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Effect of irrigation regimes on growth and yield of wheat (*Triticum aestivum* L.); economic analysis

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ABSTRACT

The study was design to evaluate the effect of water regimes on overall performance of wheat and optimum need of water. Wheat was tested under 2, 3 and 4 numbers of irrigations named as I_1, I_2 and I_3 respectively. Treatments were arranged in randomized complete block design (RCBD) with factorial arrangement. Sowing was started in November 2018 by automatic drill in Rabi. Observations on growth and yield parameters of wheat were recorded by following standard procedures. The data collected were analyzed statistically by applying least significant difference test (LSD) at 5% probability level for comparison among treatment's means. The I_3 had significantly ($P<0.05$) high leaf area index, plant height, spike length (cm), no. of spikelets/spike, biological yield of wheat, grain yield (t ha^{-1}), straw yield of (t ha^{-1}), harvest index (%) significantly While the days to booting, tillers (m^{-2}), no. of grains/spike, grain weight/spike, weight of 1000 grains had not significant differences. It was concluded that the I_3 with 4 irrigations had a potentially high yield, performance and economically beneficial.

Keywords Irrigation regimes, Growth, Yield, Wheat (*Triticum aestivum* L.), Economic analysis

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1. Introduction

In Pakistan, wheat is the most essential food crop which is growing in Rabi season, in irrigated areas of Punjab and Sindh. As per above scenario, wheat seems to be the most precious crop during the Rabi season and staple diet of people [1]. Wheat is grown over an area of more than 8 million hectares in the country, which contributes 66% of the area under food grains and 37% of the total cropped area. It contributes about 74% of the total production of food grains[2].

Water is becoming a critical and limiting resource in the Punjab agriculture which is much more dependent on Indus basin irrigation flow, rainfall and water availability in dams. The seasonal rainfall is much more variable and significantly affects the flow of rivers especially during Rabi season [3]. Water is the most important factor necessary for proper growth, balanced development and higher yield of all crops. Water deficiency effects plant growth and grain yield in wheat and other cereals is the end result of a number of contributing and inter-related components such as number of grains per ear, number of ear per unit area and mean grain mass [4]. Tillers of irrigated plants produced 94% ears, compared to 79% of the stressed plants. Grain yield was reduced to 65% in the stressed plants compared to that of irrigated plants. Wheat crop produced highest grain yield by applying irrigation at all definable growth stages [4]. Increase in yield per unit area necessary for efficient use of inputs and irrigation water is the mainly valuable input which is decreasing day by day. The significance for efficient use of water is ineluctable because requirement for food and clean water is rising [5].

Earlier research showed that irrigation consistently increased wheat yield in Pakistan [6]. Moreover, the wheat crop produced highest grain yield by applying irrigation at all definable growth stages [4]. Therefore "effect of irrigation regimes on growth and yield of different variety of wheat (*Triticum aestivum* L.) and economic analysis" studied to evaluate the optimum water uses and recommends potential administration for growth and yield.

2. Materials and methods

2.1. Experimental site

A field study to determine the comparative performances of wheat under different irrigation regimes was conducted at the Agronomy farm, University of Agriculture Faisalabad.

2.2. Experimental design

The experiment was laid out in Randomized Completely Design with factorial arrangements having three replications. Total number of plots was 15 and each replication had 5 plots with five different varieties with three irrigation level. This experiment was conducted during the Rabi season 2018-2019. It was comprised of one field experiment as show in (Table 1). Five wheat lines 9496, ZA-10, Galaxy-2013, ZA-6 and 9493 were allocated as V1, V2, V3, V4 and V5 respectively. During last week of November 2018, the crop was sown. Recommended agronomic practices were followed to manage the crop during growing season. Seed was sown in the well-prepared field in Lines with automatic drill. A fertilizer dose @ 140 Kg N +P_2O_5/ ha was applied. At the time of sowing all phosphorus was applied with half dose of nitrogen while left over amount of nitrogen was given with first irrigation in all cases.

