ORIGINAL ARTICLE

ISSN (Print): 2517-9675
ISSN (Online): 2518-2625

NITROGEN MANAGEMENT STRATEGIES FOR IMPROVING THE GROWTH AND YIELD OF WHEAT (*TRITICUM AESTIVUM* L.)

Mudassir Aziz[1] • Muhammad Aamer Sajjad[2] • Muhammad Ehsan Safdar[2]* • Ahsan Aziz[2] • Muhammad Asif[2] • Muhammad Ashraf[3] • Rizwana Kausar[4] • Muhammad Arshad Javed[5]

AUTHOR'S AFFILIATION

[1]Department of Agronomy, Muhammad Nawaz Sharif University of Agriculture, Multan, Pakistan
[2]Department of Agronomy, College of Agriculture, University of Sargodha, Sargodha 40100, Punjab, Pakistan
[3]Department of Soil and Environmental Sciences, College of Agriculture, University of Sargodha, Sargodha 40100, Punjab, Pakistan
[4]Soil and Water Testing Laboratory for Research, Sargodha 40100, Punjab, Pakistan
[5]Department of Agri-Extension, College of Agriculture, University of Sargodha, Sargodha 40100, Punjab, Pakistan.
*Corresponding author's e-mail: ehsan_safdar2002@yahoo.com

Keywords:
Broadcast, foliar application, growth stages, nitrogen application, yield, wheat

ABSTRACT

Background There is little bit poor understanding among wheat growers regarding best nitrogen (N) fertilizer application strategy for this crop to avoid N losses, and improving yield under agro-ecological conditions of Sargodha, Pakistan.

Methodology A field study was conducted for optimizing the time and method of N fertilizer application for improving the growth and yield of wheat at Experimental Farm of University of Sargodha, Pakistan. Recommended N dose (120 kg ha^{-1}) was divided into splits which were applied at different growth stages through soil and foliar application methods. Treatments included ½ N at sowing + ½ N at tillering (broadcast), ½ N at sowing + ¼ N at tillering (broadcast) + ¼ N at anthesis (broadcast), $^{1}/_{3}$ N at sowing + $^{1}/_{3}$ N at tillering (broadcast) + $^{1}/_{3}$ N at anthesis (broadcast), ½ N at tillering (broadcast) + ½ N at anthesis (broadcast), 94% N at sowing + 3% N as foliar application at tillering + 3% N as foliar application at anthesis, and ½ N at sowing + ½ remaining N in equal splits as foliar application at tillering, jointing, booting and anthesis with 15 days interval starting at 45 days after sowing (DAS).

Results Maximum crop growth in terms of growth rate (30.3 g m^{-2} day^{-1}), leaf area index (5.43), leaf area duration (up to 245.5 days) and net assimilation rate (7.49 g m^{-2} day^{-1}) was shown by wheat plants fertilized with ½ N at sowing + ½ remaining N in equal splits as foliar application at different growth stages (from tillering to anthesis) with 15 days interval starting at 45 DAS. The same N fertilizer application treatment also gave significantly the highest number of spikelets per spike (15.57), grains per spike (46.37), spike length (10.85 cm), 1000-grain weight (48.71 g) and grain yield (3.61 t ha^{-1}) of wheat. However, the wheat plant height, number of tillers per m^2 remained significantly higher compared to control with treatments receiving N in two, three and four splits either as foliar or soil broadcast application. Contrastingly, the highest biological yield (9.65 and 8.12 t ha^{-1}) was noted with N application as ½ N at sowing + ½ N at tillering (broadcast) and ½ N at sowing + ½ remaining N as foliar application in equal splits with 15 days interval starting at 45 DAS, respectively.

Conclusion It can be concluded that nitrogen application as ½ N at sowing + ½ as foliar application in equal splits with 15 days interval starting at 45 DAS is the best strategy that gave the highest grain yield of wheat.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the leading cereal crops and most favored staple food of 35% of world population (Paux et al. 2008). Wheat occupies leading position in Pakistan by contributing about 9.6% to value added to agriculture and 1.9% to gross domestic product (Anonymous 2017). Being primary diet, it carries immense importance by providing about 50% of the total calories and protein intake in Pakistan

Cite As: Aziz M, MA Sajjad, ME Safdar, A Aziz, M Asif, M Ashraf, R Kausar, MA Javed (2018) Nitrogen management strategies for improving the growth and yield of wheat (*Triticum aestivum* L.). *J. Environ. Agric.*, 3(1): 289-300.

(Ahmad et al. 2012).

There are several factors responsible for maximum growth and productivity of wheat. In addition to favorable environmental conditions, some other factors including optimum seed rate, proper land preparation, adequate irrigation facilities and fertilizer management are important in determining the yield and productivity of cereal crops. Precise use of N fertilizer is the key factor affecting yield and profitability of wheat (Diacono et al. 2013). Nitrogen is one of essential elements for getting maximum grain yield, and is major constraint of crop growth after water. A ton of wheat grain needs nearly 25 kg N for its production. Crop growth rate, light use efficiency as well as development of leaf area are highly responsive to N (Abbate et al. 1995). Due to losses of nitrogenous fertilizers in terms of volatilization, denitrification, leaching and runoff, wheat crop fails to show its full yield potential (Ramu 2008). Nitrogen is the integral part of many constituents of plant structure like amino acid, enzyme, chlorophyll that ultimately build up the body of plant. Nitrogen also plays very active role in plant processes like photosynthesis and protein synthesis that finally contribute to the growth and yield of wheat (Ali et al. 2012). Adoption of most appropriate method of N application is an attractive strategy to enjoy the maximum benefit of N fertilization in crop yield improvement. Foliar application is smart farm tool for application of N fertilizer with relatively less losses. Foliar fertilization is advantageous due to quick and efficient response of plants to applied nutrients, less dependence on soil conditions as well as less amount of fertilizer needed. It is also well known that supply of nutrients through foliar application method during crop growth considerably enhances the mineral status of plants, and ultimately increases the crop yield (Kolota and Osinska 2001). Application of foliar urea at different growth stages has pronounced effect on growth and yield of wheat as compared to soil applied fertilizers (Shah et al. 2007).

Nitrogen application in splits is considered the best method for increasing the wheat grain yield. Split application has been proved to be an effective strategy for improvement of grain yield and protein contents of wheat (Fisher et al. 1993). Application of N in different splits and at different growth stages is viable tool for maximizing N use efficiency and grain yield of wheat as compared to basal applied N in single dose (Rahman et al. 2002). Moreover, split application of N increases number of grains spike^{-1}, plant height, number of productive tillers plant^{-1}, 1000-grain weight, spike length, grain yield and straw yield (Patel 1999). Nitrogen is absorbed in greater amount by wheat plants, but usually is not applied in required amount and at proper growth stage (Wendling et al. 2007). Adoption of appropriate strategy in order to improve N utilization efficiency is one of viable option towards economic wheat production. Maximum benefit from applied N can be taken if it applied through efficient method, in right quantity and at right time. Unbalanced and insufficient application of N fertilizer results in reduction of yield as well as overall profit (Ramu 2008). Nitrogen application at right time is very important in increasing the crop productivity. As heavy losses of N at the very beginning of growing season occur as a result of applying higher N dose basally, a practice common among farmers, split N application at critical growth stages of crop is usually recommended. In the light of foregoing discussion, present study was conducted to study the most suitable timing and method of N application in wheat.

