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Physiological parameters, yield and seed quality of wheat as influenced by irrigation and split application of nitrogen

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ABSTRACT

The experiment was conducted at the Agronomy Field Laboratory, University of Rajshahi to study the effect of moisture stress and nitrogen split application on the physiological parameters, yield and seed quality of wheat. Four moisture treatments *viz.* control, one irrigation at crown root initiation (CRI) stage, two irrigations, at CRI and stem elongation stages and three irrigations, at CRI, stem elongation and flowering stages; and four nitrogen treatments *viz.* control, basal application, $\frac{1}{2}$ basal + $\frac{1}{2}$ top dressed at 1st irrigation and $\frac{1}{3}$ basal + $\frac{1}{3}$ top dressed at 1st irrigation + $\frac{1}{3}$ top dressed at 2nd irrigation were used. Results showed that total dry matter (TDM), crop growth rate (CGR) and leaf area index (LAI) increased with the increase of number of irrigation. Three irrigations produced the highest TDM, CGR and LAI. The highest net assimilation rate (NAR) was found in control at all sampling dates except 65 to 80 DAS. Growth parameters like TDM, CGR and LAI increased with the increase of splits of nitrogen application. Three splits of nitrogen showed the highest TDM, CGR, and LAI. Grain and straw yields were varied significantly due to irrigation levels. Grain and straw yields were increased with the increase of irrigation frequencies. The highest grain and straw yields were found in three irrigations. Grain and straw yields were found to be significant in respect of nitrogen splits. Significantly the highest values were observed in three splits of nitrogen. Irrigation had significant effect on all most all seed quality parameters. The highest germination, vigour index, nitrogen content in grain and protein content in grain were obtained in three irrigations. With some exceptions, the highest germination, vigour index, nitrogen content in grain and protein content in grain were found in three splits of nitrogen. Interaction effects of irrigation and nitrogen splits was significant for almost all the parameters. with some exception, the highest value was obtained from three irrigations with three splits of nitrogen ($I_3 \times N_3$) treatment combination for almost all the cases. From the results it may be concluded that application of nitrogen in three equal splits at basal, crown root initiation and stem elongation stages and three times irrigation at crown initiation, stem elongation and flowering stages is better for maximizing yield and seed quality of wheat.

Keywords: Wheat, irrigation, nitrogen, physiology, yield, quality

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1 Introduction

Drought is a serious problem for agriculture all over the world and water shortage is now becoming the number one ecological predicament facing mankind. Wheat is widely grown as a rain-fed crop in semi areas, where large fluctuation occurs in the amount and frequency of rainfall within years. In Bangladesh wheat is grown during winter as rabi crop and the rabi season in Bangladesh is usually dry because adequate rainfall does not take place during this period. The meteorological data show that rainfall which occurs during the growing period is insignificant and unpredictable.

The yield of wheat is very low in Bangladesh in comparison to other wheat growing countries of the world. The low yield of wheat in Bangladesh is attributable to a number of reasons viz., traditional cultural practices, poor field management, unavailability of quality seed, inadequate fertilizer use, irregular irrigation and fertilizer management including splitting of nitrogen application (Bukhari et al., 1991). For achieving higher yield per unit area, use of high yielding varieties along with improved agronomic practices are felt to be most important. Among the improved agronomic practices irrigation and nitrogen management are important for increasing yield of wheat.

Sensitivity to moisture stress at different growth stages of wheat varies widely. Soil moisture stress cause significant reduction in wheat yield (Choudhury et al., 2013). Crown root initiation (CRI) stage of wheat was determined by the BARI scientists to be the most sensitive growth stage producing the highest seed yield with one irrigation (BARI, 1990). In case of adequate water supply, three irrigations given each at three defined growth stages viz., CRI, maximum tillering and grain filling stages significantly increased seed yield (BARI, 1986). Irrigation increases the availability of water and nutrient through the establishment of relatively favourable moisture condition around the root zone of the crop plant. So, adequate moisture supply is necessary for getting higher yield.

Nitrogen for wheat production is important to realize yield potential and more prominent and significant over other fertilizers. Increasing crop yield through adequate nitrogen fertilization is a pertinent farm management tool. The basic requirement for high yield and quality of wheat is that the plant receives optimum amount of nitrogen through the growing season. It is reported that split application of nitrogen is better than single application in increasing the yield of wheat (Gravelle et al., 1988). The yield response varies with number of splits and time/stage of nitrogen application (Haque et al., 2012). Hence, it would be a good effort to develop an effective schedule for nitrogen management for wheat crop by the

way of quantity, split and time of application on a particular set of environmental situation. Therefore present study was under taken to find out the effect of irrigation scheduling and nitrogen management on growth, yield and seed quality of wheat.

