Timing of First Irrigation and Split Application of Nitrogen for Improved Grain Yield of Wheat in Old Himalayan Piedmont Plain of Bangladesh

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Authors’ contributions

This work was carried out in collaboration between all authors. MAZS and AH conceived the experiments and experimental design. MAZS, AH and JATdS assessed and analyzed the data. MAZS, AH and JATdS wrote all drafts of the paper, approved the final draft for submission and take full public responsibility for its content. All three authors abide by and satisfy the conditions of authorship as defined by the four clauses of the ICMJE.

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ABSTRACT

Soil water and nitrogen (N) are the two most important factors in wheat for obtaining higher grain yield. In this context, a field trial was conducted at the research farm (25°38’ N, 88°41’ E and 38.20 m above sea level) of the Wheat Research Centre (WRC), Bangladesh to identify the timing of first irrigation (Fl) and its combination with a split application of N (N⁰) for improved yield of wheat. The treatments applied were two levels of N (75 and 100 kg ha⁻¹) and different amounts of N in splits with different application times of Fl to verify the Fl and its interaction with Fl timing in light soil and to minimize N use by rescheduling the Fl. Existing wheat variety ‘Prodip’ was used as the experimental material. The interaction between Fl and N⁰ on yield and yield-related components of wheat, except for 1000-grain weight, did not vary significantly. However, higher grain yield (3.39 t ha⁻¹) was obtained when the crop was irrigated at 15 days after sowing (DAS) than when irrigated latter (20, 25 and 30

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1. INTRODUCTION

Wheat (Triticum aestivum L.) production in arid and semi-arid regions is constrained by many factors including high temperatures, moisture deficit, and low soil fertility [1,2,3]. Among these, nitrogen (N) deficit is one of the most important due to a deficit in soil moisture. Water stress and N deficiencies reduce photosynthesis because of stomatal closure and early leaf senescence [2,4], which ultimately affect processes related to grain development. The uptake and assimilation of N, a key factor to achieving optimum grain yield, are governed by various agronomic factors [5,6]. The addition of N fertilizer to wheat is required to ensure the N availability throughout the growing season, due to its important role in promoting both vegetative and reproductive growth. In particular, N plays a dominant role in various growth processes since it is an internal part of chlorophyll, a constituent of enzyme proteins and nucleic acids [2,6,7].

High temperature is also a major challenge to wheat production in arid and semi-arid regions. It reduces grain yield by altering physiological processes, accelerating vegetative growth and reducing the rate and duration of grain filling [8,9]. Ageeb [10] and Badaruddin et al. [11] reported that wheat yield in hot environments could be improved by modifying the crop micro-climate through cultural practices such as mulching, frequent irrigation and application of N fertilizer. They also reported that N fertilizers could increase, in wheat, above-ground dry matter production and grain yield by increasing leaf area index and green leaf area duration, ground cover and the area of green spikes. The application of N under heat stress significantly increased canopy temperature depression, biomass production and grain yield [11,12]. Canopy cooling in dry, heat-stressed areas is regarded as one of the most physiologically efficient ways to attain high grain yields in wheat. Twelve wheat genotypes were grown with four N levels in a two-year field trial to investigate the efficiency of adding non-canopy cooling and high chlorophyll accumulation under a dry but irrigated environment in Sudan [13]. The application of N fertilizer was reflected in a cooler canopy under dry heat stress, resulting in higher dry matter accumulation and grain yield, although the response was cultivar-dependent.

Previous findings showed that crops respond better to a split application of N than to a single application. For example, the growth, N uptake, and yield-related attributes of wheat were significantly higher under split (two or three) applications of N compared to N applied as a single application [14]. Timsina et al. [15] conducted a two-year field experiment in the northwest of Bangladesh: A split application of N resulted in better crop performance (yield and yield-related components) under irrigated than rainfed conditions.

Researchers have been looking for ways and means to increase the efficiency of N fertilizer use to increase productivity to meet the demand of increasing world populations [16]. In recent years, intensive management studies have shown that split topdressing of N fertilizer as an efficient use of N fertilizer is important for economical wheat production and to sustain the quality of ground and surface waters. Insufficient N fertilizer results in reduced wheat yield and reduced profits compared to a properly fertilized wheat crop [16]. However, excessive N produces wheat plants that are susceptible to disease, resulting in reduced yield and increased input cost. The potential for nitrate (NO₃) enrichment of ground and surface waters also increases with excessive N fertilization.

