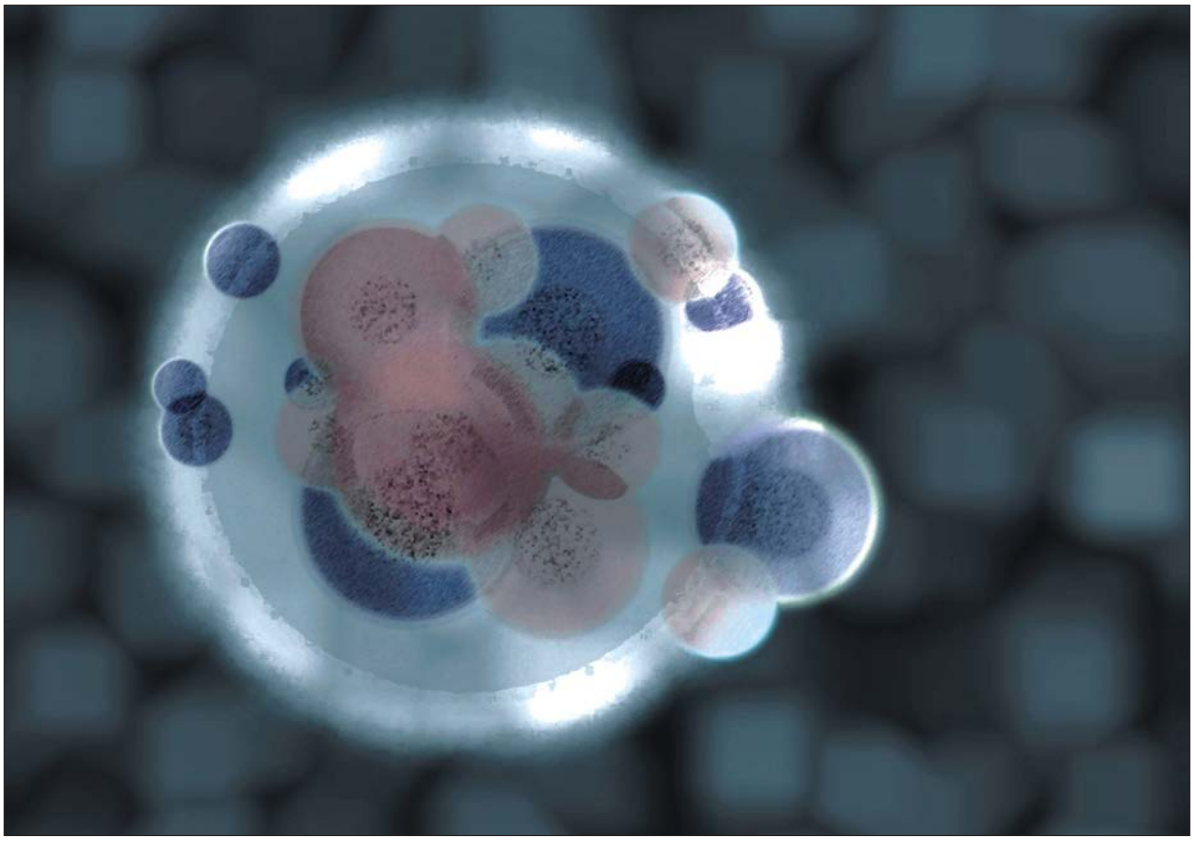

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# Research Article
# Phenology, Growth, Yield and Protein Content of Wheat as Influenced by Foliar Application of Nitrogen

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## Abstract

**Background and Objective:** Foliar application of nitrogen (N) is an important technique in overcoming N deficit from different stresses particularly drought of wheat crop. However, the wheat crop response to foliar N are inconstant and there is limited understanding of its effects in Bangladesh. The aim of this study was to evaluate the effect of foliar spray of N on phenology, growth, yield and protein content of late sown wheat in rice-based cropping was pattern in Bangladesh. **Materials and Methods:** There were 10 treatments such as recommended fertilizer dose in soil (RD) with Foliar Spray (FS) of N at 40 Days After Emergence (DAE) ($T_1$), RD with FS of N at booting stage ($T_2$), RD with FS of N at heading stage ($T_3$), RD with FS of N at milking stage ($T_4$), RD with FS of N at 40 DAE and booting stage ($T_5$), RD with FS of N at 40 DAE+heading stage and milking stage ($T_6$), RD with FS of N at 40 DAE+booting stage and milking stage ($T_7$), RD ($T_8$, control treatment), half RD of N ($T_9$) and half RD of N with FS of N at booting stage ($T_{10}$). The experiment was laid out in a randomized block design with three replications. Three percent urea was used for foliar spray. Data were analyzed using Analysis of variance ANOVA and mean separation was done by LSD at $p = 0.05$. **Results:** The highest dry matter (1811.41 g $m^{-2}$), grain yield (4.02 t $ha^{-1}$) and protein content (12.37%) were obtained from $T_7$ treatment. Gross return, gross margin and BCR were also higher in $T_7$ than any other treatments and the lowest BCR (2.43) was calculated in half of recommended fertilizer dose of N ($T_9$). **Conclusion:** Recommended fertilizer dose with foliar spray of N at 40 DAE+booting stage and milking stage delayed the senescence which lead to lengthen the duration of reproductive phase, increasing the grain yield (28.84%) as well as protein content (29%) compare to half of recommended fertilizer dose of N.

