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Growth and yield response of wheat to irrigation at different growing stages

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Abstract

An experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Bangladesh during November 2011 to March 2012 to study the growth and yield of wheat to irrigation stages. Four irrigation stages viz. I_0: No irrigation; I_1: Irrigation at crown root initiation (CRI) stage (18 DAS); I_2: Irrigation at pre-flowering stage (45 DAS) and I_3: Irrigation at both CRI and pre-flowering stage were used following Randomized Complete Block Design with three replications. Maximum number of tiller/hill (5.2), CGR (6.7 gm^{-2}day^{-1}), RGR (0.03 gg^{-1}day^{-1}), dry matter content (28.7%), number of spikes/hill (4.5), number of spikelets/spike (19.0), ear length (17.5), filled grains/spike (30.8), total grains/spike (32.9), weight of 1000-grains (47.1 g), grain yield (3.9 tha^{-1}), straw yield (4.9 tha^{-1}), biological yield (8.8 tha^{-1}) and harvest index (45.9%) were found from I_3 whereas minimum from I_0. On the other hand, early flowering (70.6 days), maturity (107.2 days) and minimum number of unfilled grains/spike (2.1) were also found from I_3.

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Introduction

Wheat (*Triticum aestivum* L.) is grown during Rabi season, dry and inadequate soil moisture in this season limits yield in Bangladesh. Irrigation plays a vital role on proper growth and development of wheat. Insufficient soil moisture affects both seed germination and nutrients uptake from soil. Irrigation frequency influences on growth and yield of wheat (Khajanij and Swivedi, 1988). Shoot dry weight, number of grains, grain and biological yield, harvest index decreased to a greater extent when water stress was imposed at the anthesis stage while imposition of water stress at booting stage caused a greater reduction in plant height and number of tillers (Gupta *et al.*, 2001). The lowest value corresponded with irrigation during grain filling and under rainfed conditions (Bazza *et al.*, 1999). Lack of irrigation facilities was found to be a major constrain for 38% wheat growers and 25% of the farmers of Bangladesh could not grow wheat due to this problem (Gao *et al.*, 2009). Identifying growth stages allows irrigation scheduling for both maximum crop yield and most efficient use of water resources (Doorenbos and Kassam, 1979). Considering these situation, present research work was carried out to find out the effect of irrigation stage on growth and yield of wheat.

Materials and methods

The experiment was conducted at experimental field of Sher-e-Bangla Agricultural University, Bangladesh during the period from November 2011 to March 2012 to study the growth and yield of wheat as influenced by irrigation stages. Experiment consisted four different irrigation stages viz. I_0: No irrigation i.e., control condition; I_1: Irrigation at crown root initiation (CRI) stage (18 DAS); I_2: Irrigation at pre-flowering stage (45 DAS) and I_3: Irrigation at both CRI and pre-flowering stage following Randomized Complete Block Design with three replications. BARI Gom-21 (Shatabdi) was used. Seeds were sown with maintaining 20 cm line to line distance and plant to plant 5 cm. Cowdung, Urea, TSP, MP, Gypsum were applied @ 10 tha^{-1}, 200 $kgha^{-1}$, 180 $kgha^{-1}$, 50 $kgha^{-1}$ and 120 $kgha^{-1}$ respectively as basal dose (BARI, 2006). Data were colleted on plant height, number of tiller/hill, dry matter content/plant, crop growth rate, relative growth rate, days to flowering, days to maturity, number of spike/hill, ear length, number of filled grains/spike, number of unfilled grain/spike, number of total grain/spike, weight of 1000-grains, grain yield/ha, straw yield/ha, biological yield and harvest index. Using the data on dry matter the following growth parameters were derived (Hunt, 1978).

