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Yield and Seed Quality of Wheat as Affected by Seeding Dates and Boron Levels at Rampur, Chitwan

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ABSTRACT

Yield and seed quality of wheat is affected by sowing dates through its impacts on growing environment, soil moisture content and terminal heat stress. Boron fertilization also impacts on number of seed per spike and quality of the seed. A field experiment was laid out in split-plot design with four sowing dates (15 November, 30 November, 15 December and 30 December) in main plot and four boron levels (0, 1, 2 and 3 kg ha^{-1}) on sub-plot, replicated thrice to assess the effect of sowing dates and boron levels on yield and seed quality of wheat at Rampur, Chitwan during winter season of 2019. The results revealed that significantly highest grain yield was obtained on November sown wheat compared to December sowing. Highest grain yield was obtained with the application of boron at 3 kg ha^{-1}, significantly higher than 0 and 1 kg ha^{-1} boron application. Significant interaction among sowing dates and boron levels was found on grain and seed yield. Seed quality parameters viz; seedling root and shoot length, vigour indices I and II were better in the earlier sown wheat and with 3 kg ha^{-1} boron application. The germination was also higher in earlier sown wheat but not affected by boron levels. Therefore, wheat with high seed quality can be sown from 15 to 30 November with 3 kg ha^{-1}boron application in Chitwan and under similar environments.

Keywords: Boron, seed quality, sowing date, wheat, yield

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INTRODUCTION

Wheat (*Triticum aestivum* L., 2n=2x=42) is third important cereal crop after rice and maize in Nepal, however, it ranked second in terms of productivity. Wheat is grown on 0.70 million hectares in Nepal, with production of 2.1 million tons and a productivity of 3.09 tons per hectare in 2019 (MoALD 2021). However, in comparison to neighboring countries India and China, wheat productivity is low (FAOSTAT 2021). The low productivity of wheat is due to various factors, such as low quality of seed (Farooq et al 2008), lack of high-yielding varieties, less use of inputs such as fertilizers and irrigation (Kibe et al 2006), lack of effective weed management (Abouziena et al 2008), late sowing (Akhtar et al 2006), among them some threaten the sustainability of production system.

A proper sowing date is a primary factor for production of wheat. Late sowing of wheat in Nepal is strictly observed in Rice-Wheat cropping system (Chauhan et al 2012). The principal causes of late sowing are excess of soil moisture at the time of land preparation, which leads to longer turnaround time, long duration of rice varieties and their delayed harvesting (Giri 1993). Optimum sowing date for wheat crop has been reported as mid-November and deviation from this date resulted nearly 30-50 kg day^{-1}ha^{-1} reduction in grain yield (Giri 1996). The decreased yield is attributed to the sub-optimal temperature during the germination, stand establishment, as well as supra-optimal during the reproductive growth (Sattar et al 2010). The late sown wheat is more affected by high temperature stress leading to reduced yield and quality (Wardlaw and Veringley 1994). Furthermore, late sowing also affects the seed quality of wheat due to short duration for growth and grain filling. Late sowing results in poor germination of seed and produces seed having low vigour (Khan et al 2010).

Even though cereals are considered to be insensitive to boron (B) deficiency, B deficiency cases have been reported from many wheat growing countries since 1960s including Nepal, India, Bangladesh and China (Rerkasem and Jamod 2004). B plays a vital role in pollination, fruit and seed set (Berger et al 1957). It has been reported that the viability of pollen grain was inhibited by B deficiency. Rerkasem et al (1993) reported that B deficiency in wheat results in a failure of fertilization due to the impaired development of anthers and poor pollen germination. They also found reduced fertility of both male and female parts of wheat flowers on B deficient plants.

The use of other inputs such as fertilizer, irrigation, plant protection only, does not yield good economic return without the use of quality seed. The interaction among sowing dates and B is the significant determinant of productivity and quality of wheat seed production. There are limited studies on effect of sowing dates on quality seed production of wheat in Nepal. Also, it is necessary to explore the impact of boron levels on wheat seed quality in Nepal. In this context, to address these research gaps, the current research was designed with the major objective of determining productivity and seed quality of wheat at different sowing dates, B levels, and their interactions.

