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Influence of irrigation regimes and nitrogen fertilizer management on the performance of spring wheat in Bangladesh

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Abstract
A field experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University from November 2016 to March 2017 to find out the effect of irrigation regimes and nitrogen (N) fertilization on the yield performance of spring wheat. The experiment was comprised five levels of irrigation *viz*., no irrigation (I_0); CRI (crown root initiation stage) (I_1)*;* CRI + maximum tillering stage (I_2); CRI + maximum tillering stage + flowering Stage (I_3); CRI + maximum tillering stage + flowering stage + grain formation stage (I_4); and six levels of nitrogen *viz*., 0, 60, 80, 100, 120 and 140 kg ha^{-1} under Split Plot design with three replicates. Except few all the yield contributing characters and yield of wheat were significantly influence by the application of irrigation and nitrogen. The highest number of total tillers hill^{-1} (4.15), effective tillers hill^{-1} (3.63), number of spikelets spike^{-1} (14.67), grain yield (2.862 t ha^{-1}), straw yield (3.45 t ha^{-1}), biological yield (6.312 t ha^{-1}) and harvest index (45.34%) were obtained from two irrigation at CRI+ Maximum tillering stage. In nitrogen management, the highest plant height (91.17 cm), number of spikelets spike^{-1} (15.24), number of grains spike^{-1} (44.46), spike length (10.89 cm), grain yield (2.93 t ha^{-1}), straw yield (3.478 t ha^{-1}) and biological yield (6.408) and harvest index (45.72%) were obtained from application of 120 kg N ha^{-1}. In interaction, the highest grain (3.897 t ha^{-1}), straw (4.76 t ha^{-1}) and biological yield (8.661 t ha^{-1}) and harvest index (45.02%) were achieved from two irrigation at CRI + maximum tillering stage with application of 120 kg N ha^{-1}. The lowest grain yield (1.22 t ha^{-1}) was achieved from one irrigation at CRI with no nitrogen application. Whereas, the lowest straw (2.13 t ha^{-1}) and biological yield (3.78 t ha^{-1}) were achieved from no irrigation with 60 kg N ha^{-1}. Based on these results it may conclude here that farmers may apply two irrigations (one at CRI and another at maximum tillering stage) with 120 kg N ha^{-1} to obtain the higher yield of wheat under Bangladesh context.

Keywords: Wheat, irrigation regimes, nitrogen level, yield

Introduction
Wheat (*Triticum aestivum* L.) is one of the most important grain and primary food for more than one third of the world population. After maize and rice, it covers the more land area than any other food crop and wheat production is the third largest cereal production in the world. It is estimated that global grain demand will be doubled by the year 2050 (Cassmann, 1999; Tilman *et al.*, 2002) [1, 2]. By 2050, the demand for wheat in the developing world is projected to increase 60% from now (FAO, 2013) [3]. Wheat grains contain 33% Protein, 29% Carbohydrate, 5% Fat (USDA, 2014) [4]. Currently about 65% of wheat crop is used for food, 17% for animal feed and 12% in industrial applications (FAO, 2013) [3]. In Bangladesh, wheat is the second important cereal crop next to rice (Al-Musa *et al.*, 2012) [5] and the area under wheat cultivation during 2015 was 436814 ha producing 1347926 ton of wheat with an average yields of 3.033 ton ha^{-1} (BBS, 2015) [6]. Whereas, in the year of 2016-17 wheat was cultivated in 444805 hectares of land producing 13, 11,473 tons of wheat with an average yields of 3.158 ton ha^{-1} (BBS, 2018) [7]. However, the average yield of wheat in Bangladesh can be raised up to 6.8 ton ha^{-1} (BARI, 2010) [8]. The low yield of wheat in Bangladesh is attributable to a number of reasons, viz. the traditional cultural practices, poor field management, lack of using proper plant densities, late planting, unavailability of quality seed, use of local cultivars, climatic hazards, intensive cropping and non-replenishment of soil nutrients, inadequate fertilizer use, irregular irrigation and fertilizer management including

splitting of N application (Bukhari *et al*., 1991; Arabinda *et al*., 1994; Jahiruddin and Hossain, 1994; Ahmed and Meisner, 1996) [9, 10, 11, 12].

