***Original Research Article***

**Yield Response of Spring Wheat to Seed Rate and Row Spacing**

**ABSTRACT**

|  |
| --- |
| Seed rate and row spacing play a vital role for establishing optimum plant densities which is a pre-requisite for increasing grain yield. A field experiment was carried out at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh, from November 2022 to March 2023 to evaluate the yield response of wheat to different seed rates and row spacings. The study utilized wheat variety BARI Gom-33 as the planting material. The experiment comprised two factors, Factor A: seed rate such as (i) 100 kg ha-1 (ii) 120 kg ha-1 (iii) 140 kg ha-1 (iv) 160 kg ha-1 (v) 180 kg ha-1; Factor B: row spacing such as (i) Continuous sowing in 20 cm apart line (ii) Continuous sowing in 15 cm apart line (iii) Continuous sowing in 10 cm apart line. The experiment was laid out in a randomized complete block design with three replications. Results clearly indicated that seed rate, row spacing and their interaction exerted significant effect on yield contributing characters and yield of wheat. It was observed that the highest grain yield (3.06 t ha-1) was obtained with seed rate 160 kg ha-1. It was the outcome of the highest plant height, number of spikes m-2, number of spikeletes spike-1, number of grains spikeletes-1, number of grains spike-1 and 1000-grain weight, grain yield, straw yield and biological yield. Row spacing had significant effect on yield contributing characters and yield of wheat such as plant height, number of spikes m-2, number of spikelets spike-1, number of grains spikeletes-1, number of grains spike-1, grain yield, straw yield, biological yield and except 1000-grain weight and harvest index. 15 cm row spacing produced highest plant height, number of spikes m-2, which consequently produced the highest grain yield (2.81 t ha-1) and the lowest yield (2.50 t ha-1) was found in 10 cm. The highest grain yield (3.33 t ha-1) was obtained from 160 kg ha-1 seed rate with 15 cm row spacing. Therefore, it can be concluded that BARI Gom-33 should be cultivated at 160 kg ha-1 seed rate with 15 cm row spacing for obtaining higher yield. |

Keywords: *Wheat; Seed rate; Row spacing; Grain yield.*

1. INTRODUCTION

Wheat (Triticum aestivum L.) is the second largest grain worldwide based on grain acreage and second largest based on total production volume. The global wheat production is 791 million tons (FAO, 2024). From nutritional point of view, wheat is superior to rice for its higher protein content. The grains of wheat have high nutritive value containing 14.70% protein, 2.14% fat, 78.10% starch and 2.10% mineral matter (Kumar et al., 2011; Halder et al., 2024). It is one of the most important cereals in human diets. To ensure food for the rapidly growing world population, wheat production needs to double by 2050 (FAO Foresight, 2011). Thus, a continuous increase in wheat demand is expected, which can be satisfied by improving crop yield per unit area (Neumann et al., 2010) as expansion in cultivated land is unlikely due to negative social and environmental impacts (Foley et al., 2011).

In Bangladesh, wheat is the second important cereal crop next to rice (Al-Musa et al., 2012). It occupies 3,16,832 hectares of the country with a total production of 3.876 MT per hectare and this was a increase of about 7.07% to the previous year (BBS, 2023). This indicates that wheat cultivation may solve food problem to a considerable extent and save huge foreign currency of the country as well. But the average yield of wheat in Bangladesh is not satisfactory. The low yield of wheat in Bangladesh is attributable to a number of reasons viz. high temperature, poor field management, late planting, unavailability of quality seed, improper seed rate, plant spacing, climatic hazards, intensive cropping and non-replenishment of soil nutrients, inadequate fertilizer use, irregular irrigation and infestation of weed as well as diseases and insects. Among the factors responsible for low wheat yield, delay in sowing, traditional sowing methods, low seed rate and improper row spacing are very important (Iqbal et al., 2010).

Optimum seed rate is an important determinant for improving yield of wheat. Seed rate plays a vital role for establishing optimum plant densities which is a pre-requisite for increasing grain yield. Seed rate influences the yield contributing characters and yields of wheat (Fazli et al., 2004). It is of particular importance in wheat production because it is under the farmer's control in most cropping systems (Slafer and Satorre, 1999). Seeding density is a limiting factor for plants to capture environmental resources (Lloveras et al., 2004). It is considered one of the cultivation practices that most influences grain yield and other agronomical characters. Changes in seeding density have special importance in wheat crops since they have a direct effect on grain yield and its components (Ozturk et al., 2006) according to the cultivation environment (Lloveras et al., 2004). Previous research showed that seeding rates significantly affected biological yield (Islam, 2013), spike number and weight (Laghari et al., 2011). Higher wheat grain yield with better qualities requires appropriate sending rate for different cultivar.

Very few studies have found full grain yield compensation under very low seed rates. For example, Puckridge and Donald (1967) reported an optimum grain yield at 35 plant m−2 for wheat due to the increased number of spikelets per spike and grains per spikelet. Bustos et al. (2013) assessed spring wheat cultivars and doubled haploid lines at a seed rate of 44 plants m−2 found full compensation among yield components, despite the plants relatively short crop cycle (4.2 months from seedling emergence to physiological maturity). The effect of low seed rate on wheat traits other than grain yield, such as grain quality traits, nutrient uptake, and partitioning remains little known in most wheat growing environments including the high-yielding cropping systems. With respect to grain quality traits, contrasting results have been reported for wheat in response to seed rate.