Key words: Foliar application, wheat, rice based cropping system, high ganges flood plain, crop growth and yield, benefit cost ratio

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Wheat is temperature sensitive and the second most important cereal crop after rice[1]. The crop is grown in an area of 436.8 million ha with an annual production of 1347.9 million Mt in Bangladesh[2]. Generally wheat is sown after rice and utilizes residual soil water of the rice field in Bangladesh. Farmers of few areas in Bangladesh cultivate long duration rice cultivar in the wet season which hampers the timely planting of wheat. Wheat establishment in rice-based cropping system depends on residual moisture in the soil profile after rice cultivation[3]. Late sown wheat experiences high temperature stress (above 30°C) at grain filling stage causing forced maturity and lower yield due to short spell of winter in Bangladesh[4,5].

Nitrogen is one of the major yield limiting nutrients and play a vital role to improve the growth and yield of wheat. This element is frequently deficient in agricultural soils of Bangladesh[6]. Foliar application of nitrogen could an important practice in the production of wheat. The combination of soil and foliar nitrogen is efficient use of N to fulfill the crop requirement and reduces N losses[7]. Moreover, foliar application of urea [2% spray of urea (at two leaves, booting and tillering stage) or 3% spray of urea (at tillering and booting stage)] along with soil application is economical and can compensate the yield loss but the lower concentration of urea (1% six sprays) is not much effective of wheat[8]. The grain yield is increased by 32% when 4% urea solution is applied as foliar at tillering, stem elongation and booting stage but further increase in the concentrations of urea spray is not found to be useful and economical. It declines the grain yield by 25% or even more probably due to its toxicity[9]. Besides, greater grain yield of wheat was obtained at pre-anthesis foliar feeding with urea (16 kg N $ha^{-1}$) as compared with later applications due to nitrogen use efficiency[10]. Gul *et al.*[11] and Saeed *et al.*[12] also supported the same theory that foliar application of urea at tillering, stem elongation and booting stage increase significantly plant height, spike length, number of grains per spike, 100 grain weight and grain yield. Likewise, foliar application of nitrogen increases juvenility of crop plant and delayed anthesis and physiological maturity[13].

However, the researches on foliar application of N in wheat are limited in Bangladesh. Therefore, this study has been undertaken to evaluate the effect of foliar N on the phenology, growth, yield and protein content of late sown wheat in Bangladesh.

## MATERIALS AND METHODS

The experiment was carried out during the rabi (Winter) season for two consecutive years of 2012-13 and 2013-14 at Regional Agricultural Research Station, BARI, Ishurdi, Pabna. Geographically, the experimental area is located at 24.03°N latitude and 89.05°E longitude at the elevation of above 16 m from the sea level. The climate of the experimental site is subtropical in nature and it belongs to the agro-ecological zone-11 (high ganges flood plain) in Bangladesh. The land was medium high and the soil was clay loam in texture. Soil chemical properties of experimental site are given in Table 1.

In case of weather condition, the initial average relative humidity was 73% in the entire wheat growing period in 2012-13. The maximum relative humidity (95%) was measured in 5th week (December) when the average weekly rainfall was 2.14 mm. Then, there was downward trend of humidity up to maturity with litle fluctuation. Precipitation was recorded very few (2.54 mm) in the whole growing period. At first week, the average minimum and maximum temperature was recorded 18 and 24°C, respectively meanwhile the lowest average minimum (7°C) and maximum temperature (21°C) was observed in 8th week (Fig. 1). In second year of 2013-14 cropping season, the crop received 10.32 mm rainfall during grain filling stage. The lowest average weekly minimum (11°C) and maximum (16°C) temperatures were found in the 6th week (end of December). The crop experienced more terminal heat stress at grain filling to mature stage in the first year than second year (February-March). The relative humidity was lower in the first year than second year (Fig. 1, 2).

The experiment was laid out in a randomized complete block design with three replications. The unit plot size was 4×5 m. Ten treatments *viz*., recommended fertilizer dose applied in soil (RD) with Foliar Spray (FS) of N at 40 DAE ($T_1$), RD with FS of N at booting stage ($T_2$), RD with FS of N at heading stage ($T_3$), RD with FS of N at milking stage ($T_4$), RD with FS of N at 40 DAE+booting stage ($T_5$), RD with FS of

Table 1: Initial soil chemical properties of experimental site at Ishurdi, Pabna, Bangladesh

| Cropping seasons | N (%) | P (ppm) | K (me 100 $g^{-1}$) | S (ppm) | Zn (ppm) | pH | OM (%) |
|---|---|---|---|---|---|---|---|
| 2012-13 | 0.02 | 9.5 | 0.36 | 2.7 | 1.16 | 8.6 | 0.34 |
| 2013-14 | 0.04 | 12.9 | 0.42 | 7.6 | 2.57 | 8.5 | 0.73 |

N: Nitrogen, P: Phosphorus, K: Potasium, S: Sulphur, Zn: Zinc, OM: Organic matter