In Bangladesh, wheat is grown during Rabi season and the duration extends from the month of November to March. The rabi season in Bangladesh is dry and as such, the inadequate soil moisture in this season limits the use of fertilizers, specially nitrogen and consequently results in decreased grain yield. About 42.78% of the total wheat area in the country is irrigated and the rest of the area is cultivated under rainfed condition (BBS, 2015) [6]. Irrigation plays a vital role in terms of bringing good growth and development of wheat. Insufficient soil moisture affects both the germination of seed and uptake of nutrients from soil. Irrigation frequency also has a significant influence of growth and yield of wheat (Khajanij and Swivedi, 1988) [13]. These suggested irrigation water should be supplied precisely at the peak period of crop growth, which may provide good yield of this crop.

Fertilizers are necessary for enhancing productivity in crops, especially in wheat, indiscriminate use of macronutrients and low use of micronutrients leading to an imbalance of soil chemical. A proper fertilization program with macronutrients and micronutrients in plant nutrition is very essential in the high production with good quality products, so there is a need of balance use of fertilizers and proper agronomic practices are needed to increase yield of this crop. High yielding varieties of wheat need adequate N fertilization to satisfy crop demands. Generally the total crop N demand increases with the potential biomass and grain yields. Nitrogen plays an important role to increase the tillering capacity of plants which ultimately increase production. Very low level of nitrogen fertilizer does not supply proper nutrients to plants while high levels encourage vegetative growth rather than reproductive growth, which eventually reduces the yield. Optimum supply of nitrogen raises the protein content, nutritive value of grain and also improves backing qualities (Filipov, 2000) [14]. Thus, a careful and judicious application of nitrogen and water is necessary. Therefore, the present study was undertaken to evaluate the effect of irrigation regimes and nitrogen level irrigation regimes on the yield performance of spring wheat in *Rabi* season in Bangladesh.

Materials and Methods

Experimental Site

The field experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh which is located at 24.75°N latitude and 90.50°E longitude of 18 m above the sea level. The experimental site belongs to the Old Brahmaputra Floodplain (AEZ-9). The experimental field was of a medium high land having silty clay loam soil, more or less neutral in reaction, low in organic matter content (1.29%) and its general fertility level was also low with soil bulk density (1.33 g cm^{-1}). The experimental area is situated under a subtropical climate, which is characterized by scantly rainfall and low temperature during October to March. The average temperature (from October to March) was 13-26 ^{0}C, rainfall 7 mm and relative humidity 80.5%. The test crop was wheat variety BARI Gam 24 (Pradip), developed by the scientists of Bangladesh Agricultural Research Institute (BARI) at 2005, can be grown all over the country.

Experimental design and treatments

The two sets of treatments were included in the experiment: A- Irrigation regimes (5): No irrigation (I_0), CRI- Crown Root Initiation Stage (I_1), CRI + Maximum tillering stage (I_2), CRI + Maximum tillering stage + Flowering Stage (I_3), CRI + Maximum tillering stage + Flowering stage + Grain formation stage (I_4). B- Nitrogen levels (6): No nitrogen (N_0), 60 kg N ha^{-1}(N_1), 80 kg N ha^{-1}(N_2), 100 kg N ha^{-1}(N_3), 120 kg N ha^{-1}(N_4), and 140 kg N ha^{-1}(N_5). The experiment was laid out in a split-plot design with three replications. Each replication was divided into five main plots and each of the main plots was then subdivided into six unit plots. The total number of plots was 90 (5×6×3) with each plot area 10 m^2 (4.0 m × 2.5 m). The irrigation regime was assigned to the main plots and nitrogen fertilizer level in sub-plot within each replication. The distances between the plot and block were 0.75 m and 1.0 m, respectively having a provision of irrigation channel.

Crop Husbandry

The land was prepared by repeated ploughing by a power tiller. Weeds and stubble of the previous crop were collected and removed from the field. After leveling, the experimental plots were laid out as per the treatments and design. All the fertilizers except nitrogenous were applied at the rate of BARI recommended dose as 180 kg ha^{-1}Triple Super Phosphate (TSP), 50 kg ha^{-1} Muriate of Potash (MoP), 120 kg ha^{-1} Gypsum (BARI, 2010) [8]. Nitrogen was applied as per experimental specification through urea. The total amount of TSP, MOP, gypsum and one third of the urea were applied at the time of final land preparation prior to sowing. The remaining two-thirds of urea were top-dressed in two equal splits on 20 and 55 days after sowing (DAS). Seeds were sown in the field at the rate of 120 kg ha^{-1} in 25 cm apart rows. Intercultural operations were done to ensure normal growth of the crop. Irrigations were done according to the treatment. Weeding was done twice during the whole growing period, one after 20 DAS and the other after 55 DAS. The crop was harvested at maturity when 90% of the grains became golden yellow in color from each plot were bundled separately and brought to the threshing floor. The crops were threshed and sundry weights of both the grain and straw were recorded for every plot and the weight in g $plot^{-1}$ was converted to kg ha^{-1}.