A common seed rate of 120 kg ha-1 is used for all the varieties (Islam et al., 2004; Razzaque et al., 2000). But farmers are using very higher seed rate, sometimes even double of the recommendation for controlling weed, repelling birds and expecting higher yield. It is found that varieties having large seed size, seed rate should be used higher and varieties having smaller seed size, seed rate should be used lower. Generally, farmers yield is lower compare to research field due to shorter spike length and lower number of grains per spike resulted mostly from higher plant density. If optimal seedling rate exceeds, yield reductions often occur (Harrison and Beuerlein, 1995; Beuerlein and Lafever, 1989).

Higher seed rate above optimum level may only enhance production cost without any increase in grain yield (Rafique et al., 2010). Higher seed rate than recommended one generally increases plant population resulting intra crop competition there by affecting the yield. Many farmers in developing countries prefer to use a higher seed rate than recommended, because they perceive it as a good strategy to control weeds and reduce the risks of crop production. On the other hand, lower seed rate may reduce the yield drastically as the grain yield is positively correlated with plant population (Vukadinovic et al., 1986).

Currently, the density used for the wheat crop can range from 300 to 400 viable seeds per square meter (Comissão Sul-Brasileira de Pesquisa de Trigo, 2005). Such recommendation does not take into account genotype differences, especially concerning tiller production and survival. Furthermore, the ideal should take into account environmental conditions, such as altitude, temperature, soil and seeding time (Gade, 1995; Klepper et al., 1982). Such effects have been observed in favorable and unfavorable conditions, where there is an uniform/disuniform culm population and regularly/irregularly spaced tillers, respectively (Rickman et al., 1983). This last scenario (unfavorable conditions) leads to a lower nutrient use efficiency.

Establishment of optimum row spacing is important factor for securing good yield and growth of wheat. Optimum row spacing ensures proper growth of the aerial and underground parts of the plant through efficient utilization of solar radiation and nutrient uptake as well as air space and water (Nazir et al., 1987; Chatha and Nazir, 1984) found that 40 cm row spacing gave higher yield in wheat cultivation while (Oliveira and Bego, 1983) suggested 25 cm row spacing is optimum for achieving higher yield. 20 to 30 cm row spacing is found to be superior by many authors (Singh and Uttam, 1995; Raj-Sing et al., 1992; Barthakur et al., 1979). If the row is too wide, the crop is unable to rapidly shade the inter-row area to capture sunlight and weeds quickly become established. If the row is too narrow, inter-row crop competition results in poorer yields, difficulties in disease and insect control, and greater likelihood of lodging. Seeding rate above or below the optimum may reduce the yield significantly (Peter et al., 1988).

Maximum yield of a particular crop in a given environment can be obtained at a row spacing where competition among the plants is minimum. This can be achieved with optimum spacing which not only utilize soil moisture and nutrients more effectively but also avoids excessive competition among the plants. However, beyond certain limit yield cannot be increased with decreasing/ increasing row spacing. Hence, optimum row spacing induces the plant to achieve its potential yield (Armara et al., 2017).

Given that, wheat population is directly relevant to the growth and development of individual plant. An individual wheat plant consists of main stem and tillers. With the higher number of plant, we will get more tiller and more spike and spikelets, as a result grain yield will be increased (Zhang et al., 2010). Tillers are an important part of the wheat plant. Grain yield depends on plants per area, tillers per plant, kernels per tiller, and weight per kernel. Therefore, tillering is essential for productivity. Studies estimate that under normal conditions, approximately 30 to 50% of the grain yield of wheat comes from the main stem and 50 to 70% comes from the tillers. However, only some tillers produce grain; others fail to develop a spike (head) and die before the main stem matures (Thiry et al., 2002).

1. material and methods
	1. Experimental Site

Geographically, the Agronomy Field Laboratory, BAU was located at 24°75′ N latitude and 90°50′ E longitude at an elevation of 18 m above the sea level under Old Brahmaputra Floodplain Agro-ecological zone- “AEZ 9”. The land was medium high with silt loam texture. The soil of the experimental land belongs to the Sonatola series of the non-calcareous dark-grey floodplain soil under the Old Brahmaputra Alluvial Tract. The experimental field was of a medium high land having silt loam soil. The soil of the experimental field was more or less neutral in reaction, low in organic matter content and its general fertility level was also low. The morphological characteristics, physical properties and chemical composition of soil have been presented in Table 1. The experimental site belongs to the subtropical area characterized by heavy rainfall during *kharif* season (April to September) and scanty in the *rabi* season (October to March) associated with moderately low temperature and plenty of sunshine. The information in respect of rainfall pattern, sunshine hours, temperature fluctuation and relative humidity during the period of the present study have been presented in Table 2.

**Table 1. Soil properties of the experimental field**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Soil Properties** |  |
| **Physical** |  | **Chemical (0-15 cm depth)** |  |
| Sand (%) (0.0-0.02 mm) | 20 | Soil pH  | 6.7 |
| Silt (%) (0.02-0.002 mm) | 67 | Organic carbon (%) | 0.86 |
| Clay (%) (<0.002 mm) | 13 | Total nitrogen (%) | 0.16 |
| Soil textural class | Silt loam | Available phosphorus (ppm) | 17.05 |
| Particle density (g/cc) | 2.60 | Available potassium (me/100g soil) | 0.10 |
| Bulk density (g/cc) | 1.35 | Zinc (ppm) | 10.35 |
| Porosity (%) | 46.67 | Sulphur (ppm) | 5.85 |
|  |  | Boron (ppm) | 1.12 |
|  |  | Molybdenum (ppm) | 0.063 |