2 Materials and Methods

2.1 Experimental site and Soil

An experiment was carried out at the Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi during November 2009 to March 2010 to study the physiological parameters, yield and seed quality of wheat as affected by moisture stress and nitrogen split application. The experimental field was well drained. The top soil is silty loam and slightly alkaline in reaction.

2.2 Experimental treatments and design

The experiment consists of two factors. Factor A; irrigation scheduling viz, control, One irrigation (at CRI stage), Two irrigations (at CRI and stem elongation stages) and three irrigations (at CRI, stem elongation and flowering stages) and factor B; four nitrogen treatments viz., control (N_0), basal application (N_1), $1/2$ basal + $1/2$ top dressed at 1st irrigation (N_2) and $1/3$ basal + $1/3$ top dressed at 1st irrigation + $1/3$ top dressed at 2nd irrigation (N_3) were used. The experiment was laid out in a split plot design with 3 replications. The irrigations were assigned in the main plots and nitrogen in the sub plot. Wheat variety Saurav was used as planting material.

2.3 Crop husbandry

The land was fertilized with 100 kg N, 86 kg P, 30 kg K and 20 kg S ha^{-1} . Before sowing collected seeds were treated with Vitavax-200 @ 0.25% to prevent seeds from the attack of soil borne diseases. Seeds were sown on 26 November 2009 in 25 cm apart rows opened by specially made an iron hand tine. Weeding was done with the help of niri when necessary. Irrigation and nitrogen were applied as per treatment specification.

2.4 Data collection

From each plot, five rows of crop were used for collecting data on growth. Growth study was started from 20 days after sowing (DAS) and continued up to 80 DAS at 10 days interval. Data on yields at harvest were recorded. Harvesting was done after proper maturity. The harvested crop was bundled separately, tagged properly and taken to the clean threshing floor. After harvesting, crop of each plot was dried separately for four days. After that, threshing, cleaning

and drying of grains were done plot-wise. Then the yields of grain and straw of each plot were recorded and the yields were then converted to hectare basis. Seed quality parameters were studied in the laboratory after harvest.

2.5 Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. The data were analyzed statistically using the analysis of variance technique and the mean differences among the treatments were adjudged by Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

3 Results and Discussion

3.1 Effect of irrigation on physiological parameters

A variation of total dry matter (TDM) was slow at the early stages of plant growth and wider at later growth stages. The total dry matter increased with the advancement of plant age. Total dry matter production decreased with the increase of moisture stress intensity (Choudhury et al., 2013). On the other hand Crop growth rate (CGR) increased slowly at the early stages of plant growth and reached the peak at 50-65 DAS and thereafter it declined. TDM and CGR increased with the increasing irrigation frequencies. This might be due to the increase in the level of soil moisture while water stress decreased cell division, elongation and enlargement that might have ultimately led to reduction in TDM and CGR. TDM and CGR production were significantly higher in the irrigated treatments than the control. Three irrigations produced highest TDM (10.47, 47.99, 215.79, 891.93 and 1184.93 at different days after sowing) and CGR (2.50, 11.18, 45.91 and 18.71 at different sampling dates). These results are inconsistent with the findings of Nahar and Paul (1998). The lowest TDM (9.01, 43.03, 190.28, 806.26 and 1014.26) and CGR (2.27, 9.79, 41.05 and 13.86 at different sampling dates) were recorded in no (control) irrigation (Fig. 1).

In the present investigation, starting from a lower value, LAI increased with the increase of plant age. This might be due to the increase of leaf expansion at the later stage of plant growth. The value of LAI was higher in the irrigated treatments than the control at all the growth stages. This results were supported by Choudhury et al. (2013). Three irrigations treatment Showed the highest LAI (0.26, 1.33, 2.57, 3.62, and 4.44 at different sampling dates). This might be due to the increase of leaf expansion in the irrigated plants. Increase in soil moisture resulted in increased turgor pressure in the cells and turgor forces played a part in the process of leaf expansion. Soil moisture increased

relative leaf water content which increased cell expansion and ultimately leaf area was increased. The lowest LAI (0.225, 1.05, 2.18, 3.05 and 3.55 at different sampling dates) was observed in control treatment at all sampling dates (Fig. 2).