For wheat varieties developed since 1998, the Wheat Research Center (WRC) at the

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On average, higher grain yield (3.58 t ha⁻¹) was obtained from 100 kg N ha⁻¹ when it was applied half as basal and half as one top dressing than 75 kg N ha⁻¹ when applied half as basal and half as one top dressing. Large grains were obtained when the FI was applied at 25 DAS in all N treatments except for 75 kg N ha⁻¹ when applied half as basal at the time of final land preparation and half as top dressing, on 30 DAS in half N as basal at both levels of N and at 15 DAS when 100 kg N ha⁻¹ was applied half as basal and half as top dressing. So, it is evident that the amount and split application of N with first irrigation are the most important factors determining higher grain yield and yield-related components of wheat in light soil of Bangladesh. According to our research findings, 100 kg N ha⁻¹ is recommended, 1/2 as basal and 1/2 as top dressing at the time of FI at 15 or 20 DAS.
Bangladesh Agricultural Research Institute (BARI) has recommended that the timing of first irrigation (FI) be 17-21 days after sowing (DAS) of seeds and that a larger amount of N be applied as basal during final land preparation [17]. There are no research findings for recommendations related to the timing of first irrigation (FI) and its combination with the split application of N (N\textsubscript{30}) for varieties developed from 1998 to 2014. Considering these facts, this experiment was established to assess the timing of FI with different amounts of N as basal and top dressing with the sole objective of improving the grain yield of wheat.

2. MATERIALS AND METHODS

This study was conducted at the experimental field of the WRC, Bangladesh in two wheat-growing seasons (November to April, 2007-2008 and 2008-2009). The Agro Ecological Zone (AEZ) of the area is the Old Himalayan Piedmont Plain (AEZ-1). The geographical position of the area is between 25°38’ N, 89°41’ E and 38.20 m above sea level. The experimental site covers about 21% of the wheat-growing area of Bangladesh. The climate of the district is suitable due to a comparatively cooler and longer winter. However, the soil is sandy-loam and its reaction is strongly acidic (pH ranges from 4.5 to 5.5), organic matter content is less than 1%, N, K (potassium), S (sulfur), B (boron), Mg (magnesium) and Zn (zinc) was below the critical level, but P (phosphorus) was higher than the critical level, but not in a plant-available form [18]. The maximum and minimum weekly average temperatures (°C) in the growing seasons were recorded and are presented in Fig. 1.

The experiment was laid out in split-plot design with three replications having a unit plot size of 4x5 m. Four irrigation times viz., at 15 (FI\textsubscript{15DAS}), 20 (FI\textsubscript{20DAS}), 25 (FI\textsubscript{25DAS}) and 30 (FI\textsubscript{30DAS}) days after sowing (DAS) were assigned to main plots and four amounts of N and splitting methods were assigned to sub-plots: I) T\textsubscript{1} =75 kg N ha\textsuperscript{-1} (2/3 as basal and 1/3 as top dressing); II) T\textsubscript{2} =75 kg N ha\textsuperscript{-1} (1/2 as basal and 1/2 as top dressing); III) T\textsubscript{3} = 100 kg N ha\textsuperscript{-1} (2/3 as basal and 1/3 as top dressing); IV) T\textsubscript{4} = 100 kg N ha\textsuperscript{-1} (1/2 as basal and 1/2 as top dressing). A blanket dose of P-K-S-B was applied as basal at 26-40-20-1 kg ha\textsuperscript{-1}.

Variety ‘Prodip’ is a popular variety in Bangladesh due to its attractive grain colour and size, and spike length (longest, compared to other varieties). Research finding have indicated that ‘Prodip’ has the potential to produce higher yield under optimum conditions, although it is sensitive to early and late heat stress [19]. On the other hand, Badaruddin et al. [11] reported that wheat yield in hot environments could be improved by modifying the crop’s micro-climate through cultural practices such as mulching, frequent irrigation and the application of N fertilizer. Considering this information, ‘Prodip’ was used to better assess and quantify its yield potentiality. ‘Prodip’ seeds treated with Provax-200 were sown at 140 kg ha\textsuperscript{-1} on 22 November 2008. Provax-200 WP (seed-treated fungicide) contains Carboxin and Thiram. Research at the WRC [20] indicates that Provax-200 WP is a perfect match for controlling fungi in Bangladesh soil, for achieving excellent seed germination and for protecting wheat cultivars from fungal attacks during the seedling stage.