MATERIALS AND METHODS

The present study was conducted at Experimental Farm, University College of Agriculture, University of Sargodha, Punjab, Pakistan. Experimental treatments included ½ N at sowing + ½ N at tillering (broadcast), ½ N at sowing + ¼ N at tillering (broadcast) + ¼ N at anthesis (broadcast), $^1/_3$ N at sowing + $^1/_3$ N at tillering (broadcast) + $^1/_3$ N at anthesis (broadcast), ½ N at tillering (broadcast) + ½ N at anthesis (broadcast), 94% N at sowing + 3% N as foliar application at tillering + 3% N as foliar application at anthesis, and ½ N at sowing + ½ remaining N in equal splits as foliar application at tillering, jointing, booting and anthesis with 15 days interval starting at 45 DAS. The experiment was laid out in randomized complete block design with four replications. Net plot size was 2.25×6 m^2. Various treatments included in study are enlisted in Table 1.

Sowing of wheat crop (variety AaS-2011) was done manually with the help of single row hand drill with 22 cm row to row distance. Seed rate of 125 kg ha^{-1} was used for sowing. Full dose of phosphorus (P) and potash (K) were applied at sowing time in the form of diammonium phosphate and sulphate of potash, while urea was applied as source of N. Experimental crop was sprayed once with fenoxaprop-*p*-ethyl (Puma Super) and fluroxypyr + MCPA (Starane-M) in order to keep the crop free from weeds. First irrigation was done 20 DAS and subsequent as per need of the crop and soil. A total of five irrigations were made during the whole growth period. All other agronomic practices were kept uniform for all the treatments. The crop was harvested manually. At appropriate growth stage, data of crop growth and yield related characteristics were recorded as per their prescribed procedures.

Table 1 Treatments description

Treatments	Description
T_1	Control (without N application)
T_2	½ N at sowing + ½ N at tillering (broadcast)
T_3	½ N at sowing + ¼ N at tillering (broadcast) + ¼ N at anthesis (broadcast)
T_4	$^1/_3$ N at sowing + $^1/_3$ N at tillering (broadcast) + $^1/_3$ N at anthesis (broadcast)
T_5	½ N at tillering (broadcast) + ½ N at anthesis (broadcast)
T_6	94% N at sowing + 3% N as foliar application at tillering + 3% N as foliar application at anthesis
T_7	½ N at sowing + ½ remaining N in equal splits as foliar application at different growth stages with 15 days interval 45 DAS

Growth and development traits

Crop growth rate (g m^{-2} d^{-1})

Crop growth rate (CGR) was determined fortnightly starting from 45 DAS up to 108 DAS by harvesting plants in row of 15 cm at random from each plot. After taking plant samples, the fresh weight of each sample was taken and then sun dried. After sun drying, the plant samples were dried in oven at 70℃ until a constant dry weight was achieved. The samples dry weight was calculated and used to find out crop growth rate by the formula as described by Hunt (1978).

$$\text{Crop growth rate} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where:
W_1 = dry weight (g) at first harvest
W_2 = dry weight (g) at second harvest
t_1-t_2 = time duration between two harvests (days)

Leaf area index (LAI)

Leaf area was computed at fortnight interval by using leaf area meter (CI-203 area meter made by CID, Inc. USA. First sample was taken after 45 DAS of wheat and terminated at 108 DAS. A row of 15 cm was selected at random, and all plants in that row were harvested. Leaves of all plants were separated and then total leaf area was measured with the help of leaf area meter. LAI was computed by the formula as proposed by Watson (1952).

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Land area}}$$

Leaf area duration (LAD)

Leaf area duration (LAD) was calculated with the formula given by Hunt (1978).

$$\text{LAD} = \frac{[(\text{LAI}_1 + \text{LAI}_2) \times (t_2 - t_1)]}{2}$$

LAI_1 = leaf area index at time t_1
LAI_2 = leaf area index at time t_2
t_1 = time corresponding to first harvest (days)
t_2 = time corresponding to second harvest (days)

Net assimilation rate (g $m^{-2}$$day^{-1}$)

Net assimilation rate (NAR) is dry weight accumulated per unit leaf area per unit time, and it was calculated at fortnight interval by the formula described by Hunt (1978).

$$\text{Net assimilation rate} = \frac{\text{TDM}}{\text{LAD}}$$

Where:
TDM = Total dry matter at harvest
LAD = Leaf area duration

Yield contributing traits

Germination count (m^{-2})

For germination count, the number of seedlings emerged in an area of one m^2 at three different locations in each treatments were counted after 15 days of emergence and average was taken.

Number of tillers m^{-2}

Number of tillers was counted from an area of one meter square at three different locations of each experimental unit and then averaged.

Plant height (cm)

Plant height was recorded by using measuring tape from base to apex from 10 randomly selected plants from each treatment at harvest and average was calculated.

Spike length (cm)

Length excluding awn of main spike of 10 randomly selected plants was measured in centimeters by using a scale from peduncle end to the tip of ear borne on the main shoot at maturity and average was taken.

Number of spikelets spike^{-1}

Number of spikelets spike^{-1} were counted for 10 randomly selected spikes from each treatment and then averaged.

Number of grains spike^{-1}

Individual spikes from 10 randomly selected spikes were threshed separately. The grains were counted and average number of grains spike^{-1} was worked out.

1000-grain weight

1000-grains were counted from each treatment and weighed.

Biological yield (kg ha^{-1})

Crop was harvested from randomly selected three quadrats of one m^2 in each treatment. Total biomass was computed and converted to kg ha^{-1}.

Grain yield (kg ha^{-1})

The samples taken for biological yield were threshed manually for grain yield and converted to kg ha^{-1}.

Straw yield (kg ha^{-1})

The samples taken for biological yield were threshed manually for straw yield and converted to kg ha^{-1}.

Harvest index (%)

Harvest index was calculated with the help of following formula:

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

The data obtained on each parameter was tabulated and analyzed by using the Fisher's analysis of variance technique, and the treatment means were compared by the least significant difference test at 0.05 level of probability (Steel et al. 1997).

RESULTS AND DISCUSSION

Growth and development traits

Crop growth rate (g m^{-2} day^{-1})

Crop growth rate of wheat in all N application strategies increased steadily and reached its maximum value at 75-90 DAS and later on declined (Figure 1). Different N management strategies affected CGR of wheat significantly. At 60 DAS, maximum CGR (10.4 g m^{-2} day^{-1}) was observed in plants where N fertilizer of 120 kg ha^{-1} was applied as ½ (50%) at sowing and other ½ (50%) applied as foliar application in equal splits at tillering, jointing, booting and anthesis with 15 days interval during crop growth period that attained the highest peak (30.3 g m^{-2} day^{-1}) at 90 DAS portraying that this treatment outclassed all other treatments. Minimum crop growth rate (8.45 g m^{-2} day^{-1}) was achieved in unfertilized control. The regression showed that strong linear positive relationship was found between crop growth rate and grain yield (Figure 2). These results are in line with those found by Waraich et al. (2007), Laghari et al. (2010), Ghazanfar et al. (2013) and Saeed et al. (2013).