Data collection

For collecting data on plant characters, five plants were selected at random and uprooted from each plot prior to harvesting. The grain and straw yields were recorded plot-wise at 14% moisture basis and expressed as ton ha^{-1}. The data on the yield and yield contributing parameters (presented in the tables) were recorded accordingly. The harvest index was calculated as follows:

Biological yield= Grain yield + Straw yield

$$\text{Harvest index (\%)} = \frac{Grain\ yield}{Biological\ yield} \times 100$$

Data analysis

The recorded data were subjected to statistical analysis. Analysis of variance was done following two factors Split Plot Design with the help of computer package MSTAT-C. The mean differences among the treatments were adjusted by Duncan's Multiple Range Test (DMRT) at 5% level of significance.

Results and Discussion

1. Effect of irrigation regimes on yield characters and yield

The yield contributing characteristics and yield varied significantly with different level of irrigations (Table 1). The highest number of tillers $hill^{-1}$(4.15), number of effective tillers hill^{-1} (3.63), number of spikelets spike^{-1}(14.67), grain yield (2.862 t ha^{-1}), straw yield (3.45 t ha^{-1}), biological yield (6.312 t ha^{-1}) and harvest index (45.34%) were observed by the application of two irrigations. The lowest number of tillers hill^{-1}(3.71), number of effective tillers hill^{-1} (3.25) from three irrigation, number of spikelets spike^{-1}(14.32) from four irrigation, grain yield (1.487 t ha^{-1}), straw yield (2.28 t ha^{-1}), biological yield (3.767 t ha^{-1}) and harvest index (39.47%) from control (no irrigation) were observed. The plant height, number of non-effective tillers hill^{-1}, number of sterile spikelet spike^{-1}, number of grains spike^{-1}, spike length and 1000-grain weight were not significantly influenced by the irrigations. The highest plant height (86.92 cm), number of grains spike^{-1}(41.23), spike length (10.72 cm), 1000-grain weight (53.57g) from two irrigations, number of non-effective tillers hill^{-1}(0.56), number of grains spike^{-1}(39.38) from one irrigation, number of sterile spikelet spike-1(3.12) from control (no irrigation) were recorded. The lowest plant height (84.20 cm), number of sterile spikelet spike^{-1}(2.86) from two irrigations, number of non-effective tillers hill^{-1}(0.46), 1000-grain weight (53.24g) from three irrigations, spike length (10.26 cm) from control (no irrigation) and were recorded. The plant height is a varietal character of wheat, which may be influenced to some extent by irrigation/soil moisture condition. Shirazi *et al.* (2014) [15] observed that plant height was gradually increased with increasing number of irrigations. Islam *et al.* (2018) [16] and Rummana *et al.* (2018) [17] also observed similar results. Patel *et al.* (1992) [18] explained that 12 cm depth of irrigation significantly increased the plant height compared with 6 cm irrigation. Irrigation from tillering to heading of wheat had a beneficial effect on tiller plant^{-1} (Massunaka *et al.*, 1992) [19]. Effective tillers plant^{-1} was significantly superior in irrigation treatments to no irrigation treatment (Singh *and* Singh, 1991) [20]. Irrigation plays a positive role in increasing the number of tillers plant^{-1} (Ali and Amin 2007) [21] of wheat. Hefni *et al.* (1983)[22] found that the number of grains spike^{-1} and ear length reduced significantly if irrigation would be stopped at tillering and booting stages of wheat. Wheat plant growth was poor and spike length was low at rain fed condition (Singh and Singh, 1996) [23]. The fertile spikelets spike^{-1} was increased significantly under four irrigation and six irrigation treatments than two irrigations (Naik *et al.*, 1997) [24]. Bhoi *et al.* (1993) [25] explained that irrigation applied at critical growth stages showed maximum number of grains spike^{-1}. Number of grains spike^{-1} dominated by irrigation (Wajid *et al*. 2016) [26]. Water stress reduced grain number of winter wheat by 33% (Music and Duseck, 1980) [27] while the single mild drought at heading significantly decreased the grain yield, by 18.34% (Ding *et al*. 2018) [28]. Thousand grain weights declined or decreased with the increase in moisture regime (Naik *et al.*, 1997) [24] or the irrigation frequencies (Joarder *et al.*, 1986) [29]. Bhoi *et al.* (1993) [25] reported that 1000-grains weight was maximum when irrigations were applied at critical stages. Naser (1996) [30] reported that two irrigations at 30 and 50 DAS significantly increased grain and straw yields over control. The highest spike length, grain and straw yields, the maximum number of tillering plant^{-1}, number of grains spike$^{-'}$ were recorded where two irrigations were applied. Two irrigation treatment increased grain and straw yields by 58.1% and 54.5%, respectively, over control.