All N top dressings were applied once after FI in accordance with the main plot treatments. Second irrigation was applied at 51, 54, 61 and 63 DAS, and third irrigation was applied at 72, 74, 78 and 80 DAS in plots where FI was applied at 15, 20, 25 and 30 DAS, respectively. On plots where FI was applied at 15 DAS, another essential irrigation was applied at 82 DAS due to deficit soil moisture (data not shown). At the time of first, second and third irrigation, we applied only 0.0835 m or 8.35 cm water in 20 m\textsuperscript{2} size plot. Treatment of the experiment was timing of first irrigation with split application of N. So, we only measured soil moisture immediately before all of the first irrigated plots. Soil moisture varied 12-14% before first irrigation. We calculated amount of irrigation water by following way:

\[
\text{Irrigation water per plot} = \frac{\text{Irrigation meter reading}}{\text{Area under irrigated}}
\]

\[
\text{Irrigation needed for 20 m}^2 = 1.67 \text{ m}^3/20 \text{ m}^2 = 0.0835 \text{ m or 8.35 cm}
\]

Other intercultural operations were conducted in accordance with the recommendation of the WRC by considering soil moisture.

The crop was harvested plot-wise at full maturity. The sampled plants were harvested separately. Yield-related attributes were recorded after harvesting (124 DAS). The plots were harvested in strips 3 m long by using 10 (3x2 m) middle rows in all replications to avoid a border effect. The harvested crop of each plot
was bundled separately, tagged and threshed in threshing floor. The bundles were thoroughly dried in bright sunshine before their weights were recorded. Data were recorded for number of spikes m$^{-2}$ (NS), plant height (PH) (cm), spike length (SL) (cm), number of spikelets spike$^{-1}$ (NSS), number of grains spike$^{-1}$ (NGS), 1000-grain weight (1000-GW) (g), grain yield (GY) (t ha$^{-1}$), straw yield (SY) (t ha$^{-1}$) and harvest index (HI) (%). HI was calculated according to the following equation [21]:

$$HI \% = \left( \frac{\text{Grain yield}}{\text{Grain yield} + \text{Straw Yield}} \right) \times 100$$

Data collected during this study was statistically analyzed using MSTAT statistical package of Michigan State University, USA [22]. Duncan’s new multiple range test (DNMRT) at $P<0.05$ was used to test the differences between means [23].

3. RESULTS AND DISCUSSION

3.1 Weather Conditions in Experimental Period

Fluctuations in weather conditions affect crop growth and development and ultimately yield. Weather parameters such as maximum and minimum air and soil temperature, rainfall and relative humidity are the most important climatic factors for the growth and development of plants, especially in areas of dry land cultivation. The ideal timing for sowing a crop is linked to favorable climatic conditions. In this study, the wheat crop was sown on 22 November based on findings by Hossain et al. [19], Hossain et al. [24] and Hakim et al. [25], Hossain and Teixeira da Silva [26], who reported optimum sowing time for existing wheat varieties of Bangladesh, is mid-November to the first week of December. The weather conditions in our experimental period were suitable for good yield (Fig. 1) since, in the vegetative stage, average temperature was below 25°C and at the grain-filling stage average temperature was below 20°C, which are suitable conditions for good yield in a wheat crop. Wang et al. [27] evaluated wheat var. ‘Yang 9’ in Nanjing, China. The plants were divided into two batches. One batch of plants was subjected to high temperature acclimation at a day/night temperature of 32/28°C in one growth chamber for two days while another batch was moved into another growth chamber at a day/night temperature of 24/20°C as the non-acclimated treatment. At the same time, the remaining plants were moved to another chamber with a temperature regime of 26/22°C as the control. Results of the study indicated that pre-anthesis high temperature acclimation alleviated the negative effects of post-anthesis heat stress on stem-stored carbohydrate remobilization and grain starch accumulation, which ultimately affected grain yield.

