Asian Research Journal of Agriculture

15(4): 77-85, 2022; Article no.ARJA.89540
ISSN: 2456-561X

Combined Effect of Nitrogen Fertilization and Seeding Rate on Regional Wheat Yield and Yield Components in Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Authors KKS and APC designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Author MH managed the analyses of the study. Authors KKS and APC managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARJA/2022/v15i430169

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/89540

Original Research Article

Received 16 May 2022
Accepted 21 July 2022
Published 28 July 2022

ABSTRACT

Seed rate and nitrogen fertilization are two main critical factors that affect wheat (*Triticum aestivum* L.) growth and yield. But a little knowledge on the interaction effects of these two factors in wheat cultivation under course, strong acidic nutrient deficit soil condition aimed us to conduct this research. We grew wheat at the field laboratory of the department of Agronomy and Haor Agriculture, Sylhet Agricultural University, Sylhet-3100, Bangladesh, during crop growing period (November-March) of wheat 2021-2022 with split plot design assigning seed rate (100, 120, 140 & 160 kg ha^{-1}) in main plot and nitrogen fertilizer (0, 120, 140, 160 & 180 kg ha^{-1}) in sub plot. The maximum grain yield (3.0 t ha^{-1}) was obtained at 140 kg ha^{-1} and 160 kg ha^{-1} seeding rate and nitrogen fertilization respectively. Whereas, the minimum grain yield (1.5 t ha^{-1}) was recorded in control treatment (100 kg ha^{-1} seed with zero nitrogen). The highest value of the entire yield contributing parameters i.e. effective tillers plant^{-1} (2.9), spike length (14.7 cm), spikelet spike^{-1} (17.0), florets spike^{-1} (52.3), grain spike^{-1} (51.0) and 1000 seed weight (42.6 g) were recorded at 140 kg ha^{-1} and 160 kg ha^{-1} seeding rate and nitrogen fertilization respectively and the values were increased with the increase of seeding rate and nitrogen fertilization rate upto 140 kg ha^{-1} and 160 kg ha^{-1} respectively then declined. The growth parameter i.e. plant height (114.1 cm) increased

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with the increase of seeding rate 160 kg ha^{-1} and nitrogen fertilization upto 160 kg ha^{-1} and the minimum value (54.1 cm) was recorded at control treatment.

Keywords: Growth and yield; nitrogen fertilizer; seed reta; wheat.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is a major cereal crop, produced 778.6 million tons in an area of more than 220 million ha of land by 2021, ranked first in terms of production worldwide [1]. In Bangladesh, wheat is considered as second most important cereal crop after rice with a production of 1.09 million tons in an area of 812805 acres of land [2]. World wheat production depends on genotypes [3], environmental conditions as well as management practices including nitrogen fertilization, seeding rates, water application, sowing time and their combined interactions [4, 5, 6, 7]. Nitrogen fertilization, as per recommended doses and methods, is very crucial for crop production as well as soil and environmental health [7, 8]. However, over fertilization of nitrogenous fertilizer may increase 23-60% nitrous oxide (N_2O, a greenhouse gas) emission by 2030 [9, 10] which may have negative impact on crop growth and development, soil and environmental health [7,11]. Therefore, appropriate rate of nitrogen fertilization is very essential in wheat cultivation to reduce leaching loss and correlated environmental hazard with better crop growth and development.

Moreover, seeding rate along with nitrogen fertilization is another crucial factor which regulates successful implementation of crop production in wheat production system [5, 12]. Very high to low seeding rates abate the potentiality of obtaining full yield of specific genotype of wheat [13, 14, 15]. An increased yield response [14, 15] or optimum yield response [16] was found with the increase of seeding rate in wheat. High seeding rate increases overall cost of production but minimize the risk of reducing yield associated with lower seeding rate [17, 36]. However, Fang et al. [18] reported a negative yield response with increased seeding rate. A mixed response of seeding rate on grain yield of wheat demands more specific research combined with nitrogen fertilization.