Crop growth rate (CGR) was calculated using the following formula:

$$CGR = \frac{1}{GA} \times \frac{W_2 - W_1}{T_2 - T_1} \; g\, m^{-2} day^{-1}$$

Where; GA = Ground area (m^2), W_1 = Total dry weight at previous sampling date (T_1), W_2 = Total dry weight at current sampling date (T_2), T_1 = Date of previous sampling, T_2 = Date of current sampling

Relative growth rate (RGR) was calculated using the following formula:

$$RGR = \frac{LnW_2 - LnW_1}{T_2 - T_1} \; (g\, g^{-1} day^{-1})$$

Where; W_1 = Total dry weight at previous sampling date (time T_1); W_2 = Total dry weight at current sampling date (time T_2); T_1 = Date of previous sampling; T_2 = Date of current sampling; Ln = Natural logarithm

Biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield

Harvest index was calculated using the following formula-

$$HI\ (\%) = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (total dry weight)}} \times 100$$

Collected data were analyzed statistically using MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Results and discussion

Plant height: Significant variation was found for plant height of wheat due to different stages of irrigation at different days after sowing (DAS) and harvest under. Tallest plant was found from I_3 (92.4 cm) which was statistically similar I_2 (87.3 cm) and I_1 (84.3 cm) while minimum from I_0 (78.1 cm) at harvest (Fig. 1). Providing 2 irrigations at crown root initiation stage and pre flowering stage ensured the optimum vegetative growth of the wheat and the ultimate results were the longest plant. Water stress significantly inhibited the growth and yield of winter wheat (Zhai *et al.*, 2003). Water stress was imposed at booting stage caused a greater reduction in plant height (Gupta *et al.*, 2001). Plant height increased with increasing number of irrigations (Islam, 1997).

Number of tillers/hill: Maximum number of tillers/hill was found from I_3 (5.16) which was statistically similar with I_2 (4.9) and I_1 (4.7) while minimum from I0 (4.0) at 80 DAS (Fig. 2). Application of 2 irrigations at crown root initiation stage and pre flowering stage ensured the optimum vegetative growth of the wheat with highest number of tillers/hill. Water stress was imposed at the booting stage caused a greater reduction in number of tillers (Gupta *et al.*, 2001).

Crop Growth Rate (CGR): Maximum CGR was found from I_3 (6.8, 6.4 and 6.7 gm^{-2}day^{-1} at 50-60, 60-70 and 70-80 DAS respectively) which was statistically similar with I_2 and I_1 while minimum from I_0 (4.7, 5.9 and 2.1 gm^{-2}day^{-1} at 50-60, 60-70 and 70-80 DAS respectively) (Fig. 3). Highest crop growth rate were recorded when two irrigations were applied (Naser, 1996).

Relative Growth Rate (RGR): Maximum RGR was found from I_1, I_2 and I_3 (0.06, 0.04 and 0.03 gg^{-1}day^{-1} at 50-60, 60-70 and 70-80 DAS respectively) while minimum from (0.05, 0.03 and 0.01 g g^{-1}day^{-1} at 50-60, 60-70 and 70-80 DAS respectively) from I_0 (Fig. 4).

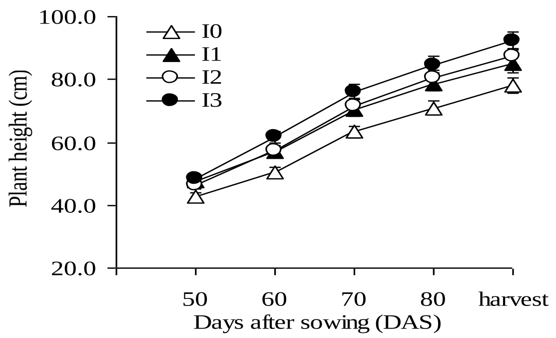

Fig. 1. Effect of different stages of irrigation on plant height of wheat at different days after sowing.

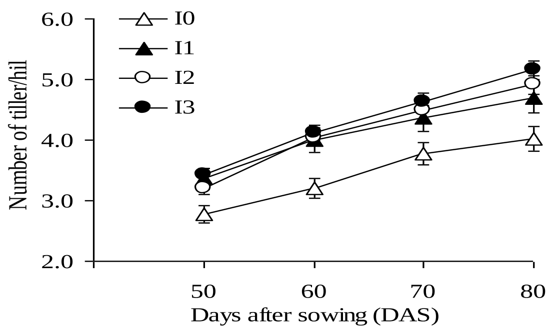

Fig. 2. Effect of different stages of irrigation on number of tiller/hill of wheat at different days after sowing.