2. Effect of nitrogen levels on yield characters and yield

The yield contributing characteristics and yield varied significantly with different level of nitrogen (Table 2). The highest plant height at harvest (91.17 cm), number of tillers hill^{-1}(4.14), number of effective tillers hill^{-1} (3.61), number of spikelets spike^{-1}(15.24), spike length (10.89 cm), number of grains spike^{-1}(44.46), grain yield (2.93 t ha^{-1}), straw yield (3.478 t ha^{-1}), biological yield (6.408 t ha^{-1}) and harvest index (45.72%) by nitrogen application @ 120 kg ha^{-1}were observed. The number sterile spikelet spike^{-1} and 1000-grain weight were not significantly influenced by nitrogen fertilizer. The highest number of sterile spikelet spike^{-1}(3.07) from control-no nitrogen, number of non-effective tillers hill^{-1} (0.598) from nitrogen application @ 100 kg ha^{-1}, 1000-grain weight (53.53 g) by nitrogen application @ 120 kg ha^{-1} were observed. The lowest plant height at harvest (75.71cm), number of tillers hill^{-1}(3.46), number of effective tillers hill^{-1} (2.99), number of spikelets spike^{-1}(13.27), spike length (10.09 cm), number of grains spike^{-1}(37.67), grain yield (1.05 t ha^{-1}), straw yield (1.76 t ha^{-1}), biological yield (2.81 t ha^{-1}), harvest index (37.31%) by control nitrogen, number of non-effective tillers hill^{-1} (0.493), number of sterile spikelet spike^{-1}(2.9), 1000-grain weight (53.27 g) by nitrogen application @ 80 kg ha^{-1} were observed. Walsh *et al*. (2018) [31] conducted an experiment to investigate the effect of using different rates and split application of N on the performance of spring wheat in dry land cropping systems. The results showed that at-planting N fertilizer application of 90 kg N ha^{-1} has significantly increased GY (Grain Yield), GP (Protein Content in Grains) and NUP (N Uptake). Gismy (2017) [32] found that the highest plant height (96.23 cm), number of effective tillers plant^{-1} (4.00), grain yield (5.25 t ha^{-1}) and straw (6.30 t ha^{-1}) yield were obtained from application of 100 kg N ha^{-1}. The lowest plant height (84.0 cm), number of effective tillers plant^{-1} (2.33), grain yield (4.25 t ha^{-1}) and straw yield (5.42 t ha^{-1}) were observed with the application of 0 kg N ha^{-1}. Zahan (2017) [33] reported the highest plant height (92.44 cm), number of effective tillers plant^{-1} (4.17), grain yield (4.79 t ha^{-1}) and straw yield (5.76 t ha^{-1}) at the application of 100 kg N ha^{-1}. The lowest plant height (80.07 cm), number of effective tillers plant^{-1} (3.16), grain yield (3.94 t ha^{-1}) and straw yield (4.84 t ha^{-1}) were observed with the application of 0 kg N ha^{-1}. Badsha (2016) [34] found that the time of application of nitrogen is showed significant effect on yield and yield contributing characters of plants. The highest values for non-effective tillers hill^{-1} (0.73), number of spikelets spike^{-1} (20.16), 1000 grain weight (42.75 g), grain yield (3.42 t ha^{-1}), straw yield (4.57 t ha^{-1}), biological yield (7.99 t ha^{-1}) was observed in four times application of N (20, 35, 50 and 65 DAS). Saeed *et al*. (2013) [35] conducted a field experiment in Peshawar, Pakistan and concluded that N and S spray at the rate of 10-15% during different growth stages would improve the grain yield and yield components of wheat in the study area and contributed significantly to increased production.