MATERIALS AND METHODS

The experiment was conducted at Agriculture and Forestry University Rampur, Chitwan, Nepal from November 2019 to April 2020. Geographically, it is located at an altitude of 184.86 meter above sea level; 27 0 64″ North latitude and 84 0 34″ East longitude (Google Earth 2022). The soil of the experimental field was sandy loam in texture with acidic in reaction (pH 5.64), medium in soil OM (3.07 %) and total nitrogen (0.15%), low in available phosphorus (22.04 kg ha^{-1}) and potassium (80.04 kg ha^{-1}), very low in boron (0.19 kg ha^{-1}).

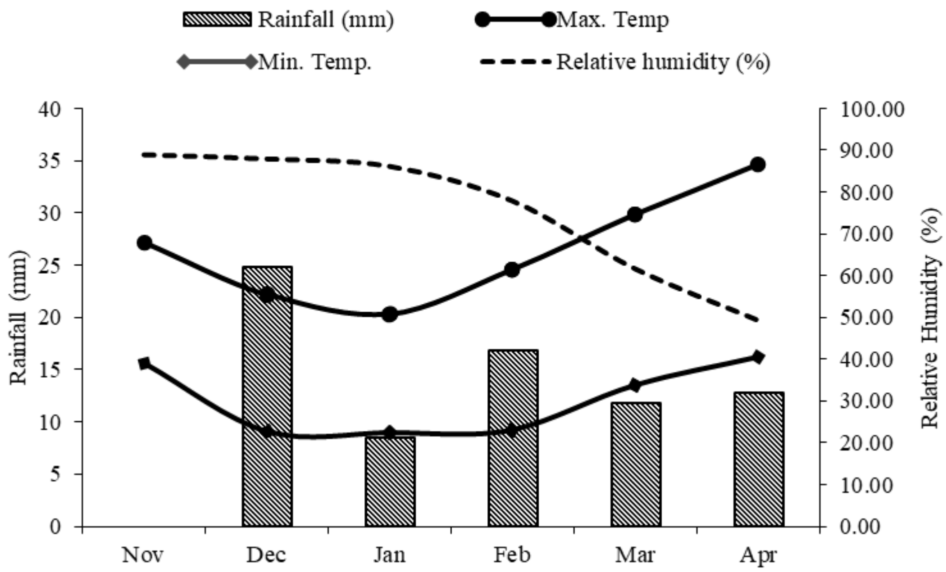

Figure 1. Weather data of experimental site during crop growing period in 2019-20 at Agronomy Farm, AFU, Rampur, Chitwan, Nepal

The average maximum temperature ranged from 20.3 ^{o}C to 34.7 ^{o}C during November to April. Similarly, the average minimum temperature ranged from 9.02 ^{o}C to 16.17 ^{o}C. The total rainfall during the cropping period was 74.4 mm. The maximum relative humidity for the cropping period was 88.93 % (November, 2019) and minimum was 49.27 % (April, 2020).

The experiment was laid out in split plot design with 16 treatments comprising of combination of four dates of sowing in main plots (November 15, November 30, December 15 and December 30) and four levels of boron application in the sub-plots (0, 1, 2 and 3 kg ha^{-1}). Each treatment was replicated thrice. The individual plot size was 3 m x 2.5 m and seeds of the wheat variety BL-4341 at 120 kg ha^{-1} were sown continuously in rows with spacing of 25 cm. The crop was fertilized with dose of 100:50:50 N, P_2O_5 and K_2O kg ha^{-1}. B was applied in the soil in the form of sodium borax at the time of final land preparation as basal application. It was applied only in the plots specified for B application at specified rate in the experimental design as per the treatments. All other recommended practices were followed and kept uniform for all treatments.

At harvest, effective tillers were determined by counting the total number of tillers bearing spike in a row randomly from net plot area of each plot (7 rows each 2.5 m length). Total number of grains and florets per spike were counted from 20 spikes that were collected randomly from the non-destructive sampling rows of each plot just before harvesting. Sterility percentage was determined using method by Subedi et al (1991):

$$\text{Sterility percentage} = \frac{\text{Total number of florets per spike} - \text{Number of grains per spike}}{\text{Total number of florets per spike}} \times 100$$

Thousand kernels from each bulk of each net plot were separated and weighed in grams with the help of electronic balance for the determination of thousand grain weight.

