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SEASONAL GROWTH ATTRIBUTES OF WHEAT (*Triticum aestivum* L.) GENOTYPES IN RESPONSE TO MOISTURE REGIMES UNDER SEMI ARID ENVIRONMENT

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A field experiment for the comparison among different wheat genotypes (Iqbal-2000, Chenab-2000, Aqab-2000) for its maximum yield potential in response to different moisture regimes, a randomized complete block design (RCBD) with split plot arrangement in triplicate run was carried out during the year 2006-07. Factors were: wheat genotypes (Iqbal-2000, Chenab-2000, Aqab-2000) in main plots and five irrigation levels I_0= no irrigation (control), I_1= irrigation at tillering, I_2= irrigation at tillering + booting, I_3= irrigation at tillering + booting + anthesis and I_4= irrigation at tillering + booting + anthesis + milking in subplots. Results showed that maximum LAI was attained on 2 February and 4 March harvest and genotype Iqbal-2000 was superior compared to other genotypes. Irrigated treatments significantly increased LAI than control (I_0) treatments at all harvest dates. Iqbal-2000 showed maximum CGR (32.69 g m^{-2} d^{-1}) and LAD (319.42) compared with lowest CGR (25.49 g m^{-2} d^{-1}) and LAD (278.50) given by genotype Chenab-2000 under I_3 and I_4 treatments throughout the growing season. Radiation use efficiency ranged from 17.58-18.27 DM MJ^{-1} of intercepted radiation. Mean accumulated radiation interception (754, 736 and 784 MJm^{-2}) was assessed in genotypes (Iqbal-2000, Chenab-2000 and Aqab-2000), respectively but not significant effect on net assimilation rate. Genotype Iqbal-2000 and Aqab-2000 had highest TDM (21670; 21220 kg ha^{-1}) respectively while I_4 (Irrigation at tillering + booting + anthesis + milking) had the highest TDM 22240 kg ha^{-1} verses I_0 (no irrigation) 18070 kg ha^{-1}. Aqab-2000 showed the highest grain yield (5458.78 kg ha^{-1}) as compared to Chenab-2000 (4536.71 kg ha^{-1}) whereas I_4 (Irrigation at tillering + booting + anthesis + milking) produced more grain yield (6376.25 kg ha^{-1}) than all other irrigation treatments.

Key words: Wheat genotypes, moisture regimes, CGR, LAI, drought, radiation use efficiency, *Triticum aestivum* L.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important cereal crop used as a staple food in Pakistan as grown on an area of 8.805 million hectares with total production of 24.21 million tons and an average grain yield of 2750 kg ha^{-1} (Govt. of Pakistan, 2011). Water is extremely an important for the yield of wheat (Abd-El-Gawad *et al.,* 1993; Hussain *et al.,* 1997). Because of irrigation an expensive input, farmers, agronomist, economist, and engineers have a great need to know the response of yield to irrigation. During this span, the normal growth and development of wheat crop primarily depends upon available irrigation water. The need of crops for water is related to moisture sensitive periods. Salter and Goude (1967) defined such periods as certain development phases in which the plant appears by its observed response, to be more sensitive to moisture sensitive conditions. If moisture sensitive periods could be identified for wheat crop under field conditions, it would have important implications for irrigation practice.

Plant dry weight under water deficit conditions is also an important indicator of adaptation in crop species i.e. barley was found to have the highest yield over wheat, attributed entirely to its greater dry matter production rather than harvest index (Gergory *et al.,* 1992). It is therefore, necessary to understand the process of dry weight production under high water deficits in order to yield differences among various irrigation regimes. The mechanism involves changes in the crop's ability to intercept solar radiation and efficiency of its use or time available for both as photosynthesis process controlled by the temperature and water. According to Jamieson *et al.* (1995) drought at tillering stage has shown a linear decrease in radiation use efficiency of a cereal crop and drought at the middle or late period of growing season does not have any effect on radiation use efficiency. Efficient water supply during the early growth season increases the leaf area of a crop, enabling it to intercept most of the incoming radiations (Sharif, 1999). This could results in the increase of the carbohydrates formation in leaves which travels towards grain and ultimately cause higher grain yield (Gallagher and Biscoe, 1978). High temperature after anthesis coupled with drought generally decrease kernel number, reproductive duration and ultimately grain yield (Gibson and Pansisen, 1994).