3. Interaction effect of irrigation regime and nitrogen levels on yield characters and yield

Crop yield contributing characteristics and yield response significantly to the interaction effect of different irrigation regime and nitrogen levels (Table 3). The highest plant at harvest (100.4 cm), number of tillers hill^{-1}(4.8), number of effective tillers hill^{-1} (4.13), number of spikelets spike^{-1}(15.84), number of grains spike^{-1}(46.36), grain yield (3.897 t ha^{-1}), straw yield (4.76 t ha^{-1}), biological yield (8.661t ha^{-1}) and harvest index (45.02%) at two irrigation with nitrogen application @ 120 kg ha^{-1}, number of non-effective tillers hill^{-1} (0.73) at one irrigation with nitrogen application @ 60 kg ha^{-1}, number of sterile spikelet spike^{-1}(3.39) from control (no irrigation and nitrogen) were observed. The spike length and 1000-grain weight was not significantly influenced by the interaction. The highest spike length (11.65 cm) & 1000-grain weight (54.45 g) at two irrigation with nitrogen application @ 120 kg ha^{-1} were observed. The lowest plant at harvest (66.0 cm), number of tillers $hill^{-1}$ (2.93), number of effective tillers $hill^{-1}$ (2.53), grain yield (1.22 t ha^{-1}) & harvest index (29.12%) at one irrigation with control nitrogen, number of non-effective tillers $hill^{-1}$ (0.27) at two irrigation with control nitrogen, number of spikelets $spike^{-1}$(12.78) at four irrigation with control nitrogen, number of sterile spikelet $spike^{-1}$(2.6) at one irrigation with nitrogen application @ 80 kg ha^{-1}, spike length (9.46 cm), number of grains $spike^{-1}$(35.47) & 1000-grain weight (52.90 g) at four irrigation with nitrogen application @ 140 kg ha^{-1}, straw yield (2.13 t ha^{-1}) & biological yield (2.28 t ha^{-1}) at control irrigation with nitrogen application @ 60 kg ha^{-1} were observed. Gangwar *et al.* (2018) [36] reported that yield contributing factors and yield were significantly affected by different doses of nitrogen and irrigation regimes.120:60:60 NPK kg ha^{-1} application and fourth irrigation have found most suitable and economic combination for wheat crop under the existing conditions of Bundelkh and region in Uttar Prodesh. Shirazi *et al*. (2014) [15] found the interaction between 200 mm irrigation and 120 kg N ha^{-1} was the best combination treatment to obtain maximum grain yield in wheat cv. Kanchan. Parvej *et al.* (2010) [37] found he highest grain yield (4.82 t ha^{-1}) was obtained with 280k g Flobond ha^{-1} as chemical water retainer and 100 kg N ha^{-1}. The lowest one (1.53 t ha^{-1}) was obtained from 35 kg Flobond ha^{-1} and no nitrogen. On the other hand, the highest straw yield (6.68 t ha^{-1}) was obtained with 100 kg N ha^{-1} under two irrigation and the lowest one (3.42 t ha^{-1}) was found in 35 kg Flobond ha^{-1} and with no nitrogen. Rahman *et al.* (2000) [38] reported that maximum plant height, dry matter accumulation, leaf area index, crop growth rate, tiller number per plant and grain and straw yields were recorded from an irrigation depth of 6 cm. Nitrogen at 100 kg ha^{-1} when top dressed just after irrigation, also improved all the attributes (Saren *et al*., 2001) [39].Singh *et al.* (1996) [23] reported that grain yield was maximum (4.47 t ha^{-1}) with pre-sowing irrigation plus irrigation at crown root initiation stages at a nitrogen level of 150 kg ha^{-1}.

