Scholars Bulletin *(Agriculture)*
An Official Publication of "Scholars Middle East Publishers"
Dubai, United Arab Emirates
Website: www.saudijournals.com
ISSN 2412-9771 (Print)
ISSN 2412-897X (Online)

Effects of Nitrogen and Zinc Fertilization Levels on Growth and Yield of Late Sown Wheat

Akhi Paul Chowdhury[1*], Mrityunjoy Biswas[2&3], P Mandal[4], Bonani Bhattacharjee Tithi[1], M Kadir[5]
[1]MS student, Department of Agronomy and Haor Agriculture, Sylhet Agricultural University, Bangladesh
[2]Professor, Department of Agronomy and Haor Agriculture, Sylhet Agricultural University, Bangladesh
[3]Present address: Professor, Department of Agro Product Processing Technology, Jashore University of Science and Technology, Bangladesh
[4]Assistant Professor, Department of Agronomy and Haor Agriculture, Sylhet Agricultural University, Bangladesh
[5]Principal Scientific Officer, Bangladesh Agricultural Research Institute, Bangladesh

***Corresponding author**
Akhi Paul Chowdhury

Article History
Received: 29.04.2018
Accepted: 12.05.2018
Published: 30.05.2018

DOI:
10.36348/sb.2018.v04i05.006

Abstract: The experiment was carried out at the Regional Agricultural Research Station, Jamalpur under Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701 during the period from December, 2015 to April, 2016 to observe the effect of nitrogen and zinc on the growth and yield of late sown wheat. The experiment comprised four nitrogen levels viz. (i) N_0= Control (No nitrogen), (ii) N_1=140 kg ha^{-1}, (iii) N_2=160 kg ha^{-1}, (iv) N_3=180 kg ha^{-1} and five zinc levels viz. (i) Zn_0 = Control (No zinc), (ii) Zn_1= 2 kg ha^{-1}, (iii) Zn_2 = 4 kg ha^{-1}, (iv) Zn_3=6 kg ha^{-1}, and (v) Zn_4=8 kg ha^{-1}. The experiment was laid out in a split-plot design with three replications assigning N-levels in the main plots and Zn-levels in the sub-plots. The interaction effect of N and Zn levels showed significant variation regarding grain yield and the highest grain yield (1.96 t ha^{-1}) was found in N_2Zn_3 combination ascribed to the highest number of tiller (376.33 $plant^{-1}$), grain (37.07 $spike^{-1}$) and 1000-grain weight (36.26 g) significantly different from other combinations. Grain yield decreased significantly beyond the levels N_2 and Zn_3 due to their either individual effect or interaction effect. The lowest level, N_0 and Zn_0 gave significantly the lowest grain yield due to their either individual effect or interaction effect (0.69, 1.24 and 0.61 t ha^{-1} respectively).
Keywords: Nitrogen, Zinc, Yield, Late Sown,Wheat

INTRODUCTION

Wheat is the second most important grain crop of Bangladesh after rice in economic and consumption importance. It states first both in area (21,360 thousand hectares) and production (5,76,317 thousand metric ton) in the whole world [1]. This cereal crop accounting for 30% of all cereal food worldwide and is a staple food for over 10 billion people in 43 countries of the world. Wheat is widely used to prepare bread, cake, crackers, cookies, pastries, flour and so many food items. It comprises about 12.1% protein, 69.60% carbohydrate, 1.72% fat, 27.60% minerals and a good origin of vitamin B complex [2]. It provides about 20% of the total food calories for the human being [3]. At present, production of wheat is increasing day by day, although the country still imports significant quantities of wheat to meet up the fast growing domestic demand of Bangladesh [4]. Bangladesh imported 3.1 million metric tons of wheat each year to ensure the local demand [5]. At this crisis situation, to increase the wheat production, proper management of the crop is to be ensured rather than horizontal increment of cultivation as about 1% of agricultural land is decreasing in each year for urbanization and industrialization. In Bangladesh, it is a rabi season crop which requires dry weather and bright sunlight and the best time of sowing of wheat is the second half of November. Because of long duration transplant aman rice cultivation, a considerable land area goes under late sown condition beyond first week of December. The crop under late sown condition experienced late heat stress at flowering and grain filling period. A favorable balance of macro and micronutrients may be useful for optimum crop production under the situation. Among the macronutrients,nitrogen is the main that is taken by the plants in comparatively large quantities which is highly deficient in Bangladesh soils. Nitrogen fertilizer is known to affect the number of tillers m^{-2}, number of spikelet's $spike^{-1}$, number of grains $spike^{-1}$, spike length and 1000-grain weight. Wheat yield increases with the raise of nitrogenous fertilizer [6].Grain yield of wheat increases with increasing the nitrogen level up to 120 kg ha^{-1} [7]. The maximum grain yield (3385 kg ha^{-1}), protein contents (12.26%) and harvest index were obtained from plots given with nitrogen full dose at sowing @ 150 kg ha^{-1} [8].