In Bangladesh, fertilization in wheat is largely depends on the soil analysis interpretation ranged from very low to optimum soil nutrient content [19]. Very low nutrient content soil demands high amount of fertilizer supplementation in contrast to optimum. Our study area, Sylhet region, is a very important agricultural production area in Bangladesh includes two major Agro Ecological Zones i.e. Surma-Kushiyara Flood Plain (AEZ-20) and Sylhet Basin (AEZ-21). Strong soil acidity, heavy soil texture and deficient nutrient status of soils are the main obstacles of crop production in this area. High soil acidity adversely affects crop production in two ways: directly by its acidifying effects and indirectly through reducing nutrient availability for crops. However, fertility status of this area is medium to high with very low to low concentration of nitrogen and medium to low concentration of phosphorus [19]. So, our hypothesis is that high amount of nitrogen fertilization than the optimum recommendation will be required for better growth and yield of wheat in this region. Along with this, the higher seeding rate than the optimum will provide better yield. With this regards, our study was conducted to evaluate the optimum seeding rate and nitrogen fertilizer level for wheat production in sylhet region of Bangladesh.

2. MATERIALS AND METHODS

The experiment, to observe the effect of seeding rates and different doses of nitrogen, was conducted at the field laboratory of the department of Agronomy and Haor Agriculture, Sylhet Agricultural University, Sylhet-3100, Bangladesh, during crop growing period (November-March) of wheat 2021-2022. A recognized drought resistant variety BARI Gom-28 seeds were obtained from Bangladesh Wheat and Maize Research Institute (BWMRI) and sown at seeding rates of 100, 120, 140 and 160 kg ha^{-1} with five nitrogen (N) levels of 0, 120, 140, 160 and 180 kg N ha^{-1} to fulfill the objectives of the current study. The experiment was laid out in split plot arrangement placing seeding rate in main plot and fertilizer doses in sub plots with three replications. The total number of experimental plot was 60 (5 × 4 × 3). The size of each sub plot was 6 m^2 (3.0 m × 2.0 m). Seed bed was prepared by ploughing the field for 3 times followed by laddering. The field was fertilized with P, K, S, Zn and B at the rate of 40-120-20-1.5-1.5 kg ha^{-1} [19] including N in the form of triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate , boric acid, and urea respectively. The whole amount of P, K, S, Zn, B 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 20 days after emergence of seedlings. Wheat crop seed was sown manually by maintaining row to row distance of 25 cm. All experimental plots received uniform cultural practices other than treatments. Data on yield and its different contributing components were recorded as per recommended procedure. The recorded data were analyzed statistically by using statistical software package R (version 3.13.2). 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.

3. RESULTS AND DISCUSSION

3.1 Plant Height

The results of our study showed that, plant height was statistically influenced by different seeding rates and nitrogen levels (N) (Table 1). The tallest plant (95.8 cm) was recorded at the seeding rate 160 kg ha^{-1} and gradually decreased 77.8 cm, 69.9 cm and 62.5 cm with the decreased of seeding rate i.e. 140 kg ha^{-1}, 120 kg ha^{-1} and 100 kg ha^{-1} respectively (Table 2). Nitrogen has also showed noticeable effect on plant height. Results indicated that plant height increased sharply with the increment of N levels. The tallest plant (86.6 cm) was produced by the treatment N_3 (160 kg ha^{-1}) while the smallest one (64.5 cm) recorded in N_0 (control) treatment (Table 2). The interaction effect of these two variables was found significantly correlated with each other (Table 3). Moreover, at 140 kg ha^{-1} seeding rate with a combination of 160 kg ha^{-1} N level produced the taller plant in our study. The highest plant height might be the result of better utilization of nitrogen fertilizer with fewer tillers per plant. However, our result of seeding rate is in a contradiction with some other previous findings [13, 20], suggesting that 125 kg ha^{-1} seeding rate produced the tallest plant. The course soil texture, strong acidity and nutrient deficit soil condition in our study region could contribute high seeding rate in wheat cultivation. Additionally, the results of N level is in a coordination with Iqbal et al. [20] Bhatta et al. [15] and Wang et al. [7] suggested that increased N application impact on high photosynthesis rate thus provided the higher biomass accumulation and distribution which contributed on higher plant height.