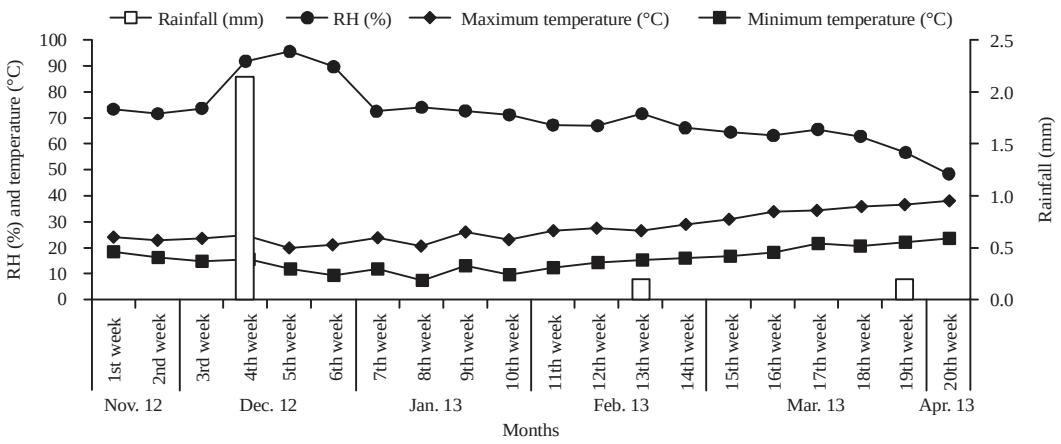


Fig. 1: Weekly average maximum and minimum air temperature, rainfall and Relative Humidity (RH) at cropping period 2012-13 at Ishurdi, Pabna, Bangladesh (Sorce: BSRI)

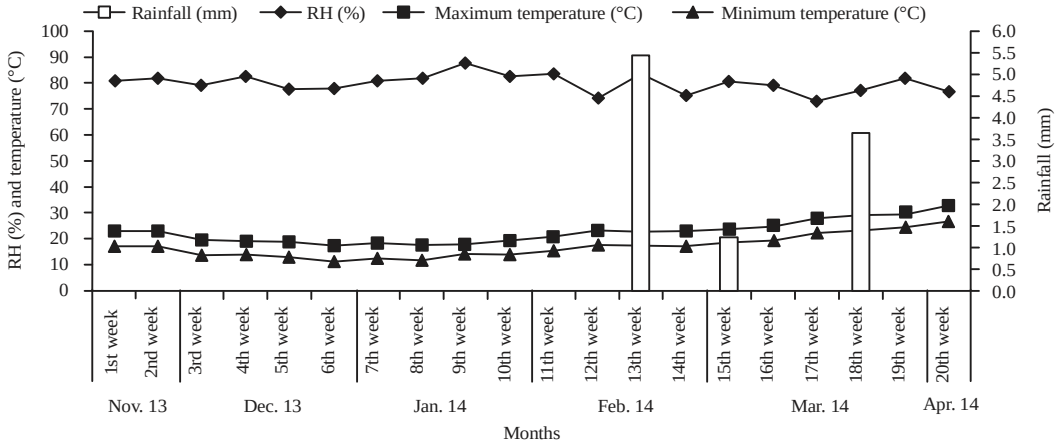


Fig. 2: Weekly average maximum and minimum air temperature, rainfall and Relative Humidity (RH) at cropping period 2013-14 at Ishurdi, Pabna, Bangladesh (Source: BSRI, Ishurdi)

N at 40 DAE+heading stage and milking stage ($T_6$), RD with FS of N at 40 DAE+booting stage and milking stage ($T_7$), RD ($T_8$, control treatment), half RD of N ($T_9$) and half RD of N with FS of N at booting stage ($T_{10}$) were included. A wheat variety, BARI Gom-26 was sown continuously in 20 cm apart line at the rate of 120 kg $ha^{-1}$ on 20th December both in 2012-13 and 2013-14 cropping seasons. Recommended fertilizer dose was at 120, 30, 90, 15, 2.6 and 1.0 kg $ha^{-1}$ of N, P, K, S, Zn and B, respectively[4]. Two-thirds of N and a full amount of the other fertilizers were applied as a basal during final land preparation in the form of urea, triple superphosphate, muriate of potash, gypsum, zinc sulphate and boric acid, respectively. The remaining one third of N was top dressed immediately after the first irrigation (20 days after sowing). Additional 3% urea was applied as foliar and this concentration was prepared by the addition of urea fertilizer (15 kg $ha^{-1}$) in water (30 g urea 1000 $mL^{-1}$ water or w $v^{-1}$) without adjuvant. The crop was irrigated uniformly thrice at 20, 45 and 65 Days After Sowing (DAS). Weeds were controlled by hand weeding once at 30 DAS. The crop was harvested on 2nd April 2013 and 7th April 2014 in 2012-13 and 2013-14 cropping seasons, respectively. The yield contributing and yield data were recorded from each plot at maturity and grain growth rate was measured after anthesis. Plant samples (10 plants) were collected randomly from each treatment. Plant parts were dried at 70°C for 72 h in oven until constant weight to determine the dry matter. The total nitrogen of the wheat grain sample was determined by micro-Kjeldahl method as described by Jackson[14] and then the percentage of protein in grain was calculated by multiplying the standard factor.