Source: Soil Science department, Bangladesh Agricultural University, Bangladesh

**Table 2. Weather data from November 2022 to March 2023 at the experimental site during the growing season of wheat**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Month and year** | **Air temperature (oC)** | **Total rainfall (mm)** | **Average Relative humidity (%)** | **Total Sunshine (hrs.)** |
| **Maximum** | **Minimum** | **Average** |
| November 2022 | 30.4 | 18.3 | 24.4 | 0 | 81.6 | 187.8 |
| December 2022 |  25.4 | 13.5 | 19.8 | 17.7 | 80.2 | 201.3 |
| January 2023 | 24.02 | 12.15 | 19.22 | 0.00 | 84.35 | 227.2 |
| February 2023 | 26.8 | 15.54 | 21.28 | 1.17 | 83.00 | 164.8 |
| March 2023 | 30.65 | 17.70 | 23.76 | 1.90 | 73.19 | 208.2 |

Source: Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh

* 1. **Experimental Treatments and Design**

There were two factors of the experimental treatment. Such as, Factor A: seed rate such as (i) 100 kg ha-1(S1) (ii) 120 kg ha-1 (S2) (iii) 140 kg ha-1 (S3) (iv) 160 kg ha-1 (S4) (v) 180 kg ha-1; (S5). Factor B: row spacing such as (i) Continuous sowing in 20 cm apart line (B1) (ii) Continuous sowing in 15 cm apart line (B2) (iii) Continuous sowing in 10 cm apart line (B3). The experiment was laid out in a randomized complete block design with three replications. The total number of plots was 45. The unit plot size was 2.5 m x 2.0 m i.e. 5 m2. Block to block and plot to plot distance was 1.0 m and 0.5 m, respectively.

**2.3 Description of the Plant Material**

Wheat variety BARI Gom-33 was used as plant material. BARI Gom-33 is a modern wheat variety released by Wheat Research Centre, Bangladesh Agricultural Research Institute (BARI) in 2017. Stem and leaf are dark green color, tillers are semi-erect during heading. Flag leaf is wide and droopy. It takes about 60-65 days for heading and 110-115 days to get physiological maturity. Glaucosity is weak in spike. It is a Zn-enrich and wheat blast resistant variety. The weight of 1000 seeds is 45-50 g. Optimum seed rate is 130 kg ha-1 and row spacing is 20 cm. Grain yield under optimum management is 4-5 t ha-1.

* 1. **Conduction of the Experiment**

**2.4.1 Land preparation and fertilizer application**

The land was prepared in the third week of November 2022. It was prepared by repeated ploughing by a power tiller. Weeds and stubble of the previous crop were collected and removed from the field. After leveling, the experimental plots were laid out as per the treatments and design. One-third of the nitrogenous fertilizers and the entire amount of other fertilizers were applied at the rate of 240 kg ha-1 of urea, 150 kg ha-1 of triple super phosphate (TSP), 110 kg ha-1 of muriate of potash (MoP), 120 kg ha-1 of gypsum and 8 kg ha-1 of boric acid were applied during the final land preparation. The remaining two-third of urea was top-dressed in two equal splits at 20 and 55 days after sowing (DAS).

**2.4.2 Seed sowing**

Seeds were sown on 30 November, 2022, maintaining different seed rate and spacing as per treatments. Soil was opened by a specially made iron tine by hand. Seeds were sown continuously in line. After sowing, the seeds were covered with soil and slightly pressed by hands.

**2.4.3 Intercultural operation**

Intercultural operations were done to ensure the normal growth of the crop. Three irrigations were done, the first irrigation was given at 20 days after sowing (DAS) at crown root initiation (CRI) stage, the second irrigation at the heading stage (55 DAS), and the third irrigation at the grain filling stage (80 DAS). Weeding was done manually twice during the whole growing period at 20 DAS and 55 DAS.

**2.4.4 Harvesting**

At full maturity, crop was harvested separately plot-wise on 22 March 2023, respectively. The harvested crop of each plot was bundled and separately tagged and brought to the clean threshing floor. The bundles were sun-dried, threshed and then the grains were cleaned. The grain and straw yields were taken plot-wise and converted into tha-1.

**2.5 Methods of Data Collection**

For collecting data on plant characters, ten hills were selected at random and uprooted from each plot prior to harvesting. The grain and straw yields were recorded plot-wise at 14% moisture basis and expressed as t ha-1. The following parameters, which were measured: plant height, spikes m-2, spikelets spike-1, grains spikelet-1, grains spike-1, 1000-grain weight (g), grain yield, straw yield, biological yield, harvest index (%).

**2.6 Statistical Analysis**

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was done with the help of computer package MSTAT at 5% level of probability. The mean differences among the treatments were adjudged by Duncan’s Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

1. **RESULT**
	1. **Plant Height**

The plant height of wheat was significantly influenced by the seed rate. The tallest plants, reaching 89.82 cm, were recorded at a seed rate of 160 kg ha⁻¹, while the shortest plants, measuring 82.40 cm, were observed at a seed rate of 100 kg ha⁻¹ (Table 3). Row spacing also had a significant effect on plant height, with the maximum height of 87.56 cm recorded at 15 cm spacing and the minimum height of 82.92 cm at 10 cm spacing (Table 4). However, the interaction between seed rate and row spacing did not show a statistically significant impact on plant height. Nevertheless, the highest numerical plant height (92.10 cm) was found at the combination of 160 kg ha⁻¹ seed rate and 15 cm row spacing, while the lowest (79.70 cm) was recorded at 100 kg ha⁻¹ seed rate with 10 cm row spacing (Table 5).