3.2 Effective Tillers Plant^{-1}

Vegetative growth in the form of tillers is very crucial to final yield in wheat (*Triticum aestivum* L.) [21]. In wheat, numbers of effective tillers per plant is influenced by seeding rates and nitrogen levels [20]. However, the highest number of tillers (2.6) was recorded at 140 kg ha^{-1} seeding rate while less number of tillers (2.3) was observed at 100 kg ha^{-1} which was statistically similar with S_3 treatment where 160 kg ha^{-1} seed rate was applied (Table 2). Number of tillers was also affected by nitrogen fertilization (Table 1). Maximum numbers of tillers were produced by the nitrogen level of 160 kg ha^{-1} followed by 140 kg ha^{-1} and 120 kg ha^{-1} (Table 2) which was statistically similar to each other. At control treatment, the minimum numbers of tillers (2.2 tillers Plant^{-1}) were recorded where no nitrogen fertilizer was applied. However, the result of effective tiller per plant indicated a positive interaction effect between seeding rate and nitrogen fertilization. More number of tillers was recorded at S_2N_3 treatment combination where 160 kg ha^{-1} nitrogen was applied along with 140 kg ha^{-1} seed rate. Sarker et al. [22] reported that the number of spikes per unit area was increased with the increase in seed rate upto 140 kg ha^{-1} and the increasing rate of spikes per unit area was less compared to increasing rate of plant population. Increase in number of tillers per unit area is due to increased seeding rate [20]. Nitrogen doses also contributed in increasing tiller production up to an optimum level [20, 23, 24, 25] and above optimum, tillers number is decreased due to the competition for space.

3.3 Spike Length (cm)

The spike length is significantly affected by seed rate and N level (Table 1). The longest spike 12.6 cm was recorded at 140 kg ha^{-1} seed rate followed by 160 kg ha^{-1} while the shortest one 7.0 cm was recorded at 100 kg ha^{-1} seed rate (Table 2). Nitrogen fertilizer also significantly influenced the spike length. Longer spike length was observed at the nitrogen level of 160 kg ha^{-1} followed by 180 kg ha^{-1} and 140 kg ha^{-1} while the shorter one (8.3 cm) was observed at control (100 kg ha^{-1}) treatment (Table 2). Spike length increased sharply with increasing N level up to a certain level then declined with further increased. This result was in line with the results of Sushila & Gajendra [26] and Asif et al. [27]. The interaction between seed rate and nitrogen was found significant (Table 3). Longest spike (14.3) was found at 140 kg seed rate in a combination with 180 kg ha^{-1} N and shortest one (5.9 cm) from 100 kg seed rate with zero level of nitrogen.

3.4 Spikelet's Spike^{-1}

As like spike length, spikelet's spike^{-1} was also significantly influenced by different seed rates and N lavels (Table 1). Maximum number of spikelet's spike^{-1} (14.7) was observed at seeding rate 140 kg ha^{-1} followed by 160 kg ha^{-1} and 120 kg ha^{-1} while the minimum (9.3) was observed at 100 kg ha^{-1} seed rate (Table 2). Nitrogen fertilizer significantly influenced the spikelet's spike^{-1}. Highest number of spikelet's spike (14.3) was noted in 160 kg ha^{-1} followed by 180 kg ha^{-1} N (13.0), while the lowest number (10.6) in control treatment. Nitrogen fertilizer and seed rate had significant effects on the number spikelet's spike (Table 3). Highest value of number of spikelet's spike^{-1} (17.0) was recorded when 160 kg ha^{-1} N and140 kg ha^{-1}seed rate was used in S_2N_3 treatment combination while less value was noted viz. 8.0 for number of spikelet's spike^{-1} when no nitrogen (control) and 100 kg seeds ha^{-1} were used in S_0N_0 treatment combination. However, in a combine the number of spikelet's increases with the increase of seeding rate and nitrogen fertilizer level upto 140 kg seeds ha^{-1} and 160 kg N ha^{-1} respectively then decline. Although, our findings is favorably compared with the previous findings of Islam et al. [25] and Iqbal et al. [20], but a contrast finding that spikelet's spike^{-1} is increased with the increase of seeding rate [28].