Crop Growth Rate (CGR) was calculated as follows proposed by Gul *et al.*[15]:

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{GA} (g\ m^{-2}\ day^{-1}) \quad (1)$$

Where:

$W_1$ = Initial weight
$W_2$ = Final weight
$T_1$ = Time at the start of period
$T_2$ = Time at the end of period
GA = Ground area

Benefit cost analysis was performed considering the prevailing price of fertilizers and wheat at harvesting period in the local market. Benefit Cost Ratio (BCR) was calculated by following the Eq. 2[16]:

$$BCR = \frac{\text{Gross return (Tk.)}}{\text{Variable cost (Tk.)}} \quad (2)$$

**Statistical analysis:** Collected data were analyzed according to Gomez and Gomez[17], using the computer MSTAT.C statistical analysis package by Russel[18]. Analysis of variance test, RCBD, (one-way ANOVA)[17] following by Least Significance Difference (LSD) test was used to determine the difference among the treatment means ($p<0.05$).

## RESULTS AND DISCUSSION

### Growth parameters

**Plant height:** The plant height was significantly affected by foliar spray of N (Table 2). Recommended fertilizer dose (RD) with FS of N at 40 DAE+booting stage and milking stage ($T_7$) showed the longest plant height and the smallest plant height was observed in the half recommended fertilizer dose of N ($T_9$) at all of the growth stages (40, 60 and 80 DAE). At maturity stage, the highest plant height (104 cm) was recorded from $T_7$ which was 6.41% higher than the plant height obtained from $T_9$. This variation might be caused due to half recommended dose of fertilizer. This result was similar with the findings of Khan *et al.*[9]. However, Saleem *et al.*[8] observed that plant height was statistically similar in application of all urea in soil as basal and urea soil as basal at sowing with 2 sprays of 2% urea at tillering and booting stage.

**Total dry matter:** The total dry matters at 20, 40, 60 and 80 DAE and at maturity are presented in Table 3. Significant variation in total dry matter was found among treatments. RD with FS of N at 40 DAE+booting stage and milking stage ($T_7$) gave the highest dry matter (1811g $m^{-2}$) accumulation followed by RD with FS of N at 40 DAE+heading stage and milking stage ($T_6$) and the lowest dry matter (1397 g $m^{-2}$) accumulation was calculated at half RD of N ($T_9$). Results showed that foliar spray of N accumulates more photosynthate to the plant contributing increased dry matter. With the advancement of growth, the dry matter production showed an increasing trend with the increases of foliar spray. The foliar spray of urea had non-significant effect on plant dry weight at tillering stage but varied at heading stage[19].

**Crop Growth Rate (CGR):** A significant variation in CGR ($p \leq 0.05$) was found among the treatments at different growing stages. The crop growth rate was slower in early vegetative phase of the crop; there after it increased sharply up to 80 DAE in all the treatments and it declined at maturity caused by mutual shading and leaf senescence which might reduce the photosynthetic efficiency and ultimately reduced the dry matter accumulation rate. The highest CGR (20.11 g $m^{-2}$ $day^{-1}$) was calculated from RD with FS of N at 40 DAE+booting stage and milking stage ($T_7$) and the lowest CGR (13.58 g $m^{-2}$ $day^{-1}$) was obtained in half RD of N ($T_9$) at 80 DAE (Fig. 3). The half recommended fertilizer dose of N decreased the crop growth rate compared to

Table 2: Plant height (cm) of wheat at different intervals from 20 days after emergence to maturity as affected by foliar spray of N at Ishurdi, Pabna, Bangladesh

| Treatments | 20 DAE | 40 DAE | 60 DAE | 80 DAE | At maturity |
|---|---|---|---|---|---|
| $T_1$ | 27.05 | 49.77 | 85.20 | 93.28 | 102.61 |
| $T_2$ | 26.67 | 51.90 | 85.85 | 92.94 | 102.50 |
| $T_3$ | 26.44 | 52.96 | 86.11 | 93.24 | 102.55 |
| $T_4$ | 27.36 | 52.82 | 86.66 | 93.93 | 103.21 |
| $T_5$ | 27.19 | 53.29 | 85.18 | 94.21 | 103.77 |
| $T_6$ | 27.17 | 51.82 | 87.80 | 94.54 | 102.27 |
| $T_7$ | 28.05 | 53.46 | 88.04 | 96.03 | 104.11 |
| $T_8$ | 26.94 | 52.57 | 85.94 | 93.46 | 102.22 |
| $T_9$ | 25.50 | 46.61 | 82.03 | 85.21 | 97.83 |
| $T_{10}$ | 26.22 | 47.86 | 83.04 | 87.00 | 99.49 |
| $LSD_{(0.05)}$ | NS | 2.30 | 3.140 | 2.98 | 2.41 |
| CV (%) | 4.64 | 3.83 | 3.13 | 2.76 | 2.02 |

