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Growth Indices of Winter Wheat as Affected by Irrigation Regimes Under Iran Conditions

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Abstract: An experiment was conducted during 2004-2006 at the Agricultural Research Station, Islamic Azad University, Khorasgan Branch, Isfahan, Iran. The purpose of this study was to evaluate the effects of irrigation regimes on growth indices of three bread wheat (*Triticum aestivum* L.) genotypes. A split plot layout with a randomized complete block design with four replications was used. Irrigation treatments (irrigation after 70 (I_1), 90 (I_2) and 110 (I_3) mm cumulative evaporation from class A evaporation pan) were considered as the main plot and three wheat genotypes (Mahdavy, Ghods and Roshan-Backcross) as subplots. The I_1 and I_2 did not differ significantly for all growth indices, total dry matter and grain yield. Delay in irrigation from the I_2 to I_3 significantly reduced growth indices, total dry matter and grain yield. Trend of changes in Leaf Area Index (LAI), Total Dry Matter (TDM), Net Assimilation Rate (NAR) and Crop Growth Rate (CGR) were similar in the I_1 and the I_2. In all samplings, delay in irrigation from the I_2 to I_3 reduced all growth indices. The trend of changes in crop growth rate was more similar to leaf area index, than to net assimilation rate. Genotypes were not significantly different in respect to growth indices. The results indicate that irrigation after 90 mm cumulative evaporation from class A evaporation pan might be suitable for winter wheat production under conditions similar to this experiment where irrigation water during spring is not abundant.

Key words: Irrigation regimes, leaf area index, total dry matter, net assimilation rate, crop growth rate, wheat

INTRODUCTION

Growth analysis has been widely used to study crop and cultivar response to environmental conditions in an effort to identify factors important to the development of economic yield. In the breeding programs, growth analysis can be useful for the identification of important plant developmental phases or components related to high yield under a particular environment (Clark *et al*., 1984).

Crop production is governed by the interception of radiant energy and the efficiency of converting this energy to dry matter (French and Schultz, 1984). Leaf Area Index (LAI) reduction is a common drought avoidance mechanism (Clark *et al*., 1984). Numerous studies have shown a reduction in the LAI and duration under drought stress conditions (Ali *et al*., 1999; Hirasawa *et al*., 1998; Mccree, 1986; Robertson and Giunta, 1994; Volkenburgh and Boyer, 1985). Water deficit has a significant effect on the reduction of Net Assimilation Rate (NAR) (Hirasawa *et al*., 1998). This has been attributed to the phenomena of stomata closer, respiration increase, reduction in leaf area expansion and promotes senescence (Ali *et al*., 1999). In numerous studies, Crop Growth Rate (CGR) reduction has been reported as the result of water stress (Hirasawa *et al*., 1998; Karimi and Siddique, 1991). Water deficit stress through the reduction in the LAI and plants photosynthetic capacity reduces CGR and eventually Total Dry Matter (TDM) (Karimi and Siddique, 1991). However, Nakagami *et al*. (2004) reported a non-significant difference in the LAI, CGR and TDM during the full irrigation and with 80% field capacity.

Considering the lack of rainfall as well as the limit of irrigation water in Isfahan province on the one hand and the allocation of irrigation water to other more economical products such as summer plants on the other hand, makes the access to the reduction threshold level of consumption irrigation water for hindering water supplies to be wasteful and obtaining an optimum yield in water limited conditions, inevitable.

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Since there exists no sufficient investigations about the response of wheat cultivars to various irrigations regimes in Isfahan circumstances (Salemi and Afyuni, 2005). The aim of this study was to evaluate the effects of various irrigation regimes on growth indices, total dry matter and grain yield of three winter wheat cultivars commonly planted in Isfahan province, Iran.