3.5 Floret's Spike^{-1}

Results showed the maximum number of floret's spike^{-1} (44.9) was observed at 140 kg ha^{-1} seeding rate followed by 160 kg ha^{-1} and 120 kg ha^{-1} while the minimum (26.9) was observed at 100 kg ha^{-1} seed rate (Table 2). Additionally, 160 kg ha^{-1} N level produced the highest number of floret's spike^{-1} (41.4) followed by 180 kg ha^{-1} N (37.6) which was statistically similar with 140 kg ha^{-1} N (37.2) .On the other hand, the lowest number of floret's spike^{-1} (31.8) was recorded in zero lavel of nitrogen application. The variables like seeding rate, nitrogen fertilization and interaction between them were found statistically significant (Table 3).

3.6 Grains Spike^{-1}

Grains spike^{-1} is an important yield contributing attribute to the ultimate grain return of wheat crop. Number of grains spike^{-1} was statistically influenced by all the variables i.e. seeding rate, nitrogen levels and interaction between them (Table 1). The maximum number of grains (51.0) spike^{-1} were observed in seeding rate of 140 kg ha^{-1} in a combination with 160 kg ha^{-1} N level while the lowest number of grains (17.0) spike^{-1} were recorded in zero level of nitrogen at 100 kg ha^{-1} of seeding rate (Table 3). However, the result showed that, after 160 kg ha^{-1} N level the grain spike^{-1} reduced significantly because of detrimental effect of excessive application of N in wheat cultivation [19]. This result can be compliant with the results of Mozumder [29], Ali et al. [30] and Iqbal et al. [20], found significant effect of seeding rate and N levels on grains spike^{-1}. Additionally, Islam et al. [25] obtained maximum grains spike^{-1} at 170 kg N ha^{-1}.

3.7 Thousand-Grains Weight

As like as grains spike^{-1}, grain weight is also an important yield contributing character. We measured grain weight in the form of random 1000 grains from harvested wheat for various treatments. The obtained 1000 grains weights were statistically significant for seeding rate and interaction factors but non-significant for N levels (Table 1). The heaviest grains weight (40.1 g) was observed at seeding rate of 140 kg ha^{-1}, which was statistically similar with the seeding rate 160 kg ha^{-1} while lowest grains weight (38.0 g) was recorded at 100 kg ha^{-1} seeding rate (Table 2). Although, the effects of nitrogen fertilization was insignificant but had noticeable difference on 1000-seeds weight which might lead significant difference in interaction. The 140 kg ha^{-1} seeding rate in a combination with 160 kg ha^{-1} N level contributed the height grain weight in our study (Table 3). The result indicated that the 1000 grain weight is increased with the increase of N level [30, 31] and seeding rate [20, 32].

3.8 Grain Yield

Seed yield is the ultimate outcome of its unique yield attributes in response to nitrogen levels and seeding rate of the crop. We found that the final outcome was statistically influenced by seeding rate, nitrogen fertilization and interaction between them. The highest grain yield (3.0 t ha^{-1}) was recorded in 140 kg ha^{-1} seeding rate plus 160 kg ha^{-1} nitrogen fertilization treatment. However, the

Table 1. Mean square values of different yield and yield components of wheat

Source of variance	df	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Spikelet's spike^{-1}	Floret's spike^{-1}	Grain spike^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})
Seed rates	3	3065.8***	0.35**	92.3***	85.5***	925.0***	1096.6***	11.4*	2.8***	18.5***
Nitrogen levels	4	844.8***	0.30***	25.0***	24.5***	161.3***	179.7***	10.6^{NS}	0.19***	1.5***
S×N	12	52.3***	0.95**	0.94***	0.57*	3.6***	7.3***	16.9***	0.05***	0.27***
Error	32	9.9	0.02	0.12	0.23	0.4	1.3	4.1	0.01	0.06

Table 2. Effect of seeding rates and nitrogen levels on yield and yield components of wheat