The net plot consisting of 7 rows each 2.5 m length (4.375 m^2) was harvested for the record of grain yield. The grain yield from each net plot was checked for moisture percentage using moisture meter and then adjusted at 12 % moisture respectively.

$$\text{Grain yield (kg ha}^{-1}\text{) at 12\% moisture} = \frac{(100 - MC) \text{ x grain yield at actual moisture content}}{(100 - 12)}$$

Where MC = moisture content of the grain

Grain from net plot was graded using the Oblong sieve size of 2.30 mm. Grain that passed through the sieve were regarded as small grain and other as seed. Both of them were weighed to calculate the seed and small grain yield per ha.

Seeds obtained after grading were used for the seed quality analysis using standard seed testing procedures. Germination test was conducted by using germination paper in which seeds for germination test was put between two papers per ISTA rules, 1993. Germination percentage was calculated from the normal seedlings only by using following formula as:

$$\text{Germination percent} = \frac{\text{Number of normal seedlings}}{\text{Number of seeds set for test}} \text{ x } 100$$

For measuring the root, shoot length and seedling dry weight, seeds were grown on sand in tray and 10 seedlings were selected and their root, shoot length and seedling dry were measured. Vigour index I and II were calculated using the following formula (Abdul-Bakiand Anderson (1975)):

Vigor index I = Germination% x (Root length + Shoot length)

Vigor index II = Germination% x Average seedling dry weight

Data were statistically analyzed by R-Studio and graphs were constructed using MS-Excel. All the analyzed data were subjected to DMRT for mean comparison at 5% level of significance.

RESULTS

Yield attributing characters

Effective tillers per square meter: The number of effective tillers per square meter was found to be non-significant for both sowing dates and the B levels (**Table** 1).

Number of Grains Per Spike: November sown wheat produced higher number of grains per spike as compared to December sowing (**Table** 1). Highest number of grains per spike was obtained by the application of 3 kg B ha^{-1} which was statistically at par with 2 kg B ha^{-1}.

Thousand grains weight (g): 1000 grains weight was found significant for sowing dates but non-significant for B levels. The highest 1000 grains weight was obtained on November 15 sown wheat followed by November 30^{th} and they were statistically at par with each other **(Table** 1**)**.

Sterility %: The sterility percentage was significantly affected by both sowing dates and B levels **(Table** 1**)**. The sterility percentage was found to be increased gradually with delay in sowing. The last date of sowing had significantly higher sterility percentage followed by third sowing date which was statistically at par with 2^{nd} date of sowing (30^{th} November). The lowest sterility percentage was found with the application of 3 kg B ha^{-1}, followed by 2 kg B ha^{-1} (**Table** 1).

Grain filling period

Grain filling period was significantly influenced by the sowing dates but non-significant for B levels. 15 November sown wheat had significantly longer grain filling period followed by 30 November sown wheat and it was statistically at par with each other (**Table** 2).

Grain yield (kg ha^{-1})

The grain yield of wheat was significantly influenced by sowing dates, B levels and their interaction (**Table** 2). 30 November produced the highest grain yield followed by November 15 sown wheat which was statistically at par with each other. 30 December sown wheat produced the least grain yield. Application of 3 kg B ha^{-1} produced significantly higher grain yield followed by 2 kg B ha^{-1} which was statistically at par with each other. No B produced the least grain yield.

Table 1. Yield attributing characters of wheat as influenced by sowing dates and boron levels at Rampur, Chitwan, 2019

Treatment	No. of grains spike^{-1}	No. of effective Tillers^{-2}	1000 grains Weight (g)	Sterility %
Sowing date				
Nov. 15	48.91^{a}	292.13	45.53^{a}	32.74^{c}
Nov. 30	47.00^{a}	322.00	42.70^{ab}	34.18^{bc}
Dec. 15	43.00^{b}	271.20	39.99^{b}	36.28^{b}
Dec. 30	39.58^{c}	263.87	33.37^{c}	40.07^{a}
SEm(±)	0.19	4.78	0.30	0.21
LSD (=0.05)	2.60	NS	4.10	2.91
CV, %	5.80	23.00	10.20	7.40
Boron level (kg ha^{-1})				
0	40.50^{b}	309.20	40.98	38.18^{a}
1	42.33^{b}	286.13	40.01	37.09^{a}
2	46.83^{a}	284.80	40.21	34.44^{b}
3	48.83^{a}	269.07	40.38	33.56^{b}
SEm(±)	0.21	3.13	0.13	0.16
LSD (=0.05)	2.51	NS	NS	1.87
CV, %	6.70	15.10	4.30	6.20
Grand Mean	44.63	287.3	40.40	35.86