The present study was therefore undertaken with the objectives to determine the effect of drought at various growth stages of different wheat cultivars and to assess the drought sensitive stage at which irrigation is necessary for obtaining maximum grain yield.

MATERIALS AND METHODS

The study was carried out at the Agronomic Research Area, University of Agriculture, Faisalabad during Rabi season 2006-07. The treatments were allocated in a triplicate run by using RCBD with split plot arrangement. Experimental treatments consist of three cultivars (Iqbal-2000, Chenab-2000, Aqab-2000) in main plots and five irrigation levels I_o= no irrigation (control), I_1 = irrigation at tillering, I_2= irrigation at tillering + booting, I_3= irrigation at tillering + booting + anthesis and I_4= irrigation at tillering + booting + anthesis + milking in subplots, respectively. Each plot consists of six rows and 25 cm row spacing apart constituted a net plot size 7.0m × 1.5m. Soil analysis for its physico-chemical properties showed a textural class was sandy clay loam, electrical conductivity (1.13 dS m^{-1}), pH (8.2), organic matter (0.61%), nitrogen content (0.07%), phosphorus content (6.9 mg kg^{-1}) and potassium content (116 mg kg^{-1}) before starting the experiment. The meteorological data regarding rainfall, relative humidity, temperature, wind velocity, sunshine and evapotranspiration etc. were recorded from meteorological observatory in the immediate vicinity of the field during the phase of crop development (Table 1). The crop was sown manually with the help of a single row hand drill at 125 kg seeds ha^{-1} in the 2^{nd} week of November 2006. Nitrogen and phosphorus were applied at 150 and 100 kg ha^{-1}, respectively. Half dose of nitrogen and full dose of phosphorus was applied during seedbed preparation while remaining half nitrogen was applied with first irrigation. All other cultural operation was kept normal and uniform except irrigation levels.

Observations recording**:** Data on leaf area index, total dry matter accumulation (TDM), leaf area duration (days), crop growth rate (g m^{-2} d^{-1}), net assimilation rate (g m^{-2} d^{-1}), radiation use efficiency and grain yield (t ha^{-1}) were collected by using standard procedures. Leaf area and total dry matter were measured by taking a sub sample of 10 g green foliage on leaf area meter and average was computed. These sub samples were drying under sun for 24 hrs and then oven dry at 70^oc for 24 hrs to achieve a constant weight to determine the total dry matter. Leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR) and net assimilation rate (NAR) was calculated as:

Leaf area index= Leaf area / Land area

Leaf area duration= $LAD_1 + LAD_2 + LAD_3 \ldots\ldots\ldots\ldots LAD_n$

$LAD_1 = (LAI_1 + LAI_2) \times (t_2 - t_1) / 2$

Where, $LAI_1 + LAI_2$ represent the leaf area index at time t_1 and t_2, respectively

Crop growth rate= $(W_2 - W_1) / (t_2 - t_1)$

Where, W_1 and W_2 represent the total dry weights at time t_1 and t_2 respectively.

Net assimilation rate= TDM / LAD

Statistical Analysis: The data collected were analyzed statistically using Fisher's Analysis of Variance techniques and LSD test at 5% probability level was employed to compare the differences among the treatments' means (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

Growth attributes:

Leaf area index (LAI)**:** Genotypes differences in LAI development were significant at 12 January, 4 March and 30 March harvests but highly significant at 2 February. Among all different genotypes Aqab-2000 showed better development of LAI on all harvest dates except during late harvests. Maximum LAI was reached at 2 February in all the genotypes, which ranged from 5.32 to 6.61 as shown in Fig .1. As regard irrigation levels, also influenced LAI significantly during mid to late season growth (Fig. 2) irrigated treatments until final harvest. Similarly I_1 (Irrigation at tillering) also significantly reduced LAI than all other treatments i.e., I_2 (irrigation at tillering + booting), and I_3 (irrigation + booting + anthesis) and I_4 (Irrigation at tillering + booting + anthesis + milking) as shown in Fig 2. Difference between I_3 and I_4 treatments were also significant