**3.2 Number of Spikes m-2**

The seed rate had a significant impact on the number of spikes m⁻² in wheat. The highest spike number (316.33 spikes m⁻²) was recorded at a seed rate of 180 kg ha⁻¹, whereas the lowest (178.33 spikes m⁻²) was observed at a seed rate of 100 kg ha⁻¹ (Table 3). In contrast, row spacing did not have a statistically significant effect on spike density. However, numerically, the highest spike number (261.67 spikes m⁻²) was noted at 15 cm row spacing, while the lowest (254.00 spikes m⁻²) was recorded at 20 cm spacing (Table 4). The interaction between seed rate and row spacing significantly influenced the number of spikes m⁻². The highest spike count (321.00 spikes m⁻²) resulted from the combination of 180 kg ha⁻¹ seed rate and 15 cm row spacing, followed closely by the interactions of 180 kg ha⁻¹ with 10 cm and 20 cm row spacing. The lowest spike count (174.67 spikes m⁻²) was observed at the combination of 100 kg ha⁻¹ seed rate and 20 cm row spacing (Table 5).

**3.3** **Number of Spikelets Spike-1**

The number of spikelets spike-1 in wheat is a crucial yield-contributing factor that significantly influences grain production. The seed rate had a significant effect on this trait, with the highest number of spikelets spike-1 (17.94) recorded at a seed rate of 100 kg ha⁻¹ (Table 3). Similarly, row spacing also had a significant impact, with the maximum spikelet count (16.42 spikelets spike⁻¹) observed at 20 cm row spacing, while the lowest (15.00 spikelets spike⁻¹) was recorded at 10 cm spacing (Table 4). The interaction between seed rate and row spacing was statistically significant in determining the number of spikelets spike-1. The highest spikelet number (18.36 spikelets spike⁻¹) was achieved with the combination of a 100 kg ha⁻¹ seed rate and 20 cm row spacing (Table 5).

**3.4 Number of Grains Spikelet-1**

The number of grains spikelet-1in wheat was significantly influenced by the seed rate. The highest grain spikelet-1 (3.01) was recorded at seed rates of 100 kg ha⁻¹ and 120 kg ha⁻¹, while the lowest (2.00) was observed at 180 kg ha⁻¹ (Table 3). Row spacing also had a significant impact on the number of grains spikelet-1, with the highest value (2.82) recorded at 20 cm spacing, followed by 15 cm spacing, whereas the lowest (2.34) was found at 10 cm spacing (Table 4). Furthermore, the interaction between seed rate and row spacing had a significant effect on grain production spikelet-1. The highest number of grains spikelet-1 (3.26) was obtained from the combination of 120 kg ha⁻¹ seed rate and 20 cm row spacing, which was statistically similar to 100 kg ha⁻¹ seed rate × 20 cm row spacing and was followed by 120 kg ha⁻¹ seed rate × 15 cm row spacing and 140 kg ha⁻¹ seed rate × 20 cm row spacing. The lowest value (1.80) was recorded at 180 kg ha⁻¹ seed rate with 10 cm row spacing (Table 5).

**3.5 Number of Grains Spike-1**

Number of grains spike-1 was significantly affected by the seed rate. Highest number of grains spike-1 (54.29) was produced by 100 kg ha-1 seed rate and followed by 120 kg ha-1 seed rate. Lowest number of grains spike-1 (25.56) was obtained from 180 kg ha-1 seed rate (Table 3). On the contrary, number of grains spike-1 of wheat was significantly affected by the row spacing. Highest number of grains spike-1 (47.20) was produced by 20 cm row spacing followed by 15 cm row spacing. Lowest number of grains spike-1 (35.94) was obtained from 10 cm row spacing (Table 4). Results showed that the combined effect of seed rate and row spacing of wheat significantly affected the number of grains spike-1. The highest number of grains spike-1 (58.44) was obtained from the interaction of 100 kg ha-1 seed rate × 20 cm row spacing, which was statistically similar with 120 kg ha-1 seed rate × 20 cm row spacing. The lowest number of grains spike-1 (22.09) was obtained from the interaction of 180 kg ha-1 seed rate × 10 cm row spacing (Table 5).

**3.6** **1000-Grain Weight**

The 1000-grain weight of wheat was significantly influenced by the seed rate. The highest weight (43.21 g) was recorded at a seed rate of 100 kg ha⁻¹, while the lowest (36.51 g) was observed at 180 kg ha⁻¹ (Table 3). Row spacing did not have a statistically significant effect on 1000-grain weight. However, numerically, the highest weight (41.20 g) was found at 20 cm row spacing, followed by 15 cm spacing, whereas the lowest (40.76 g) was recorded at 10 cm spacing (Table 4). The interaction between seed rate and row spacing had a significant effect on 1000-grain weight. The highest value (43.36 g) was obtained from the combination of 100 kg ha⁻¹ seed rate and 20 cm row spacing, which was statistically similar to the combinations of 100 kg ha⁻¹ with 15 cm and 10 cm row spacing, as well as 120 kg ha⁻¹ with 20 cm and 15 cm row spacing. The lowest 1000-grain weight (36.23 g) was recorded at the interaction of 180 kg ha⁻¹ seed rate with 10 cm row spacing (Table 5).

