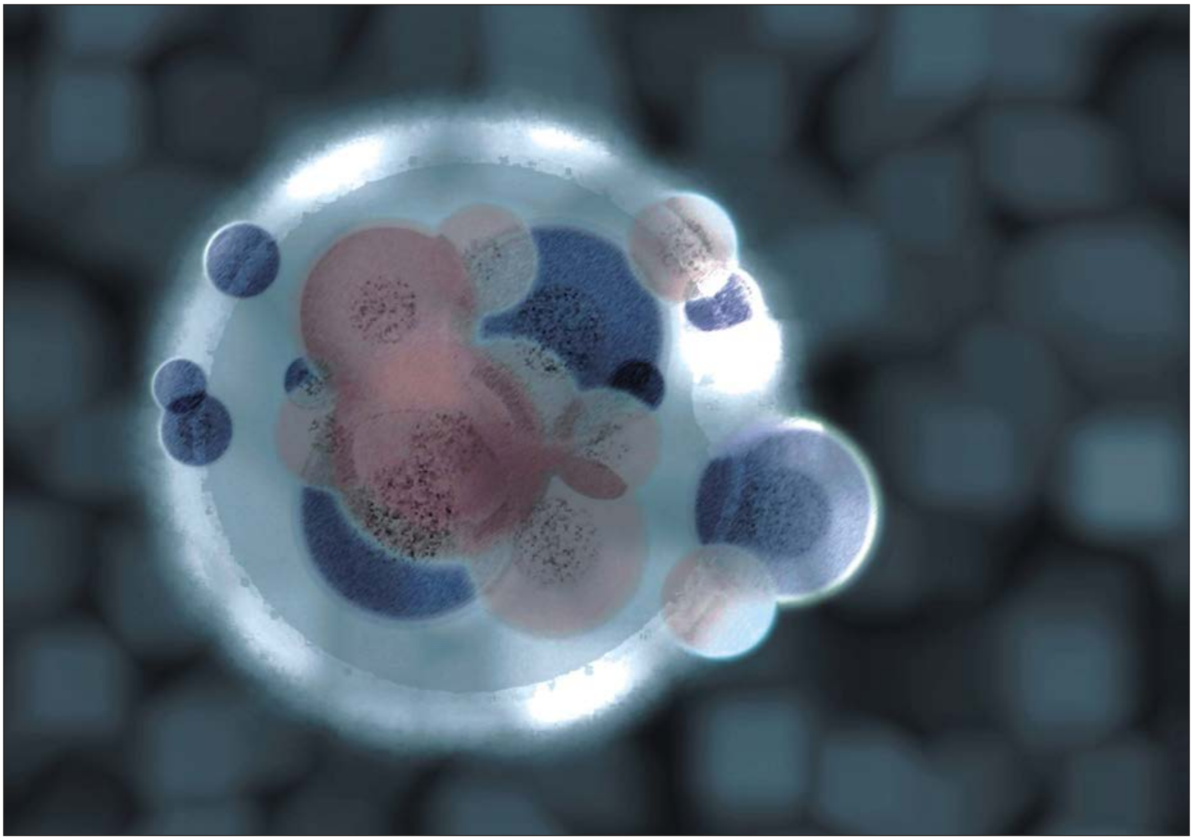

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Contribution of Irrigations to Grain Yield of Wheat (*Triticum aestivum* L.) At Critical Crop Growth Stages

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Abstract: A wheat genotype V-85205 grown for three years under different cultural practices differing in soil moisture status under slightly different climatic conditions. A pre-fixed moisture deficit irrigation schedule was maintained with application of two fertilizer levels. Multiple regression analysis was done for grain yield and the contribution of each irrigation towards total linear variation in wheat grain yield was worked out through backward elimination method. The average contribution of each irrigation to total variation in grain yield were 50-54, 10, 1-0, 4 -5% at the two fertilizer levels at tillering, booting, flowering and grain filling stages respectively. At low fertilizer inputs there was more irrigation contribution to grain yield. The contribution of irrigations at earlier stages was 94 and 90% of the total irrigation contribution-saving 50% irrigation water losing only 6-11% grain yield at the two fertilizer levels respectively. The irrigation productivity factor (YicF) was generally more under low fertilizer inputs and irrigation application at earlier crop stages.