Again zinc as a plant nutrient which has received considerable attention because of its less occurrence in the soil and critical for plant growth. It is obvious important both for human and plants. Zinc plays a significant role in enzymes activation as well. The efficiency of such kind of element is improved when it is used in combination with other elements like N and K [9-10]. Applying Zn fertilizers to cereal crops improve not only productivity, but also grain Zn concentration of plants. Based on the soil conditions and application form, Zn fertilizers can increase grain Zn concentration up to fourfold under field conditions [11-15]. Affluence of cereal grains with Zn is, therefore, a high attention area of research and will avail to cut down Zn deficiency-related health problems in humans. Among the interventions currently being used as major resolution to Zn deficiency in humans, food fortification and supplementation are being widely applied in some countries. However, these pathways appear to be expensive and not easily receivable by those living in developing countries [16-17]. The substitute way is to apply Zn fertilizers to soil in rectification of Zn deficiency and flourishing plant growth and yield [15, 18-21].

Wheat variety BARI Gom-28, released by BARI in the recent year has been gaining popularity for its high yield and late sown potentiality. Several works have been done for optimum doses of nitrogen and zinc for wheat under optimum sowing condition but still limited works have been done under late-sown condition with BARI Gom-28 for its growth and yield. Hence, in view of the importance of nitrogen and zinc, the present study was carried out.

MATERIALS AND METHODS

Study area

The research work was conducted at the Regional Agricultural Research Station (RARS), Jamalpur under Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701. The geographic coordinates of the area located between $24^0 34'$ and $25^0 26'$ N latitude and between $89^0 40'$ and $90^0 12'$ E longitude at a height of15 m above the mean sea level (AEZ 9). The selected land was above flood level and sufficient sunshine was available during the experimental period. The average monthly maximum, minimum and mean temperatures, relative humidity and rainfall during the crop growing period from December 2015 to April 2016 have been presented in Table 1.

Experimental design and procedure

The experiment was laid out in a Split-plot design with three replications. The experiment consisted of two factors and that were the different levels of nitrogen and zinc fertilizers. Four levels of nitrogen viz. N_0:Control, N_{140}:140 kg ha^{-1}, N_{160}:160 kg ha^{-1} and N_{180}: 180 kg $ha^{-1}$and five levels of zinc viz. Zn_0: Control, Zn_2:2 kg ha^{-1}, Zn_4: 4 kg ha^{-1}, Zn_6:6 kg ha^{-1} and Zn_8:8 kg ha^{-1}. The test crop was wheat (*Triticumaestivum*) and variety named BARI Gom-28 was released by Bangladesh Agricultural Research Institute in 2012 for cultivation throughout Bangladesh. The field was fertilized with P, K, S and B at the rate of 40-120-20-1.5 kg ha^{-1} [22] including N and Zn in the form of triple super phosphate (TSP), muriate of potash (MoP), gypsum, boric acid, urea, and zinc sulphate respectively. Seeds were sown continuously in 20 cm apart line on 15 December 2015 @ 125 kg ha^{-1}. Nitrogen and zinc fertilizers were applied as per treatments. The whole amount of TSP, MoP, gypsum, boric acid, zinc sulphate and half of N were incorporated in the soil at the time of final land preparation in each plot. The remaining amount of N was top dressed at Crown root initiation stage (CRI) after first irrigation at 20 days after sowing (DAS) of seeds. Intercultural operations were done to ensure and maintain optimum growth and development of the crop. Weeding was done twice during the whole growing period, the first one at 28 DAS and the second one at 49 DAS. Two irrigations were applied, the first one at 20 DAS at crown root initiation (CRI) and the second one at 50 DAS at the start of booting stage. Irrigation was applied so carefully that excess water could not flow from one plot to another or overflow the boundary of the plot. Initial soil sample was collected before land preparation from 0-15 cm and 15-30 cm soil depths. Then the samples were air dried and sieved through a 10 mesh sieve and stored in a clean plastic container for chemical analysis in the laboratory. Then the soils were analyzed for determination the values of pH, organic matter, total nitrogen, exchangeable K, available phosphorus, available sulfur, available boron and available zinc. The crop was harvested at maturity on April 27, 2016 When 80% of the spike become straw color. Prior to harvest, five hills from each plot were randomly selected to collect data on plant characters, yield and yield attributes. After harvesting the crop of each plot was bundled and brought out in the threshing floor. After drying in the sun at the threshing floor for three days grain and straw were separated by beating. Grain yield of each plot was expressed as t ha^{-1} on 12% moisture basis. The following developed formula was used to calculate harvest index [23].

Equation (1) $$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Data analysis

The analysis of variance (ANOVA) was performed by using R program. The difference among the treatment means was estimated by LSD (Least Significance Difference) test at 5% level of probability wherever F values were found significant [24].

RESULTS AND DISCUSSION

This chapter comprised with presentation and discussion of the results obtained from the experiment. The results are described, discussed, compared and interpreted with proper justification.

