IV	IC	VC	IVC
0.05	0.73	NS	NS	0.95	1.12	NS	1.46

2. Water Use Efficiency

Table 9 presents the informative data about amounts of irrigation water applied. Total amount of irrigation water applied varied from 65 mm to 245 mm depending on the irrigation intervals, biofertilizers and cultivar. The total amount of *ETa* was 429, 330 and 278 mm for irrigation every 10, 20 and 30 days, respectively. These values were quite nearly than results for the same crop under different climatic and environmental conditions in Iraq. The differences on yield can be explained by the variations inoculation *Pseudomonas putida* on
yield, WUE_f and WUE_c.

Table 10 and 11 shows high value of WUE_f and WUE_c at every 20 and 30 days compared to the treatment every 10 days. The reason for the high value of WUE_f and WUE_cevery 20 and 30 days to lower amounts of added water formed greater proportion of lower grain yield as well as the availability of rain and low temperatures help the formation the plant dry matter contributed to mainly in grain filling during the period of interruption rain. While the reason
low efficiency, due to increased evaporation transpiration in treatment.

The results also showed that the irrigation intervals significantly improved the wheat WUE_f and WUE_c (Table 10 and 11), rising from 1.27 to 2.72 $kg.m^{-3}$ and from 0.66 to

0.82 kg.m^{-3} for WUE_f and WUE_c, respectively. The highest water use efficiency (WUE_f and WUE_c) were obtained from plants exposed to the lowest of water supply. These result indicted the role of rainfall, increased wetted soil volume inside root zone and this mean increasing in water volume which was stored in root zone.

Table 9. Amounts of irrigation water applied of wheat as affected by the irrigation intervals, bio-fertilizers and cultivars

I	V_1		V_2		V_3		Mean
	C_0	C_1	C_0	C_1	C_0	C_1	
10	230	205	233	210	245	220	224
20	128	110	140	116	136	122	125
30	76	65	75	70	81	73	73
Mean	145	127	149	132	154	138	
Mean	136		141		146		
LSD	I	V	C	IV	IC	VC	IVC
0.05	50	NS	6.2	4.4	2.2	4.1	9.98

Table 10. Water use efficiency field of wheat as affected by the irrigation intervals, bio-fertilizers and cultivars

I	V_1		V_2		V_3		Mean
	C_0	C_1	C_0	C_1	C_0	C_1	
10	1.01	1.51	0.88	1.31	1.33	1.58	1.27
20	1.84	2.73	1.66	2.18	2.09	2.57	2.18
30	2.39	3.98	2.64	3.39	2.19	2.75	2.72
Mean	1.5	2.28	1.42	1.93	1.71	2.08	
Mean	1.86		1.66		1.88		

Table 11. Water use efficiency crop of wheat as affected by the irrigation intervals, bio-fertilizers and cultivars

I	V_1		V_2		V_3		Mean
	C_0	C_1	C_0	C_1	C_0	C_1	
10	0.54	0.75	0.47	0.67	0.73	0.82	0.66
20	0.71	0.95	0.68	0.79	0.83	0.96	0.82
30	0.65	0.96	0.71	0.86	0.62	0.72	0.75
Mean	0.62	0.87	0.6	0.76	0.73	0.84	
Mean	0.74		0.68		0.78		

Conclusions

The possibility of obtaining grain yield good in case of normal rain years (average precipitation is 200-250 mm) and the rate of production no different from in case full irrigation.

The requirement two - three irrigations during the growing season wheat crop in case the rate of precipitation 200-250 mm.

Recommending using cultivars IPA 99, Research 22 and Abu-Ghraib 3 characterized by qualities of a good vegetative growth and production at the limited water conditions.
Recommendation for using inoculation with bacteria *Pseudomonas putida* in wheat seed.

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