Note: NS, non-significant; treatments mean followed by common letter (s) within the column are not significantly different among each other based on DMRT at 5% level of significance

Table 2. Grain filling period, grain, seed and discarded grain yield of wheat as influenced by sowing dates and boron levels at Rampur, Chitwan, 2019

Treatment	Grain filling period (Days)	Grain Yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Discarded seed yield (kg ha^{-1})
Sowing date				
Nov. 15	41.83^{a}	4850.34^{a}	4724.59^{a}	125.76^{c}
Nov. 30	40.25^{ab}	4993.25^{a}	4705.55^{a}	287.71^{b}
Dec. 15	37.67^{b}	3968.24^{b}	3543.57^{b}	424.67^{a}
Dec. 30	36.50^{b}	2728.64^{c}	2197.53^{c}	531.12^{a}
SEm(±)	0.269	10.84	14.71	8.10
LSD (=0.05)	3.73	150.02	203.59	112.13
CV, %	9.60	3.60	5.40	32.80
Boron level (kg ha^{-1})				
0	37.25	3976.57^{b}	3680.80	295.77
1	39.25	3988.13^{b}	3644.48	343.65
2	39.41	4268.39^{ab}	3921.37	347.02
3	40.33	4307.39^{a}	3924.58	382.81
SEm(±)	0.28	24.25	24.55	8.19
LSD (=0.05)	NS	283.14	NS	NS
CV, %	10.00	8.10	9.00	33.20
Grand Mean	39.06	4135.12	3792.81	342.31

Note: NS, non-significant; treatments mean followed by common letter (s) within the column are not significantly different among each other based on DMRT at 5% level of significance

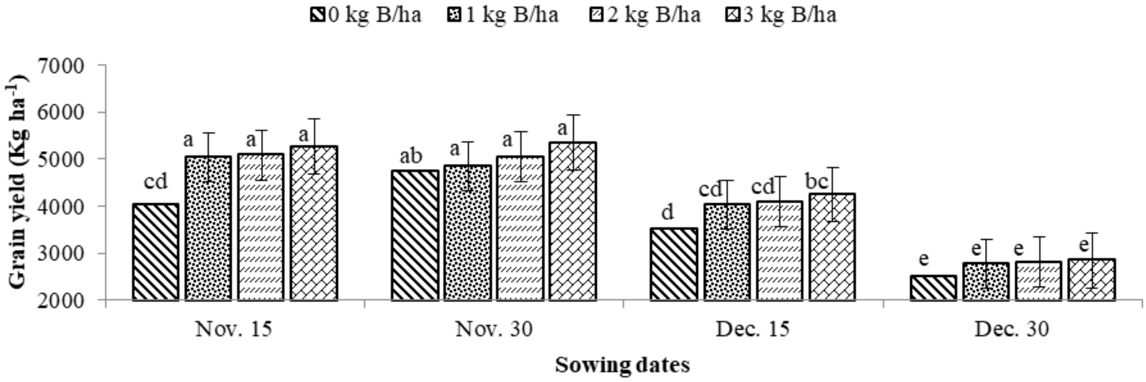

Figure 2. Grain yield (kg ha^{-1}) as influenced by the interaction between sowing dates and boron levels of wheat at Rampur, Chitwan, 2019.

Note: The common letter/s over the bar is not significantly different from each other based on DMRT 0.05.

The interaction effect of sowing dates and B levels was found significant for grain yield (**Figure** 1). Grain yield of wheat sown on November 15th and December 15th was significantly influenced by the application of boron while grain yield of wheat sown on November 30th and December 30th was not influenced by the application of boron. The application of boron significantly increased the grain yield of wheat sown on November 15th and December 15th. Boron omission had significantly the lowest grain yield of wheat sown on November 15th and December 15th.

Seed yield (kg ha^{-1})

The highest seed yield was obtained on November 15th sown wheat which was followed by November 30th sown wheat and it was statistically at par with each other (**Table** 2). The lowest seed yield was obtained on December 30th sown wheat. Boron levels had non-significant effect on seed yield. The interaction effect of sowing dates and B levels was found significant for seed yield (**Figure** 1). The seed yield of wheat sown on November 15th was significantly influenced by the application of boron. The highest seed yield was obtained on November 15 sown wheat with 3 Kg B per ha application and the least grain yield was obtained on December 30 sown wheat without B application.