NAR significantly differed due to irrigation levels during 20-35, 35-50, 50-65 and 65-80 DAS. With some exception the highest NAR was observed in control. Net assimilation rate (NAR) measured the amount of dry matter production per unit area of leaf surface and it is an indicator of photosynthetic efficiency. It was established that NAR become higher during vegetative phase and decline rapidly as growth progressed (Han et al., 2005). With some exception the highest NAR was found in control treatment (0.43, 0.63, 1.59 and 0.49 at different sampling dates). In the irrigated crops, NAR (0.38, 0.58, 1.48 and 0.42 at different sampling dates) was lower (Fig. 2). Similar result was supported by Rahman et al. (2006).

3.2 Effect of nitrogen on physiological parameters

There was significant effect of nitrogen on TDM and CGR at all sampling dates. The total dry matter production and crop growth rate response varies with number of splits and time/stage of nitrogen application (Haque et al., 2012). Significantly the highest TDM (10.60, 49.17, 218.38, 898.28 and 1197.99 at different sampling dates) and CGR (2.57, 11.28, 46.29 and 19.00 at different sampling dates) were found in three splits of nitrogen than other treatments. This might be due to steady availability of nitrogen during growth. Similar results were also observed by Rahman et al. (2006). The lowest TDM (8.95, 43.12, 188.16, 800.20 and 996.75 at different sampling dates) and CGR (2.28, 9.66, 40.80 and 13.12 at different sampling dates) were obtained from control (Fig. 3).

LAI increased over control (zero) nitrogen treatment at all the growth stages. This result was agreement with the findings of Rahman et al. (2006) The highest LAI (0.28, 1.39, 2.64, 3.79 and 4.45 at different sampling dates) was observed in three splits of nitrogen. Similar result was reported by Roy et al. (2003) in rice. This might be due to the effect of split application of nitrogen that contributed to the increased number of leaves per unit area resulting in increased leaf area. The lowest LAI (0.19, 1.02, 2.03, 2.60 and 3.21 at different sampling dates) was found in three splits of nitrogen. With a few exceptions, no nitrogen treatment showed the highest (0.46, 0.66, 1.76 and 0.49 at different sampling dates) NAR (Fig. 4). Similar result was reported by Rahman et al. (2006). The lowest NAR (0.37, 0.57, 1.42 and 0.42) at different sampling dates) was obtained from different splits.

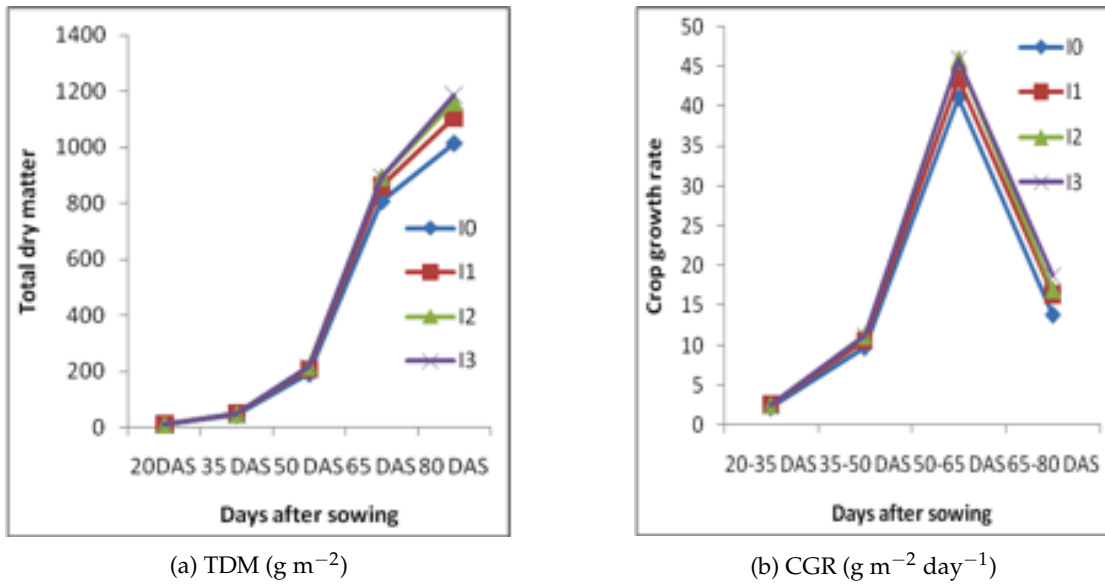


Figure 1. Effects of irrigation on total dry matter (TDM) and crop growth rate (CGR) of wheat at different days after sowing (DAS)