NS: Non-significant, DAE: Days after emergence

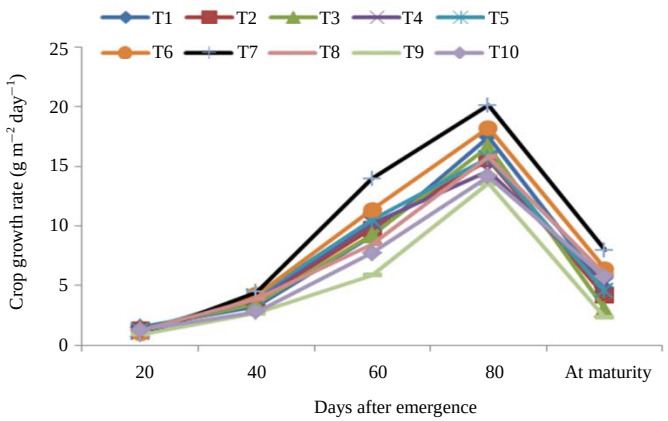


Fig. 3: Crop growth rate of wheat at different intervals from 20 days after emergence to maturity as affected by foliar spray of N at Ishurdi, Pabna, Bangladesh

Table 3: Dry matter (g) accumulation in wheat at different intervals from 20 days after emergence to maturity as affected by foliar spray of N at Ishurdi, Pabna, Bangladesh

| Treatments | 20 DAE | 40 DAE | 60 DAE | 80 DAE | At maturity |
|---|---|---|---|---|---|
| $T_1$ | 40 | 223 | 727 | 1065 | 1500 |
| $T_2$ | 43 | 240 | 720 | 1045 | 1555 |
| $T_3$ | 44 | 225 | 766 | 1105 | 1592 |
| $T_4$ | 37 | 223 | 761 | 1100 | 1491 |
| $T_5$ | 42 | 232 | 789 | 1110 | 1526 |
| $T_6$ | 40 | 262 | 745 | 1129 | 1750 |
| $T_7$ | 50 | 281 | 815 | 1168 | 1811 |
| $T_8$ | 35 | 221 | 681 | 1009 | 1478 |
| $T_9$ | 29 | 187 | 572 | 938 | 1397 |
| $T_{10}$ | 32 | 198 | 709 | 1006 | 1463 |
| $LSD_{(0.05)}$ | NS | 4.4 | 78.8 | 90 | 117.9 |
| CV (%) | 9.73 | 10.1 | 9.2 | 7.1 | 6.4 |

$T_1$: Recommended fertilizer dose (RD) with foliar spray (FS) of N at 40 DAE, $T_2$: RD with FS of N at booting stage, $T_3$: RD with FS of N at heading stage, $T_4$: RD with FS of N at milking stage, $T_5$: RD with FS of N at 40 DAE+booting stage, $T_6$: RD with FS of N at 40 DAE+heading stage+milking stage, $T_7$: RD with FS of N at 40 DAE+booting stage+milking stage, $T_8$: RD (Control), $T_9$: Half RD of N, $T_{10}$: Half RD of N with FS of N at booting stage, NS: Non-significant, DAE: Days after emergence

recommended fertilizer dose. The results are similar with the findings of Hossain *et al.*[20].

**Phenology:** Phenological parameter like at booting stage, spike emergence, heading stage, physiological maturity and grain filling duration are presented in Table 5. The RD with FS of N at 40 DAE+booting stage and milking stage ($T_7$) lengthened the duration than no foliar spray of N treatments. The treatment $T_7$ was showed 104 days growth duration whereas $T_9$ took 100 days of growth duration. Foliar application of nitrogen delayed senescence that contributed to more photosynthetic activity reducing the force maturation lead to increased reproductive phase[21]. Mian *et al.*[22] reported that 15 November sowing showed longer crop growth duration and it decreased chronologically with the shortest in 30 December sowing.

**Grain growth:** Grain growth rate started from anthesis to maturity is presented in Table 4. Grain growth showed significant difference ($p \leq 0.05$) among the treatments. There was an upward trend of single grain weight of all treatments at 5 days after anthesis to maturity. Foliar spray of N increased the grain dry weight. The highest grain dry weight (46.73 mg gain$^{-1}$) was obtain from RD with FS of N at 40 DAE+booting stage and milking stage ($T_7$) followed by RD with FS of N at 40 DAE, heading stage and milking stage ($T_6$) (43.49 mg gain$^{-1}$) and the lowest grain dry weight (40.26 mg gain$^{-1}$) was amounted from half recommended dose of N ($T_9$). Foliar application of N increased the grain growth period increasing grain weight due to indirect effect on higher post anthesis N uptake[7]. Delay sowing causes shorter grain growth duration resulted in lower grain weight[22].

**Yield, yield components and protein content (%)**

**Spikes number:** Number of spikes per meter square was significantly ($p \leq 0.05$) affected by different treatments (Table 6). The highest number of spikes per meter square (335)

Table 4: Grain growth (mg per grain) of wheat at different intervals from 5 days after anthesis to maturity as affected by foliar spray of N at Ishurdi, Pabna, Bangladesh