Table 1: Effect of irrigation regime on yield contributing characters and yield of wheat

Irrigation regime	Plant height (cm)	No. of tillers $hill^{-1}$	No. of effective tillers $hill^{-1}$	No. of non-effective tillers $hill^{-1}$	Number of spikelets $spike^{-1}$	No. of sterile spikelet $spike^{-1}$	Spike length (cm)	No. of grains $spike^{-1}$	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_0	85.13	3.84b	3.30b	0.54	14.34b	3.12	10.26	39.83	53.37	1.487 c	2.28b	3.767b	39.47d
I_1	84.20	3.87b	3.32b	0.56	14.63a	3.04	10.35	39.38	53.33	2.031 bc	2.988b	5.019b	40.47c
I_2	86.92	4.15a	3.63a	0.52	14.67a	2.86	10.72	41.23	53.57	2.862 a	3.45a	6.312a	45.34a
I_3	85.51	3.71b	3.25b	0.46	14.50ab	2.96	10.47	40.73	53.24	2.51 b	3.463b	5.973b	42.02b
I_4	85.87	3.81b	3.33b	0.48	14.32b	3.03	10.30	40.21	53.31	2.184 bc	3.201b	5.385b	40.56c
$S\bar{x}$	0.592	0.085	0.069	0.024	0.053	0.050	0.236	0.492	0.480	0.034	0.039	0.051	0.632
Level of significance	NS	*	*	NS	**	NS	NS	NS	NS	**	**	**	**
CV (%)	2.94	9.29	8.65	19.57	1.54	7.07	9.59	5.18	3.81	9.17	7.09	5.50	6.70

I_0 = No irrigation, I_1 = CRI (Crown Root Initiation Stage), I_2 = CRI + Maximum tillering stage, I_3 = CRI + Maximum tillering + Flowering stage, I_4 = CRI + Maximum tillering + Flowering + Grain formation stage

Table 2: Effect of level of nitrogen on yield contributing characters and yield of wheat

Level of nitrogen (Kg ha^{-1})	Plant height (cm)	No. of tillers $hill^{-1}$	No. of effective tillers $hill^{-1}$	No. of non-effective tillers $hill^{-1}$	Number of spikelets $spike^{-1}$	No. of sterile spikelet $spike^{-1}$	Spike length (cm)	No. of grains $spike^{-1}$	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
0	75.71d	3.46c	2.99c	0.468cd	13.27d	3.07	10.09c	37.67d	53.38	1.05d	1.76e	2.81f	37.37e
60	81.24c	3.90b	3.37b	0.531bc	14.30c	3.03	10.11c	39.28c	53.43	1.52c	2.31d	3.83e	39.69d
80	88.41ab	3.85b	3.41b	0.439d	14.89b	2.90	10.41abc	41.06b	53.27	1.92b	2.804c	4.724c	40.64c
100	89.80ab	4.01ab	3.41b	0.598a	14.28c	2.95	10.33bc	39.87bc	53.48	2.15b	3.023c	5.173d	41.56b
120	91.71a	4.14a	3.61a	0.532bc	15.24a	2.90	10.89a	44.46a	53.53	2.93a	3.478a	6.408a	45.72a
140	86.29b	3.89b	3.40b	0.494cd	14.95b	3.05	10.70ab	41.33b	53.09	1.87a	2.66b	4.53b	41.28b
$S\bar{x}$	1.42	0.062	0.063	0.023	0.086	0.045	0.164	0.320	0.488	0.033	0.042	0.052	0.597
Level of significance	**	**	**	**	**	NS	**	**	NS	**	**	**	**
CV (%)	6.42	6.15	7.27	17.50	2.31	6.05	6.09	3.08	3.54	8.00	6.70	5.14	5.78

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT)

** =Significant at 1% level of probability, * =Significant at 5% level of probability, NS = Not significant.

Table 3: Interaction effects of irrigation regime and level of nitrogen on yield contributing characters and yield of wheat