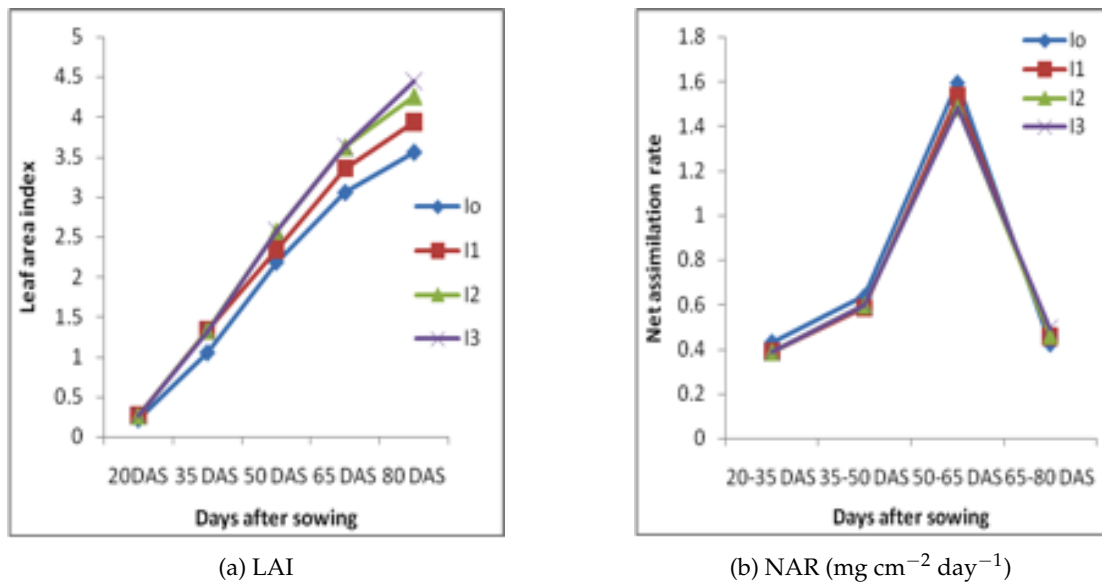


Figure 2. Effects of irrigation on leaf area index (LAI) and net assimilation rate (NAR) of wheat at different days after sowing (DAS)

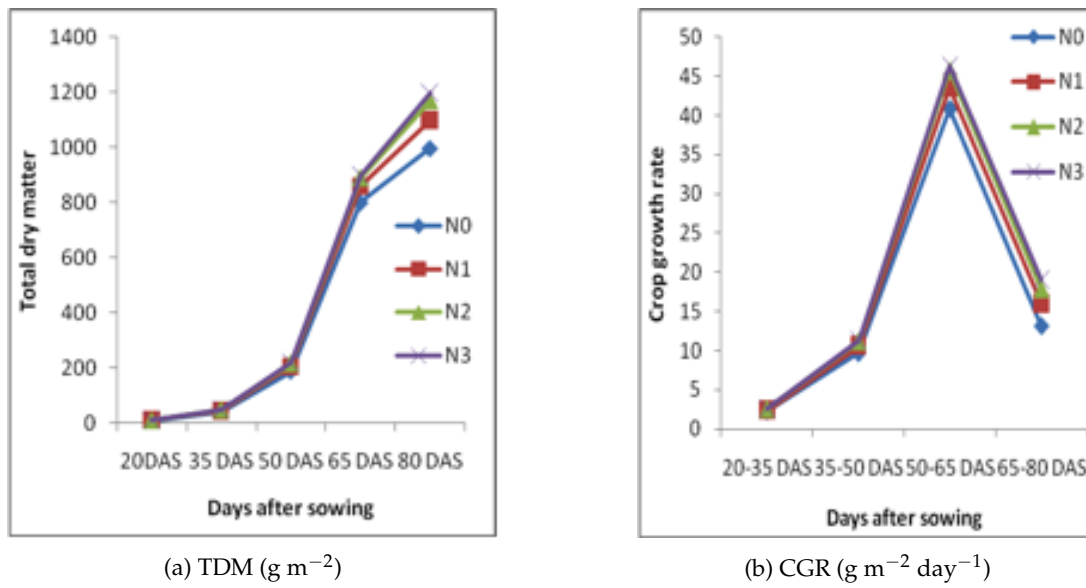


Figure 3. Effects of nitrogen on total dry matter (TDM) and crop growth rate (CGR) of wheat at different days after sowing (DAS)