Key words: Irrigation productivity factor, osmotic potential, yield response factor, wheat, mungbean, evapo-transpiration, water use efficiency

Introduction

Wheat (*Triticum aestivum* L.) is the staple food of this region and more than 70% of it, is grown under irrigated conditions. Maintenance of crop root zone soil moisture at optimum level is necessary to avoid the temporary or prolonged drought. Drought causes substantial losses in crop yield, estimated to millions of dollars in some areas (Moseley, 1983). So it is necessary to identify the crop growth stages, tolerant to drought. Ashraf and Khan (1993) reported that higher biomass producing varieties had greater water potential and turgor potential leading to higher relative water contents to resist moisture stress condition at early stages. Some varieties showed adaptive mechanism for drought resistance by maintaining a significant lower osmotic potential under increased moisture stress. However, drought tolerance also related to the intensity and plant growth stages. Studies on assessment of sensitivity to drought at different crop stages have been conducted extensively. Day and Intalap (1970) found the jointing stage as critical period for moisture stress. Cheema *et al.* (1973) found crown root initiation as the most critical stage and its omission at this stage, reduced the grain yield by 27%. Gill and Singh (1980) reported increased wheat yield by irrigation at milk and soft dough stages. Kramer (1963) reported that booting to maturity stages are sensitive to moisture stress.

Nayak and Sengupta (1981) recommended only three irrigations at crown root initiation, late tillering and peak flowering stages for wheat variety Sonalika. Nayak and Sengupta (1981) recommended three irrigations for successful growth and yield viz., crown root initiation, late tillering and peak flowering stages. Similarly Mandal *et al.* (1985) found highest ear bearing tillers by the application of three irrigations in wheat variety Sonalika. Bajwa *et al.* (1993) recommended 3-4 irrigations i.e., first at crown root initiation, second at boot stage, third at grain filling stage and fourth if required at drought stage. The present study was undertaken to evaluate the contribution of irrigations to the total variation in wheat grain yield of a pre-selected wheat variety.

Table 1: Site characteristics

Location:	Lat.31°-26` N and Long.73°-06`E at 192 m elevation from sea
Environment:	Semi-arid environment characterised by large seasonal fluctuations
Evapotranspiration:	>1650 mm. γ-1classA pan evaporation,
Precipitation:	350 mm.y
Soil Characteristics:	Loam up to 0.95cm, fine lime nodules(10-15%) 95-120 cm followed by increasing sand content downward gradually

Table 2: Irrigation schedule of field experiments for the period 1991-94

Treatment	1991-92	1992-93	1993-94
T_1	1111	1111	-
T_2	1100	1100	1111
T_3	0011	0011	0000
T_4	1001	1001	1000
T_5	1011	1011	1001
T_6	0111	0111	0101
T_7	1101	1101	1100
T_8	1110	1110	1101
T_9	0000	0000	-
T_{10}	-	-	1000
T_{11}	-	-	1001
T_{12}	-	-	0101
Rainfall	87 mm	41 mm	42 mm

Materials and Methods

The research was conducted at NIAB, Faisalabad, Pakistan. The site characteristics are given in Table 1. The experiment was carried out on the field plots previously used for rice or mungbean cultivation and fallow for first, second and third year respectively. The experiments consisted of four replications in first and second years and three replications for the third year and plots of 9 × 6 m. sq. size. During the first year no pre-soaking treatment was applied, to utilize the soil moisture stored during rice crop. However, in second and third year, a pre-sowing irrigation was applied to facilitate the seed germination. All experiments were conducted in split plot design with irrigations in the main and fertilizer levels in the sub-plots. Two fertilizer levels of 100:100:60 (F_1) and 50:50:30 (F_2) kg ha^{-1} of N:P_2O_5:K_2O were maintained in sub-plots. A pre-selected wheat variety V-85205 was sown at 100 kg seed ha^{-1} at 20 cm intra row distance

Table 3: Percentage contribution of irrigation in total variation of wheat grain yield at two fertilizer levels..

Grain Yield	Fertilizer Level	Ist Irrig. Control	2nd Irrig.	3rd Irrig.	4th Irrig.	Total Irrig.	Other Sources
1991-92	F1	41.0	8.7	1.3	1.9	52.9	47.1
	F2	55.5	9.9	0.1	5.2	70.7	29.3
1992-93	F1	52.2	8.5	0.1	5.8	66.6	33.4
	F2	54.4	12.4	0.8	0.6	68.2	31.8
1993-94	F1	57.3	21.0	0.5	0.1	69.9	21.1
	F2	53.3	7.8	0.1	7.8	79.0	21.0
Average:	F1	50.2	12.7	0.6	2.6	63.1	33.9
	F2	54.4	10.1	0.3	4.5	72.6	27.4