2.3. Irrigation levels (main plots)

Irrigation regimes were I_1: 2 irrigations, I_2: 3 irrigations and I_3: 4 irrigations. Following observations were recorded using standard procedure.

2.3.1. Parameters

2.3.1.1. Allometry, phenology and morphology

The leaf area index and days to booting are measured as following procedure.

2.3.1.2. Leaf area index

Leaf area index (LAI) is a dimensionless quantity that characterizes plant canopies. It is defined as the one-sided green leaf area per unit ground surface area. Leaf area was measured according to following formula.

LAI=$\frac{leaf\ area\ (m^2)}{ground\ area\ (m^2)}$ in broadleaf canopies.

2.3.1.3. Days to booting

The developing head within the sheath of the flag leaf becomes visibly enlarged during the booting stage. The booting stage ends when the first awns emerge from the flag leaf sheath and the head starts to force the sheath open.

2.3.1.4. Yield related traits

The number of tillers/$m^{2,}$ plant height (cm), spike length (cm), No. of spikelets/spike, No. of grains/spike, grain weight per spike, weight (g) thousand grains, Biological yield (t ha^{-1}), Grain yield (t ha^{-1}) and Harvesting index (%) were measured.

2.3.2. Procedure used for recording data

2.3.2.1. Number of tillers/m^2

The number of tillers was determined by counting them from each plant in the plots.

2.3.2.2. Plant height

Ten tillers were selected randomly from each plot and individual plant height was measured from soil surface to the top of ear, with the help of meter rod and then average height was calculated.

Table 1 Layout of experiment during the 2018-2019 of wheat evaluation by water regimes.

R_1	**Sub water channel**															**Main water Channels**
	I_3					I_1					I_2					
	V_1	V_2	V_3	V_4	V_5	V_2	V_3	V_4	V_5	V_1	V_3	V_4	V_5	V_1	V_2	
	Sub-Path															
R_2	I_2					I_3					I_1					
	V_2	V_3	V_4	V_5	V_1	V_3	V_4	V_5	V_1	V_2	V_4	V_5	V_1	V_2	V_3	
	Sub water channel															
R_3	I_3					I_1					I_2					
	V_3	V_4	V_5	V_1	V_2	V_4	V_5	V_1	V_2	V_3	V_5	V_1	V_2	V_3	V_4	
	Sub-Path															

2.3.2.3. Spike length (cm)

Spike length of selected plants was measured with the help of meter rod and then average spike length was calculated.

2.3.2.4. Number of spikelets/spike

From each plot spikes were taken and number of spikelets in each spike was counted and their mean was worked out.

2.3.2.5. Number of grains/spike

Grains from the ten randomly selected spikes were threshed and counted separately. Then average number of grains per spike was calculated.

2.3.2.6. Weight (g) of thousand-grains

One thousand grains were counted from grain sample of each plot 2 times from each and weighted on an electrical balance. The mean was calculated.

2.3.2.7. Biological yield (t ha^{-1})

From each plot the crop was harvested and tied into bundles. Then it was weighted using an electrical balance. Then weight of each plant with total biomass was determined. The result of present study was in agreement with the previous study conducted by [7].

2.3.2.8. Grain yield (t ha^{-1})

Grain yield from each plot was recorded after threshing the each plot plants separately.

2.3.2.9. Harvesting index (%)

Harvesting index is a ratio of economic yield to biological yield expressed in percentage. It was calculated by following formula as given by Hunt (1978).

$$H.I = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

2.3.2.10. Statistical analysis

For each wheat parameter, determined by the irrigation regimes, ANOVA was conducted using the statistical package SPSS, version 22 and the LSD test, at $P<0.05$, was used for mean comparisons.

3. Results and discussion

3.1. Leaf area (cm^2)

In the present study the leaf area of different irrigation levels are shown in (Table.2). The analysis of variance showed that irrigation had a significant effect on leaf area and the I_3 regime had a significant increased area of leaf. It might be due to adequate moisture which helps in cell enlargement.