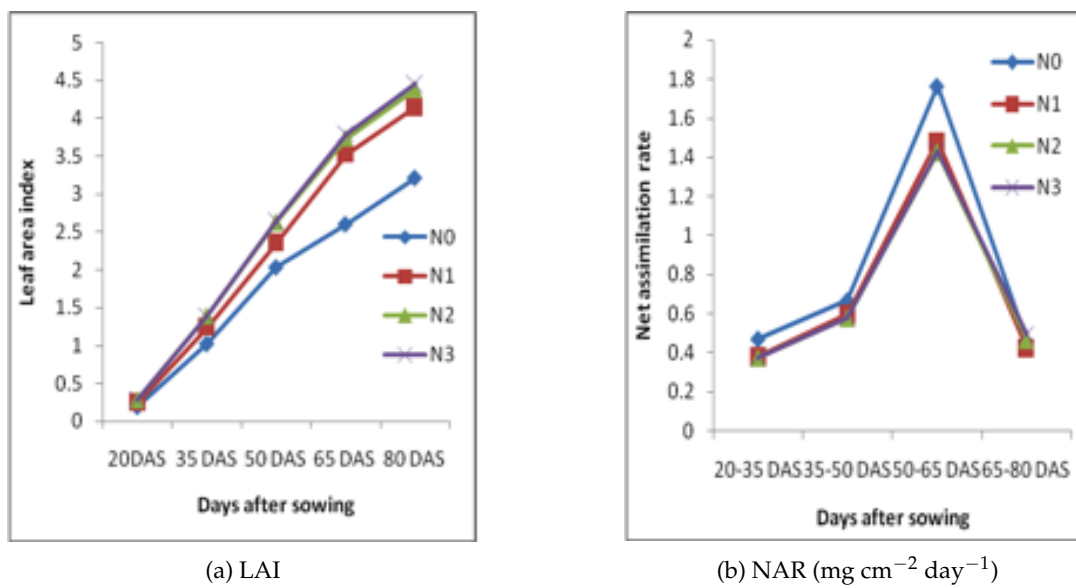


Figure 4. Effects of nitrogen on leaf area index (LAI) and net assimilation rate (NAR) of wheat at different days after sowing (DAS)

Table 1. Interaction effect of irrigation and nitrogen on TDM and CGR at different days after sowing

I×N	Total dry matter (g m ⁻²)					Crop growth rate (g m ⁻² day ⁻¹)			
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
I ₀ N ₀	7.98f	39.44f	171.51o	738.16e	895.19p	2.10 f	8.80 k	37.77 k	10.46 o
I ₀ N ₁	9.15e	41.78e	188.30m	797.37d	997.24n	2.17 e	9.68 i	40.60 i	13.32 m
I ₀ N ₂	9.46 c	45.48c	200.17j	839.55cd	1067.40k	2.40 c	10.31 g	42.58 h	15.19 k
I ₀ N ₃	9.46 c	45.44c	201.16i	849.95bcd	1097.20i	2.39 c	10.38 f	43.25 f	16.48 h
I ₁ N ₀	9.28 d	44.37d	187.63n	790.94de	985.55o	2.39 c	9.55 j	40.22 j	12.97 n
I ₁ N ₁	10.67 b	46.83b	204.66h	850.20bcd	1087.88j	2.41 c	10.52 e	43.03 g	15.84 i
I ₁ N ₂	10.98 a	50.43a	216.19e	892.14abc	1157.74g	2.63 a	11.05 d	45.06 e	17.70 g
I ₁ N ₃	10.97 a	50.37a	218.08d	903.22ab	1186.63e	2.59 b	11.17 c	45.67 c	18.89 d
I ₂ N ₀	9.28 d	44.33c	196.71 l	835.70cd	1040.53m	2.33 d	10.15 h	42.59 h	13.65 l
I ₂ N ₁	10.67 b	46.84b	214.03f	895.30abc	1143.32h	2.41 c	11.14 c	45.41 d	16.53 h
I ₂ N ₂	10.98 a	50.38a	225.29b	887.76abc	1213.12d	2.62 a	11.66 b	47.49 b	18.35 e
I ₂ N ₃	10.97 a	50.37a	227.14a	948.96a	1241.48b	2.62 a	11.78 a	48.12 a	19.50 c
I ₃ N ₀	9.28d	44.35d	196.78k	835.99cd	1065.73 l	2.33 d	10.16 h	42.61 h	15.39 j
I ₃ N ₁	10.67 b	46.83b	213.93g	894.98abc	1167.04f	2.41 c	11.14 c	45.40 d	18.27 f
I ₃ N ₂	10.97 a	50.38a	225.16c	937.72a	1238.29c	2.62 a	11.65 b	47.50 b	20.03 b
I ₃ N ₃	10.97 a	50.39a	227.16a	890.99abc	1266.66a	2.62 a	11.78 a	48.14 a	21.15 a
LS	0.01	0.01	0.01	0.01	0.01	7.16	8.68	5.78	7.44
CV (%)	6.43	8.02	6.14	7.72	9.16	0.05	0.01	0.01	0.01