**3.7 Grain Yield**

The results indicated that the seed rate had a significant impact on wheat grain yield. The highest grain yield (3.06 t ha⁻¹) was recorded at a seed rate of 160 kg ha⁻¹, which may be attributed to a greater number of effective tillers per plant, spikelets per spike, grains per spike, and individual grain weight. Conversely, the lowest grain yield (2.14 t ha⁻¹) was observed at a seed rate of 100 kg ha⁻¹ (Table 3).Similarly, row spacing also had a significant effect on grain yield. The maximum grain yield (2.81 t ha⁻¹) was achieved at 15 cm row spacing, likely due to an increased number of effective tillers per plant, spikelets per spike, grains per spike, and individual grain weight. The lowest grain yield (2.50 t ha⁻¹) was recorded at 10 cm row spacing, which was statistically similar to 20 cm row spacing (Table 4).

Regarding the interaction between seed rate and row spacing, variance analysis revealed a significant influence on wheat grain yield. The highest yield (3.33 t ha⁻¹) was obtained from the combination of 160 kg ha⁻¹ seed rate and 15 cm row spacing, while the lowest (2.06 t ha⁻¹) resulted from the interaction of 100 kg ha⁻¹ seed rate with 10 cm row spacing (Table 5).

S1B1 S1B2 S1B3 S2B1 S2B2 S2B3 S3B1 S3B2 S3B3 S4B1 S4B2 S4B3 S5B1 S5B2 S5B3

**Figure 1. Grain yield of wheat *cv.* BARI Gom-33 as influenced by the interaction between seed rate and row spacing. Bar represents grain yields at different interaction**

*S1= 100 kg seed ha-1, S2= 120 kg seed ha-1, S3= 140 kg seed ha-1, S4=160 kg seed ha-1, S5= 180 kg seed ha-1, B1= Continuous sowing in 20 cm apart line, B2= Continuous sowing in 15 cm apart line, B3= Continuous sowing in 10 cm apart line.*

**3.7 Straw Yield**

The effect of seed rate exerts significant effect on the straw yield of wheat. The maximum straw yield (3.68 t ha-1) was recorded from 160 kg ha-1 seed rate. The minimum straw yield (2.66 t ha-1) was recorded from 100 kg ha-1 seed rate (Table 3). Row spacing has a significant impact on straw yield. The maximum straw yield (3.39 t ha-1) was recorded from 15 cm row spacing. The minimum straw yield (3.14 t ha-1) was recorded from 10 cm row spacing (Table 4). The interaction effect of seed rate and row spacing exerted significant influence on the straw yield. The highest straw yield (3.86 t ha-1) was obtained from the interaction of 160 kg ha-1 seed rate × 15 cm row spacing. The lowest straw yield (2.53 t ha-1) was obtained from the interaction of 100 kg ha-1 seed rate × 10 cm row spacing (Table 5).

**Table 3. Effect of seed rate on yield contributing characters and yield of wheat *cv.* BARI Gom-33**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Seed rate (kgha-1)** | **Plant height** **(cm)** | **Spikes** **m-2****(no.)** | **Spikelets spike-1****(no.)** | **Grains Spikelets-1****(no.)** | **Grains Spike-1****(no.)** | **1000-grain weight** **(g)** | **Grain yield** **(t ha-1)** | **Straw yield** **(t ha-1)** | **Biological yield** **(t ha-1)** | **Harvest Index** **(%)** |
| 100 | 82.40 b | 178.33 e | 17.94a | 3.01a | 54.29a | 43.21a | 2.14 d | 2.66 d | 4.81 e | 44.57 |
| 120 | 83.85ab | 232.56 d | 17.41a | 3.01a | 52.60a | 42.94ab | 2.46 c | 3.17 c | 5.64 d | 43.68 |
| 140 | 86.12ab | 264.67 c | 15.71b | 2.67ab | 42.48 b | 42.27b | 2.73 b | 3.30 c | 6.03 c | 45.27 |
| 160 | 89.82a | 296.44 b | 14.95b | 2.38 bc | 35.83 b | 40.13c | 3.06a | 3.68a | 6.75a | 45.35 |
| 180 | 85.76ab | 316.33a | 12.82c | 2.00 c | 25.56 c | 36.51d | 2.80 b | 3.47 b | 6.27 b | 44.58 |
| Sx | 2.31 | 5.35 | 0.53 | 0.16 | 3.18 | 0.26 | 0.07 | 0.06 | 0.08 | 0.88 |
| Level of significance | \* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | NS |
| CV (%) | 5.72 | 4.40 | 7.11 | 12.60 | 16.02 | 1.36 | 5.31 | 3.81 | 2.75 | 4.16 |

*\*\* =Significant at 1% level of probability, \* =Significant at 5% level of probability, NS = Non-significant*

**Table 4. Effect of row spacing on yield contributing characters and yield of wheat *cv.* BARI Gom-33**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Row spacing****(cm)** | **Plant height** **(cm)** | **Spikes** **m-2****(no.)** | **Spikelets spike-1****(no.)** | **Grains Spikelets-1****(no.)** | **Grains Spike-1****(no.)** | **1000-grain weight** **(g)** | **Grain yield** **(t ha-1)** | **Straw yield** **(t ha-1)** | **Biological yield** **(t ha-1)** | **Harvest Index** **(%)** |
| 20 | 86.29ab | 254.00 | 16.42a | 2.82a | 47.20a | 41.20 | 2.61 b | 3.24 b | 5.86 b | 44.57 |
| 15 | 87.56a | 261.67 | 15.88ab | 2.69a | 43.32a | 41.08 | 2.81a | 3.39a | 6.20a | 45.23 |
| 10 | 82.92 b | 257.33 | 15.00 b | 2.34 b | 35.94 b | 40.76 | 2.50 b | 3.14 b | 5.64 c | 44.27 |
| Sx | 1.79 | 4.14 | 0.41 | 0.12 | 2.47 | 0.20 | 0.05 | 0.05 | 0.06 | 0.68 |
| Level of significance | \* | NS | \*\* | \*\* | \*\* | NS | \*\* | \*\* | \*\* | NS |
| CV (%) | 5.72 | 4.40 | 7.11 | 12.60 | 16.02 | 1.36 | 5.31 | 3.81 | 2.75 | 4.16 |