Table 2 The mean value of allometry, phenology and morphology and yield related traits of wheat in different irrigation regimes during 2018-2019.

Traits	Irrigation type					
	I_1	I_2	I_3	LSD	F-Value	*P-Value*
Leaf area index	4.6^c	5.0^b	5.3^a	0.265	17.18	<0.05
Days to booting	93.4	93.7	93.8	NS	0.25	>0.05
Plant Height	77.2^c	80.1^b	82.8^b	2.681	9.21	<0.05
Tillers (m^{-2})	260	264	296	NS	2.14	>0.05
Spike length (cm)	8.83^c	9.43^b	9.71^a	0.178	52.80	<0.05
No. of spikelets/spike	16.4^b	16.8^b	17.3^a	0.448	9.20	<0.05
No. of grains/spike	37.2	37.7	39.1	NS	0.92	>0.05
Grain weight/spike	1.6	1.7	1.8	NS	3.21	>0.05
Weight of 1000 grains	40.4	40.5	41.3	NS	0.79	>0.05
Biological yield of wheat	13.60^b	14.66^a	15.35^a	0.932	7.53	<0.05
Grain yield (t ha^{-1})	3.79^c	4.69^b	5.41^a	0.335	49.37	<0.05
Straw yield of (t ha^{-1})	1.6^b	1.8^b	2.1^a	0.188	13.27	<0.05
Harvest index (%)	31.6^c	34.2^b	37.6^a	2.531	13.67	<0.05

Different superscript showed significant difference within groups at significance level of (P<0.05).

3.2. Days to booting

The days to booting did not differ significantly between the different irrigation groups. Result of the present study is in agreement with the study conducted by [8].

3.3. Plants height (cm)

Statistical analysis revealed that plant height was significantly increased by irrigation in the I_3 regime. The previous study is not in agreement with the present study [8] Generally this parameter is used to calculate plant growth which is mostly the result of crop nutrition as well as environmental conditions. Plant height is also the main contributor to straw yield and effect the grain yield as well and assists the vegetative growth.

3.4. Number of tillers per m^2

Irrigations regimes did not differed significantly to the tiller production. This study is in agreement with [9] that no irrigation differ the number of tillers while the previous study not in agreement with present study by [10] reported a decline in number of tillers per plant under water deficit condition while working on millet in Iran. Numbers of tillers contribute to the estimation of yield under the given circumstances. Wheat has significant importance among cereals for yield production by production of tillers.

3.5. Spike length (cm)

Spike length was significantly higher in I_3 irrigation regime. The present study is in agreement with the results reported by [8, 11] the spike length increased significantly with increasing the level of irrigation. Also found a trend towards irrigation. The spike length is key factor for yield in wheat. More spike length leads to more grain production per spike that result the higher wheat yield.

3.6. Number of spikelets/spike

Number of spikelet per spike was significantly higher in I_3 irrigation regime. Also found a trend towards irrigation. The present study was not in agreement with the [12] which showed no significant difference between the different water regimes. In wheat the key factor for yield is the quantity of spikelets per spike which describes the eventual straw and grain yield.

3.7. Number of Grains/spike

The statistical analysis of data revealed that the number of grain/spike of wheat did not differ significantly by irrigation regimes. The previous studies was in agreement with the study conducted by [8, 13]. In wheat performance the key defining factor and directly related with yield is the quantity of number of grain/spike. The data regarding number of grains per spike showed that irrigation had a not significant effect on number of grain per spike.

3.8. Grain weight/spike

The statistical analysis of data revealed that the grain weight/spike of wheat did not differ significantly (P>0.05) by irrigation regimes which is not in agreement with the study of [8] presented in Table 2.