| Treatments | 68 DAS | 73 DAS | 78 DAS | 83 DAS | 88 DAS | 94 DAS | At harvest |
|---|---|---|---|---|---|---|---|
| $T_1$ | 3.82 | 9.38 | 21.59 | 31.20 | 38.85 | 40.54 | 42.37 |
| $T_2$ | 4.34 | 9.83 | 22.70 | 31.51 | 38.59 | 39.88 | 42.48 |
| $T_3$ | 3.86 | 8.82 | 21.70 | 31.68 | 38.74 | 40.28 | 42.22 |
| $T_4$ | 4.13 | 9.41 | 21.59 | 31.85 | 39.08 | 39.82 | 43.49 |
| $T_5$ | 4.12 | 9.43 | 22.74 | 31.54 | 39.29 | 40.04 | 44.03 |
| $T_6$ | 4.34 | 9.58 | 23.70 | 32.77 | 39.54 | 41.74 | 44.58 |
| $T_7$ | 4.65 | 11.30 | 24.58 | 33.50 | 40.26 | 42.32 | 46.73 |
| $T_8$ | 3.38 | 9.26 | 21.61 | 30.05 | 38.27 | 39.43 | 41.56 |
| $T_9$ | 2.52 | 7.57 | 20.13 | 28.98 | 35.72 | 38.03 | 40.26 |
| $T_{10}$ | 3.44 | 8.60 | 20.41 | 28.82 | 37.31 | 38.82 | 40.68 |
| $LSD_{(0.05)}$ | 0.94 | 0.98 | 2.048 | 2.60 | 2.79 | 0.96 | 2.23 |
| CV (%) | 10.72 | 9.01 | 7.92 | 7.12 | 6.19 | 4.58 | 4.45 |

Table 5: Duration required for phenological development in wheat as influenced by foliar spray at Ishurdi, Pabna, Bangladesh

| | Days | | | | | |
|---|---|---|---|---|---|---|
| Treatments | Booting stage | Heading stage | Anthesis | Milking stage | Physiological maturity | Grain filling duration |
| $T_1$ | 62 | 65 | 68 | 79 | 100 | 35 |
| $T_2$ | 60 | 64 | 68 | 79 | 101 | 37 |
| $T_3$ | 60 | 63 | 67 | 79 | 101 | 38 |
| $T_4$ | 60 | 63 | 67 | 79 | 102 | 36 |
| $T_5$ | 62 | 66 | 69 | 80 | 103 | 37 |
| $T_6$ | 63 | 64 | 68 | 80 | 103 | 39 |
| $T_7$ | 63 | 66 | 69 | 80 | 104 | 39 |
| $T_8$ | 60 | 63 | 67 | 78 | 100 | 37 |
| $T_9$ | 60 | 63 | 67 | 78 | 100 | 37 |
| $T_{10}$ | 60 | 64 | 68 | 79 | 100 | 37 |
| Mean | 61 | 64 | 68 | 79 | 101 | 37 |
| Standard deviation | 1.13 | 1.03 | 0.88 | 0.88 | 1.37 | 1.22 |

$T_1$: Recommended fertilizer dose (RD) with foliar spray (FS) of N at 40 DAE, $T_2$: RD with FS of N at booting stage, $T_3$: RD with FS of N at heading stage, $T_4$: RD with FS of N at milking stage, $T_5$: RD with FS of N at 40 DAE+booting stage, $T_6$: RD with FS of N at 40 DAE+heading stage+milking stage, $T_7$: RD with FS of N at 40 DAE+booting stage+milking stage, $T_8$: RD (Control), $T_9$: Half RD of N, $T_{10}$: Half RD of N with FS of N at booting stage

Table 6: Yield and yield contributing characters of wheat as affected by N foliar application (pooled average of two years) at Ishurdi, Pabna, Bangladesh

| Treatments | Spike per meter square (No.) | Spike length (cm) | Grains per spike (No.) | 1000 grain weight (g) | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|
| $T_1$ | 334 | 10.71 | 56 | 40.36 | 3.79 | 6.84 |
| $T_2$ | 307 | 10.49 | 55 | 40.43 | 3.88 | 6.96 |
| $T_3$ | 322 | 10.67 | 56 | 40.63 | 3.86 | 6.90 |
| $T_4$ | 315 | 10.93 | 55 | 40.63 | 3.74 | 7.14 |
| $T_5$ | 358 | 10.86 | 56 | 40.43 | 3.89 | 7.26 |
| $T_6$ | 331 | 10.90 | 56 | 40.96 | 3.94 | 7.45 |
| $T_7$ | 357 | 11.14 | 57 | 44.63 | 4.02 | 8.19 |
| $T_8$ | 325 | 10.97 | 55 | 40.63 | 3.55 | 6.84 |
| $T_9$ | 294 | 10.31 | 53 | 39.26 | 3.12 | 5.45 |
| $T_{10}$ | 304 | 10.51 | 54 | 39.73 | 3.46 | 6.08 |
| $LSD_{(0.05)}$ | 32 | 0.39 | NS | 2.22 | 0.42 | 0.72 |
| CV (%) | 8 | 3.20 | 5.23 | 4.67 | 9.64 | 8.82 |

NS: Non-significant

was recorded in RD with FS of N at 40 DAE+booting stage and milking stage ($T_7$) and the lowest spikes per meter square (255) was in half recommended dose of N ($T_9$). Though spikes per meter square were influenced by foliar treatments, it was probably due to recommended fertilizer dose and half of recommended fertilizer dose of N. Number of tillers increased with foliar spray of urea over soil application[19].