*\*\* =Significant at 1% level of probability, \* =Significant at 5% level of probability, NS = Non-significant*

**Table 5. Interaction effect of seed rate and row spacing on yield contributing characters and yield of wheat *cv.* BARI Gom-33**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Seed rate****× row spacing** | **Plant height** **(cm)** | **Spikes** **m-2****(no.)** | **Spikelets spike-1****(no.)** | **Grains Spikelets-1****(no.)** | **Grains Spike-1****(no.)** | **1000-grain weight** **(g)** | **Straw yield** **(t ha-1)** | **Biological yield** **(t ha-1)** | **Harvest Index** **(%)** |
| S1B1 | 83.23 | 174.67 h | 18.36a | 3.16ab | 58.44a | 43.36a | 2.73 gh | 4.90 ij | 44.22 |
| S1B2 | 84.26 | 181.67 h | 18.10ab | 3.03abc | 55.14ab | 43.23a | 2.73 gh | 4.93 ij | 44.61 |
| S1B3 | 79.70 | 178.67 h | 17.36abc | 2.83a-d | 49.29a-d | 43.03a | 2.53 h | 4.60 j | 44.89 |
| S2B1 | 84.26 | 230.67 g | 17.90ab | 3.26a | 58.31a | 43.13a | 3.23 def | 5.76 fgh | 43.93 |
| S2B2 | 86.53 | 235.33 efg | 17.03a-d | 3.06abc | 52.49ab | 43.03a | 3.26 c-f | 5.83 fg | 43.97 |
| S2B3 | 80.76 | 231.67 fg | 17.30abc | 2.70a-e | 47.02a-e | 42.66a | 3.03 fg | 5.33 hi | 43.14 |
| S3B1 | 87.26 | 259.33 d-g | 17.03a-d | 3.03abc | 51.52abc | 42.56a | 3.36 b-f | 6.10 d-g | 44.80 |
| S3B2 | 87.33 | 269.00 b-e | 16.26a-e | 2.73a-e | 44.35a-f | 42.33a | 3.40 b-f | 6.33 b-e | 46.30 |
| S3B3 | 83.76 | 265.67 c-f | 13.83 def | 2.26 b-e | 31.55 c-g | 41.93ab | 3.13 ef | 5.66 gh | 44.70 |
| S4B1 | 89.83 | 292.67a-d | 15.73a-f | 2.60a-e | 41.18a-g | 40.16 c | 3.63abc | 6.60 bc | 44.94 |
| S4B2 | 92.10 | 301.33ab | 14.96 b-f | 2.46a-e | 36.58 b-g | 40.30 bc | 3.86a | 7.20a | 46.26 |
| S4B3 | 87.53 | 295.33abc | 14.16 c-f | 2.10 cde | 29.74 d-g | 39.93 c | 3.56a-d | 6.46 bcd | 44.85 |
| S5B1 | 86.86 | 312.67a | 13.06 ef | 2.03 de | 26.56 fg | 36.76 d | 3.26 c-f | 5.93 efg | 44.94 |
| S5B2 | 87.60 | 321.00a | 13.03 ef | 2.16 cde | 28.03 efg | 36.53 d | 3.70ab | 6.73ab | 45.03 |
| S5B3 | 82.83 | 315.33a | 12.36 f | 1.80 e | 22.09 g | 36.23 d | 3.46 b-e | 6.16 c-f | 43.78 |
| Sx | 3.99 | 9.26 | 0.92 | 0.27 | 5.51 | 0.45 | 0.10 | 0.13 | 1.52 |
| Level of significance | NS | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | NS |
| CV (%) | 5.72 | 4.40 | 7.11 | 12.60 | 16.02 | 1.36 | 3.81 | 2.75 | 4.16 |

*\*\* =Significant at 1% level of probability, NS = Non-significant*

*S1= 100 kg seed ha-1, S2= 120 kg seed ha-1, S3= 140 kg seed ha-1, S4=160 kg seed ha-1, S5= 180 kg seed ha-1*

*B1= Continuous sowing in 20 cm apart line, B2= Continuous sowing in 15 cm apart line, B3= Continuous sowing in 10 cm apart line*

**3.8 Biological Yield**

The seed rate had a significant impact on the biological yield of wheat. The highest biological yield (6.75 t ha⁻¹) was recorded at a seed rate of 160 kg ha⁻¹, while the lowest (4.81 t ha⁻¹) was observed at 100 kg ha⁻¹ (Table 3). Similarly, row spacing also had a significant effect on biological yield, with the maximum yield (6.20 t ha⁻¹) obtained at 15 cm row spacing and the minimum (5.64 t ha⁻¹) recorded at 10 cm row spacing (Table 4). The interaction between seed rate and row spacing significantly influenced biological yield. The highest yield (7.20 t ha⁻¹) was achieved from the combination of 160 kg ha⁻¹ seed rate and 15 cm row spacing, whereas the lowest (4.60 t ha⁻¹) resulted from the interaction of 100 kg ha⁻¹ seed rate with 10 cm row spacing (Table 5).