Table 1. Meteorological conditions of the experimental site during 2006-07

Month	Temperature			R.H.	Rain fall	Pan evaporation	Sun shine	Wind speed	ET_o
	Max.	Min.	Avg.						
	ºC	ºC	ºC	%	mm	mm	hours	Km/h	mm
Nov.10	27.1	10.5	18.8	62.3	00.0	02.5	08.5	02.6	02.1
Dec.10	21.0	05.8	13.4	70.4	00.0	01.3	07.3	03.1	01.1
Jan.11	15.9	04.3	10.1	73.4	00.0	01.3	05.4	04.3	00.9
Feb.11	20.2	08.7	14.4	73.0	20.6	01.7	05.5	06.2	01.2
Mar.11	26.4	13.1	19.8	59.8	06.8	03.5	08.4	05.8	02.5
Apr.11	32.0	17.2	24.8	47.0	20.9	05.9	09.3	07.2	04.2

Latitude = 31º- 26' N, Longitude = 73º- 06' E, Altitude = 184.4m from early March until final harvest. Maximum treatments on 2 February harvest, thereafter it declined to less than 1_3 on 30 March. The interactions showed non-significant results. Minimum LAI was produced at I_o (no irrigation). These results are in line with Mosaad *et al.,* (1995); Shehzad *et al.,* (2012) who concluded that water stress during vegetative growth stage causes reduction in LAI of wheat.

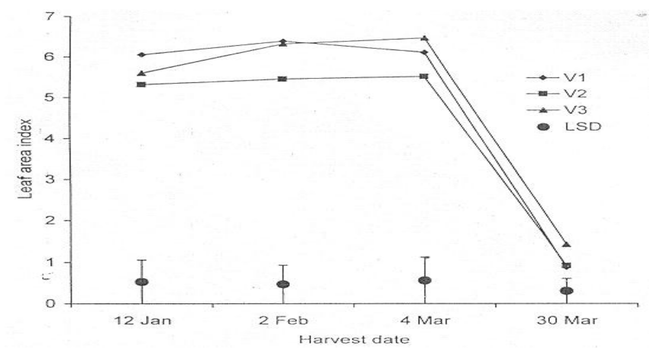

Figure 1. Effect of different genotypes on leaf area index (LAI) of wheat

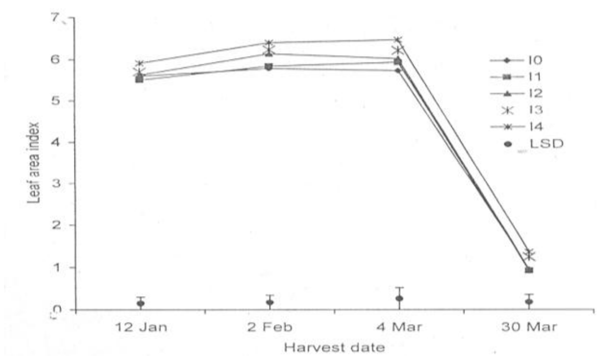

Figure 2. Effect of different irrigation levels on leaf area index (LAI) of wheat genotypes