Table 4: Irrigation productivity factor response at two fertilizer levels

Treat. No.	Irrigation Treatment	Year	YF1	YF2	YicF1	YicF2
			(kg ha^{-1})		(kg grain mm $rain^{-1}$ kg $fert^{-1}$)	
T_1	1111	1991-92	5131	4023	2.43	4.11
		1992-93	3911	3159	1.75	3.17
		1993-94	5662	5014	1.47	3.67
T_2	1100	1991-92	4942	3945	4.50	7.93
		1992-93	3397	3032	2.52	5.86
		1993-94	5605	4561	2.83	5.61
T_3	0011	1991-92	2633	2154	0.06	1.04
		1992-93	2633	1649	1.02	0.54
		1993-94	-	-	-	-
T_4	1001	1991-92	4501	3692	3.65	6.95
		1992-93	3404	2611	2.53	4.24
		1993-94	4990	4547	1.65	5.55
T_5	1011	1991-92	4377	3702	2.27	4.66
		1992-93	3496	2952	1.81	3.70
		1993-94	-	-	-	-
T_6	0111	1991-92	3533	2904	1.19	2.61
		1992-93	2688	2292	0.77	2.01
		1993-94	-	-	-	-
T_7	1101	1991-92	4738	4102	2.74	5.69
		1992-93	4170	3279	2.67	4.54
		1993-94	5619	4778	1.91	4.29
T_8	1110	1991-92	4773	3869	2.78	5.09
		1992-93	3667	3120	2.02	4.13
		1993-94	-	-	-	-
T_9	0000	1991-92	2603	1884	-	-
		1992-93	2087	1509	-	-
		1993-94	4132	3103	-	-
T_{10}	1000	1993-94	4831	4425	2.69	10.17
T_{11}	0101	1993-94	4412	4143	0.54	4.00

with the help of a sowing drill. Irrigation schedule is shown in Table 2. Generally, irrigation (75 mm) was applied at tillering, booting, flowering and grain filling stages respectively in control (conventional) treatment (1111) and un-irrigated moisture deficit during rain fed treatment (0000) in the irrigation schedule. Other moisture deficit treatments consisted of combination of irrigation (1) or moisture deficit (0) at the respective stage. During 1993-94 year irrigation schedule was modified on the basis of results obtained from the experiments of 1991-93.

The crop was grown to maturity for grain yield. The data was subjected to multiple linear regression analysis and the contribution of each irrigation to total variation in wheat grain yield was worked out through backward elimination method. All results were compared at 95% level of confidence (Steel and Torrie, 1980).

Results and Discussions

Soil and climate variations: The experiment during 1991-92 was conducted on a rice field without a pre-soaking irrigation. During the crop season a total of 87 mm of rainfall recorded which was well distributed over booting to grain filling stages. The temperature cycle and humidity were normal with plenty of soil moisture storage available for the crop. In 1992-93, experiment was conducted on fields after harvest of Mungbean (*Vigna radiata*) crop, with exhausted soil moisture storage, therefore, a pre-sowing irrigation was applied for land preparation. During this year, the crop season was relatively dry and hot with a high temperature cycle by 4°C above average from 41 to 60 days after sowing (DAS) and also no rainfall occurred during this period. A total rainfall of 41 mm occurred out of which 35 mm was received during flowering stage. Due to high temperature cycle the productive stage started 10-15 days earlier which decreased the grain yield as reported by Aggarwal and Kalra (1994). In 1993-94, the experimental field was left fallow from monsoon rains, to the wheat sowing. After mild showers, rotavator application was done for weeding followed by sohaga application (i.e., mild compressing during levelling) for soil moisture conservation. A pre-sowing irrigation was applied to facilitate land preparation for sowing. The crop observed normal season with respect to normal temperature and rainfall (42 mm) split over booting to grain filling stages. Adequate soil moisture in the crop stages II, uniformly distributed rainfall, normal temperature and mineralised nutrient of fallow soil led to a good crop. The evapotranspiration (ETa), water use efficiency Ef and Ec and yield response factor Ky are discussed elsewhere (Kirda *et al*., 1998).

Irrigations and the grain yield: The statistical analysis showed a regular pattern for the contribution of irrigations to the total variation in the wheat grain yield for the three years (Table 3). The first irrigation at tillering contributed maximum to grain yield followed by second irrigation at booting stage which may be due to increased tillers. Similar finding were reported by Cheema *et al.* (1973) for crown root initiation as the most critical stage and its omission at this stage reduced the grain yield by 27% followed by late tillering and flowering stage which resulted reduction in grain yield by 23 and 20% respectively. Yasin *et al*. (1993) has also reported that irrigation at booting stage is essential for wheat. At flowering stage the response of irrigations to grain yield was lowest which is in contradiction to the findings of Nayak and Sengupta who recommended irrigation at this stage to wheat V-Sonalika. This may be due to genetic diversity as reported by many research workers Bajwa *et al.* (1993), Day and Intalap (1970) and Hassan *et al*. (1987) who had not quoted flowering stage as sensitive to limited drought like other stages. The irrigation contribution by two earlier stages was 94.5 and 88.8% of the total contribution by irrigations at the two fertilizer levels respectively. Therefore, loss of 6-11% grain yield can be save at 50% of irrigation inputs two fertilizer levels.