Soil properties before planting

The chemical properties of the soil before planting are indicated in Table 2. The analyzed soil was with a pH of 6.39 in case of 0-15 cm (near neutral) and 7.00 in case of 15-30 cm depth (neutral). The soil sample from 0-15 cm contained 3.31% organic matter which was higher than soil sample of 15-30 cm depth contained 0.81% organic matter. The status of K is medium for 0-15 cm depth soil and very low in case of 15- 30 cm depth soil. The status of P, S, B, and Zn of 0-15 cm depth are low, medium, medium and high respectively. On the other hand, the status is very low, low, medium and medium for P, S, B and Zn respectively. In general fertility status was low.

Table-1: Weather data of the experimental site during the crop growing period

Month	Average Temperature (^{0}C)			RH (%)			Rainfall (mm)
	Max.	Min.	Mean	Max.	Min.	Mean	
December 2015	33.59	23.44	28.48	81.37	67.29	80.08	5
January 2016	23.99	12.41	17.98	89.56	67.41	88.36	15
February 2016	28.29	15.61	21.95	82.58	58.88	62.15	2.5
March 2016	32.57	19.77	26.17	72.87	62.10	69.33	9.0
April 2016	35.20	24.77	29.98	79.67	61.30	83.80	7.5

Source: Mini Weather Station, RARS, Jamalpur, Bangladesh

Table-2: Chemical properties of soil before planting

Soil characteristics	0-15 cm	15-30 cm	Critical level
Soil pH	6.39	7.00	-
Organic matter (%)	3.31	0.81	-
Total nitrogen (%)	0.191	0.047	0.12
Exchangeable K (milimol 100g^{-1} soil)	0.13	0.08	0.12
Available P (µg g^{-1} soil)	14.21	5.46	7.0
Available S (µg g^{-1} soil)	18.42	10.86	10.0
Available B (µg g^{-1} soil)	0.37	0.34	0.2
Available Zn (µg g^{-1} soil)	1.98	0.98	0.6

Source: Soil Resource Development Institute (SRDI), Regional Office, Sylhet, Bangladesh

Effects of nitrogen on the growth, yield and yield attributes

The nitrogen levels showed a significant variation in terms of growth, yield and yield attributes of wheat as the results for all intended treatments are given in Table-3. The yield and yield attributes were highly significant ($p<0.001$) at various doses of nitrogen applied in that experiment. The tallest plant (77.51 cm) was noted in N_3 where 180 kg N ha^{-1} was used while the shortest height (54.35 cm) was recorded in N_0 (control, no nitrogen was used). Result showed that there was a progressive increased plant height with increasing the N levels. This finding was agreed with the result of [25, 26] and dissimilar with [27]. The highest number of effective tillers plant^{-1}(3.57) was noted in N_2 while the lowest (2.75) was recorded in N_0. Number of tillers m^{-2} (310.73) was produced highest by N_2 receiving 160 kg N ha^{-1} and N_0 (control) gave the lowest tillers m^{-2} (192.87). This result was in conformity with [28, 29]. Spike length was found highest (7.81 cm) from the treatment N_2 when 160 kg ha^{-1} was used while the lowest length (4.03 cm) from N_0 where no nitrogen was applied. Spike length increased sharply with increasing N level up to a certain level then declined with further increased. This result was in line with [30-32]. Results also indicated that highest number of spikelets spike^{-1} (12.35) and number of florets spike^{-1} (38.97) were noted in N_2 where 160 kg ha^{-1} was used and N_0 (no nitrogen) produced the lowest number of spikelets spike^{-1} (7.48) and florets spike^{-1} (18.89). The highest number of grains spike^{-1} (31.85) was recorded by the treatment N_2 (160 kg N ha^{-1}) and lowest grains spike^{-1} (9.36) from N_0 (control). Compared to N_2 level significantly reduced number was obtained from N_3 might be due to adverse effect of excessive dressings of N on the grain formation in wheat. The results partially corroborated with [33, 34]. Result showed that highest number of empty florets spike^{-1} (9.53) was recorded in N_0 (control) while the lowest from N_2 receiving 160 kg ha^{-1}. The highest 1000-grain weight (34.42 g) was recorded in N_2, whereas, the lowest 1000-grain weight (26.91 g) was recorded in $N_{0.}$ The results obtained from the treatment N_2 (160 kg ha^{-1}) and N_3 (180 kg ha^{-1}) was statistically similar to each other. The results coincide with that of [25, 33] and disagreed with [29, 35]. The highest grain yield (1.70 t ha^{-1}) was noted in N_2 receiving 160 kg ha^{-1} beyond which grain yield decreased significantly while N_0 (control) produced the lowest grain yield (0.69 t ha^{-1}). Grain yield was attributed by the higher number of tiller m^{-2}, grain spike^{-1} and 1000-grain weight in the N_2 treatment. The results are in agreement with the results of [36, 37]. The highest straw yield (2.85 t ha^{-1}) was noted in N_3 where 180 kg ha^{-1} was used and N_0 gave the lowest (1.32 t ha^{-1}). Result also indicated that the highest harvest index (40.19%) was noted in N_2 (where 160 kg ha^{-1} was used as treatment) and lowest (34.58%) from N_0 with no nitrogen. Results showed that most of the parameters were increased with increasing the N level up to N_2 (160 kg ha^{-1}). The further increment decreased those parameters. So, N_2 gave the best result was statistically different from others.