3.2 Yield and Yield-related Components of Wheat

Yield and yield-related components of wheat are considerably increased by increasing the level of N [28]. GY is a complex trait and is greatly influenced by many genetic factors and environmental fluctuations. Khan et al. [29] reported in rice that GY plant$^{-1}$ was positively correlated and varied significantly with PH, SL, flag leaf area and NGS. Latiri-Soki et al. [30] reported that irrigation and N increased dry matter production and GY, possibly due to increased leaf area index (LAI), area of green spikes and an increase in the period in which the crop remained green which resulted in increased capture efficiency of radiation energy and consequently more dry matter production. The responses of a crop to N fertilizer are directly related to the status of soil moisture [31,32].

3.3 Effect on Number of Spikes m$^{-2}$

NS is one of the major components of GY in wheat. Matsunaka et al. [33] reported an increase in GY of wheat as NS per unit area increased. NS of wheat depends on several factors such as inherent characters, environmental factors, irrigation frequency and timing, and balanced fertilizers, among them the times and frequency of irrigation being the most important. Waraich et al. [34] reported that FI at the tillering stage increased the number of tillers, ultimately increasing the NS, and resulting in 69% higher GY than the second (54%) and third irrigation (16%). Even though three irrigations could increase GY, FI is the most important one. In our experiment, higher NS was obtained from F$_{15}$DAS and lower NS from F$_{25}$DAS (Table 1). N supplementation had a positive effect on crop productivity, and therefore higher NS was observed in plots where N was applied. The increase in NS with the rate of N is in agreement with the findings of Melaj et al. [35] and Mandal et al. [36], who also reported that when N was applied as split doses, it increased NS more than a single dose of N applied either early or late. On the other hand, NS$_{SA}$ in different methods
3.6 Number of Grains Spike\(^{-1}\)

NGS plays a vital role in GY [40,41]. Dokuyucu and Akkaya [42] also found a positive effect between NGS and GY in Turkish wheat genotypes. In our experiment, \(F_{\text{15DAS}}\) and interaction effects did not significantly influence NGS, but \(N_{\text{SA}}\) was significantly influenced. This might be related to the genetic makeup of this variety, an assumption supported by Schwarte et al. [43], who stated that the NGS is determined at the panicle primordial formation stage, which is strongly dependent on genetic factors rather than management factors. On the other hand, under field observation, Rahman et al. [44] stated that in severe boron-deficient soil, partial or complete spike sterility might occur, resulting in lower NGS. In our experiment, higher NGS was found \(F_{\text{20DAS}}\) in \(T_4\) and statistically similar results were found in terms of the amount of N and its split application, except for \(T_2\) as top dressing. However, highest NGS was found in \(T_4\) (Table 2). The increase in NGS is similar to that observed by Mandal et al. [36], who stated from a three-year field experiment that increasing production of wheat from a limited water supply can result from efficient irrigation and nutrient management. They also noticed that the highest GY and seasonal ET increased significantly with an increase in water supply in every nutrient treatment, being highest in three irrigations (CRI, maximum tillering and flowering stage) with 100% NPK + farmyard manure (FYM-10 t ha\(^{-1}\)) \((l_0F_2)\) and lowest in \(l_0F_0\) (i.e., without fertilizers and irrigation).

3.7 1000-grain Weight

1000-GW is the most important parameter for final GY. This assumption is also supported by other researchers who stated that GY was significantly and positively correlated with 1000-GW and NS [45]. In our present study, 1000-GW was significantly influenced by the interaction effect of \(F_{\text{15DAS}}\) in combination with \(N_{\text{SA}}\) (Table 2). The highest 1000-GW was found at \(F_{\text{15DAS}}\) in \(T_4\), statistically followed by \(F_{\text{25DAS}}\) in \(T_2\), \(F_{\text{25DAS}}\) in \(T_1\), and NS.
Fl_{25DAS} in T_3, Fl_{30DAS} in T_4 and Fl_{25DAS} in T_4 (Table 2). Rahman et al. [46] conducted a field experiment in Bangladesh with three doses of N (80, 100, and 120 N kg ha^{-1}) in the form of urea, which were assigned as the main plots and four methods of N splitting (viz., application of all N as basal; 2/3 basal + 1/3 as top dress at the crown root initiation (CR1) stage; 1/2 basal + 1/2 as top dress at the CR1 stage; 1/3 basal + 1/3 as top dress at CR1 + 1/3 as top dress at the first node stage) which were tested in the sub-plots. Higher yield was achieved when N was applied at 120 kg ha^{-1} as three equal splits of 1/3 as basal during final land preparation, 1/3 as top dressing during CR1 and the remaining 1/3 as top dressing at the first node stage.