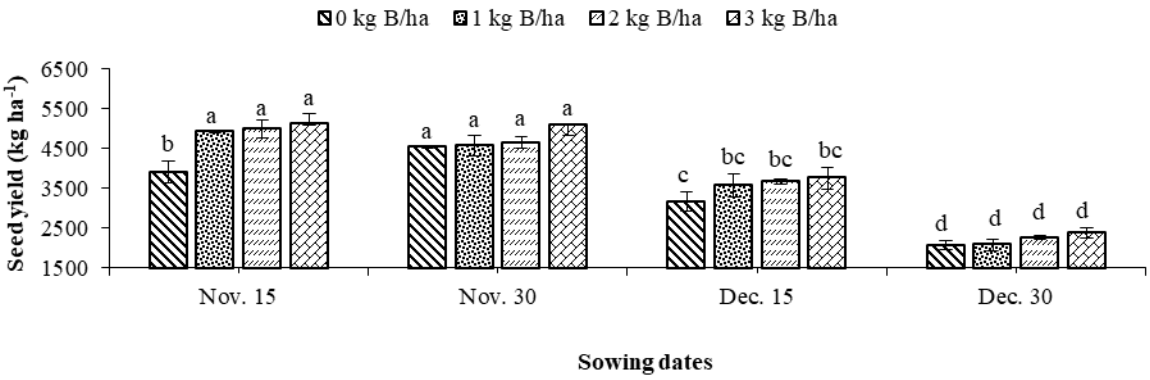

Figure 3. Seed yield (kg ha^{-1}) as influenced by the interaction between sowing dates and boron levels of wheat at Rampur, Chitwan, 2019.

Note: The common letter/s over the bar is not significantly different from each other based on DMRT 0.05

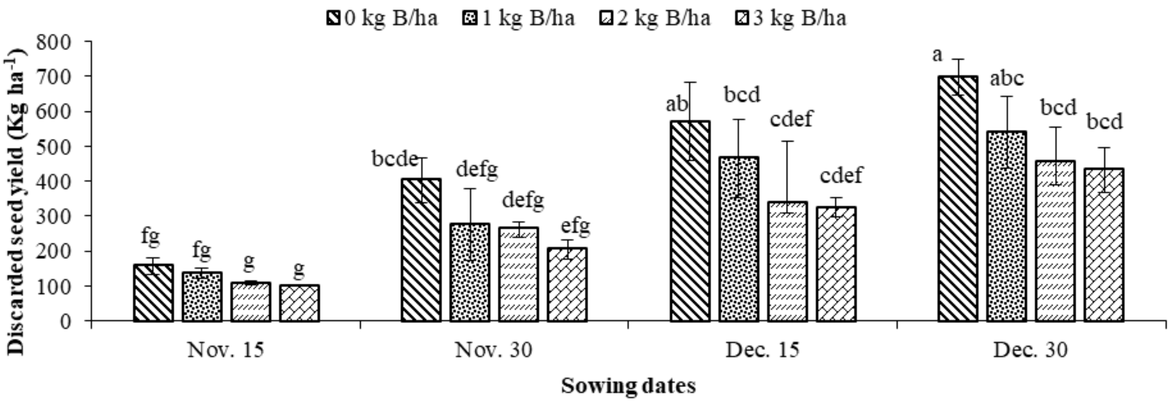

Figure 4. Discarded seed yield (kg ha^{-1}) as influenced by the interaction between sowing dates and boron levels of wheat at Rampur, Chitwan, 2019.

Note: The common letter/s over the bar are not significantly different from each other based on DMRT 0.05.

Seed quality analysis

Germination Percent:

Highest germination percent was found on November 15 sown wheat (**Table** 3). Germination percent was not significantly affected by the B levels.

Table 3. Germination percent, root, shoot length, root-shoot ratio, vigour index I and II of wheat seed as influenced by sowing dates and boron levels at Rampur, Chitwan, 2019