[†] In a column the figures bearing same letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT [‡] LS = Level of significance [§] CV = Co-efficient of variation

Table 2. Interaction effect of irrigation and nitrogen on LAI (leaf area index) and NAR (net assimilation rate) at different days after sowing

I×N	LAI					NAR (mg cm ⁻² day ⁻¹)			
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
I ₀ N ₀	0.17d	0.80g	1.82e	2.24h	2.77o	0.51 a	0.71 a	1.83 a	0.42 bc
I ₀ N ₁	0.22bc	1.05f	2.17d	3.16e	3.62k	0.41 c	0.63 bc	1.53 b	0.39 c
I ₀ N ₂	0.25ab	1.18cd	2.36c	3.37d	3.87j	0.40 cd	0.60 cd	1.50 b	0.42 bc
I ₀ N ₃	0.25ab	1.18cd	2.37 c	3.43c	3.95i	0.40 cd	0.60 cd	1.51 b	0.45 bc
I ₁ N ₀	0.20cd	1.08ef	2.01d	2.57g	3.12n	0.45 b	0.63 bc	1.76a	0.46 bc
I ₁ N ₁	0.25ab	1.33b	2.09d	3.46c	4.03h	0.36 d	0.57 de	1.47 bc	0.43 bc
I ₁ N ₂	0.29a	1.46a	2.61ab	3.67b	4.26g	0.36 d	0.55 e	1.45 bc	0.45 bc
I ₁ N ₃	0.29a	1.46a	2.63ab	3.72b	4.34f	0.36 d	0.56 e	1.45 bc	0.47 bc
I ₂ N ₀	0.20cd	1.13de	2.15d	2.80f	3.41m	0.44 b	0.65 b	1.73 a	0.44 bc
I ₂ N ₁	0.25ab	1.33b	2.58b	3.73b	4.36 f	0.37 d	0.59 de	1.45 bc	0.41 c
I ₂ N ₂	0.29a	1.46a	2.76a	3.95a	4.60 d	0.36 d	0.57 de	1.32 c	0.52 ab
I ₂ N ₃	0.29a	1.46 a	2.78a	4.00a	4.65 c	0.36 d	0.57 de	1.43 bc	0.45 bc
I ₃ N ₀	0.20cd	1.08ef	2.15d	2.80f	3.55 l	0.45 b	0.65 b	1.73 a	0.49 abc
I ₃ N ₁	0.25ab	1.24c	2.58b	3.73b	4.56 e	0.37 d	0.59 de	1.45 bc	0.44 bc
I ₃ N ₂	0.29a	1.46a	2.76a	3.95a	4.80 b	0.36 d	0.57 de	1.42 bc	0.46 bc
I ₃ N ₃	0.29a	1.46a	2.78a	4.00a	4.86 a	0.36 d	0.57 de	1.31 c	0.57 a
LS	8.6	7.33	9.13	11.35	8.45	0.01	0.01	0.05	0.05
CV (%)	0.01	0.01	0.01	0.01	0.01	6.55	6.34	8.9	16.25

[†] In a column the figures bearing same letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT [‡] LS = Level of significance [§] CV = Co-efficient of variation

3.3 Interaction effect on physiological parameters

The differential effects of one factor on another are called interaction. The interaction effect of irrigation and nitrogen on TDM, CGR and LAI was significant. The significant interaction indicates that the factors are not independent. With a few exceptions three irrigations with three splits of nitrogen ($I_3 \times N_3$) treatment combination gave the highest TDM, CGR and LAI and the lowest values were obtained in no irrigation with no nitrogen application ($I_0 \times N_0$) treatment combination at all sampling dates. NAR varied significantly due to interaction of irrigation and nitrogen during 20-35, 35-50, 50-65 and 65-80 DAS. With some exceptions no irrigation with no nitrogen application ($I_0 \times N_0$) treatment combination gave highest NAR (Table 1, Table 2).