Leaf area index

Leaf area index is the main physiological determinant of the crop yield due to its major role in utilization of light during crop growth. Leaf area index recorded at various intervals i.e. 45, 60, 75, 90, 105 and 120 DAS is represented in Figure 3 that indicated that peak LAI in all treatments was achieved 90 DAS. Leaf area index was less at early growth stages and slowly increased to acquire its largest increment at 90 DAS thereafter, steady decline was observed in all treatments till 120 DAS. Data revealed that LAI was significantly affected by the application of N in different doses and at different stages. Maximum LAI (5.43) at peak vegetative growth (90 DAS) was observed with treatment receiving ½ N at sowing + ½ remaining N as foliar application in equal splits at tillering, jointing, booting and anthesis with 15 days interval starting at 45 DAS. It was followed by the corresponding LAI (5.38) attained by the N application strategy where 94% N was applied at sowing and then 3% N each as foliar application at tillering and anthesis, respectively. However, the lowest value of LAI (4.13) at its peak was recorded with non-treated control. Lowest leaf area index was found in T_1 (control) at 45, 60, 75, 90, 105 and 120 DAS. There was a positive and linear relationship between leaf area index and grain yield of wheat (Figure 4). Increase in LAI with N application might be ascribed to increase rate of leaf expansion. These results are in agreement with those reported by Srinivas (2002). Significant increase in leaf area index with different N management strategies was also confirmed by Sarakhsi et al. (2010).

Leaf area duration

Leaf area duration is one of the most important growth contributing parameter of the crop. It is the measure of persistence period of assimilatory surface. Photosynthetic capacity is chiefly dependent on LAD as it is the function of leaf longevity and LAI. Data presented in Figure 5 showed significant effect of N management strategies on LAD of wheat. The highest LAD (245.4 days) was observed in treatment receiving ½ N at sowing + ½ remaining N as foliar application in equal splits at tillering, jointing, booting and anthesis with 15 days interval starting at 45 DAS which was statistically similar to plots treated with 94% N at sowing + 3% N as foliar application at tillering + 3% N as foliar application at anthesis). Minimum LAD (185.5 days) was recorded in non-treated control. A linear positive relationship was observed between LAD and grain yield (Figure 6).

Foliar application of nitrogen in equal splits with 15 days interval resulted in better development of leaves which led towards longer LAD. Similar results were reported by Srinivas (2002) and Mahmoodi et al. (2011) as they confirmed significant effect of N application and management on LAD.

Net assimilation rate (g m^{-2} day^{-1})

Net assimilation rate is an essential factor of crop growth. It determines the photosynthetic efficiency of plants, which has major contribution in yield. Nitrogen application through foliar as well as broadcast method significantly increased NAR as displayed in Figure 7. The highest NAR (7.49 g m^{-2} day^{-1}) was observed in plots fertilized with ½ N at sowing + ½ remaining N as foliar application in equal splits at tillering, jointing, booting and anthesis stage with 15 days interval starting at 45 DAS, whereas unfertilized control gave the lowest (5.37 g $m^{-2}day^{-1}$) NAR. Net assimilation rate positively correlated with grain yield (Figure 8). The higher LAD with increased photosynthetic efficiency might have resulted into more total dry matter and net assimilation rate as well might be major reason of increase in NAR of this treatment. These results are in close conformity to those of Ghazanfar et al. (2013).

Agronomic and yield traits

Plant height (cm)

Plant height is a function of genetic makeup and environmental conditions to which plants were exposed during growth period. Data of plant height of wheat recorded near crop harvest are presented in Table 2 that showed significant effect of different N application treatments on this parameter. Among all treatments, plots fertilized with ½ N at sowing + ½ remaining N as foliar application in equal splits at tillering, jointing, booting and anthesis with 15 days interval starting at 45 DAS produced the tallest wheat plants (86.9 cm) which was statistically at par to plants harvested from plots treated with ½ N at sowing + ½ N at tillering (broadcast), $^1/_3$ N at sowing + $^1/_3$N at tillering (broadcast) + $^1/_3$N at anthesis (broadcast) and ½ N at tillering (broadcast) + ½N at anthesis (broadcast). The lowest plant height (76.2 cm) was recorded in control where N was not applied. The higher plant height due to split application of N fertilizer might be due to more efficient uptake of N which resulted in more vegetative development, enhanced mutual shading and more intermodal extension. These results are similar to the results reported by Islam et al. (1993), Khan et al. (2009), Bakht et al. (2010) and Sarakhsi et al. (2010) who found increased plant height in different crops by foliar N application.

Number of tillers m^{-2}

Number of tillers per unit area is very important parameter due to its role in production of grain yield of wheat crop. Data in Table 2 depict the response of different N management strategies on number of tillers m^{-2}. Significant enhancement in this parameter of wheat compared to control was observed in ½ N at sowing + ½ N at tillering (broadcast) that produced highest number of tillers m^{-2} (289). It might be due to balanced availability of N at sowing as well as at tillering which in turn contributed towards increased efficiency regarding number of tillers per unit area. These results are in harmony with the results reported by Maitlo et al. (2006) as they also observed significant effects of split application of foliar N on number of grains $spike^{-1}$.

Number of spikelets $spike^{-1}$

Number of spikelets $spike^{-1}$ is most important contributory factor in crop yield. Data regarding the effect of different treatments on number of spikelets $spike^{-1}$ are presented in Table 2. Maximum number of spikelets $spike^{-1}$ (15.5) was obtained in ½ N at sowing + ½ remaining N as foliar application in equal splits at tillering, jointing, booting and anthesis stage with 15 days interval starting at 45 DAS. Control plots (T_1) produced lowest number of spikelets $spike^{-1}$ (14.025). But these results indicated that number of spikelets $spike^{-1}$ in wheat was greatly influenced by the application method of N fertilizer, with maximum value in case of soil and foliar application of N at different growth stages. Similar finding were observed by Gami et al. (1986) as they reported increase in number of spikelets $spike^{-1}$ with the splits application of foliar N at tillering, booting and grain filling stage.

Number of grains $spike^{-1}$

Number of grains $spike^{-1}$ is the most important contributory factor towards grain yield of wheat. Significant differences in number of grains $spike^{-1}$ were recorded due to splits application of N through broadcast as well as foliar application methods at various growth stages of wheat i.e. tillering, jointing, booting and anthesis (Table 2). It was found that significantly the higher number of grains $spike^{-1}$ (46.3) in wheat was found in the treatment where N was applied as ½ N at sowing (broadcast) + ½ remaining N as foliar application in equal splits at tillering, jointing, booting and anthesis stage with 15 days interval starting at 45 DAS. Lowest (36.835) number of grains $spike^{-1}$ was recorded in control (without N application). Maximum number of grains $spike^{-1}$ in aforementioned treatment could be attributed to balanced N availability to plants not only at different stages of crop growth but especially at anthesis stage which led towards more number of grains per spike.