3.9 Harvest Index

HI is defined as the percentage grain in the total plant biomass. Genetic improvement of GY in wheat is closely associated with increases in HI, but not with increases in total biomass [47]. In our present experiment, only N_{SA} significantly influenced HI. The highest HI was found in T_4 (Table 3). The three other treatments showed the lowest values and were not significantly different to each other. On the other hand, higher HI (42.22) was found at Fl_{25DAS} in T_4. A similar result was observed by Waraich et al. [34], who conducted a two-year experiment, with four irrigation levels i.e., one irrigation (irrigation at the tillering stage), two irrigations (irrigations at tillering and anthesis stages), three irrigations (irrigations at tillering, anthesis and grain development stages), four irrigations (irrigations at tillering, stem elongation, anthesis and grain development stages) and four N levels i.e., 0, 50, 100 and 150 kg N ha^{-1} were tested in Pakistan. They revealed from their study that GY and all primary yield components increased linearly in response to irrigation and N in both seasons.

3.10 Straw Yield

The interaction of Fl_{till}, N_{SA} and the single effect of Fl_{till} did not significantly influence SY. However, the single effect of N_{SA} did significantly influence this trait. A higher SY was recorded in T_4 which was statistically at par with T_2 and T_2. Significantly lower SY was observed in T_1 (Table 3). A similar result to our study was reported by Afridi et al. [48], who stated that, compared to the control, N level increased NS, NGS, 1000-GW and SY. Similarly, the split application of N improved NS, NGS, GW and SY more than the control, whereas 1000-GW and HI were not affected by N_{SA}.

![Fig. 1. Weather information during the wheat growing period (Source: Meteorological Station, Wheat Research Centre, Nashipur, Dinajpur, Bangladesh)](image-url)
Table 1. Spikes $m^{-2}$, plant height and spike length of wheat as influenced by time of first irrigation, amount and splitting application methods of nitrogen. $1^{st}$ irrigation at 15 DAS = FI$_{15DAS}$; $1^{st}$ irrigation at 20 DAS = FI$_{20DAS}$; $1^{st}$ irrigation at 25 DAS = FI$_{25DAS}$; $1^{st}$ irrigation at 30 DAS = FI$_{30DAS}$; T1 = 75 kg N ha$^{-1}$ (2/3 as basal and 1/3 as top dressing), T2 = 75 kg N ha$^{-1}$ (1/2 as basal and 1/2 as top dressing), T3 = 100 kg N ha$^{-1}$ (2/3 as basal and 1/3 as top dressing), T4 = 100 kg N ha$^{-1}$ (1/2 as basal and 1/2 as top dressing)

| Treatments   | T1  | T2  | T3  | T4  | Mean | CV (%) (Irrigation) |
|--------------|-----|-----|-----|-----|------|---------------------|
| Number of spikes $m^{-2}$ |     |     |     |     |      |                     |
| FI$_{15DAS}$ | 182 | 173 | 173 | 194 | 180  |                     |
| FI$_{20DAS}$ | 180 | 169 | 177 | 181 | 177  |                     |
| FI$_{25DAS}$ | 168 | 175 | 176 | 176 | 174  | 13.20               |
| FI$_{30DAS}$ | 175 | 170 | 182 | 184 | 177  |                     |
| Mean         | 176 AB | 172 B | 177 AB | 184 A |      |                     |
| CV (%) (N and interaction) | 5.23 |      |      |      |      |                     |

Within each trait, means followed by the same lower-case letter(s) in a column or in a row followed by the same capital letter(s) indicate significant differences ($P \leq 0.05$) according to DMRT