3.9. Weight of thousand grains (g)

In wheat, thousand grain weights is an important yield attribute and also had a fair contribution to the wheat grain yield. The yield contributing trait of thousand-grain weight has prime importance in estimation of yield among the other traits. A seed which is heavier will have more contribution to yield. So, the yield potential of a line can be easily estimated through the thousand grain weight. The statistical analysis of data in (Table 2) the thousand-grain weight of wheat revealed that, it did not differ significantly by the various number of irrigation regime. The previous study was not in agreement with the present study conducted by the [8]. The previous study not in agreement by [4] reported significant effect of irrigation on thousand-grain weight.

3.10. Biological yield (t ha^{-1})

Biological yield differed significantly (P<0.05) between the groups. Statistical analysis revealed that the I_3 had the significantly high values of biological yield (t. ha^{-1}). The present study is in agreement with the previous study conducted by [8]. Also found a trend towards irrigation.

3.11. Grain yield (t ha-^{1})

Grain yield differed significantly (P<0.05) between the groups. Statistical analysis revealed that the I_3 had the significantly high values of grain yield (t. ha^{-1}). Also found a trend towards irrigation. These results verify the findings of [4] who reported that wheat yield increased with increasing irrigation levels.

3.12. Straw yields (t ha-^{1})

The probability of a harvest to a mass dry matter in its vegetative parts is communicated in straw yield it is a direct result of the consolidated impact of all development parameters like tiller per range and the last plant height. The data regarding of straw yield are shown in (Table 2). The analysis of variance showed that straw yield differed significantly between the groups. Also found a trend towards irrigation. Statistical analysis revealed that the I_3 had the significantly high values of straw yield (t. ha^{-1}).

3.13. Harvest index (%)

Physiological efficiency of wheat plant convert dry matter into the grain yield is measured is term of harvest index. Higher harvest index (HI) value, more the physiological efficiency of plant to convert dry matter into grain yield. The assimilation of photosynthetic into grain production was through the physiological competency of wheat crop and it was calculated in the form of harvest index. The data regarding of harvest index are shown in (Table 2). The analysis of variance showed that harvest index differed significantly between the groups. Also found a trend towards irrigation. Statistical analysis revealed that the I_3 had the significantly high values of harvest index (t. ha^{-1}). The present study was in an agreement with [7].

The present study varied in some aspects from the previous studies these differences occur due to variations in climate conditions, different agricultural land, different geographical area, different varieties of wheat and difference in management.

3.14. Economic analysis

The (Table 3 and 4) showed the cost of production. It includes all the costs of operations primary tillage and seed bed preparation, sowing charges, fertilizer, plant protection, irrigation and harvesting charges. Moreover, it also includes the markup on investment and management charges of the crop and land rest as well. Our estimate calculated the production cost of one hectare was (Rs. 113071) for wheat crop during six-month. In the (Figure 1) all the irrigation regimes profits were exhibited clearly showed that the I_3 had the highest profit in term of income. The results showed I_1 poor yield, growth and profit (Rs. 2440) while I_2 showed moderate profit (Rs. 28000) while I_3 showed the highest profit (Rs. 49694). It showed a trend increasing the water to an optimum level increase the production and benefit for farmer.

Table 3 The economic analysis of the cost of production and income of wheat during 2018-2019.

Economic Analysis	**Irrigation**		
	I_1	I_2	I_3
Yield t ha^{-1}	3.79	4.69	5.41
Adjusted Yield t ha^{-1}	3.41	4.22	4.87
Straw Yield t ha^{-1}	1.66	1.82	2.12
Adjusted Straw Yield t ha^{-1}	1.494	1.638	1.908
Gross income in Rs.	115511	141071	162765
Cost of production in Rs.	113071	113071	113071
Gross benefits in Rs.	2440	28000	49694

Table 4 The cost of all the operations and input during the study and total cost.