Treatments	Germination %	Root length (cm)	Shoot length (cm)	Root-shoot ratio	Vigour index I	Vigour index II
Sowing dates						
Nov. 15	98.00^{a}	17.84^{a}	18.80^{a}	0.85	3595.81^{a}	3.66^{a}
Nov. 30	95.80^{b}	17.24^{a}	18.27^{a}	0.94	3404.11^{a}	2.59^{b}
Dec. 15	94.81^{c}	16.58^{ab}	16.77^{b}	0.99	3161.00^{b}	1.45^{c}
Dec. 30	94.27^{c}	14.94^{b}	15.62^{b}	0.96	2881.88^{c}	1.07^{c}
SEm(±)	0.066	0.139	0.097	0.010	16.13	0.021
LSD (=0.05)	0.92	1.92	1.34	NS	223.26	0.29
CV, %	1.00	11.60	7.80	14.60	6.90	13.30
Boron level (kg ha^{-1})						
0	95.55	14.39^{b}	15.84^{c}	0.91	2891.70^{c}	1.83^{b}
1	95.69	15.54^{b}	17.17^{b}	0.91	3133.08^{b}	2.13^{ab}
2	95.82	17.81^{a}	18.14^{a}	0.98	3446.93^{a}	2.25^{ab}
3	95.82	18.87^{a}	18.36^{a}	1.03	3571.09^{a}	2.55^{a}
SEm(±)	0.059	0.104	0.082	0.008	12.49	0.039
LSD (=0.05)	NS	1.24	0.960	NS	145.84	0.45
CV, %	0.90	8.7	6.6	11.9	5.30	24.6
Grand Mean	95.72	16.65	17.38	0.96	3260.70	2.19

Note: NS, Non-significant; treatments mean followed by common letter(s) within the column are not significantly different among each other based on DMRT at 5% level of significance.

Root and shoot length:

Significantly higher root and shoot length was found on 15 November sown wheat (**Table** 3). Application of B at 3 Kg ha-1 produced significantly longer shoot and root length of wheat.

Root-shoot ratio:

Root shoot ratio was not significantly influenced by both sowing dates and boron levels (**Table** 3).

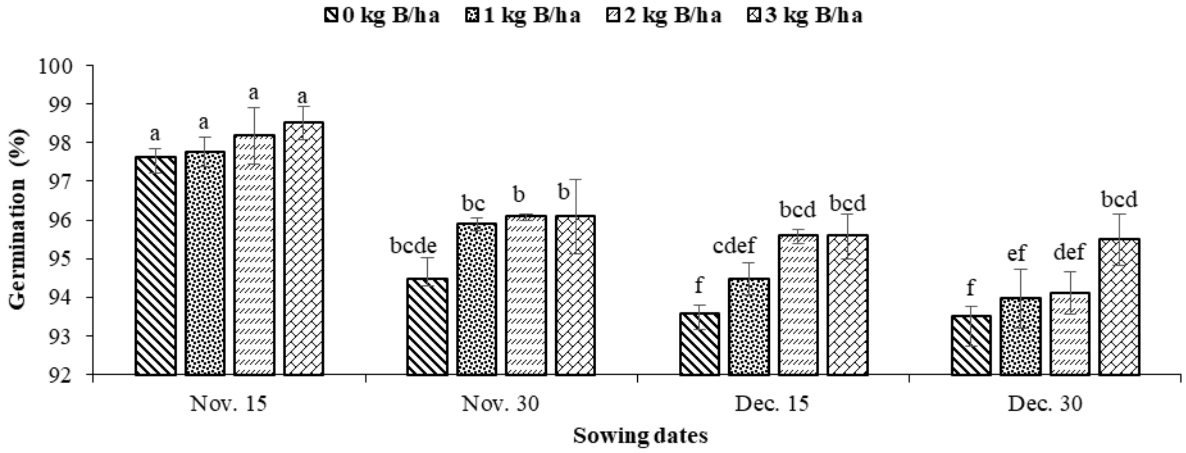

Figure 5. Germination percent of wheat seed as influenced by the interaction between sowing dates and boron levels at Rampur, Chitwan, 2019.

Note: The common letter/s over the bar are not significantly different from each other based on DMRT 0.05.

Vigour index I and II:

Maximum vigour indexes I and II were obtained on November 15 sown wheat followed by November 30 sown wheat (**Table** 3). Vigour indexes were found to be decreasing with delay in sowing. B application at 3 Kg ha-1resulted higher vigour index I and II, followed by 2 kg B ha^{-1} (**Table** 3). Root and shoot length were significantly higher on 3 kg ha^{-1} applied wheat (Table 3), so vigour index was higher in higher levels B applied wheat seed.