Table 2. Spikelets spike$^{-1}$, grains spike$^{-1}$ and 1000-grain weight of wheat as influenced by the timing of first irrigation, amount and splitting application methods of nitrogen. Treatment details are as for Table 1

| Treatments   | T1  | T2  | T3  | T4  | Mean | CV (%) (Irrigation) |
|--------------|-----|-----|-----|-----|------|---------------------|
| Spikelets spike$^{-1}$ (no.) |     |     |     |     |      |                     |
| FI$_{15DAS}$ | 19.17 | 19.03 | 18.50 | 20.70 | 19.35 | 4.14               |
| FI$_{20DAS}$ | 19.50 | 18.73 | 18.90 | 19.73 | 19.22 | 4.14               |
| FI$_{25DAS}$ | 19.63 | 17.70 | 19.00 | 20.63 | 19.24 | 4.14               |
| FI$_{30DAS}$ | 18.87 | 20.00 | 18.67 | 20.70 | 19.56 | 4.14               |
| Mean         | 19.29 B | 18.87 B | 18.77 B | 20.44 A |      |                     |
| CV (%) (N and interaction) | 3.80 |      |      |      |      |                     |

Within each trait, means followed by the same lower-case letter(s) in a column or in a row followed by the same capital letter(s) indicate significant differences ($P \leq 0.05$) according to DMRT

| Treatments   | T1  | T2  | T3  | T4  | Mean | CV (%) (Irrigation) |
|--------------|-----|-----|-----|-----|------|---------------------|
| Grains spike$^{-1}$ (no.) |     |     |     |     |      |                     |
| FI$_{15DAS}$ | 42.00 | 41.70 | 45.70 | 45.10 | 43.60 | 4.60               |
| FI$_{20DAS}$ | 44.80 | 41.30 | 46.30 | 47.20 | 44.90 | 5.76               |
| FI$_{25DAS}$ | 45.40 | 41.50 | 44.20 | 44.60 | 43.90 | 5.76               |
| FI$_{30DAS}$ | 42.80 | 46.90 | 45.30 | 45.10 | 45.00 | 5.76               |
| Mean         | 43.80AB | 42.80 B | 45.40 A | 45.5 A |      |                     |
| CV (%) (N and interaction) | 5.33 |      |      |      |      |                     |

Within each trait, means followed by the same lower-case letter(s) in a column or in a row followed by the same capital letter(s) indicate significant differences ($P \leq 0.05$) according to DMRT

| Treatments   | T1  | T2  | T3  | T4  | Mean | CV (%) (N and interaction) |
|--------------|-----|-----|-----|-----|------|---------------------------|
| 1000-grain weight (g) |     |     |     |     |      |                           |
| FI$_{15DAS}$ | 57.8 bc | 57.7 bcd | 56.9 bcd | 60.3 a | 58.2 |                           |
| FI$_{20DAS}$ | 57.5 bcd | 57.3 bcd | 55.3 d | 56.0 cd | 56.5 |                           |
| FI$_{25DAS}$ | 59.3 ab | 57.7 bcd | 59.1 ab | 58.3 abc | 58.6 | 3.63                     |
| FI$_{30DAS}$ | 57.0 bcd | 60.1 a | 56.4 cd | 58.8 ab | 58.1 |                           |
| Mean         | 57.9 AB | 58.2 A | 56.9 B | 58.4 A |      |                           |
| CV (%) (N and interaction) | 2.16 |      |      |      |      |                           |

Within each trait, means followed by the same lower-case letter(s) in a column or in a row followed by the same capital letter(s) indicate significant differences ($P \leq 0.05$) according to DMRT
3.1 Grain Yield

On average, higher GY was obtained from Fl15DAS plots. Since Fl was applied earlier, these plots also needed irrigation earlier than when Fl was applied later. These plots also needed irrigation more during the grain-filling stage (82 DAS). This may have consequently increased grain size with a subsequent higher GY in these plots. Roy and Pandit [49] reported Fl at crown root initiation stage (15-21 DAS) increased wheat GY by 43% more than the non-irrigated crop. Rahman et al. [50] also reported that irrigation at an early growth stage (18-21 DAS) of wheat increased GY compared to other irrigation treatments. Waraich et al. [34] reported that irrigation at the tillering stage increased GY 69% more than irrigation at anthesis (54%) and grain-filling (16%) stages.