Treatments (Kg ha^{-1})	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Spikelet's spike^{-1}	Floret's spike^{-1}	Grain spike^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})
Individual mean comparisons of seeding rates									
S_0	62.5d	2.3c	7.0d	9.33d	26.9d	23.1	38.0c	1.7c	4.3c
S_1	69.9c	2.4b	9.3c	11.47c	33.7c	31.5c	38.7bc	2.5b	6.4b
S_2	77.8b	2.6a	12.6a	14.73a	44.9a	43.3a	40.1a	2.6a	6.8a
S_3	95.8a	2.3c	11.4b	13.60b	40.3b	36.9b	39.3ab	2.4b	6.3b
LSD (*P*=.05)	6.2	0.15	0.63	0.71	1.6	1.9	1.1	0.09	0.26
Individual mean comparisons of nitrogen levels									
N_0	64.5e	2.2d	8.3e	10.6e	31.8d	28.4d	38.6	2.1c	5.5d
N_1	72.7d	2.4bc	9.0d	11.3d	34.2c	31.6c	39.2	2.3b	5.7c
N_2	77.7c	2.5b	10.3c	12.5c	37.2b	34.7b	37.7	2.4a	6.1b
N_3	86.6a	2.6a	12.0a	14.3a	41.4a	38.7a	39.2	2.5a	6.4a
N_4	81.0b	2.3cd	10.7b	13.0b	37.6b	35.1b	40.3	2.3b	6.0b
LSD (*P*=.05)	2.6	0.13	0.29	0.40	0.53	0.96	1.7	0.09	0.21

Table 3. Effect of seeding rates and nitrogen levels on yield and yield components of wheat

Seed rates (kg ha^{-1})	Nitrogen levels (Kg ha^{-1})	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Spikelet's spike^{-1}	Floret's spike^{-1}	Grain spike^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})
S_0	N_0	54.1m	1.9i	5.9p	8.0k	22.0l	17.0m	36.8de	1.5k	3.9k
	N_1	60.2l	2.3fgh	6.4p	8.7jk	25.0k	21.0l	36.9de	1.6jk	4.1jk
	N_2	65.9kl	2.3fgh	7.1o	9.3ij	27.7j	24.0k	37.4cde	1.7ij	4.4ij
	N_3	66.4ijk	2.7abc	8.2lm	10.7gh	30.3h	26.7j	39.5abcd	1.8i	4.8i
	N_4	66.1jk	2.3fgh	7.3no	10.0hi	29.3hi	26.7j	39.5abcd	1.7ijk	4.3jk
S_1	N_0	61.3kl	2.1ghi	7.8mn	10.0hi	29.0i	25.0jk	35.7e	2.3h	5.8h
	N_1	66.3jk	2.4def	8.6kl	10.7gh	31.7g	30.0i	37.7cde	2.4fgh	5.2fgh
	N_2	71.5hi	2.5cde	9.2ij	11.7ef	34.7f	32.7h	37.8cde	2.6cde	6.6def
	N_3	76.8fg	2.8ab	11.0ef	13.0cd	38.0e	36.3ef	40.0abcd	2.8b	7.1bc
	N_4	73.5gh	2.3efg	9.7hi	12.0ef	35.0f	33.7gh	42.1ab	2.4fgh	6.3efg
S_2	N_0	65.0kl	2.5cdef	10.4fg	13.0cd	40.3d	39.0cd	39.6abcd	2.4fgh	6.2fgh
	N_1	71.1hi	2.5cde	11.3e	13.7c	42.3c	40.7c	39.9abcd	2.5efg	6.3efg
	N_2	78.8f	2.5cde	13.3c	14.7b	44.7b	43.0b	37.6cde	2.7bcd	6.8cd
	N_3	89.1de	2.9a	14.7a	17.0a	52.3a	51.0a	42.6a	3.0a	7.6a
	N_4	84.8e	2.6bcd	13.3c	15.3b	44.7b	42.7b	40.4abc	2.7bc	7.2ab
S_3	N_0	77.8fg	2.3fgh	9.0jk	11.3fg	35.7f	32.7h	42.2ab	2.4gh	6.1gh
	N_1	93.1cd	2.3efg	9.9gh	12.3de	37.7e	34.7fg	42.2ab	2.5def	6.3defg
	N_2	94.5bc	2.6bcd	11.5e	13.3c	41.7c	39.0cd	38.1cde	2.6cde	6.6de
	N_3	114.1a	2.1ghi	14.0b	16.3a	45.0b	40.7c	34.8e	2.3h	6.1gh
	N_4	99.6b	2.1hi	12.6d	14.7b	41.3cd	37.3de	39.2bcd	2.4gh	6.3efg
	LSD (P=.05)	5.23	0.26	0.58	0.80	1.05	1.92	3.35	0.17	0.41