Table-3: Yield and yield attributes of late sown wheat as influenced by Zn levels during rabi season 2015-2016

N-levels	Plant height (cm)	Number of effective tillers plant^{-1}	Number of tillers m^{-2}	Spike length (cm)	Number of spikelets spike^{-1}	Number of florets spike^{-1}	Number of grains spike^{-1}	Number of empty florets spike^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
N_0	54.35d	2.75d	192.87d	4.03d	7.48d	18.89d	9.36d	9.53a	26.91c	0.69d	1.32c	34.58c
N_1	63.49c	3.20c	242.40c	6.87c	8.65c	23.05c	14.48c	8.57b	29.21b	1.60c	2.44b	39.45a
N_2	68.44b	3.57a	310.73a	7.81a	12.35a	38.97a	31.85a	7.12d	34.42a	1.70a	2.52b	40.19a
N_3	77.51a	3.38b	275.53b	7.24b	10.76b	32.13b	23.90b	7.79c	33.15a	1.67b	2.85a	36.85b
Level of significance	***	***	***	***	***	***	***	***	***	***	***	***
$LSD_{0.05}$	2.35	0.17	6.92	0.18	0.54	1.87	1.69	0.54	2.21	0.03	0.11	1.39
CV(%)	3.98	6.01	3.03	3.08	6.20	7.42	3.54	7.26	8.03	3.16	5.53	4.14

Note: In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD test at 5% level of probability; N_0 =0 kg ha^{-1}, N_1 =140 kg ha^{-1}, N_2 =160 kg ha^{-1}, N_3 =180 kg ha^{-1}, *** indicates mean values are significantly different at 0.1% level of probability.

Effects of zinc on the growth, yield and yield attributes

Data presented on Table 4 showed that various Zn levels were highly significant (p<0.001) on all the parameters of wheat. All parameters gave highest value in Zn_3 treatment where 6 kg Zn ha^{-1} was applied except plant height and straw yield were found maximum in Zn_4 with 8 kg Zn ha^{-1}. The tallest plant (71.93 cm) was obtained from treatment Zn_4 which was statistically different from others and the shortest one (59.92 cm) from Zn_0 treatment (control). The result is in agreement with [38]. The highest number of effective tillers plant^{-1} (3.51) was noted in Zn_3 and Zn_0 (control) gave the lowest one (2.89). Data from Zn_3 receiving 6 kg ha^{-1} produced the highest number of tillers m^{-2} (305.17) whereas the lowest number (214.17) was noted in Zn_0 (control). This result agreed with findings of [39]. The highest values of spike length (7.28 cm), number of spikelets spike^{-1} (11.27) and number of florets spike^{-1} (33.39) were noted in Zn_3 and lowest values of spike length (5.81 cm), number of spikelets spike^{-1} (8.42) and number of florets spike^{-1} (24.39) were noted in Zn_0 where no zinc was applied. The highest number of grains spike^{-1} (23.85) was found from Zn_3 and Zn_0 (control) gave the lowest number of grains spike^{-1} (16.67). This result is akin to [39]. The treatment Zn_3 receiving 6 kg Zn ha^{-1} produced the highest number of empty florets spike^{-1} (9.54) and lowest (7.18) was noted in Zn_0 (control). The highest 1000-grain weight (33.43 g) was recorded from the treatment Zn_3 while Zn_0 gave the lowest (29.08 g) in the field. That finding was in conformity with [39]. The highest grain yield (1.60 t ha^{-1}) was noted in Zn_3 where 6 kg ha^{-1} Zn was used followed by the levels Zn_4 and Zn_2 while the lowest value (1.24 t ha^{-1}) was noted in Zn_0 (control) where no Zn was used. In case of $Zn_{3,}$ higher grain yield was ascribed to higher number of tillers m^{-2}, grains spike^{-1} and 1000-grain weight in Zn_3. This result partially corroborated with [39, 40]. The treatment Zn_4 with 8 kg Zn ha^{-1} gave the highest straw yield (2.40 t ha^{-1}) and lowest yield (2.19 t ha^{-1}) from Zn_2 (4 kg ha^{-1}). The result from Zn_0, Zn_1 and Zn_3 statistically similar to each other

Table-4: Yield and yield attributes of late sown wheat as influenced by Zn levels during rabi season 2015-2016

Zn-levels	Plant height (cm)	Number of effective tillers plant^{-1}	Number of tillers m^{-2}	Spike length (cm)	Number of spikelets spike^{-1}	Number of florets spike^{-1}	Number of grains spike^{-1}	Number of empty florets spike^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Zn_0	59.92e	2.89e	214.17e	5.81e	8.42e	24.39e	16.67e	7.18e	29.08e	1.24d	2.27b	35.03d
Zn_1	63.01d	3.10d	237.17d	6.16d	9.00d	25.97d	18.30d	7.67d	29.86d	1.34c	2.27b	36.67c
Zn_2	66.13c	3.28c	254.16c	6.44c	9.86c	27.78c	19.65c	8.13c	30.73c	1.43b	2.19c	39.03b
Zn_3	68.76b	3.51a	305.17a	7.28a	11.27a	33.39a	23.85a	9.54a	33.43a	1.60a	2.29b	40.86a
Zn_4	71.93a	3.35	266.25b	6.75b	10.51b	29.77b	21.02b	8.74b	31.51b	1.45b	2.40a	37.26c
Level of significance	***	***	***	***	***	***	***	***	***	***	***	***
$LSD_{0.05}$	0.85	0.04	6.49	0.11	0.19	0.68	1.02	0.22	0.52	0.03	0.06	0.60
CV(%)	1.55	1.52	3.06	2.0	2.30	2.89	6.18	3.18	2.02	2.80	3.52	1.93