Operation/Input		Number/Amount/ Quantity	Rate Unit^{-1} (PKR)	Total Expenditure (PKR ha^{-1})
Primary tillage and seed bed preparation	Deep Ploughing	0.3	3650	1095
	Ploughing	2	1600/ha	3200
	Planking	2	1000/ha	2000
Sowing charges	Seed	125 kg/ha	40/kg	5000
	Sowing	1	2000/ha	2000
	DAP	2.5 bags	3000/bag	7500
Fertilizers	Urea	4 bags	1840/bag	7360
	Transportation charges	6.5 bags	30/bag	195
	Application charges	2 man/day	350/man day	700
Plant Protection	Hand hoeing	2	1250/1 time	2500
	Water rates (Abyana)	1	163/ha (Rabi)	163
Irrigation	Water course cleaning	2 man days	350/man day	700
	Application charges	1 man day	350/man day	350
Harvesting	Harvesting	7.5 mond/ha	1200	9000
	Threshing		4kg/40kg	13650
	Mark up on investment from 1-6 @ 9% per annum (excluding water rates)	7567 /6 months	Total mark up on investment	5058
	Management charges(Rs.30000/100 acres/month	6 months	350/ha	2100
	Land rent	6 months	50000/6 month/ha	50000
	Artisan charges	-	500	500
Total cost		-	-	113071

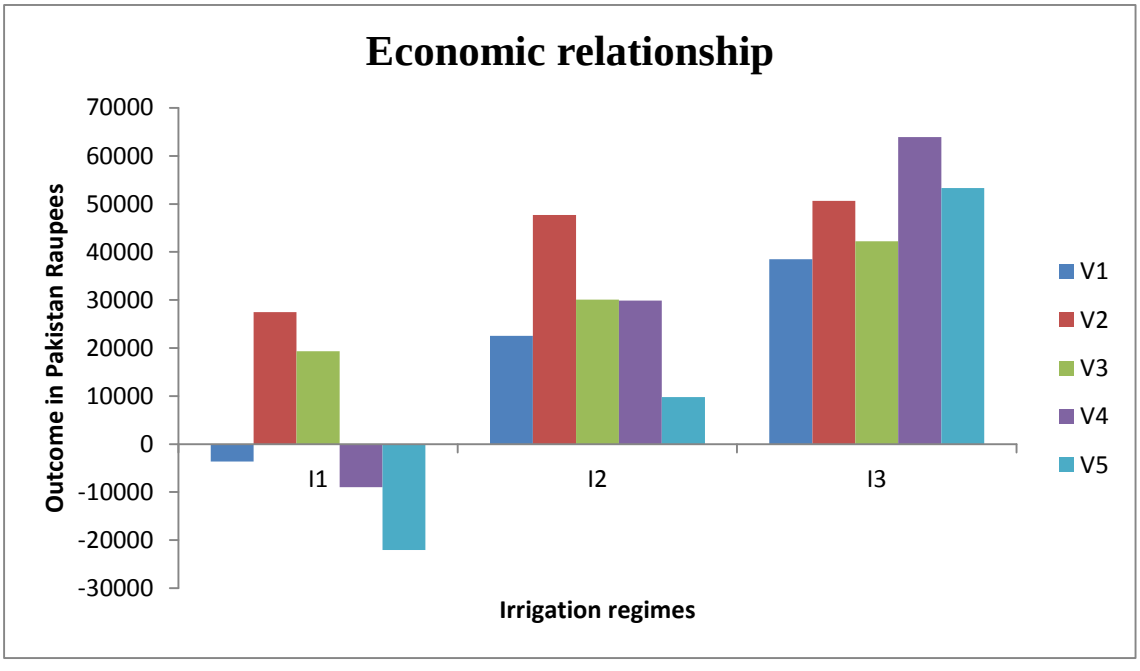

Figure 1 The economic analysis of the outcome in Pakistan rupees of wheat during 2018-2019.

4. Conclusion

It was concluded that the I_3 with 4 irrigations had a potentially high yield, performance and economically beneficial. Whereas the I_2 with 3 irrigations had an average yield and performance as well the average benefit while the I_1 with 2 irrigations had adverse effect on the plant growth and performance also decrease in the yield. The I_1 had the lowest values of yield.

Conflict of Interest

No conflict in this research work**.**

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