Compared to all Fl timing and amounts of N8A, higher GY was recorded for all Fl timing in T4. Fl15DAS was highest followed by Fl22DAS, Fl30DAS and Fl35DAS. A lower GY was obtained by Fl35DAS in T2. On average, significantly higher GY was obtained in T4 than in T3, T1 and T2 treatments always produced significantly lower GY than T3 and T4. Significantly lower GY was observed in T2 than in T1 (Table 3).

Therefore, in wheat, N is more essential in early growth stages. For this reason, 1/2 N of 75 kg ha−1 as basal was not enough for producing optimum NS, SL, NSS, NGS and HI for higher GY. Using 2/3 N of 75 kg ha−1 as basal might increase NS, SL, NSS, HI, which is similar to an application of 100 kg N ha−1. Half the amount of N (i.e., 50 kg N ha−1) as basal is enough for producing optimum NS and a slightly higher amount of N (1/2) than 1/3 N (i.e., 33.34 kg ha−1) of 100 kg N ha−1 as top dressing might have had an additive effect on GY in light soil (sandy loam) in our experimental site (Table 3).

Gorjanovic et al. [51] conducted an experiment to investigate variability of GY of 12 bread wheat genotypes using three N levels (0, 75 and 100 kg ha−1). In all three levels, the highest GY was found in var. ‘Malyska’ while the lowest GY in the control was found in var. ‘Nevesinjka’, while in the N75 and N100 rates it was found in var. ‘Tamaro’.

4. CONCLUSION

From the results and discussion of our study, it is evident that the amount and split application of N with first irrigation are the most important factors determining higher grain yield and yield-related

Table 3. Harvest index, straw yield and grain yield of wheat as influenced by time of first irrigation, amount and splitting application methods of nitrogen. Treatment details are as for Table 1

| Treatments | T1        | T2        | T3        | T4        | Mean CV (%) (Irrigation) |
|------------|-----------|-----------|-----------|-----------|--------------------------|
|            | Harvest index (%) |          |          |          |                          |
| Fl15DAS    | 40.05     | 39.82     | 39.17     | 40.16     | 39.80                    |
| Fl22DAS    | 39.54     | 39.55     | 38.63     | 41.87     | 39.90                    |
| Fl30DAS    | 39.75     | 37.78     | 38.95     | 42.22     | 39.68 5.17               |
| Fl35DAS    | 38.48     | 40.43     | 40.26     | 41.46     | 40.16                    |
| Mean       | 39.46 B   | 39.39 B   | 39.25 B   | 41.43 A   |                          |
| CV (%) (N and interaction) | 3.68      |          |          |          |                          |
| Fl15DAS    | 4.91      | 4.69      | 5.18      | 5.10      | 4.97                     |
| Fl22DAS    | 4.89      | 4.70      | 5.09      | 5.01      | 4.92                     |
| Fl30DAS    | 4.79      | 4.70      | 4.92      | 5.21      | 4.90 10.74               |
| Fl35DAS    | 5.31      | 4.50      | 4.85      | 5.26      | 4.98                     |
| Mean       | 4.97 AB   | 4.65 B    | 5.01 A    | 5.14 A    |                          |
| CV (%) (N and interaction) | 7.99      |          |          |          |                          |
| Fl15DAS    | 3.27      | 3.10      | 3.52      | 3.65      | 3.39                     |
| Fl22DAS    | 3.20      | 3.08      | 3.19      | 3.58      | 3.26                     |
| Fl30DAS    | 3.16      | 2.85      | 3.37      | 3.52      | 3.22 6.69                |
| Fl35DAS    | 3.10      | 2.96      | 3.27      | 3.57      | 3.23                     |
| Mean       | 3.18 C    | 3.00 D    | 3.34 B    | 3.58 A    |                          |
| CV (%) (N and interaction) | 5.35      |          |          |          |                          |

Within each trait, means followed by the same lower-case letter(s) in a column or in a row followed by the same capital letter(s) indicate significant differences (P ≤ 0.05) according to DMRT.
components of wheat. According to our research findings, 100 kg N ha⁻¹ is recommended, 1/2 as basal and 1/2 as top dressing at the time of FI at 15 or 20 DAS.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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