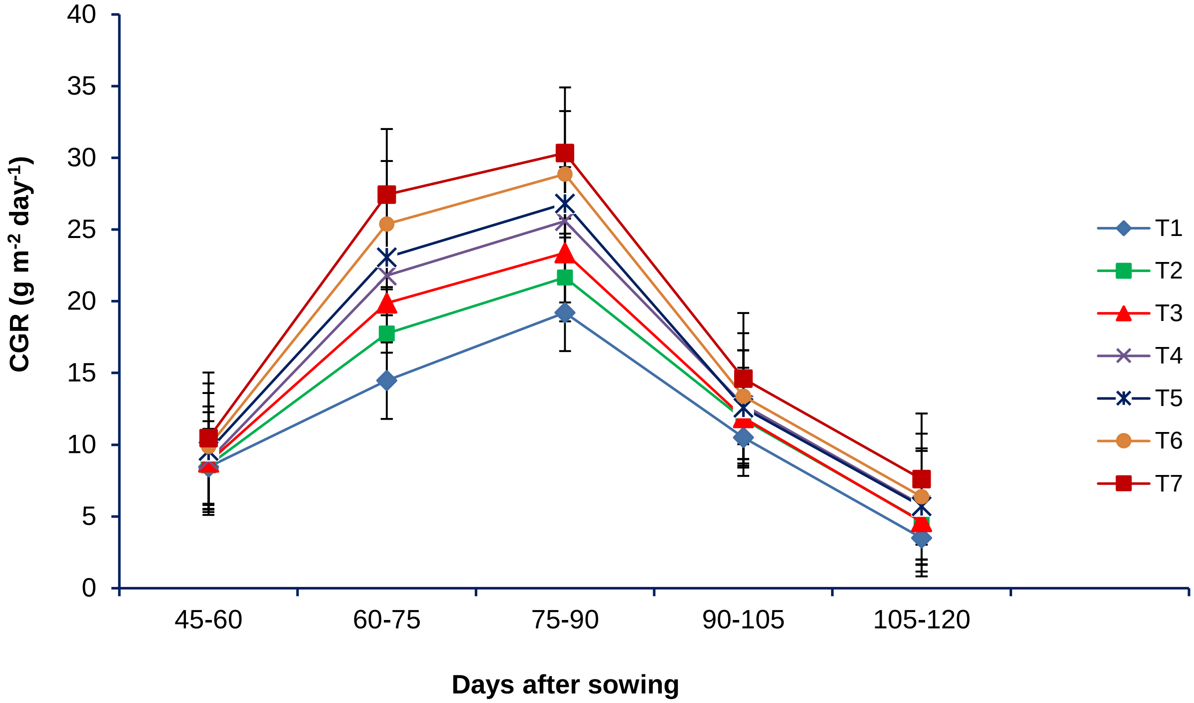

Figure 1 Effect of nitrogen management strategies on crop growth rate (CGR) of wheat

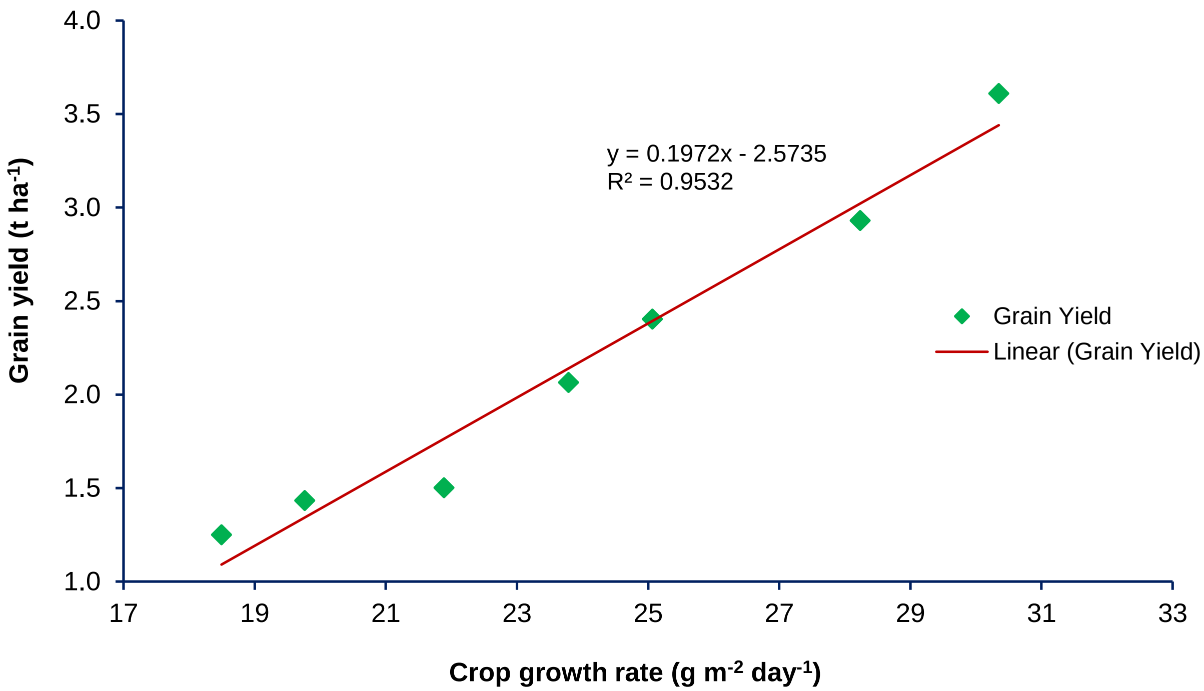

Figure 2 Relationship between crop growth rate (CGR) and grain yield of wheat

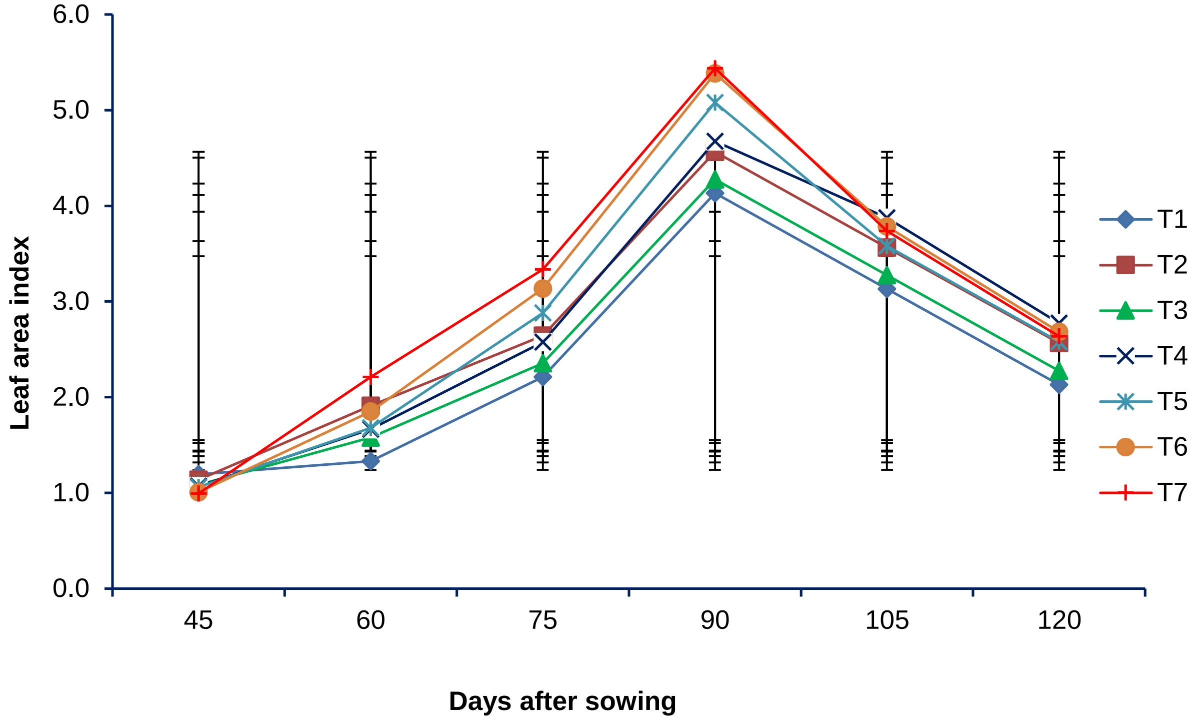

Figure 3 Effect of nitrogen management strategies on leaf area index (LAI) of wheat