DISCUSSION

Soil moisture content was sufficient at all dates of observations in all dates of sowing so, sowing dates had non-significant effect on number of effective tillers. Acharya et al (2017) also reported non-significant effect of date of sowing on effective tillers per square meter in same environmental and soil conditions of Rampur, Chitwan. B had role only in reproductive growth stage but not during vegetative growth period, so B level did not influence the effective tillers. These results are in accordance with those of Debnath et al (2012) and Dhakal (2019). The decreasing number of grains with delay sowing was due to shorter grain filling period (**Table** 2) and heat stress at grain filling stages causing increased spikelet sterility. Similar trend was observed by Hussain et al (2012) who reported that the unfavorable environmental conditions at floret formation and at grain filling period results in lower number of grains per spike. B influences the germination of pollen grain and pollen tube growth, increases flower glumes and granulation thereby enhancing the fertilization and grain formation, thus 3 kg B per ha had highest number of grains per spike. Gunes et al (2003) also obtained significantly higher number of grains per spike through the application of 5 kg B ha^{-1}. Decreasing thousand grain weights with delay sowing was due to the shorter grain filling period (**Table** 2) due to its coincidence with the high temperatures and consequently the lack of accumulated materials and its low weight. These findings are strongly supported by Shahzad et al (2002) who had also reported decreased thousand grain weight with delay in sowing. High temperature stress during grain filling period results in production of nonviable pollen or ovule, hindered pollen tube growth, and inability of fertilized embryo-sac for the transition to a seed thus, increasing the sterility in late sown wheat. Similar results were also reported by Dhakal (2019) who recorded higher sterility percentage on later sowing than earlier sown wheat. B deficiency results in the failure of pollen tube growth due to a reduction in development of the pollen tube cell wall leading to failure in fertilization, or sterility (Rerkasem and Jamjod 1997). Debnath et al (2012) also reported that with increasing levels of boron the sterility percentage declined sharply. Shorter grain filling period on late sowing was due to higher temperature stress at that period which forced the early maturity of the crop.

The higher grain yield in November sown wheat may be attributed to a greater number of grains per spike, more thousand grain weight and lower sterility percentage than December sown wheat. Hossain et al (2017) also observed higher grain weight in earlier than late sown wheat. B influences the germination of pollen grain and pollen tube growth, increases flower glumes and granulation and causes less male sterility and less grain puffiness (Metwally et al 2016). These functions of the B mentioned probably increased the number of spikelet per spike, together with the greater absorption of this nutrient, which influenced the grain yield in a positive way. Increased grain yield due to higher Boron level (3 kg ha^{-1}) application was also reported by Khan et al (2005).

The yield attributing factors such as number of grains per spike and thousand grain weight were higher whereas, sterility percentage was lower in early sown wheat thus contributing higher seed yield of wheat on early sowing than late sown wheat. Similar results were also observed by Badawi et al (2014) who reported higher seed yield on earlier than late sown wheat.

High temperature conditions during seed development and maturation causes seed damage (Grass and Burris 1995). This might be the reason for low germination in late sown wheat as they face high temperature during reproductive phase. Similar result was obtained by Ali et al (2018). Seeds acquired from plants grown at high temperatures produce smaller seedlings with lower dry weight, shorter roots, and fewer roots than seeds obtained at low temperatures (Grass and Burris 1995). As late sown wheat was exposed to high temperatures during seed development and maturation, late sown wheat seed had shorter root and shoot length. Similar result was obtained by Shaheb et al (2016) who reported later sown wheat had shorter root and shoot length. Seed developed at high temperature affect membrane integrity and cause an increase in membrane leakage of both electrolytes and macromolecules during germination, which subsequently weakens germination and seedling vigour (Hasan et al 2013). Later sown wheat was exposed to high temperature during seed formation and maturation, so later sown wheat had low vigour index. Similar findings were also reported in wheat by Ali et al (2018) who observed that vigour index I decreased with delayed sowing.

CONCLUSION

Wheat planted on November (15^{th} and 30^{th}) performed better in terms of grain and seed yield as compared to December sown wheat. Boron levels also increased grain yield. The seed yield was higher with higher boron level but not significantly different. The germination percentage, root and shoot length, vigor index I and II were also better in November planting with 3 kg B ha^{-1}. In general, earlier planting in November with 3 kg ha^{-1} boron application increased the productivity and seed quality of wheat seed.

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AUTHOR'S CONTRIBUTION

The main author Bishwo Bandhu Chhetri carried out the experiment, collected data, prepared ANOVA and manuscript, and the rest of the authors guided and helped in the entire process of the experimentation to the write-up of the manuscript.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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