**Spike length:** Spike length significantly ($p \leq 0.05$) varied among the treatments. The highest spike length (11.33 cm) was calculated in RD with FS of N at booting stage+milking stage ($T_7$) and the lowest spike length (10.22 cm) was observed in half recommended dose of N ($T_9$). Similar results were obtained by Saleem *et al.*[8] who observed that spike length was same in the treatment of application of urea at

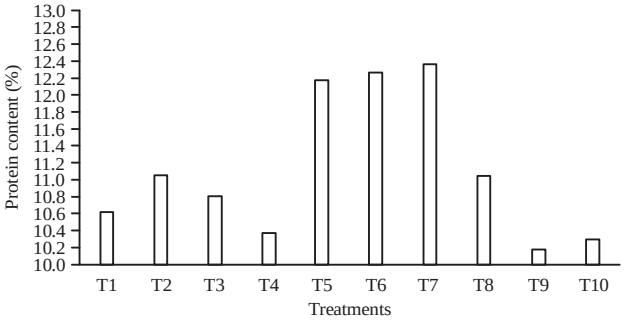


Fig. 4: Protein content of wheat grain as affected by foliar spray of N at Ishurdi, Pabna, Bangladesh

$T_1$: Recommended fertilizer dose (RD) with foliar spray (FS) of N at 40 DAE, $T_2$: RD with FS of N at booting stage, $T_3$: RD with FS of N at heading stage, $T_4$: RD with FS of N at milking stage, $T_5$: RD with FS of N at 40 DAE+booting stage, $T_6$: RD with FS of N at 40 DAE+heading stage and milking stage, $T_7$: RD with FS of N at 40 DAE+booting stage and milking stage, $T_8$: RD (Control), $T_9$: Half RD of N, $T_{10}$: Half RD of N with FS of N at booting stage

sowing with 2 sprays of 2% urea and 2 sprays of 3% urea at tillering and booting stage.

**Number of grains per spike:** There were no significant variations observed among the treatments for the number of grains spike$^{-1}$ (Table 6). The RD with FS of N at 40 DAE+booting stage and milking stage ($T_7$) gave the highest number of grains per spike (56.91) and the lowest number of grains per spike (52.72) was recorded in half of RD of N ($T_9$). This result is conformity with the findings of Amanullah *et al.*[13]. They observed that foliar application of nitrogen increased number of grains per spike and grain weight.

**1000-grain weight:** Significant differences ($p \leq 0.05$) in 1000-grain weight were noted among the treatments. The 1000-grain weight ranged 39.26-44.63 g. The treatment $T_7$ showed significantly higher 3.48 and 13.67% 1000-grain weight than $T_8$ and $T_9$, respectively. These might be due to more accumulation of photo-synthates in grains with increasing application of foliar spray of N at later growth stages of wheat. These results are in line with Khan *et al.*[9] who reported significant increase in thousand grains weight with foliar application of 4% urea solution.

**Grain yield:** The grain yield of wheat varied significantly ($p \leq 0.05$) due to foliar application of different levels of N (Table 6). The highest grain yield (4.02 t ha$^{-1}$) was achieved in RD with FS of N at 40 DAE+booting stage and milking stage ($T_7$) while RD of N was associated with lower grain yield (3.12 t ha$^{-1}$). These were happened due to apply of half of fertilizer dose of N and recommended fertilizer dose. Foliar urea spraying of N on wheat significantly increased 13.23% grain yield over recommended fertilizer dose ($T_8$) and 28.84% compare to half of recommended fertilizer dose of N ($T_9$). Johnson *et al.*[23] showed that foliar application before the booting stage resulted in significantly higher yield.

**Straw yield:** The straw yield of wheat was significantly ($p \leq 0.05$) affected by foliar application of N (Table 2). The highest straw yield (8.19 t ha$^{-1}$) was recorded in $T_7$ and the minimum straw yield (5.45 t ha$^{-1}$) was measured in half of recommended fertilizer dose of N ($T_9$). Ali *et al.*[24] reported that three foliar applications of nutrients resulted in maximum number of spikes per meter square, grains per spike, thousand grains weight and biological yield of wheat.

**Protein content:** Protein content in grain varied among the treatments (Fig. 4). Regarding the grain of wheat, the highest protein content (12.37%) was recorded from $T_7$ which was 19.28 and 21.51% higher than $T_8$ and $T_9$, respectively. The lowest protein content (10.18%) was found in $T_9$. When the supplementary use of nitrogen (N) was used in appropriate time, grain of protein was increased significantly ($p \leq 0.05$)[23]. Saleem *et al.*[8] showed that foliar application of N increased nitrogen concentration in grain as compared to soil application.

**Correlation of plant characters:** Correlation coefficients among various characters are presented in Table 7. Protein content showed significant ($p \leq 0.05$) positive correlation with almost all other characters except grain yield ($r = 0.54$). Mahmood *et al.*[25] reported that protein content are positively associated with spike length, grains per spike and negatively correlated with plant height and grain yield. Besides, plant height showed a positive significant relationship with individual spike per meter square, spike length, grains per spike, 1000-grain weight and grain yield except dry matter.