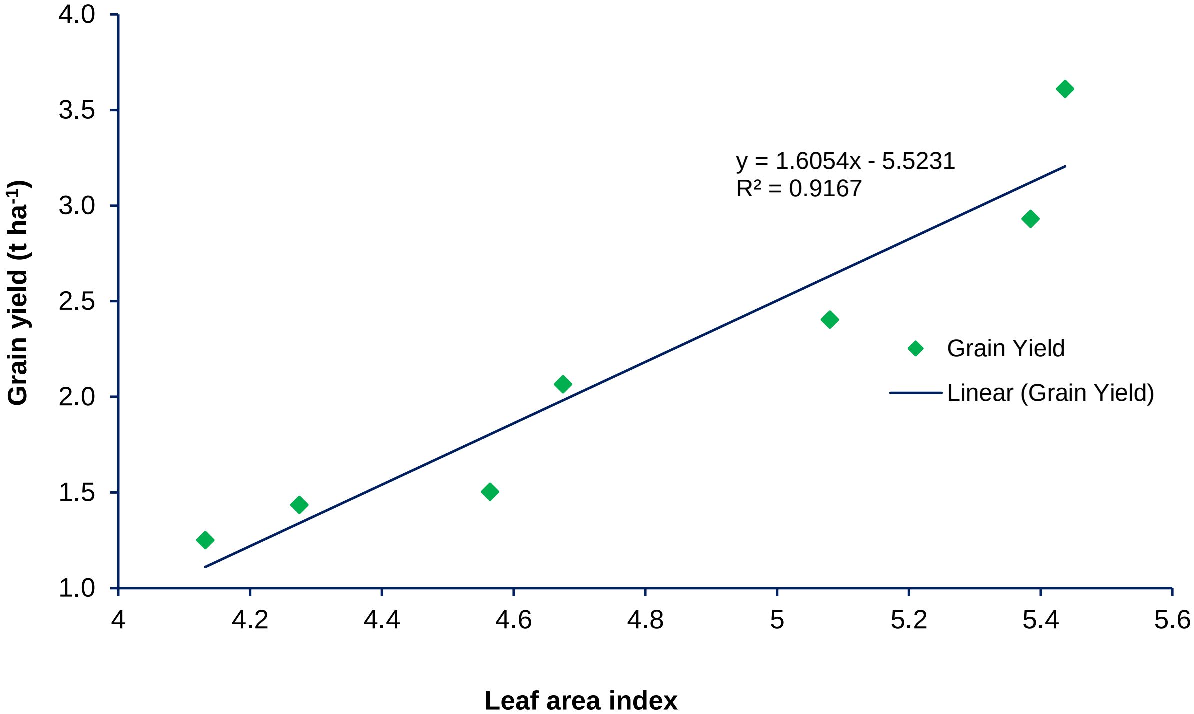

Figure 4 Relationship between leaf area index and grain yield of wheat

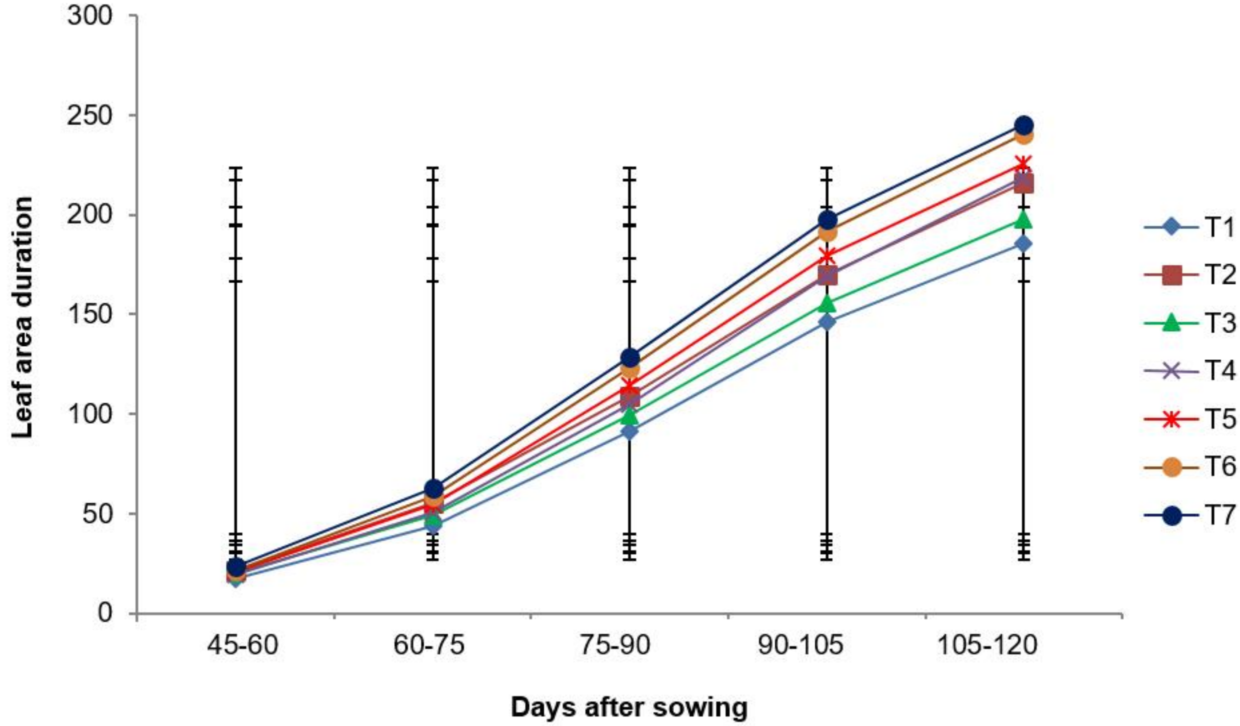

Figure 5 Effect of nitrogen management strategies on leaf area duration (LAD) of wheat