Total dry matter accumulation (TDM)**:** TDM accumulation was increased and reached its maximum value at 30 March harvest, thereafter it slightly reduced until final harvest (Fig. 3). Final TDM was greater in genotype Iqbal-2000 at 2167 gm^{-2} than genotype Aqab-2000 (2122 gm^{-2}) and Chenab-2000 were statistically at par in final TDM production (Fig. 3). TDM accumulation was also significantly affected by the irrigation levels i.e. I_o (no irrigation) decreased TDM as compared to crops irrigated at (I_1 + I_2 + I_3 and I_4) treatments. Difference in TDM accumulation between I_1 vs. (I_2 + I_4) or I_2 vs. (I_3 and I_4) were non-significant at early February harvest (2 February) and then I_o (no irrigation) significantly reduced TDM until final harvest (30 March). I_3 (irrigation at tillering + booting + anthesis) also significantly reduced TDM as compared with the I_4 (irrigation at tillering + booting + anthesis + milking) treatments throughout season. TDM accumulation at final harvest was 1807 g, 2021 g, 2112 g, 2174 g, and 2224 gm^{-2} in I_o, I_1, I_2, I_3 and I_4 treatments respectively with a mean value of 2065 gm^{-2} (Fig. 4). The results from interaction study were non-significant. These results are in agreement with those of Cheema (2006); Maqsood *et al.,* (2012a).

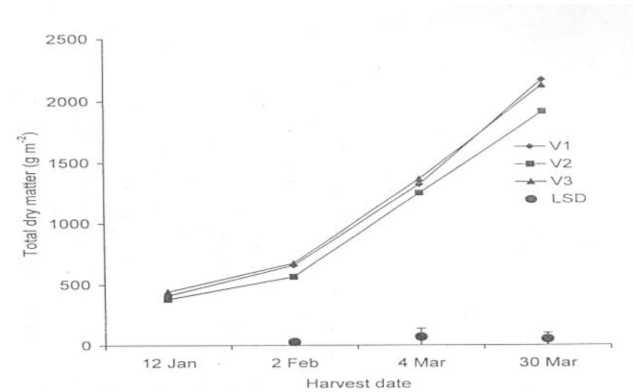

Figure 3. Effect of different genotypes on total dry matter (TDM) of wheat

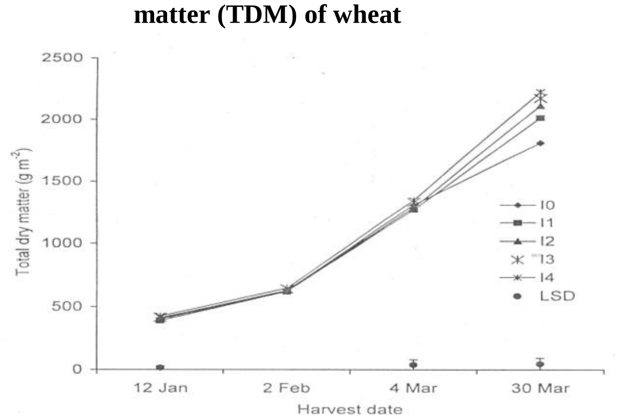

Figure 4. Effect of different irrigation levels on total dry matter (TDM) of wheat genotypes

Leaf area duration (LAD)**:** Aqab-2000 showed significantly higher leaf area duration 319.4 days than genotype Iqbal-2000 (313.0 days) and genotype Chenab (278.5 days). But the genotype Aqab-2000 and Iqbal-2000 are statistically at par in LAD. Crop plants at I_o (no irrigation) decreased LAD as compared with the plants irrigated (I_1 + I_2 + I_3 and I_4). Similarly plants irrigated at I_1 (irrigation at tillering) also gave lower yield of LAD than plants irrigated (I_2 + I_3 and I_4). Differences in LAD between I_3 and I_4 irrigation treatments were statistically at par. The value of LAD was 286.0, 295.1, 305.3, 311.6 and 320.1 days in I_o, I_1, I_2, I_3, and I_4 respectively with a mean value of 303.61 days (Table 2). Thompson and Chase, (1992) found that the LAD was decreased by decreasing the irrigation levels. There was a strong linear relationship between seasonal accumulation of TDM and LAD. Sharif, (1999) has also reported the same

Table 2. Effect of moisture regimes on growth attributes of wheat (*Triticum aestivum* L.) genotypes