3.4 Effect of irrigation on yield parameters

Grain and straw yields differed significantly due to irrigation levels. Grain yield is associated with number of effective tillers plant⁻¹, number of fertile spikelets spike⁻¹, number of grains spike⁻¹ and 1000-grain weight. Irrigation increases the number of effective tillers plant⁻¹, number fertile spikelets spike⁻¹, number of grains spike⁻¹ and 1000-grain weight which ultimately led to increase grain yield. The highest grain and straw yields (4.23 and 5.48 t ha⁻¹) were recorded in three irrigations and the lowest (3.32 and 4.18 t ha⁻¹) were in control (Table 3). Grain yield increased with the increase of irrigation frequencies. Increase the number of irrigation may increase spikelet fertility and decrease sterility resulted higher grain yield. The number of sterile spikelet decreased due to decrease in abortion of grain which was mainly due to more availability of moisture (Pratibha et al., 1994). Result showed that irrigation increases the straw yield. Similar result was observed by Rahman et al. (2006). Water availability increase cell division, elongation and enlargement that might have ultimately led to increase in straw yield. This result is in accordance with the findings of Choudhury et al. (2013). The lowest grain and straw yields (3.32 and 4.18 t ha⁻¹) were found in control treatment.

3.5 Effect of nitrogen on yield parameters

Number of effective tillers plant⁻¹, number of fertile spikelets spike⁻¹, number of grains spike⁻¹ and 1000-grain weight are important yield contributing characters of wheat. Nitrogen increases the number of effective tillers plant⁻¹, number fertile spikelets spike⁻¹, number of grains spike⁻¹ and 1000-grain weight which ultimately led to increase grain yield. Result showed that nitrogen levels had signif-

icant effect on grain and straw yields. The highest grain and straw yields (4.30 and 5.53 t ha⁻¹) were observed in three splits of nitrogen and lowest (3.17 and 4.06 t ha⁻¹) were found in control (Table 4). Grain and Straw yields increased with the increase of split of nitrogen application. This might be due to the steady availability of nitrogen during growth period. This result is partially supported reported by Haque et al. (2012) and Shajaripour and Majaddam (2015). In case of grain yield three splits of nitrogen was statistically identical with two splits of nitrogen.

3.6 Interaction effect on yield parameters

Grain yield varied significantly due to the interaction of irrigation and nitrogen but straw yield was not varied significantly. The highest grain yield was recorded in three irrigations with three splits of nitrogen ($I_3 \times N_3$) treatment combination which was statistically identical with three irrigations and two splits of nitrogen ($I_3 \times N_2$) treatment combination. The lowest grain yield was found in no irrigation with no nitrogen application ($I_0 \times N_0$) treatment combination (Table 5).

3.7 Effect of irrigation on seed quality

Germination (%), vigour index, nitrogen content (%) and protein content (%) of seed were significantly influenced due to irrigation. The highest germination% (91.45) and vigour index (40.54) of seed were observed in three irrigations treatment and lowest were (81.37 and 32.72) in control (Table 3). Germination% of seed ranges from 91.45~81.37, the rest of the seeds are failed to germinate that is these seeds may be non viable or dormant or dead. Availability of soil moisture during growth period has a substantial effect on grain nitrogen content (%) and protein content (%). The highest nitrogen content (2.17%) and protein content (12.69%) in grain was found in three irrigations. The grain protein and nitrogen content (%) progressively increased with the increase of irrigation frequencies. This might be due to availability of moisture during growth period which helps to uptake nutrient that might have ultimately led to increase grain quality (Table 3). This result is in agreement with the findings of Rahman (2007) and Ray et al. (2015).