Table 7: Correlation coefficient among the yield contributing characters of wheat as affected by foliar application of N at Ishurdi, Pabna, Bangladesh

| Parameters | Dry matter | Spike $m^{-2}$ | Spike length | Grains per spike | 1000 grain weight | Grain yield | Protein content |
|---|---|---|---|---|---|---|---|
| Plant height | 0.57 | 0.79** | 0.82** | 0.89** | 0.63* | 0.87** | 0.67* |
| Dry matter | | 0.61 | 0.64* | 0.78** | 0.84** | 0.66* | 0.82** |
| Spike per meter square | | | 0.78** | 0.86** | 0.67* | 0.54 | 0.78** |
| Spike length | | | | 0.73* | 0.74** | 0.75** | 0.65* |
| Grains per spike | | | | | 0.74** | 0.76* | 0.77** |
| 1000-grain weight | | | | | | 0.64* | 0.67* |
| Grain yield | | | | | | | 0.54 |
| Protein content | | | | | | | 1 |

*Significant at $p \leq 0.05$, **Significant at $p \leq 0.01$

Table 8: Cost benefit analysis of wheat under different treatments at Ishurdi, Pabna, Bangladesh

| Treatments | Gross return (Tk. $ha^{-1}$) | Cost (Tk. $ha^{-1}$) | Additional cost (urea+labour) | Total variable cost (Tk. $ha^{-1}$) | Gross margin (Tk. $ha^{-1}$) | Benefit cost ratio |
|---|---|---|---|---|---|---|
| $T_1$ | 139490 | 49238 | 940 | 50178 | 81852 | 2.78 |
| $T_2$ | 142760 | 49238 | 940 | 50178 | 92702 | 2.85 |
| $T_3$ | 142000 | 49238 | 940 | 50178 | 95562 | 2.83 |
| $T_4$ | 138040 | 49238 | 940 | 50178 | 93702 | 2.75 |
| $T_5$ | 143410 | 49238 | 1880 | 51118 | 88622 | 2.81 |
| $T_6$ | 145350 | 49238 | 2820 | 52058 | 90862 | 2.79 |
| $T_7$ | 148890 | 49238 | 2820 | 52058 | 99652 | 2.86 |
| $T_8$ | 131090 | 49238 | 0 | 49238 | 94172 | 2.66 |
| $T_9$ | 114650 | 47155 | 0 | 47155 | 67495 | 2.43 |
| $T_{10}$ | 127180 | 47155 | 940 | 48095 | 80025 | 2.64 |

Price; Wheat: 35 Tk. $kg^{-1}$, Seed: 40 Tk. $kg^{-1}$, Urea: Tk. 16.00 $kg^{-1}$, TSP: Tk. 22.00 $kg^{-1}$, MOP: Tk. 15.00 $kg^{-1}$, Labour: Tk. 350.00 per 8 h $head^{-1}$, Straw: 1 Tk. $kg^{-1}$, additional input: 15 kg $ha^{-1}$ urea each time and two labour per foliar spray. $T_1$: Recommended fertilizer dose (RD) with foliar spray (FS) of N at 40 DAE, $T_2$: RD with FS of N at booting stage, $T_3$: RD with FS of N at heading stage, $T_4$: RD with FS of N at milking stage, $T_5$: RD with FS of N at 40 DAE+booting stage, $T_6$: RD with FS of N at 40 DAE+heading stage and milking stage, $T_7$: RD with FS of N at 40 DAE+booting stage and milking stage, $T_8$: RD (Control), $T_9$: Half RD of N, $T_{10}$: Half RD of N with FS of N at booting stage

Similar findings are reported by Khan *et al.*[26] in wheat. Grain yield also exhibited significant positive association with all other parameters barring spike per meter square. In addition, the 1000-grain weight showed a significant positive correlation with all the characters. The spike per meter square was positively correlated with all other parameters excluding dry matter. Dry matter showed positive significant correlation with most of the traits without plant height. Therefore, the grains per spike and spike length were found significant and positively correlated with all other parameters to improve the yield. Grain yield showed significant positive correlation with number of grain per spike, number of spikes per meter square and 1000-grain weight[27].

**Benefit cost ratio:** Two years pooled wheat grain yield and straw yield were used for calculating the cost benefit ratio (Table 8). The highest gross return (Tk. 148890.00 or \$1853 $ha^{-1}$), gross margin (Tk. 99652.00 or \$1240.23 $ha^{-1}$) and BCR (2.86) were obtained from $T_7$ and the lowest gross return (Tk. 114650.00 or \$1426.89 $ha^{-1}$) gross margin (Tk. 67495.00 or \$841.85 $ha^{-1}$) and BCR (2.43) were got from half of recommended fertilizer dose of N ($T_9$). The integration of additional urea and labour cost for foliar spray were increased the total cost of production. For this reason the variation of BCR among the treatments were minimum. Saleem *et al.*[8] reported that application of N in soil and foliar spray (2% spray of urea at two leaves, booting and tillering stage or 3% spray of urea at tillering and booting stage) was economical and can compensate the yield losses.

## CONCLUSION

It is concluded that application of recommended fertilizer dose in soil with foliar spray of N at three times (at 40 DAE+at booting stage+at grain filling stage) delayed the plant senescence and lengthen the grain growth duration, increased little yield and protein content of wheat.

## SIGNIFICANCE STATEMENTS

The foliar application of N improved nitrogen use efficiency, control heat stress at later stages and thereby enhanced crop growth and yield of late sown wheat. Hence, farmers may encourage implementing this strategy for growing wheat in late condition especially rice-based cropping system. This is an on-station trai, therefore on-farm research on foliar application of N for wheat crop is critical under different climatic conditions in Bangladesh.

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