Treatments	Leaf area duration (Days)	Crop growth rate (CGR)	Net assimilation rate (NAR)	Radiation interception (Fraction of intercepted radiation (Fi.)	Spike bearing tillers	1000-grain weight (g)	Grain yield (kg ha^{-1})
Varieties (V)							
V_1	313.02 a	32.69 a	5.28 a	0.92 a	313.05 b	38.31 c	4536.71 b
V_2	278.50 b	25.49 b	5.25 a	0.89 b	289.56 c	41.55 b	4875.13 b
V_3	319.42 a	29.27 ab	5.15 a	0.92 a	339.71 a	45.27 a	5458.78 a
LSD (P=0.05)	7.22	6.63	0.55	0.02	11.24	1.87	72.21
Irrigation levels (I)							
I_0	286.00 c	19.18 c	4.71 c	0.90 d	278.32 d	35.49 c	2965.31 e
I_1	295.10 bc	28.59 b	5.24 b	0.90 d	280.53 d	36.27 c	4769.47 d
I_2	305.51 ab	31.76 a	5.39 ab	0.91 c	314.80 c	39.31 b	5364.78 c
I_3	311.62 a	32.46 a	5.51 a	0.91 b	335.28 b	42.34 b	5814.67 b
I_4	320.13 a	33.77 a	5.30 ab	0.91 a	369.02 a	44.73 a	6376.25 a
LSD (P=0.05)	10.91	2.42	0.27	0.002	7.08	1.63	85.58
Interaction (V×I)	NS	NS	NS	NS	NS	NS	NS

NS indicates non-significant; Means in the respective columns followed by different letters are significantly different by LSD test at P=0.05

results for cereals. The results from interaction study did not reach the level of significance ($P\leq 0.05$).

***Crop growth rate (CGR)*:** Crop growth rate (CGR) for the period before anthesis i.e., harvest at 04 March. Both genotypes Iqbal-2000 and Aqab-2000 had the maximum values (32.69 g m^{-2} d^{-1}) and 29.27 g m^{-2} d^{-1}) of mean CGR. The genotypes Chenab-2000 gave the minimum values of mean CGR 25.49 g m^{-2} d^{-1}. Irrigation treatments also showed significant response in CGR compared to Io (no irrigation) before anthesis (Table 2). The average CGR varied from 19.18 g m m^{-2} d^{-1} to 33.77 g m^{-2} d^{-1}. I_4 (Irrigation at tillering + booting + anthesis + milking) treatments gave the highest value of CGR (33.77 g m^{-2} d^{-1}), Io (no irrigation) had the lowest value of CGR (19.18 g m^{-2} d^{-1}), I_2 (Irrigation at tillering + booting + anthesis) treatments also produced higher values of CGR (31.76 g m^{-2} d^{-1}) and (32.46 g m^{-2} d^{-1}) than I_0 (no irrigation) treatments. The interaction study showed non-significant results. A decrease in crop growth rate with the less number of irrigations was also observed by Marani and Levi (1973) and Hussain (2002) who reported that the one irrigation application showed a slower growth rate as compared to normal and excessive irrigations.

***Net assimilation rate (NAR)*:** Genotypes showed non-significant effects in the net assimilation rates and average values of NAR ranged from 5.15 g m^{-2} d^{-1} to 5.28 g m^{-2} d^{-1} among various genotypes. Irrigation treatments showed a significant response in NAR compared to I_0 (no irrigation) treatment. Average net assimilation rate (NAR) was 4.71, 5.24, 5.39, 5.51 and 5.30 g m^{-2} d^{-1} in I_o, I_2, I_3, and I_4 respectively with overall mean value of 5.23 gm^{-2} d^{-1}. Differences in NAR between I_2 and I_4 were however, statistically at par (Table 2). Many researchers have reported similar effects (Ahmad, 2003). The interaction study showed non-significant results.

***Radiation interception and fraction of intercepted radiation (Fi)*:** Generally genotypes showed significant difference in the fraction of intercepted high radiation than the genotype Chenab-2000. Maximum radiation interception reached during 2 February harvest when genotype Iqbal-2000 and Aqab-2000 intercepted 92% whereas Chenab-2000 intercepted at 88% of incoming radiation. Irrigation treatments showed significant difference in the fraction of intercepted radiation. Crop plants at I_0 (no irrigation) decreased radiation interception of 90% which is statistically at par with I_1 compared to irrigated crop plants between the period varying from 2 February to 30th March. Treatment I_2 also decreased radiation interception compared to I_3 and I_4 treatments. Radiation interception between I_3 and I_4 treatments was small and significant only on 12 January, 2 February and 4 March harvests. Maximum radiation interception of 91% was attained from I_4 (Irrigation at tillering + booting + anthesis + milking) treated plots. The results from interaction study were non-significant (Table 2). These findings are similar with those of Whitifield and Smith (1989) who found that deficit irrigation decreases the RUE of wheat.