3.8 Effect of nitrogen on seed quality

All the above parameters were varied significantly due to nitrogen splits. Two and three splits of nitrogen showed higher germination (90.75%), nitrogen content (2.19%) and protein content (12.80%) of seed. Grain nitrogen and protein content (%) increased with increase of splits of nitrogen application (Table 4). This might be due to maximum uptake of nitrogen

Table 3. Effect of irrigation on yield and seed quality of wheat

Irrigation	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Germination (%)	Vigour index	Grain N (%)	Grain protein (%)
I ₀	3.32 c	4.18 d	81.37d	32.72d	1.97d	11.52d
I ₁	3.74 b	4.80 c	86.10c	36.49c	2.07c	12.06c
I ₂	4.09 a	5.26 b	90.08b	39.44b	2.14b	12.51b
I ₃	4.23 a	5.48 a	91.45a	40.54a	2.17a	12.69a
LS	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.26	6.46	2.35	1.93	0.85	2.54

[†] In a column the figures bearing same letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT [‡] LS = Level of significance

[§] CV = Co-efficient of variation

Table 4. Effect of nitrogen on yield and seed quality of wheat

Nitrogen	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Germination (%)	Vigour index	Grain N (%)	Grain protein (%)
N ₀	3.17d	4.06c	80.27c	32.81d	1.94c	11.35d
N ₁	3.72c	4.70b	87.45b	36.77c	2.05b	11.97c
N ₂	4.19b	5.43a	90.43a	39.01b	2.17a	12.65a
N ₃	4.30a	5.53a	90.75a	40.60a	2.19a	12.80a
LS	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.26	6.46	2.35	1.93	0.85	2.54

[†] In a column the figures bearing same letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT [‡] LS = Level of significance

[§] CV = Co-efficient of variation

Table 5. Interaction effect of irrigation and nitrogen on yield and seed quality of wheat

I×N	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Germination (%)	Vigour index	Grain N (%)	Grain protein (%)
I ₀ N ₀	2.63k	3.31i	74.33K	28.18 o	1.84	10.74 o
I ₀ N ₁	3.21i	3.97h	81.50 I	32.12m	1.93	11.30m
I ₀ N ₂	3.66fg	4.67f	84.75G	34.59 l	2.04	11.93j
I ₀ N ₃	3.77f	4.77f	84.91g	36.01j	2.07	12.10i
I ₁ N ₀	3.08j	3.93h	79.16j	31.98n	1.92	11.23m
I ₁ N ₁	3.58g	4.59fg	86.08f	36.01j	2.02	11.82k
I ₁ N ₂	4.08de	5.29d	89.25e	38.17h	2.17	12.52f
I ₁ N ₃	4.20d	5.38d	89.91d	39.80f	2.17	12.68e
I ₂ N ₀	3.42h	4.41g	83.16h	34.96k	1.99	11.62l
I ₂ N ₁	3.99e	4.99e	90.25d	38.89g	2.11	12.31g
I ₂ N ₂	4.43c	5.77c	93.41b	41.09d	2.22	12.98d
I ₂ N ₃	4.54bc	5.87bc	93.50b	42.81b	2.25	13.12c
I ₃ N ₀	3.56g	4.61f	84.83g	36.14i	2.02	11.82k
I ₃ N ₁	4.11de	5.28d	92.00c	40.06e	2.13	12.47g
I ₃ N ₂	4.57b	5.98ab	94.00a	42.20c	2.26	13.19b
I ₃ N ₃	4.68a	6.08a	94.66a	43.78a	2.28	13.30a
LS	0.01	0.01	0.01	0.01	NS	0.01
CV(%)	6.26	6.46	2.35	1.93	0.85	2.54

[†] In a column the figures bearing same letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT [‡] LS = Level of significance

[§] CV = Co-efficient of variation

and its use efficiency. Nitrogen had a regulatory effect on grain protein content and accumulation. Similar result was reported by Rahman (2007) and Ali (2011).

3.9 Interaction effect on seed quality

The interaction effect of irrigation and nitrogen was found in to be significant in respect of germination(%), vigour index, nitrogen content (%) and protein content (%) of seed. With a few exceptions, the treatment combinations of $I_3 \times N_3$ showed the higher values (Table 5).

4 Conclusion

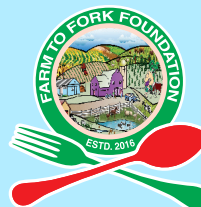
From the results of the present study the following conclusions can be drawn: (i) Irrigation applied three times at Crown root initiation, stem elongation and flowering stages, showed better performance on growth, yield and seed quality of wheat. Nitrogen applied in three equal splits at basal, crown root initiation and stem elongation stages produced higher grain and straw yields and also better for seed quality and wheat growth. (ii) For improvement and sustenance of wheat productivity, agronomic practices like irrigation and nitrogen split application should be practiced properly.

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