MATERIALS AND METHODS

This study was carried out under field conditions in Agricultural Research Station, Islamic Azad University, Khorasgan Branch, Isfahan, Iran with longitude 51/48' and latitude 32/40' during 2004-2006. The region is arid with mean annual rainfall of 110 mm. The soil in the field from 0.0 to 40.0 cm below the surface was classified as sandy loam. Experimental design was arranged as a split plot design in Randomized Complete Block Design (RCBD) with four replications. Irrigation treatments were applied from the elongation phase to ripening and were considered as the main plots, it consists irrigation after 70 (I_1), 90 (I_2) and 110 (I_3) mm cumulative evaporation from class A evaporation pan and winter wheat genotypes were allocated as subplots. Experimental materials were two winter wheat cultivars and one across (Mahdavy, Ghods and Roshan, respectively). The evaporation value was determined daily. Sowing was done in the first week of November that is the recommended time for wheat in this region. The planting rate was 80 kg m^{-2} with an inter-row space of 20 cm. The fertilizing were 120 kg ha^{-1} ammonium phosphate before planting and 100 kg ha^{-1} nitrogen in tow stage half before and half after planting used. Plant samples were taken from 0.2 m^{-2} (150 plants in per sampling) of all subplots with 20 days intervals, starting at 140 days after planting and plants green leaf area were measured with AM-300 LAI meter and oven dried at 65°C for 48 h plants weight mean were determined. The LAI, TDM, NAR and CGR were calculated as the function of days after planting using the regression procedure as described by Karimi and Siddique (1991) in the relations 1, 2, 3 and 4, respectively.

$$LAI = e^{a_1 + b_1 t + c_1 t^2} \quad (1)$$

$$W = e^{a_2 + b_2 t + c_2 t^2} \quad (2)$$

$$NAR = (b_2 + 2c_2 t)e^{(a_2 - a_1) + (b_2 - b_1) + (c_2 - c_1)t^2} \quad (3)$$

$$CGR = NAR \times LAI = (b_2 + 2c_2 t)e^{a_1 + b_2 t + c_2 t^2} \quad (4)$$

Where:

W	=	Total dry matter
t	=	Time (day)
LAI	=	Leaf Area Index
NAR	=	Net Assimilation Rate
CGR	=	Crop Growth Rate
a, b and c	=	Regression coefficients

Statistical analysis of data was performed using the MINITAB statistical software. Duncan Multiple Range Test was used to determine significant differences of means at the 5% level and figures were drawn using by Microsoft Excel software.

RESULTS AND DISCUSSION

The LAI (Leaf Area Index): The LAI in I_2, in all samples was non-significantly less than the I_1 but significantly more than the I_3 (Fig. 1), so that the I_1 and the I_2 had non-significantly difference in LAI mean and LAI maximum, but the difference among them with regard to the I_3 was much and significant (Table 1). In the I_3, the LAI did not approach 3.0 at any stages of its growth, while the I_1 and the I_2 had 4.6 and the 4.5 LAI maximum, respectively (Table 1). The increased speed of the LAI in the I_3 than the I_1 and the I_2 was extremely low (Fig. 1). Nakagami *et al.* (2004) reported a non-significant difference in the LAI during the full irrigation and with 80% field capacity. In the recent study, the low LAI in the I_3 is due to leaf's turgor potential deficiency (Li *et al.*, 1998). The small criterion of the LAI leads to the leaf's inability in receiving the maximum solar radiation. Accelerated leaves firing and senescence under sever water deficit stress lead to rapid reduction of the LAI (Ali *et al.*, 1999; Matsuda and Riazi, 1981). Genotypes had no significant difference in the LAI mean and the LAI maximum. However, the Roshan- across and Ghods had highest and lowest mean and the maximum LAI, respectively (Table 1).

The TDM (Total Dry Matter): The TDM in the I_2, in all samples was non-significantly less than the I_1 but significantly more than the I_3 (Fig. 2), so that the I_1 and the I_2 had non-significantly difference in the TDM at the ripening but the difference among them with regard to the I_3 was much and significant (Table 1). The TDM reduction after the maximum approach can come about due to abscission of the older leaves and miss of its dry matter (Morgan, 1977). Within the I_3, the TDM reduction process was more sever than that of the I_1 and the I_2 from the maximum occurrence to the ripening (Fig. 2). The more abscission of leaves under water deficit stress

Table 1: Means comparison irrigation regimes and wheat cultivars on growth indices of three wheat cultivars[a]