Interaction (Irrigation x N level)	Plant height (cm)	No. of tillers $hill^{-1}$	No. of effective tillers $hill^{-1}$	No. of non-effective tillers $hill^{-1}$	Number of spikelets $spike^{-1}$	No. of sterile spikelet $spike^{-1}$	Spike length (cm)	No. of grains $spike^{-1}$	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_0 x N_0	74.07 hij	3.80efghij	3.26defgh	0.540bcd	13.52ij	3.39a	9.77	38.18ijkl	53.37	2.08lmno	2.88lm	4.98mn	42.02bcdef
I_0 x N_1	80.33 ghi	3.40ij	2.86hi	0.530bcd	13.65ghi	3.13abcdef	9.62	36.53lm	53.33	1.65p	2.13n	3.78p	43.63bcd
I_0 x N_2	82.40ghi	4.00defgh	3.67abcde	0.330ef	14.24fg	2.72ghi	9.93	40.11efghij	53.43	2.75efghi	4.39defg	7.14efgh	38.44fghi
I_0 x N_3	87.07cdefg	3.73efghij	3.06gh	0.663ab	13.38ij	3.37ab	10.42	39.05fghijk	53.50	2.65fghij	4.66cde	7.31defg	36.27hi
I_0 x N_4	84.13efghi	3.93efgh	3.47bcdefg	0.470cde	15.58ab	3.14abcde	11.22	42.03cde	53.53	3.08cde	4.53cdef	7.61cdef	40.47bcdefgh
I_0 x N_5	84.80 efgh	4.20bcde	3.47bcdefg	0.533bcd	15.64ab	3.31abc	10.60	43.07bcd	53.03	2.51ghijk	4.44defg	6.94ghi	36.18hi
I_1 x N_0	66.00 j	2.93k	2.53i	0.400def	13.48ij	3.19abcd	10.42	37.89jkl	53.37	1.22q	2.96klm	4.18op	29.12j
I_1 x N_1	80.20ghi	3.87efghi	3.13fgh	0.730a	14.27f	3.12abcdef	10.40	39.98efghij	54.10	2.18klmn	2.80m	4.98mn	43.92bc

$I_1 \times N_2$	80.73ghi	3.53hij	3.20efgh	0.330ef	15.31abc	3.04abcdefg	10.60	44.33ab	53.23	3.35bcd	4.34defg	7.69cde	43.54bcd
$I_1 \times N_3$	97.73ab	4.13cdef	3.47bcdefg	0.670ab	14.78cdef	2.61i	10.52	40.80defgh	53.27	2.15ijkl	2.85lm	5.10lm	42.16 bcdef
$I_1 \times N_4$	84.80efgh	3.73efghij	3.20efgh	0.530bcd	14.33ef	3.04abcdefg	11.51	38.49hijkl	54.30	2.86efgh	4.94bc	7.81cd	36.74ghi
$I_1 \times N_5$	95.73abcd	4.40abcd	3.73abcd	0.670ab	15.82a	2.88defghi	10.91	38.62ghijkl	53.13	3.33bcd	5.14ab	8.47ab	39.51cdefghi
$I_2 \times N_0$	73.80 ij	3.33j	3.07gh	0.270f	12.96jk	2.71ghi	10.08	36.91klm	53.40	1.73op	2.78m	4.51no	39.12defghi
$I_2 \times N_1$	85.47defg	3.53hij	3.06gh	0.466cde	14.25fg	3.13abcdef	9.87	39.07fghijk	53.23	2.91efg	3.79hi	6.71ghij	43.51bcd
$I_2 \times N_2$	82.00 ghi	3.86efghi	3.46bcdefg	0.400def	14.53ef	2.77fghi	10.36	40.13efghij	53.37	3.01def	4.33defg	7.34defg	41.01bcdefg
$I_2 \times N_3$	94.87abcde	3.53hij	3.00gh	0.530bcd	14.69def	2.74ghi	10.37	38.50hijkl	53.87	2.75efghi	4.19efgh	6.94ghi	39.62cdefghi
$I_2 \times N_4$	100.4a	4.80a	4.13a	0.670ab	15.84a	2.94defghi	11.65	46.36a	54.45	3.897a	4.76a	8.661a	45.02a
$I_2 \times N_5$	94.53abcdef	3.87efghi	3.47bcdefg	0.400def	15.59ab	2.88defghi	11.27	43.04bcd	53.00	2.14ab	3.251jkl	5.39lm	39.74cdefghi
$I_3 \times N_0$	79.67ghi	3.60ghij	3.00gh	0.600abc	13.63hi	2.99cdefgh	10.47	38.32ijkl	53.20	1.81nop	2.76m	4.58no	39.76cdefghi
$I_3 \times N_1$	78.87ghi	4.60ab	4.07a	0.530bcd	14.18fgh	2.98cdefgh	10.16	39.52fghij	53.30	2.50hijk	4.48cdefg	6.97fgh	35.82i
$I_3 \times N_2$	96.20abc	3.80efghij	3.33defgh	0.470cde	14.53ef	2.98cdefgh	10.31	40.86defgh	53.30	2.21klm	3.11jklm	5.33lm	41.58bcdef
$I_3 \times N_3$	85.53defg	4.40abcd	3.87abc	0.530bcd	14.38ef	3.06abcdefg	10.25	40.95defg	53.33	2.66fghij	3.51ij	6.18jk	43.11bcde
$I_3 \times N_4$	86.67cdefg	4.07cdefg	3.60bcdef	0.470cde	15.22abcd	2.64hi	10.33	40.60efghi	52.90	3.51ab	4.51cdef	8.02bc	43.77abc
$I_3 \times N_5$	94.60abcde	4.46abc	3.93ab	0.530bcd	15.82a	3.13abcdef	11.28	44.16abc	53.40	3.28bcd	4.74bcd	8.02bc	40.17bcdefghi
$I_4 \times N_0$	85.00efg	3.66fghij	3.13fgh	0.536bcd	12.78k	3.16abcde	9.74	37.04klm	53.57	1.90mnop	3.30jkl	5.19lm	36.50ghi
$I_4 \times N_1$	81.33ghi	4.13cdef	3.73abcd	0.400def	15.16bcd	2.80efghi	10.52	41.31def	53.20	2.63fghij	4.23efgh	6.86ghi	38.27fghi
$I_4 \times N_2$	82.73ghi	4.06cdefg	3.40cdefg	0.666ab	14.96cde	3.00cdefg	10.84	45.89a	53.23	2.31jkl	4.03fgh	6.341ij	36.48ghi
$I_4 \times N_3$	83.80fghi	3.60ghij	3.00gh	0.600abc	14.17fgh	2.96cdefghi	10.08	40.07efghij	53.67	2.51ghijk	3.98gh	6.49hij	38.63efghi
$I_4 \times N_4$	93.47abcdef	3.60ghij	3.26defgh	0.333ef	14.67def	3.21abcd	11.19	41.04defg	53.30	2.30jkl	3.40ijk	5.69kl	40.33bcdefghi
$I_4 \times N_5$	88.87bcdefg	3.80efghij	3.46bcdefg	0.333ef	13.33ijk	3.02bcdefg	9.46	35.47m	52.90	3.43bc	4.38defg	7.81cd	44.04abc
$S\bar{x}$	3.17	0.138	0.141	0.052	0.193	0.105	0.367	0.717	0.109	0.073	0.091	0.117	1.33
Level of sig.	**	**	**	**	**	**	NS	**	NS	**	**	**	**
CV (%)	6.42	6.15	7.27	17.50	2.31	6.05	6.09	3.08	3.54	8.00	6.70	5.14	5.78