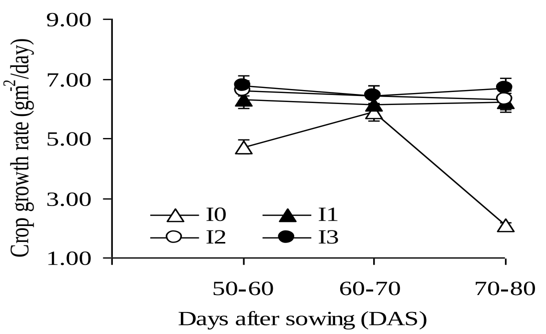

Fig. 3. Effect of different stages of irrigation on crop growth rate of wheat at different days after sowing.

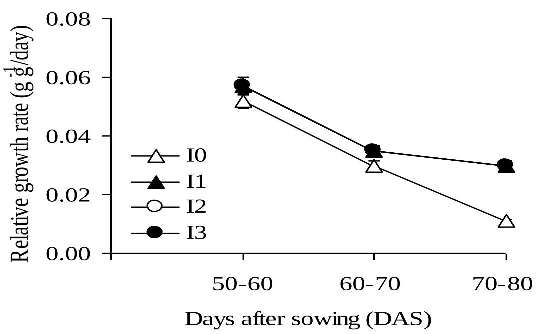

Fig. 4. Effect of different stages of irrigation on relative growth rate of wheat at different days after sowing.

Dry matter content/plant: Significant variation was found for dry matter content/plant of wheat due to different stages of irrigation at DAS. Maximum dry matter content/plant was found from I_3 (28.7 g) followed by I_2 (28.0 g) while minimum from I_0 (20.30 g).

Days to flowering: Early flowering was found from I_3 (70.6 days) which was statistically similar with I_2 (71.0 days) while I_0 (74.1 days) was the late flowering (Table 1).

Days to maturity: Minimum days required for the maturity by I_3 (107.2) followed by I_1 (109.0) and I_2 (110.8) whereas maximum from I_0 (114.1) (Table 1).

Number of spike/hill: Irrigation at different stages showed significant variation for number of spike/hill of wheat. Maximum number of spike/hill was found from I_3 (4.5) followed by I_2 (4.1) whereas minimum from I_0 (3.2) (Table 1).

Table 1. Effect of irrigation stage on dry matter content, crop duration and number of spikes/hill[X].

Irrigation stage	Dry matter content/ plant	Days to flowering	Days to maturity	Number of spikes/ hill
I_0	20.3d	74.1a	114.1a	3.2d
I_1	26.9c	71.6b	109.0b	3.7c
I_2	28.0b	71.0bc	110.8b	4.1b
I_3	28.7a	70.6c	107.2c	4.5a
LSD(0.05)	0.5	0.6	1.1	0.3
CV (%)	5.7	4.3	3.1	7.5

[X]In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Number of spikelets/spike: Maximum number of spikelets/spike was found from I_3 (19.0) which was statistically similar with I_2 (18.5) while minimum from I_0 (15.2) (Table 2). Spikelets/spike was more sensitive to drought stress in different wheat cultivars (Dencic *et al.*, 2000; Shehzadi, 1999).

Ear length: Longest ear was found from I_3 (17.5 cm) which was statistically similar with I_2 (17.1 cm) and I_1 (15.9 cm) whereas shortest from I_0 (13.2 cm) (Table 2).

Filled grains/spike: Maximum number of filled grains/spike was found from I_3 (30.8) which was statistically similar with I_2 (30.1) and I_1 (28.8) whereas minimum from I_0 (24.5) (Table 2). Number of grains decreased to a greater extent when water stress was imposed at the anthesis stage (Gupta *et al.*, 2001).

Unfilled grains/spike: Minimum number of unfilled grains/spike was found from I_3 (2.1) followed by I_1 (2.4) and I_2 (2.27) while maximum from I_0 (2.5) (Table 2).

Total grains/spike: Maximum number of total grain/spike was found from I_3 (32.9) which was statistically similar with I_2 (32.4) and I_1 (31.2) while minimum from I_0 (27.0) (Table 2). Highest number of grains/spike was recorded when two irrigations were applied (Naser, 1996).