Fertilizer and irrigations interaction: Medium fertilizer inputs partially compensated the irrigation contribution to grain yield in all treatments and experiments. Control (conventional) irrigations schedule treatment (T_1) showed least increase (5.3% per irrigation) in wheat grain by increased fertilizer input - showing least response to added fertilizers inputs. Moisture deficit at early stages (T_3) showed averaged 19.4% increase in grain yield by increased fertilizer inputs indicated that use of fertilizer under moisture deficit at earlier crop stages was more beneficial than other stages. This is in accordance with the finding of Khondakar *et al.* (1983) who found higher NPK uptake by wheat when water stress was imposed at tillering stage. The fertilizer inputs increased grain yield by 29.8% in 1992-93 in spite of dry season and high temperature spell observed at DAS 41-60. Deficit at flowering and grain filling stages led to averaged 10% increase in Ya by increasing fertilizer inputs. Moisture deficit at stage-I (T_6) and stage-II (T_5) showed 5.8 and 6.1 % increase in yield response factor (Y_a) by increased fertilizer inputs. Missing irrigation at booting stage (T_5) showed equal response (6.1% increase in Y_a per irrigation) in both normal season (1991-92) and stressed season (1992-93). Saving one irrigation at flowering (T_7) or grain filling (T_8) stages had increased 7.2 and 6.8% Ya per irrigation.

Irrigation productivity factor (YicF2) response: Productivity factor is defined as excess grain yield of irrigated treatment over control (rain fed) expressed in grain yield (kg) hectare^{-1}, mm irrigation^{-1}, kg fertilizer^{-1}, added. It was maximum at adequate pre-sowing moisture stored due to rice cultivation in 1991-92 (Table 4). Productivity factor at low fertilizer level (YicF2) was generally more than the corresponding medium fertilizer treatment the fertilizer was efficiently utilised by the crop.

Maximum productivity factor (YicF2) at low fertilizer input was achieved at T_{10} (1000) followed by T_4 (1001) respectively all involving irrigation at crop stage-I (tillering) and omitting irrigation at crop stage-III (flowering) Only one exception was observed in T_3 (00II) when low fertilizer input gave poor response compared to medium fertilizer. This may be owed to omission of two essential irrigations at tillering and no rainfall and elevated temperature at crop stage II-III in 1992-93. The irrigation productivity factor values of treatments T_3(0011) and T_9(0000) were close (minimum) possibly due to translocation of most of the produced photosynthetic material for extension of roots to deeper layers in search of water. Productivity factor increased by decreasing fertilizer inputs in almost all cases irrigation compensated for fertilizer deficiency. At medium fertilizer input, the productivity factor (YicF1) was maximum at T_2 (1100). The treatments involving irrigation at earlier stages (specially at first crop stage) gave better irrigation productivity factor compared to later stages. The irrigations at crop stage-I and II might have provided more period for availability and utility of fertilizer for crop development. This was followed by T_4 (1001), T_7 (1101) T_8 (1110) respectively all involving two or more irrigation with essential irrigation at crop stage-I. At this fertilizer input the Treatment T_{11} (1000) could not yield good productivity factor which supports our approach for two or more irrigations to efficiently benefit from more fertilizer inputs utility as observed by Gajri *et al.* (1993) who reported increased evapotranspiration estimate for elevated N-fertilizer inputs. Intra treatment comparison showed general decrease in (YicF2) values in second year due to extended drought by no rainfall and elevated temperature at booting and flowering crop stages.

So the wheat variety V-85205 grown under three different conventional post crop harvest conditions for three years with slight seasonal variation at the same station showed almost similar trend to irrigations at different crop growth stages. The order of irrigation contribution was observed as:

Tillering>Booting>Grain filling >Flowering

The contribution of irrigations at two earlier stages was 94.5 and 88.8% of the total irrigation contribution-saving 50% irrigation water losing only 5.5-11.2% grain yield at the two fertilizer levels respectively. This 50% saved water was sufficient to raise another wheat crop by growing some late sowing variety. The fertilizer and irrigations generally compensated for the deficiency of each other. The irrigation efficiency increased at low fertilizer inputs as irrigation productivity factor (YicF) was generally more under low fertilizer inputs and irrigation application at earlier crop stages.

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