**3.9 Harvest Index**

Harvest index was significantly influenced by the use of varying levels of seed rate of wheat. However, numerically the highest harvest index (45.35 %) was observed from 160 kg ha-1 seed rate and it was statistically followed by 140 kg ha-1 seed rate. The lowest harvest index (43.68 %) was recorded from 120 kg ha-1 (Table 3). But harvest index was not significantly influenced by the use of varying levels of row spacing of wheat. However, numerically the highest harvest index (45.23 %) was observed from 15 cm row spacing while the lowest harvest index (44.27 %) was recorded from 10 cm row spacing (Table 4). In terms of interactions between seed rate and row spacing of wheat harvest index was not significantly affected. However, numerically the highest harvest index (46.30 %) was obtained from the interaction of 140 kg ha-1 seed rate × 15 cm row spacing, which was statistically similar with 160 kg ha-1 seed rate × 15 cm row spacing combinations. The lowest harvest index (43.14 %) was obtained from 120 kg ha-1 seed rate × 15 cm row spacing interaction (Table 5).

1. **DISCUSSION**

Seed rate plays a vital role for establishing optimum plant densities which is a pre-requisite for increasing grain yield. Seed rate influences the yield contributing characters and yields of wheat (Fazli et al., 2004). It is of particular importance in wheat production because it is under the farmer's control in most cropping systems (Slafer and Satorre, 1999). Besides, optimum row spacing ensures proper growth of the aerial and underground parts of the plant through efficient utilization of solar radiation and nutrient uptake as well as air space and water (Chatha and Nazir, 1984; Nazir et al., 1987).

Said et al. (2012) observed that seeding rate affects the yield and yield components of wheat. Ghulam et al. (2011) reported that wheat sown at higher seed rate produced taller plant and lower seed rate resulted in shorter plants. Wheat sown at higher seed rates had significantly higher internode length and increased plant height. Lower seeding rate results in less competition for space, nutrients and water. Wheat plant height grown at the lowest seeding rate (100 kg ha-1) was significantly lower than the plant height at seeding rates ranging from 125-175 kg ha-1 (Haile et al., 2013). In this study, in this study, different seed rates had significant effect on plant height, spikes m-2, spikelets spike-1, grains spike-1, 1000-grain weight, grain yield, straw yield and biological yield. With increasing the seed rate, plant height, spikes m-2, grain yield, straw yield and biological yield is increased. Higher seed rate produced higher number of plant and tiller plant-1, as a result weed infestation is greatly reduced and less competition is occur. Highest grain yield was obtain at 160 kg ha-1 seed rate. With decreasing the seed rate, number of plant, tiller plant-1, grain yield, straw yield and biological yield is greatly reduced, but it gives highest production of the spikelets spike-1, grains spike-1,1000-grain weight. Seed rate at 100 kg ha-1 produced lowest grain yield (2.14 t ha-1). As less number of plant is produced in lower seed rate (100 kg ha-1), the spikelets spike-1, grain spike-1, 1000-grain weight is increased because of less competition and the efficient utilization of space, water and nutrient.

This study demonstrates that row spacing had significant effect on yield contributing characters and yield of wheat cv. BARI Gom-33. The wider row spacing produced the higher grain yield whereas, narrower row spacing produce lower grain yield. The highest grain yield (2.81 t ha-1) obtain at 15 cm row spacing and lowest yield (2.50 t ha-1) obtain at 10 cm row spacing. It is because increase of row spacing resulted in higher light transmission rate at the top and basal parts of plant population at booting stage and the circulation of air reinforced. With the improved aeration and light transmission condition, quality of population and individual and yield significantly increased of wheat crop (Zheng et al., 2013). Decreasing row spacing increases the intra and inter plant competition, as a result yield is greatly reduced.

From the interaction it was observed that when different seed rate interact with different row spacing differently affect the yield contributing characters and yield of wheat cv. BARI Gom-33. The highest grain yield (3.33 t ha-1) was obtained from the interaction of 160 kg ha-1 seed rate × 15 cm row spacing. The lowest grain yield (2.06 t ha-1) was obtained from 100 kg ha-1 seed rate × 10 cm row spacing interaction. Therefore, the study suggests to use 15 cm row spacing for growing wheat with 160 kg ha-1 seed rate.

From the above results and discussion it is observed that row spacing of 15 cm produced the highest grain yield. Among different levels of seed rate, it was found that 160 kg ha-1 produced highest grain yield. From the interaction it was observed that 15 cm row spacing with 160 kg ha-1 seed rate produced identical grain yield. Therefore, the study suggests to use 15 cm row spacing for growing wheat with 160 kg ha-1 seed rate. But to arrive at a valid a recommendation further studies are necessary.

5. Conclusion

In this study, different type of seed rates had significant effect on plant height, spikes m-2, spikelets spike-1, grains spike-1, 1000-grain weight, grain yield, straw yield and biological yield. With increasing the seed rate, plant height, spikes m-2, grain yield, straw yield and biological yield is increased. Higher seed rate produce higher number of plant and tiller plant-1, as a result weed infestation is greatly reduced and less competition is occur. Highest grain yield obtain at 160 kg ha-1 seed rate while seed rate at 100 kg ha-1 produced lowest grain yield (2.14 t ha-1). Beside this, row spacing had significant effect on yield contributing characters and yield of wheat *cv.* BARI Gom-33. The highest grain yield (2.81 t ha-1) obtain at 15 cm row spacing and lowest yield (2.50 t ha-1) obtain at 10 cm row spacing. It is because increase of row spacing resulted in higher light transmission rate at the top and basal parts of plant population at booting stage and the circulation of air reinforced. With the improved aeration and light transmission condition, quality of population and individual and yield significantly increased of wheat crop.