Table 2. Effect of irrigation stage on number of spikelets/spike, ear length, filled grains/spike, unfilled grains/spike and total grains/spike[X].

Irriga-tion stages	Number of spikelets/ spike	Ear length (cm)	Filled grains/ spike	Unfilled grains/ spike	Total grains/ spike
I_0	15.2 c	13.2 d	24.5 b	2.5 a	27.0 b
I_1	17.6 b	15.9 a	28.8 a	2.4 b	31.2 a
I_2	18.5 ab	17.1 a	30.1 a	2.3 b	32.4 a
I_3	19.0 a	17.5 a	30.8 a	2.1 c	32.9 a
LSD (0.05)	1.2	1.9	1.6	0.2	1.6
CV (%)	7.6	7.9	6.4	7.6	5.9

[X]In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Weight of 1000-grains: Weight of 1000-grains varied significantly among the different stages of irrigations. Maximum weight of 1000-grains was found from I_3 (47.1 g) which was statistically similar with I_2 (46.2 g) whereas minimum from I_0 (35.5 g) (Table 3). 1000 grain weight with full irrigations might be due to the more translocation of photosynthats towards grain due to the sufficient amount of water in root zone. In another hand plants having limited supply of water had produced lighter grain which might be due to the less availability of nutrients from soil solution. Irrigation had significant effect on 1000-grain weight (Wajid *et al.*, 2002) but no influence of 1000-grain weight (Islam, 1996).

Grain yield: Maximum grain yield was found from I_3 and I_2 (3.9 tha^{-1}) which was statistically similar with I_1 (3.6 tha^{-1}) whereas minimum from I_0 (3.0 tha^{-1}) (Table 3). Grain yield under non-irrigated conditions was reduced by approximately 40% (Baser *et al.*, 2004). Once water application during the tillering stage allowed the yield to be lower only than that of the treatment with three irrigations (Bazza *et al.*, 1999). Wheat grain yield was the highest with 2 irrigations (2.57 ton/ha in 1993 and 2.64 ton/ha) at flowering and/or crown root initiation stages (Meena *et al.*, 1998). It is observed that proper scheduling of irrigation to supply adequate quantum of water during the moisture sensitive period of flowering and yield formation stages, *yet al*lowing moderate stress at vegetative and maturity stages produce the optimum yield with maximum water use efficiency and water economy (Reddy and Reddy, 1993).

Straw yield: Maximum straw yield was found from I_3 (4.9 tha^{-1}) which was statistically similar with I_2 (4.7 tha^{-1}) while minimum from I_0 (3.8 tha^{-1}) (Table 3).

Biological yield: Maximum biological yield was found from I_3 (8.8 tha^{-1}) which was statistically similar with I_2 (8.6 tha^{-1}) whereas minimum from I_0 (6.8 tha^{-1}) (Table 3). Biological yield decreased to a greater extent when water stress was imposed at the anthesis stage (Gupta *et al.*, 2001).

Harvest index: Maximum harvest index was found from I_3 (45.9%) which was statistically similar with I_2 (44.9%) while minimum from I_0 (43.5%) (Table 3). Harvest index was increased under rainfed conditions (Boogaard *et al.*, 1996) and decreased to a greater extent when water stress was imposed at the anthesis stage (Gupta *et al.*, 2001; Pannu *et al.*, 1996; Giunata *et al.*, 1993).

Table 3. Effect of irrigation stage on weight of 1000-grains, grain yield, straw yield, biological yield and harvest index^{X}.

Irrigation stages	Weight of 1000-grains (g)	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
I_0	35.5c	3.0b	3.8c	6.8c	43.5c
I_1	44.9b	3.6a	4.3b	7.9b	44.5bc
I_2	46.2ab	3.9a	4.7a	8.6ab	44.9ab
I_3	47.1a	3.9a	4.9a	8.8a	45.9a
LSD(0.05)	1.7	0.4	0.4	0.8	1.3
CV (%)	4.6	6.2	6.7	5.2	3.8

^{X}In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Conclusion

Irrigation at CRI and pre-flowering stage performed better than others in relation to growth, yield contributing characters and yield of wheat.

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