***Spike bearing tillers*:** The effect of different irrigation levels significantly affected the spike bearing tillers in all genotypes. The genotypes Aqab-2000 produced higher number of tillers m^{-2} (339.71) than Iqbal-2000 (313.05) and Chenab-2000 (289.56). Total number of tillers per unit area for various genotypes differed significantly among different genotypes. Crop plants irrigated at I_1 (tillering) reduced significantly tillers population as compared to plants irrigated at I_4 (tillering + booting + anthesis + milking) also reduced tillers number per unit area than crop plants irrigated at I_3 (tillering + booting + anthesis). Both I_0 (no irrigation) and I_1 (irrigation at tillering) treatments were however, statistically at par in number of tillers per unit area. The average numbers of tillers at final harvest were 278.32, 280.53, 314.80, 335.28, 369.02 m^{-2} in I_0, I_1, I_2, I_3, I_4 treatments respectively (Table 2). The results in case of spike bearing tillers were found to be non significant. Bukhat (2005) found that maximum tiller number was associated with higher number of irrigations.

***1000-grain weight (g)*:** Significant differences in 1000-grain weight were noted among various varieties and irrigation treatments. The genotype Aqab-2000 produced highest 1000-grain weight (45.27g) parallel to control (38.31g). I_4 (irrigation at tillering + booting + anthesis + milking) treatment improved mean 1000-grain weight over I_3, I_2, I_1 and I_0 (no irrigation) treatments. Average 1000-grain weight were 35.49g, 36.27g, 39.31g, 42.34g, 44.73g in I_o, I_1, I_2, I_3 and I_4 treatments respectively (Table 2). The interaction was recorded as non significant. Adequate water at or after anthesis period not only allows the plant to increase photosynthesis rate but also gives extra time to translocation of carbohydrate to grains which improves grain size and thereby lead to increase grain yield (Zhang, 1998; Maqsood *et al.*, 2012b).

***Grain yield (kg ha^{-1})*:** Maximum grain yield (kg ha^{-1}) was recorded in Aqab-2000 (5458.78 kg ha^{-1}) which was more than Iqbal-2000 (4875.13 kg ha^{-1}) and Chenab-2000 (4536.71 kg ha^{-1}). Both genotypes i.e. Iqbal-2000 and Chenab-2000 were, however, statistically at par in grain yield (kg ha^{-1}). As regarded irrigation levels the maximum grain yield (6376.25 kg ha^{-1}) was recorded from I_4 (Irrigation at tillering + booting + anthesis + milking) which was followed by I_3 (5814.67 kg ha^{-1}) and minimum grain yield (2965.31 kg ha^{-1}) was recorded in I_o (no irrigation) treatment. The rest of the irrigation levels were also significantly different from one another. The interaction did not reach the level of significance (Table 2). These findings are supported by Kang *et al.* (2002) and Zhang *et al.* (2008) who found that grain yield increases with applying irrigation at specific time and in appropriate amount.

Conclusions: From above discussion, it can be concluded that water stress drastically altered the seasonal growth by inducing low total dry matter (TDM). Leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR) and net assimilation rate (NAR). Thus, deficiency of irrigation water appears to be more devastating one in wheat yield losses at critical growth stages. The cultivar Aqab-2000 attested to be most water economic when subjected to water deficiency, evidenced by provision of more dry matter accumulation, leaf area, crop growth and assimilation rate and eventually high yield levels. Overall, it is advised to grow wheat cultivar (Aqab-2000) in semi arid environments with narrow supply of irrigation water.

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