Note: In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD test at 5% level of probability; Zn_0= 0 kg ha^{-1}, Zn_1= 2 kg ha^{-1}, Zn_2= 4 kg ha^{-1}, Zn_3= 6 kg ha^{-1}, Zn_4= 8 kg ha^{-1}, *** indicates mean values are significantly different at 0.1% level of probability.

produced 2.27 t ha^{-1}, 2.27 t ha^{-1} and 2.29 t ha^{-1} respectively. The highest harvest index (40.86%) was noted in Zn_3 while Zn_0 (control) gave the lowest harvest index (35.03%). The results showed that all the yield attributes found highest at Zn_3 treatment where 6 kg Zn ha^{-1} was applied.

Interaction effects of nitrogen and zinc on the growth, yield and yield attributes

The results presented in Table 5 indicate that all the parameters except number of empty florets spike^{-1} of wheat were significantly affected by the interaction of nitrogen and zinc at various levels of significance. Plant height was highly significant ($p<0.01$). The tallest plant (82.27 cm) was noted in N_3 (180 kg ha^{-1}) in combination with Zn_4 (8 kg ha^{-1}) while the shortest (47.87 cm) was found under N_0Zn_0 combination. The results indicated that plant height increased with the increasing levels of N and Zn might be due to their synergistic effect on plant growth and development as Zn activates many enzymes responsible for plant growth. Data also showed that the highest values of number of effective tillers plant^{-1}(3.87 cm), number of tillers m^{-2} (376.33), spike length (8.80 cm), number of spikelets spike^{-1} (13.83), number of florets spike^{-1} (45.13) and number of grains spike^{-1} (37.07) were recorded when 160 kg ha^{-1} N and 6 kg ha^{-1} Zn was used in N_2Zn_3 treatment combination while less values were noted viz. 2.40, 163.67, 3.23 cm, 6.37, 15.87 and 7.53 respectively for number of effective tillers plant^{-1}, number of tillers m^{-2}, spike length, number of spikelets spike^{-1}, number of florets spike^{-1} and number of grains spike^{-1}when no nitrogen and zinc (control) was used in N_0Zn_0 treatment combination (Table-5). The result indicated that number of effective tillers plant^{-1}, number of tillers m^{-2}, spike length, number of spikelets spike^{-1}, number of florets spike^{-1} and number of grains spike^{-1} were increased with increasing Zn up to a certain level of Zn_3 in conjunction with any level of N. All these parameters were highly significant ($p<0.001$). Among all the parameters only number of empty florets spike^{-1} was insignificantly affected by various levels of N and Zn combinations. The highest number of empty florets spike^{-1}(11.17) was noted in N_0Zn_3 and the lowest (6.13) was recorded in N_2Zn_0. 1000-grain weight was significantly ($p<0.05$) affected. The highest 1000-grain weight (36.26 g) was noted in 160 kg N ha^{-1} with 6 kg Zn ha^{-1} (N_2Zn_3)treatment combination, while the lowest 1000-grain weight (25.27 g) was found from N_0Zn_0 treatment combination.

The data again showed that interaction between nitrogen and zinc also significantly affected grain yield ($p<0.001$). Results showed that the highest grain yield (1.96 t ha^{-1}) was recorded in 160 kg ha^{-1} N with 6 kg ha^{-1} Zn (N_2Zn_3) treatment combination while the lowest grain yield (0.61 t ha^{-1}) was noted in N_0Zn_0 (control) was similar to that of N_0Zn_1 (0.67 t ha^{-1}). A trend was found that grain yield increased gradually with increased level of Zn up to a certain level of Zn_3 in conjunction with any level of N. Zinc application tended to increase the Nitrogen Use Efficiency (NUE). The increased yield may be due to the role of nitrogen fertilizer in increasing photosynthetic rate, synthesis of metabolites and translocation of assimilates to the seed as Zinc is the activator of several enzymes in the plants [41]. In that experiment the key reason behind lower yield, temperature is one of the most important limiting factor in late planted wheat as it experienced higher temperature at seeds filling period which prevents accumulation of photosynthates in the seed causing small seed size and thus, grain yield reduces to a great extent. There attained high temperature beyond the optimum during the crop growing period (Table-1).

Data further indicated that straw yield and harvest index both were significantly ($p<0.05$) affected. The highest straw yield (3.09 t ha^{-1}) was observed in 180 kg N ha^{-1} and 8 kg Zn ha^{-1} were used at N_3Zn_4 treatment combination and the lowest (1.27 t ha^{-1}) was recorded in N_0Zn_2. On the other hand, highest harvest index (43.42%) was found in 160 kg N ha^{-1} along with 6 kg Zn ha^{-1} at N_2Zn_3 treatment combination followed by the combination N_1Zn_3 (42.11) while the lowest harvest index (32.11%) was noted in N_0Zn_0 (control).