individual 140 kg ha^{-1} seeding rate and 160 kg ha^{-1} nitrogen fertilization produced 2.6 t ha^{-1} and 2.5 t ha^{-1} seeds. All the cases the minimum seed yield was found in control treatments (0 kg ha^{-1} N, 100 t ha^{-1}seeding rate) (Table 2 & 3). The obtained highest seed yield was attributed by the higher number of tiller $plant^{-1}$, spikelets'$spike^{-1}$, florets $spike^{-1}$, grain $spike^{-1}$ and 1000-grain weight [33, 34]. Moreover, nitrogen level, nitrogen application timing and seeding rate imposed significant effect on seed yield [20] of our current study.

3.9 Biological Yield

Biological yield symbolize total growth performance of the crop and is considered to be the crucial yield attribute to acquire useful knowledge about overall growth of the wheat crop. Biological yield is highly influenced by crop nourishment and planting distance. Seeding rate and nitrogen levels were statistically influenced the biological yield (Table 1). The maximum biological yield (6.8 t ha^{-1}) was counted at seeding rate of 140 kg ha^{-1} while the minimum biological yield (4.3 t ha^{-1}) was observed at seeding rate of 100 kg ha^{-1} (Table 2). Application of nitrogen fertilizer also has prominent effect on biological yield of wheat (Table 1). Highest biological yield (6.4 t ha^{-1}) was recorded at nitrogen level of 160 kg ha^{-1}followed by 180kg ha^{-1} (6.0t ha^{-1}) while lowest grain yield (5.5 t ha^{-1}) was noted at zero level of nitrogen (Table 2). The interaction of seeding rate and nitrogen levels were found significant (Table 1). Highest biological yield (7.6 t ha^{-1}) was recorded at seeding rate of 140kg ha^{-1} with 160 kg ha^{-1} nitrogen fertilizer while lowest biological yield (3.9 t ha^{-1}) was observed at zero level of nitrogen with 100 kg ha^{-1} of seeding rate (Table 3). Higher biomass production is the result of the increased number of plant due to higher seeding rate with better nitrogen application. These results are in line with Islam et al. [25], Mojiri and Arzani [35]. Otteson et al. [4] and Iqbal et al. [20] found that biological yield was significantly increased by increasing nitrogen up to optimal levels.

4. CONCLUSION

In our study area, the effects of seeding rate on yield of wheat depend on nitrogen fertilization rate. The 140 kg seeds ha^{-1} maximize the grain and biological yield along with the entire growth and yield contributing characters i.e. plant height, effective tillers $plant^{-1}$, spike length, florets $spike^{-1}$, grain $spike^{-1}$ and 1000 seed weight, when 160 kg N ha^{-1} applied. However, the minimum yield was observed in the control treatment where 100 kg seeding rate ha^{-1} was implemented with no nitrogen fertilizer application. The value of most of the yield contributing parameters increased with the increase of seeding rate and nitrogen fertilization rate up to 140 kg ha^{-1} and 160 kg ha^{-1} respectively then decline. An exception was found in plant height where growth increases with the increase of seeding rate and nitrogen fertilization upto 160 kg ha^{-1} for both treatments. Course soil texture, strong acidity in soil and low nutrient content in soil specially nitrogen and phosphorus [19] could contribute high seeding rate and higher amount of nitrogen fertilization for optimum yield of wheat then the recommended doses in our study area. Therefore, our recommendation is that increased seeding rate and nitrogen fertilization could provide better yield and performance of wheat in sylhet region of Bangladesh. However, further research on individual effects of seeding rate and nitrogen fertilization considering more growth and yield contributing characters would provide better understanding for wheat cultivation in sylhet region of Bangladesh.

ACKNOWLEDGEMENTS

The research work was supported by a grant (R & D, Sl. No. 74 for FY 2020-2021) from Ministry of Science and Technology, Bangladesh. Authors are grateful to the Department of Agronomy and Haor Agriculture for providing Field Laboratory support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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