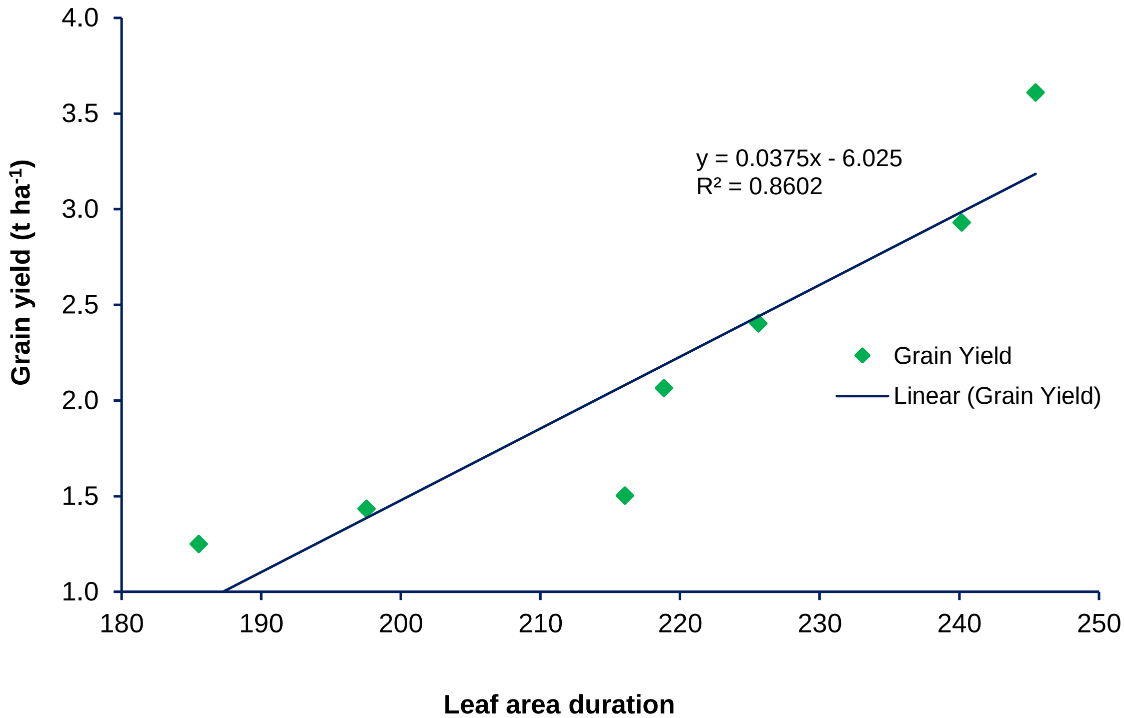

Figure 6: Relationship between leaf area duration and grain yield of wheat

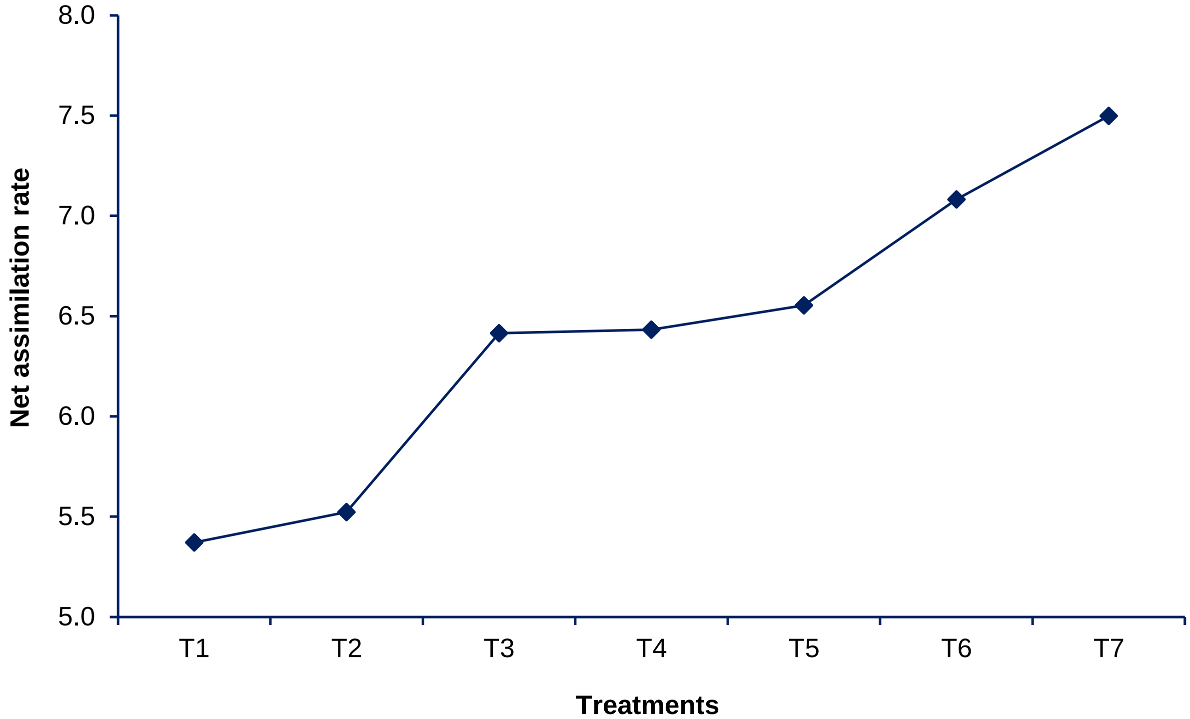

Figure 7 Effect of nitrogen management strategies on net assimilation rate (NAR) of wheat

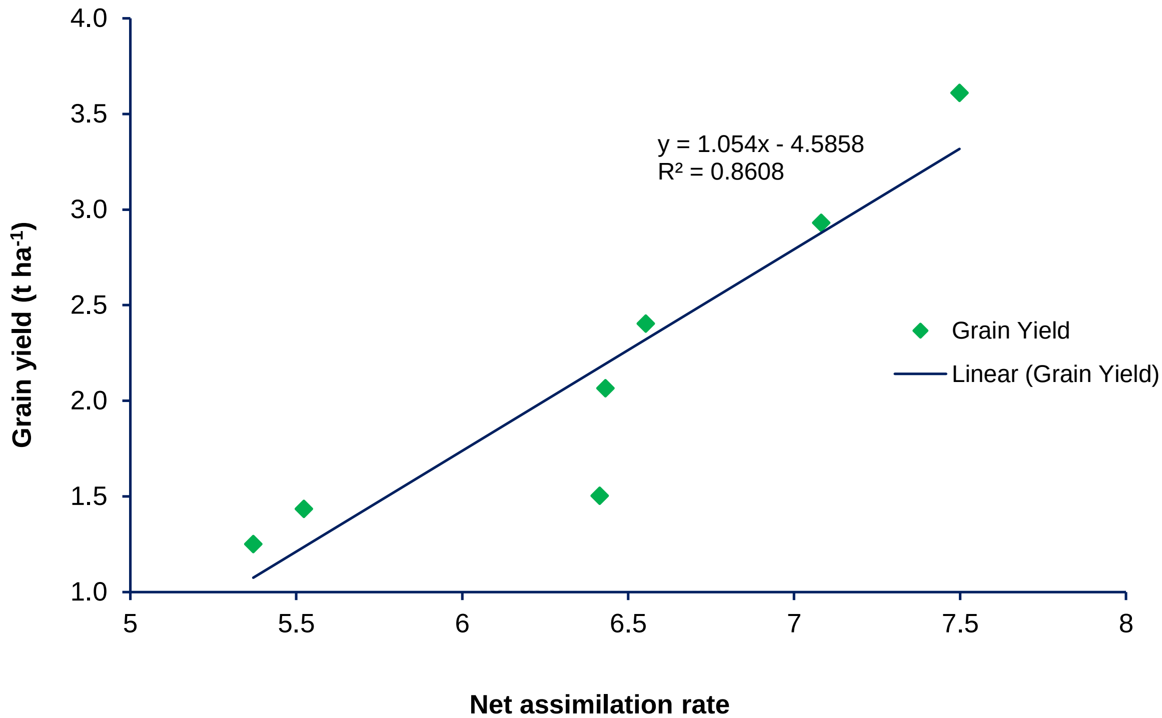

Figure 8 Relationship between net assimilation rate and grain yield of wheat

These results are in line with Islam et al. (1993), Arif et al. (2006), Khan et al. (2009) Bakht et al. (2010), Gul et al. (2011), Saeed et al. (2012) and Abbas et al. (2016) as they reported significant effect of foliar application of N on number grains spike^{-1}.