CONCLUSION

The present study was conducted to find out the optimum N and Zn doses for better yield and yield attributes of wheat (cv. BARI Gom-28) under late sown wheat. Considering the interaction effect of N and Zn it was observed that grain yield attributes were remarkably highest in late sown wheat in the treatment combination of N_2Zn_3 i.e. 160 kg N along with 6 kg Zn ha^{-1} with a blanket dose of PKS & B was also applied at the rate of 40-120-20-1.5 kg ha^{-1} as per recommendation [22]. Hence, late sown wheat may be suggested to grow with application of the abovementioned doses of fertilizers for higher grain yield in the location(s) having similar edaphic and climatic conditions of this experimental site.

Table-5: Interaction effects of N and Zn on yield and yield attributes of late sown wheat during rabi season 2015-2016

Treatment combinations (N × Zn)	Plant height (cm)	Number of effective tillers plant^{-1}	Number of tillers m^{-2}	Spike length (cm)	Number of spikelets spike^{-1}	Number of florets spike^{-1}	Number of grains spike^{-1}	Number of empty florets pike^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
N_0Zn_0	47.8 p	2.40l	163.67l	3.23o	6.37l	15.87n	7.53k	8.33ef	25.27l	0.61n	1.29j	32.11j
N_0Zn_1	50.03o	2.63k	182.00k	3.60n	6.77k	16.83mn	8.00k	8.33cd	25.77kl	0.67mn	1.33j	33.44i
N_0Zn_2	53.87 n	2.77j	192.00jk	3.87m	7.43j	17.93m	8.67jk	9.26c	26.00jk	0.70m	1.27j	35.53h
N_0Zn_3	57.67m	3.07gh	222.00i	5.07k	8.73h	23.50i	12.33i	11.17a	29.77g	0.81l	1.33j	37.85fg
N_0Zn_4	62.33k	2.87i	204.67j	4.40l	8.10i	20.30l	10.27j	10.03b	27.33ij	0.68m	1.38j	33.97i
N_1Zn_0	56.30m	2.73j	200.33j	6.10j	7.40j	20.80kl	13.30hi	7.50i	26.73ijk	1.40k	2.41hi	36.77g
N_1Zn_1	60.23l	3.00h	229.00hi	6.56i	7.87i	21.73jk	13.80hi	7.93fgh	27.76hi	1.49ij	2.46fghi	37.69fg
N_1Zn_2	64.90j	3.30f	245.67fg	6.97h	8.73h	22.47ij	14.10hi	8.37ef	28.00gh	1.62fg	2.36i	40.77cd
N_1Zn_3	67.07hi	3.53cd	284.33d	7.50de	10.00f	26.83h	16.77g	10.06b	32.90de	1.77c	2.43ghi	42.11b
N_1Zn_4	68.93g	3.43e	252.66f	7.20fg	9.27g	23.43i	14.43h	9.00c	29.83g	1.70de	2.55efg	39.91d
N_2Zn_0	62.97k	3.33f	254.00ef	7.23f	11.10e	33.13e	27.00d	6.13l	32.93de	1.52hi	2.51efgh	37.69fg
N_2Zn_1	65.97ij	3.46de	285.00d	7.47de	11.70d	36.33d	29.63c	6.70k	33.43cde	1.64ef	2.60de	38.69ef
N_2Zn_2	68.30gh	3.57bc	312.33c	7.63cd	12.20c	39.30c	32.10b	7.20ij	34.27bc	1.69de	2.39hi	41.47bc
N_2Zn_3	70.80f	3.87a	376.33a	8.80a	13.83a	45.13a	37.07a	8.06efg	36.26a	1.96a	2.55efg	43.42a
N_2Zn_4	74.17^{de}	3.63b	326.00b	7.90b	12.90b	40.97b	33.43b	7.53hi	35.20b	1.72cd	2.58def	39.71de
N_3Zn_0	72.53^{e}	3.10g	238.67gh	6.67i	8.80h	27.77gh	18.83f	6.77jk	31.40f	1.45jk	2.87b	33.55i
N_3Zn_1	75.80^{cd}	3.30f	252.67f	7.00gh	9.67f	28.97g	21.77e	7.20ij	32.46e	1.57gh	2.70cd	36.83g
N_3Zn_2	77.43^{c}	3.47de	266.67e	7.30ef	11.07e	31.43f	23.73e	7.70gh	33.43cde	1.72cd	2.77bc	38.36f
N_3Zn_3	79.50^{b}	3.57bc	338.00b	7.77bc	12.50c	38.10c	29.23c	8.87c	34.76b	1.89b	2.82bc	40.07d
N_3Zn_4	82.27^{a}	3.47de	281.67d	7.50de	11.77d	37.37e	25.96d	8.40de	33.67cd	1.69de	3.09a	35.43h
Level of significance	**	***	***	***	***	***	***	NS	*	***	*	*
$LSD_{0.05}$	1.70	0.08	12.99	0.22	0.38	1.36	2.04	0.44	1.04	0.06	0.13	1.21
CV(%)	1.55	1.52	3.05	2.00	2.30	2.86	6.17	3.18	2.02	2.81	3.53	1.93