I_0 = No irrigation, I_1 = CRI (Crown Root Initiation Stage), I_2 = CRI + Maximum tillering stage, I_3 = CRI + Maximum tillering + Flowering stage, I_4 = CRI + Maximum tillering + Flowering + Grain formation stage. N_0= Control, N_1 = Nitrogen application @ 60 kg ha^{-1}, N_2 = Nitrogen application @ 80 kg ha^{-1}, N_3 = Nitrogen application @ 100 kg ha^{-1}, N_4 = Nitrogen application @ 120 kg ha^{-1}, N_5 = Nitrogen application @ 140 kg ha^{-1}. In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT)

** =Significant at 1% level of probability, * =Significant at 5% level of probability, NS = Not significant.

Conclusion

From the above results of the present study, it may be stated that BARI Gam 24 was grown successfully for obtaining higher yield by two times irrigation (at Crown Root Initiation + Maximum tillering stage) with 120 kg N ha^{-1} in combination with recommended rates of TSP, MoP and Gypsum fertilizers to ensure optimum requirement of nutrients for commercial wheat cultivation. Further study should be undertaken on a priority basis because the fertility status of Bangladesh soils may vary from place to place or region to region. In dry winter season in Bangladesh, farmers may be advised to apply two times irrigation (at Crown Root Initiation + Maximum tillering stage) with 120 kg N ha^{-1}, respectively for proper utilization of water regime and nitrogen fertilizers to obtain higher grain yield of wheat. Before making final conclusion, further trails with the same treatment combinations on different Agro Ecological Zones (AEZ) of Bangladesh will be useful.

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