Experimental factors	LAI (max)	LAI (mean)	Total dry matter (kg ha^{-1})	NAR_{mean} (g m^{-2} leaf day^{-1})	CGR_{mean} (g m^{-2} day^{-1})	Grain yield (kg ha^{-1})
Irrigation regimes						
70 mm evaporation	4.79[a]	2.63[a]	22247[a]	4.03[a]	12.97[a]	9115[a]
90 mm evaporation	4.54[a]	2.36[a]	20795[a]	4.18[a]	12.80[a]	8861[a]
110 mm evaporation	2.82[b]	1.57[b]	9176[b]	2.38[b]	4.65[b]	3120[b]
Genotypes						
Roshan-across	4.23[a]	2.33[a]	17943[a]	3.78[a]	10.72[a]	7355[a]
Ghods	3.90[a]	2.10[a]	16458[a]	3.34[a]	10.05[a]	6464[b]
Mahdavy	4.02[a]	2.13[a]	17817[a]	3.46[a]	10.66[a]	7276[ab]

[a]: All means followed by the same letter(s) in column are not significantly different at the 5% probability level

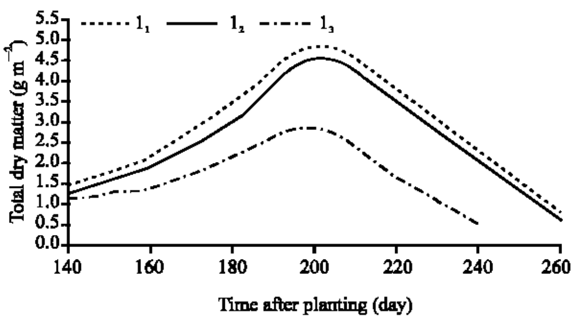

Fig. 1: Variation in the LAI in the irrigation regimes

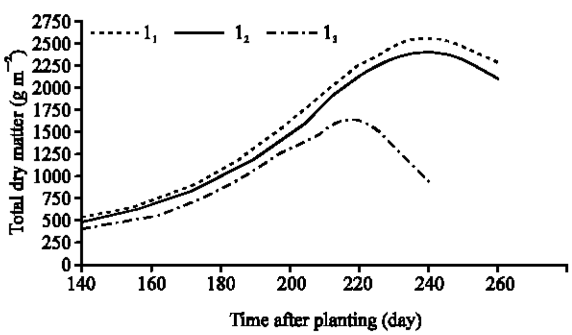

Fig. 2: Variation in the TDM in the irrigation regimes

circumstances can be the cause for the much reduction of the TDM in the I_3 (Ali *et al.*, 1999). These outcomes along with reports by Timpa *et al.* (1986) and Bajji *et al.* (2001) regarding of the TDM reduction in stress circumstances are totally convergent. The trend of changes in the TDM (Fig. 2) was more similar to the LAI (Fig. 1). We can conclude that the LAI will be decreased by increasing irrigation intervals (Fig. 1) and that the TDM can also be decreased by reduction in photosynthetic capacity (Fig. 2). Genotypes had no significant difference in the TDM at the ripening. However, Roshan-across and Ghods had highest and lowest the TDM, respectively (Table 1). These genotypes had highest and lowest the LAI (Table 1) lead to highest and lowest photosynthetic capacity, respectively.

The NAR (Net Assimilation Rate): The NAR mean in the I_3 had been significantly lower than the I_1 and the I_2. But there were no significant differences between the I_1 and the I_2 (Table 1). In the I_3, the NAR itself increased in about 165 days after planting (Fig. 3) and the mention period is compatible with the period during which the LAI began to increase linearly. The NAR was kept up for a bout 30 days at its higher surface and began to decrease because of the extra leaves shading and of less absorption of the light by the leaves placed at the lower parts of the canopy.

Thanks to the leaves faded and the photosynthesis reduction resulted from the midday stomata closer (Hirasawa *et al.*, 1998), the NAR was negated about 205 day after the planting (Fig. 3). The trend of changes the NAR had a high similarity within the I_1 and the I_2 and increased about 160 days after planting which was simultaneous with the LAI's linear increase (Fig. 1) and was kept up a bout 50 days at its higher surface. This period was corresponding with the maximum LAI period (Fig. 1). Because of the low LAI and as a result of the leaves less amount of shading, the maximum the NAR in the I_3 compared the I_1 and the I_2 was higher (Fig. 3).