Spike length (cm)

Spike length is very crucial parameter for determining grain yield of wheat. Data indicated in Table 2 is portraying the important role of different N management strategies on spike length of wheat. Maximum spike length (10.85 cm) was obtained in plots where N was applied as ½ N at sowing + ½ remaining N as foliar application in equal splits at tillering, jointing, booting and anthesis with 15 days interval starting at 45 DAS. Smallest spikes were observed in control where no N fertilizer was applied. These findings are in concurrent with Bakht et al. (2010), Khan et al. (2009) and Islam et al. (1993) who found higher spike length of wheat in response to foliar N application

1000-grain weight (g)

The grain weight is one of most important yield component measuring the final grain yield of wheat. Comparison of various treatment means illustrated that 1000-grain weight significantly differed due to split application of N at different growth stages. Data presented in Table 2 illustrated that there was progressive increment in 1000-grain weight from N management strategy from control to ½ N at sowing + ½ remaining N as foliar application in equal splits at tillering, jointing, booting and anthesis with 15 days interval starting at 45 DAS, and all treatments were statistically different from each other. Plots treated with ½ N at sowing + ½ remaining N as foliar application in equal splits at 15 days interval starting at 45 DAS resultantly produced significantly the highest (48.7 g) 1000-grain weight. Increase in 1000-grain weight of wheat in treatment receiving ½ N at sowing + ½ remaining N as foliar application in equal splits at 15 days interval starting at 45 DAS might be due to balanced supply of N at grain filling stage which lead towards more 1000-grain weight. Bakht et al., (2010) also reported significant differences in 1000-grain weight by application of foliar splits of N fertilizer. Our results are in consonance by them. Similar findings of enhanced 1000-grain weight of wheat by foliar N fertilization were also reported by Zoz et al. (2009), Khan et al. (2009), Saeed et al. (2012) and Islam et al. (1993).

Biological yield (t ha^{-1})

It is crucial parameter portraying valuable information about overall growth of crop. Application of N splits at different stages of crop growth influenced biological yield significantly. Data regarding biological yield is presented in Table 2. The highest (9.65 t ha^{-1}) biological yield was exhibited by N application as ½ N at sowing + ½ N at tillering (broadcast) which was statistically similar to treatment receiving N as ½ N at sowing + ½ remaining N as foliar application in equal splits at 15 days interval starting at 45 DAS. Lowest (5.875 t ha^{-1}) biological yield was achieved by control. More biological yield in split N application treatments might be due to the production of more number of tillers m^{-2} and it seemed to be in a consequence of supply of N. Arif et al. (2006) found significant increase in biological yield through foliar application of N in different splits. Similar results were also reported by Khan et al. (2009), Gul et al. (2011) and Saeed et al. (2012).

Grain yield (t ha^{-1})

Data about grain yield of wheat is given in Table 2 which indicated that treatments differed significantly with each other as a result of application of fertilizer with different methods and timing. It was concluded that ½ N at sowing + ½ remaining N as foliar application in equal splits at 15 days interval starting

Table 2 Effect of nitrogen management strategies on grain yield and yield related traits of wheat

Treatments	Plant height (cm)	Number of tillers m^{-2}	Number of spikelets spike^{-1}	Number of grains spike^{-1}	Spike length (cm)	1000-grain weight (g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})
T_1	76.25 c	213.7 b	14.02 b	36.83 e	8.06 e	34.37 g	5.87 c	1.25 d
T_2	85.05 ab	289.0 a	14.30 b	40.75 c	8.57 cde	46.05 b	9.65 a	2.06 c
T_3	83.87 b	219.5 b	14.55 b	39.10 d	8.88 cd	42.19 d	7.00 bc	2.40 c
T_4	86.52 ab	235.2 ab	14.20 b	40.82 c	9.18 c	37.63 e	6.87 bc	1.50 d
T_5	84.55 ab	242.7 ab	14.27 b	37.23 e	8.31 de	35.51 f	6.50 bc	1.43 d
T_6	81.5 b	258.5 ab	14.62 b	43.90 b	10.14 b	44.01 c	7.25 bc	2.93 b
T_7	86.97 a	240.0 ab	15.57 a	46.37 a	10.85 a	48.71 a	8.12 ab	3.61 a

T_1 = Control (no fertilization), T_2 = ½ N at sowing + ½ N at tillering (broadcast), T_3 = (½ N at sowing (50%) + ¼ of N at tillering (broadcast) + ¼ of N at anthesis (broadcast)), T_4 = $^1/_3$ N at sowing + $^1/_3$ N at tillering (broadcast) + $^1/_3$ N at anthesis (broadcast), T_5 = ½ N at tillering (broadcast) + ½ N at anthesis (broadcast), T_6 = 94% N at sowing + 3% N as foliar application at tillering + 3% N as foliar application at anthesis, T_7 = (½ N at sowing + ½ remaining N as foliar application in equal splits at tillering, jointing, booting and anthesis with 15 days interval starting at 45 DAS at 45 DAS N application was a leading treatment over others as it gave maximum grain yield of 3.6 t ha^{-1}. Highest value of grain yield shown by ½ N at sowing + ½ remaining N as foliar application in equal splits at tillering, jointing, booting and anthesis with 15 days interval starting at 45 DAS might be due to higher values of yield contributing parameters such as number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, spike length and 1000-grain weight under this N application treatment. Moreover, the strong positive association of CGR, LAI, LAD and NAR with grain yield as depicted by the regression analyses among them (Figures 2, 4 , 6 and 8) also proved that grain yield enhancement of wheat was attributed to improvement in these growth parameters. These results are in harmony with results reported by Islam et al. (1993), Bakht et al. (2010), Saeed et al. (2012), Arif et al. (2006), Irfan et al. (2016), Maitlo et al. (2006) and Afifi et al. (2011) that foliar N application resulted in increased grain yield of wheat.

CONCLUSION

Nitrogen application as ½ N at sowing + ½ remaining N as foliar application after 45 DAS in three splits with 15 days interval at critical stages of tillering, jointing, booting and anthesis was the best strategy that gave the highest grain yield as well as yield contributing parameters of wheat.

REFERENCES

Abbas A, ME Safdar, A Ali, M Asif, A Rehman (2016) Effect of foliar application of zinc at different growth stages on grain yield and quality of wheat (*Triticum aestivum* L.). *Journal of Environment and Agriculture*, **1:** 106−110.

Abbate PE, FH Andrade, JP Culot (1995). The effect of radiation and nitrogen on number of grains in wheat. *Journal of Agricultural Science Cambridge*, **124:** 351–360.

Afifi MHM, RKM Khalifa, CY El-Dewiny (2011) Urea foliar application as a partial substitution of soil-applied nitrogen fertilization for some maize cultivars grown in newly cultivated soil. *Australian Journal of Basic and Applied Sciences,* **5:** 826–832.