Note: In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD test at 5% level of probability; N_0 =0 kg ha^{-1}, N_1 =140 kg ha^{-1}, N_2 =160 kg ha^{-1}, N_3 =180 kg ha^{-1}; Zn_0= 0 kg ha^{-1}, Zn_1=2 kg ha^{-1}, Zn_2=4 kg ha^{-1}, Zn_3=6 kg ha^{-1}, Zn_4=8 kg ha^{-1}, *** indicates mean values are significantly different at 0.1% level of probability, ** indicates mean values are significantly different at 1% level of probability, * indicates mean values are significantly different at 5% level of probability, NS= Non-significant.

ACKNOWLEDGEMENTS

The authors are grateful to the Ministry of Science and Technology, Government of the People's Republic of Bangladesh for providing the research grant to accomplish the experiment successfully.

REFERENCES

1. FAO. (2014). Statistics Yearbook. Food and Agriculture Organisation, Rome, Italy, 79, 23-34.
2. USDA. (2012). National Nutrient Database for standard reference released, 25.
3. Reddy, S. R. (2004). Agronomy of Field Crops. Kalyani Publishers Ludhiana, 143.
4. FAO. (2009). Kenya wheat database 2009. Kenya production potential.
5. O'Brien, D. (2011). World wheat market supply. 4 November 2012.
6. Singh, G., Singh, R., & Kumari, P. (1996). Response of wheat (*Triticum aestivum*) to nitrogen, phosphorus and potassium fertilization. *Indian Journal of Agronomy*, *41*(1), 157-159.
7. Malik, C. V. S. (1981). Response of wheat-varieties to different levels of nitrogen. *Indian Journal of Agronomy*, *26*(1), 93-94.
8. Nazir, M. S., Jabbar, A., Waheed, Z., Ghaffar, A., & Aslam, M. (2000). Response of late sown wheat to seeding density and nitrogen management. *Pak. J. Biol. Sci*, *3*(6), 998-1001.
9. Rajput, A. L., Singh, D. P., & Singh, S. P. (1995). Effect of soil and foliar application of nitrogen and zinc with farmyard manure on late-sown wheat (*Triticum aestivum*). *Indian Journal of Agronomy*, *40*(4), 598-600.
10. Fathi, A. I., Abdel-Aziz, S. M., & Gawish, S. M. (1990). Effect of foliar application of some micronutrients under different levels of N-fertilization on yield and nutrient content of wheat plant. *Annals of Agricultural Science, Moshtohor*, *28*(4), 2669-2680.
11. Bansal, R. L., Singh, S. P., & Nayyar, V. K. (1990). The critical zinc deficiency level and response to zinc application of wheat on typicustochrepts. *Experimental agriculture*, *26*(3), 303-306.
12. Sharma, S. K., &Lal, F. (1993). Estimation of critical limit of DTPA zinc for wheat in pellusterts of southern Rajasthan. *Journal of the Indian Society of Soil Science*, *41*(1), 197-198.
13. Gill, M. S., Singh, T., Rana, D. S., & Bhandari, A. L. (1994). Response of maize (*Zea mays*) and wheat (*Triticum aestivum*) to different levels of fertilization. *Indian Journal of Agronomy*, *39*(1), 168-170.
14. Yilmaz, A., Ekiz, H., Torun, B., Gultekin, I., Karanlik, S., Bagci, S. A., & Cakmak, I. (1997). Effect of different zinc application methods on grain yield and zinc concentration in wheat cultivars grown on zinc-deficient calcareous soils. *Journal of plant nutrition*, *20*(4-5), 461-471.