However the amount of the NAR mean because of midday stomata closer a longer on the one hand (Hirasawa *et al.*, 1998) and promote leaves senescence (Nooden, 1988) during the I_3, on the other hand had a significant reduction (Table 1). In spite of a high the LAI value in the I_1 and the I_2 the maintenance of high the NAR quantities may be due to the continuous photosynthesis and opening of stomata during a longer as a favorable moist condition (Moustafa *et al.*, 1996).

The CGR (Crop Growth Rate): The CGR mean in the I_3 had been significantly lower than the I_1 and the I_2 (Table 1). Karimi and Siddique (1991) reported the CGR reduction as the result of water stress. There were no significant differences between the I_1 and the I_2 (Table 1) and the CGR changes trend resembled each other, but the I_1 had superiority over that of the I_2 during all the stages. The CGR reduction in the I_3 continued more violently compared with the I_1 and the I_2 after reaching their

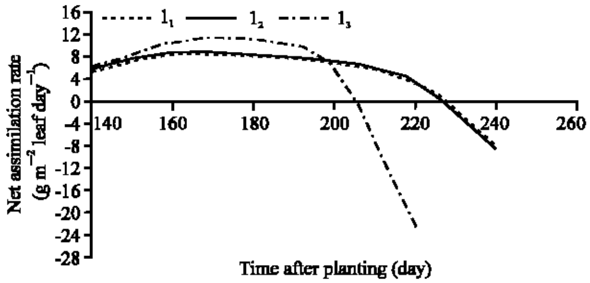

Fig. 3: Variation in the NAR in the irrigation regimes

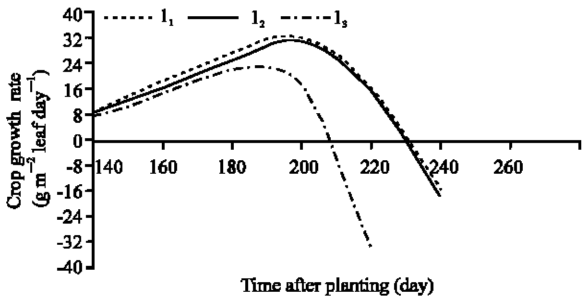

Fig. 4: Variation in the CGR in the irrigation regimes

maximum (Fig. 4). Genotypes had no significant difference in the CGR mean. However, Roshan- across and Ghods had the highest and lowest CGR, respectively (Table 1). However, these cultivars had however highest and lowest LAI and NAR lead to highest and lowest photosynthetic capacity respectively. The trend of changes in the CGR was more similar to the LAI (Fig. 1), but less resemble to the NAR (Fig. 3). Reduction of the CGR in water deficit stress conditions was due to reduction of the LAI and the NAR (Hirasawa *et al*., 1998).

Nakagami *et al*. (2004) reported a non-significant difference in the LAI, the NAR and the CGR during the full irrigation and with 80% field capacity due to the insufficiency of sever water stress, a better-developed root system and maintaining the high leaf nitrogen content in stress treatment. There were no significant differences between the I_1 and the I_2 in the LAI, the NAR and the CGR (Table 1). This reaction caused the total dry matter and grain yield in the I_1 and the I_2 had no significantly different (Table 1). Salemi and Afyuni (2005), however, reported the significant reduction of the TDM and the grain yield of wheat cultivars between full irrigation and 80% full irrigation in Isfahan region. The different outcomes obtained by them compared with those of present research, could be result of difference in experimental materials and those of various irrigation regimes. In present study, the low LAI in the I_3 (Table 1) is due to leaf's turgor potential deficiency (Li *et al*., 1998) and also might cause smaller the NAR (Table 1) by the increased midday and afternoon depression of photosynthesis in plants (Hirasawa *et al*., 1998). The smaller LAI and the NAR may be responsible for the significant decrease in the CGR (Table 1). This reaction caused the TDM and grain yield in the I_3 compared with the I_1 to decreased 58 and 65%, respectively (Table 1).

In conclusion, irrigation after 70 and 90 mm cumulative evaporation did not differ significantly for all growth indices, total dry matter and grain yield. Irrigation after 110 mm cumulative evaporation significantly reduced all growth indices, total dry matter and grain yield. In present study wheat might be irrigated after 90 mm cumulative pan evaporation to save 22% irrigation water under condition similar to this experiment.

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