Ahmad L, M Kaleem, RA Bhat (2012) Response of nitrogen and foliar spray of nutrient mixture on yield attributes and yield of wheat (*Triticum aestivum* L.). *Journal of Cereals and Oilseeds,* **3:** 28–34.

Ali A, T Khaliq, A Ahmad, S Ahmad, AU Malik, F Rasul (2012) How wheat responses to nitrogen in the field? *A Review of Crop and Environment,* **3:** 71–76.

Anonymous (2017) Pakistan Economic Survey 2016-17. Economic Adviser's Wing Economic Adviser's Wing, Finance Division, Government of Pakistan, P 23.

Arif M, MA Chohan, S Ali, R Gul, S Khan (2006) Response of wheat to foliar application of nutrients. *Journal of Agriculture and Biological Sciences,* **1:** 30–34.

Bakht J, M Shafi, M Zubair, MA Khan, Z Shah (2010) Effect of foliar vs soil application of nitrogen on yield and yield components of wheat varieties. *Pakistan Journal of Botany*, **42:** 2737–2745.

Diacono M, P Rubino, F Montemurro (2013) Precision nitrogen management of wheat. A review. *Agronomy for Sustainable Development,* **33:** 219–241.

Fisher RA, GN Howe, Z Ibrahim (1993) Irrigated spring wheat and timing and amount of nitrogen fertilizer. I. Grain yield and protein content. *Field Crops Research,* **33:** 37–56.

Gami JK, MT Parmar, JC Patel, Malavia (1986) Effect of rates and method of nitrogen application on dwarf wheat. *Indian Journal of Agronomy,* **31:** 401–402.

Ghazanfar U, GA Khan, IU Awan, MA Khan, AA Khakwani, MS Baloch, QU Khan, MS Jilani, K Wasim, S Javeria, G Jilani (2013) Wheat Response to application methods and levels of nitrogen fertilizer: I. Phenology, growth indices and protein content. *Pakistan Journal of Nutrition,* **12:** 365–370.

Gul H, A Said, B Saeed, I Ahmad, K Ali (2011) Response of yield and yield components of wheat towards foliar spray of nitrogen, potassium and zinc. *Journal of Agriculture and Biological Sciences,* **6:** 23–25.

Hunt R (1978). Plant growth analysis. Edward Arnlod (Pub.) Ltd., **96:** 8–38.

Irfan M, MY Memon, JA Shah, M Abbas (2016) Application of nitrogen and phosphorus in different ratios to affect paddy yield, nutrient uptake and efficiency relations in rice (*Oryza sativa* L.). *Journal of Environment and Agriculture*, **1:** 79–86.

Islam MN, RK Paul, TMK Anwar (1993) Effect of foliar application of nitrogen on grain yield of wheat. *Pakistan Journal of Agricultural Sciences,* **30:** 403–406.

Khan P, MY Memon, M Imtiaz, M Aslam (2009) Response of wheat to foliar and soil application of urea at different growth stages. *Pakistan Journal of Botany*, **41:** 1197–1204.

Kolota E, M Osinska (2001) Efficiency of foliar nutrition of field vegetables grown at different nitrogen rates. *Acta Horticulturae,* **563:** 87–91.

Laghari GM, FC Oad, S Tunio, AW Gandahi, MH Siddiqui, AW Jagirani, SM Oad (2010). Growth, yield and nutrient uptake of various wheat cultivars under different fertilizer regimes. *Sarhad Journal of Agriculture,* **26:** 489–497.

Mahmoodi P, M Yarnia, R Amirnia, MBK Benam (2011) Effect of nitrogen foliar application on grain filling rate and period in 3 cultivars of corn (*Zea mays* L.). *African Journal of Agricultural Research*, **6:** 6226–6231.

Maitlo A, Z Hassan, AN Shah, H Khan (2006). Growth, yield and nutrient uptake of wheat (*Triticum aestivum* L.) in relation to foliar and soil application of urea. *International Journal of Agriculture and Biology*, **8:** 477–481.

Patel JR (1999) Effect of levels and methods of nitrogen application on wheat yield. *Journal of Maharashtra Agricultural Universities,* **24:** 108–109.

Paux E, P Sourdille, J Salse, C Saintenac, F Choulet, P Leroy, A Korol, M Michalak, S Kianian, W

Spielmeyer, E Lagudah, D Somers, A Kilian, M Alaux, S Vautrin, H Bergès, K Eversole, R Appels, J Safar, H Simkova, J Dolezel, M Bernard, C Feuillet (2008) A physical map of the 1-gigabase bread wheat chromosome 3B. *Science,* **322:** 101–104.

Rahman MA, MA Sufian, M Saifuzzaman, J Chikushi (2002) Nitrogen management in rice-wheat alternating cropping system and wheat genotype identification preferable to surface seeding condition. *Journal of the Faculty of Agriculture, Kyushu University,* **46:** 295–301.

Ramu N (2008) Nitrogen management in wheat under irrigated conditions. M.Sc. Thesis. University of Agricultural Sciences, Dharwad.

Saeed B, H Gul, ZKL Parveen (2012) Growth factors and straw yield of wheat cultivars in relation with nitrogen and sulfur fertilization. *ARPN Journal of Agriculture and Biological Sciences,* **7:** 13–22.

Saeed B, H Gul, F Ali, AZ Khan, S Anwar, Nasrullah, S Alam, S Khalid, A Naz, H Fayyaz, Azra (2013) Contribution of soil and foliar fertilization of nitrogen and sulfur on physiological and quality assessment of wheat (*Triticum aestivum* L.). *Natural Science,* **5:** 1012–1018.

Sarakhsi HS, M Yarnia, R Amirniya (2010) Effect of nitrogen foliar application in different concentration and growth stage of corn (Hybrid-704). *Advances in Environmental Biology,* **4:** 291–298.

Shah KH, MY Memon, SH Siddqui, M Imtiaz, M Aslam (2007) Response of wheat to foliar applied urea at different growth stage and solution. *Pakistan Journal of Plant Pathology,* **2:** 48–55.

Srinivas A (2002) Influence of nitrogen and methods of zinc application on growth and yield of wheat (*Triticum aestivum* L.) varieties. *Indian Journal of Agricultural Sciences,* **36:** 167–171.

Steel RGD, JH Torrie, D Dickey (1997) Principles and Procedures of Statistics. A Biometrical Approach, 3rd Ed. McGraw Hill Book Co., Inc., New York, USA.

Waraich EA, R Ahmad, Saifullah, M Sabir (2007) Nitrogen nutrition and water stress effects on growth, yield and water use efficiency of wheat *(Triticum aestivum* L.). *Pakistan Journal of Agricultural Sciences,* **44:** 64–73.

Watson DJ (1952).The physiological basis of variation in yield. *Advances in Agronomy,* **4:** 101–145.

Wendling A, E Flf, C MM, A Tjc, J Mielniczuk, LT Thome (2007) Fertilizer recommendation nitrogen for wheat after maize and soybean under system tillage in Paraguay. *Brazilian Journal of Soil Science,* **31:** 985-994.

Zoz T, R Fey, JS Calegari, EP Seidel, F Steiner, L Costa (2009). Foliar application of NPK + Polihexose in the culture of wheat. *Scientia Agraria Paranaensis,* **8:** 127–140.