15. Silspour, M. (2007). The study of fe and zn effects on quantitative and qualitative parameters of winter wheat and determination of critical levels of theseelements in varamin plain soils.
16. Bouis, H. E. (2003). Micronutrient fortification of plants through plant breeding: can it improve nutrition in man at low cost?. *Proceedings of the Nutrition Society*, *62*(2), 403-411.
17. Stein, A. J., Nestel, P., Meenakshi, J. V., Qaim, M., Sachdev, H. P. S., & Bhutta, Z. A. (2007). Plant breeding to control zinc deficiency in India: how cost-effective is biofortification?. *Public health nutrition*, *10*(5), 492-501.
18. Martens, D. C., & Westermann, D. T. (1991). Fertilizer application for correcting micronutrient deficiencies.
19. Mortvedt, J. J., & Gilkes, R. J. (1993). Zinc fertilizers. In *Zinc in soils and plants* (pp. 33-44). Springer, Dordrecht.
20. Rengel, Z., Batten, G. D., & Crowley, D. D. (1999). Agronomic approaches for improving the micronutrient density in edible portions of field crops. *Field Crops Research*, *60*(1-2), 27-40.
21. BAI, B. A., & Malakouti, M. J. (2003). Effects of iron, manganese, zinc, and copper on wheat yield and quality under saline condition.
22. Guide, F. R. (2005). Bangladesh Agricultural Research Council. *Soils Publication*, (45), 48.
23. Gardner, F. P., Pearce, R. B., & Mitchell, R. L. (1985). Physiology of crop plants. Iowa State Univ. Press, Ames, IA. *Physiology of crop plants. Iowa State Univ. Press, Ames, IA.*
24. Gomez, K. A., & Gomez, A. A. (1984). Randomized complete block design analysis. *Statistical procedures for agricultural research. John Willey and Sons, New York*.
25. Akter, H. (2005). Yield and seed quality of wheat cultivars as influenced by fertilizer nitrogen level under rainfed and irrigated conditions. *M. Sc. Thesis, Dept. Agron., Bangladesh Agril. Univ*, Mymensingh.
26. Ram, P., Dwivedi, D. P., Pandey, S. N., Singh, S. K., Singh, T. K., & Verma, S. N. (2004). Effect of varieties and nitrogen doses on growth and yield of wheat in saline-alkali soil under late sown conditions. *Plant Archives*, *4*(2), 351-354.
27. Rahman, M. I. (2005). Yield and quality of wheat as influenced by nitrogen sulphr and boron under irrigated and rainfed conditions. *M. Sc. Thesis, Dept. of Agronomy. Bangladesh Agril. Univ.*, Mymensingh.
28. Pandey, I. B., Bharati, V., Bharati, R. C., & Mishra, S. S. (2004). Effect of fertilizer levels and seed rates on growth and yield of surface-seeded wheat (*Triticum aestivum*) under lowland rice ecosystem of north Bihar. *Indian Journal of Agronomy*, *49*(1), 43-45.
29. Das, P. K. (2003). Effect of row spacing and nitrogen on the growth and yield of wheat. *M. Sc. Thesis, Dept. of Agronomy, Bangladesh Agril. Univ.*,Mymensingh.
30. Asif, M., Ali, A., Safdar, M. E., Maqsood, M., Hussain, S., & Arif, M. (2009). Growth and yield of wheat as influenced by different levels of irrigation and nitrogen. *International Journal of Agriculture and Applied Sciences*, *1(1)*, 25-28.
31. Das, K. C. (2002). Effect of planting density and rate of nitrogen application on the yield of wheat cv. Kanchan. *M. Sc. Thesis, Dept. of Agronomy, Bangladesh Agril. Univ.*, Mymensingh.
32. Sushila, R., & Gajendra, G. I. R. I. (2000). Influence of farmyard manure, nitrogen and biofertilizers on growth, yield attributes and yield of wheat (*Triticum aestivum*) under limited water supply. *Indian journal of Agronomy*, *45*(3), 590-595.
33. Ali, A., Syed, A. A. W., Khaliq, T., Asif, M., Aziz, M., & Mubeen, M. (2011). Effects of nitrogen on growth and yield components of wheat. (Report). In *Biol. (Sci* 3, No. 6. 1004-1005).
34. Mozumder, A. S. M. M. H. (2001). Effect of different seed rates and levels of nitrogen on the performance of Shourav variety of wheat *M. Sc*., Thesis, Dept. of Agronomy, Banagladesh Agril. Univ., Mymensingh.
35. Mazurkiewicz, J., & Bojarczyk, M. (2004). The effect of nitrogen fertilization on technological quality of winter wheat cultivars in monoculture. *AnnalesUniversitatisMariae Curie-Sklodowska. Sectio E Agricultura (Poland)*, *59*(4), 1621-1629.
36. Malik, C. V. S. (1981). Response of wheat-varieties to different levels of nitrogen. *Indian Journal of Agronomy*, *26*(1), 93-94.
37. Ali, L., Mohy-Ud-Din, Q., & Ali, M. (2003). Effect of different doses of nitrogen fertilizer on the yield of wheat. *International Journal of Agriculture & Biology*, *5*(4), 438-439.
38. Abbas, G., Hassan, G., Ali, M. A., Aslam, M., & Abbas, Z. (2010). Response of wheat to different doses of $ZnSO_4$ under Thal desert environment. *Pakistan Journal of Botany*, *42*(6), 4079-4085.
39. Keram, K. S., Sharma, B. L., Kewat, M. L., & Sharma, G. D. (2014). Effect of zinc fertilization on growth, yield and quality of wheat grown under agro-climatic condition of Kymore plateau of Madhyapradesh, India. *The BioScan*, *9*(4), 1479-1483.
40. Sharma, G. D., Thakur, R., Raj, S., Kauraw, D. L., & Kulhare, P. S. (2013). Impact of integrated nutrient management on yield, nutrient uptake, protein content of wheat (*Triticum aestivum*) and soil fertility in a typic Haplustert. *The Bioscan*, *8*(4), 1159-1164.
41. El-Habbasha, S. F., & Taha, M. H. (2008). Increasing nitrogen use efficiency by foliar zinc application at different growth stages in groundnut.

Field Crops Research, National Research Center,
Dokki, Cairo, Egypt.