From the interaction between seed rate and row spacing, the highest grain yield (3.33 t ha-1) was obtained from the interaction of 160 kg ha-1 seed rate × 15 cm row spacing. The lowest grain yield (2.06 t ha-1) was obtained from 100 kg ha-1 seed rate × 10 cm row spacing interaction. Therefore, it may be suggested to cultivate wheat (*cv*. BARI Gom-33) with seed rate 160 kg ha-1 and row spacing 15 cm. But to arrive at a valid a recommendation further studies are necessary.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**REFERENCES**

Al-Musa, M. A. A., Ullah, M. A., Moniruzzaman, M., Islam, M. S., & Mukherjee, A. (2012). Effect of BARI Wheat Varieties on Seed Germination, Growth and Yield under Patuakhali District. *Journal of Environment Science and Natural Resources,* 5, 209-212.

Armara, M.G., & Peter, K. (2017). Effect of spacing on grain yield and above ground biomass of cowpea. *International Journal of Climatic Studies*, 1(1), 24-35.

Barthakur, B. C., Borgohain, P. K., & Borgohain, M. N. (1979). Effect of row spacing and seeding rates on grain yield of dwarf wheat. *Indian Journal of Agronomy*, 24(1), 13-16.

BBS (Bangladesh Bureau of Statistics) 2023. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics, Statistics Division of Ministry and Planning, Government of People's Republic Bangladesh, Dhaka. 80

Beverlein, J. E., & Lafever, I. H. N. (1989). Yield of soft red winter wheat as affected by row spacing and seeding rate. *International Journal of Applied Agricultural Research,* 4(1), 47-50.

Bustos, D. V., Hasan, A. K., Reynolds, M. P., & Calderini, D. F. (2013). Combining high grain number and weight through a DH-population to improve grain yield potential of wheat in high-yielding environments. *Field Crops Research*, 145, 106-115.

Chatha, M. R., & Nazir, M. S. (1984). Effect of plant population and geometry of planting on the yield and growth behavior of wheat. *Pakistan Journal of Agricultural Research,* 52(2), 138-140.

Comissão Sul-brasileria de Presquisa de Trigo (2005). Informações técnicas da Comissão Sul-Brasileira de Pesquisa de Trigo e Triticale para a safra. Passo Fundo: EMBRAPA-CNPT 159 234.

FAO (Food and Agriculture Organization) (2024). Production Yearbook. Food and Agriculture Organization, Rome, Italy. Pp. 117-161.

FAO Foresight (2011). Crop Prospects and Food Situation. Food and Agriculture Organization, Global Information and Early Warning System, Trade and Markets Division (EST). Rome.

Fazli, S., Mohammad, K., & Jamro, G. H. (2004). Effect of different planting date, seeding rate and weed control method on grain yield and yield components of wheat. *Sarhad Journal of Agriculture,* 20(1), 51-55.

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., & Gerber, J. S. (2011). Solutions for a cultivated planet. *Nature,* 478(7369), 337–342.

Gade, P. (1995). Ecophysiologie du blé Paris 144 429.

Ghulam, M. L., Oad, F. C., Tunio, S., Chachar, Q., Gandahi, A. W., Siddiqui, M. H., Hassan, S. W., & Ali, A. (2011). Growth and yield attributes of wheat at different seed rates. *Sarhad Journal of Agriculture,* 27(2), 25-31.

Gomez, K. A., & Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2nd Edition, John Wiley and Sons, New York, 680 p.

Haile, D., Nigussie, D., Abdo, W., & Grima, F. (2013). Seeding rate and genotype effects on agronomic performance and grain protein content of drum wheat in South-Eastern Ethiopia. *African Journal of Food Agriculture Nutrition Development,* 13(3), 13-16.

Halder, D., Mia, M. L., Islam, M. F., Zahedi, M. S., Sium, M. A. R., Ahammed, R., Joly, M. S. A., Islam, M. S. & Begum, M. 2024. Effect of integrated weed management on the growth performance of wheat. *International* *Journal of Sustainable Crop production,* 19(1): 16-20

Harrison, K. S., & Beuerlein, J. E. (1989). Effect of herbicide mixtures and seeding rate on soft red winter wheat (*Triticum aestivum*) yield. *Weed Technology,* 3, 505-508.

Iqbal, N., Akbar, N., Ali, M., Sattar, M., & Ali, I. (2010). Effect of seed rate and row spacing on yield and yield components of wheat (Triticum aestivum L.). *Journal of Agricultural Research*, 48(2), 151-156.

Islam, M. F. (2013). Effect of seed rate and irrigation regime on the yield of wheat cv. BARI GOM-23 (BIJOY), MS Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Islam, M. S., Sattar, M. A., Rahman, M. M., Qayum, M. A., Alam, M. S., & Mustafi, R. A. (2004). Krishi Projukti Hatboi (Handbook on Agro-technology), 3rd Ed. Bangladesh Agricultural Research Institute, Gazipur- 1701, Bangladesh. p. 560.

Klepper, B., Rickman, R. W., & Peterson, C. M. (1982). Quantitative characterization of vegetative development in small cereal grain. *Journal of Agronomy,* 74, 789-792.

Kumar, P. R. K., Yadava, B., Gollen, S., Kumar, R. K., Verma, S., & Yadav. (2011). Nutritional Contents and Medicinal Properties of Wheat. *Life Science and Medicine Research,* 22(1), 1-10.

Laghari, G. M., Oad, F. C., Tunio, S., Chachar, Q., Gandahi, A. W., Siddique, M. H., Hasan, S. W., & Ali, A. (2011). Growth and yield attributes of wheat at different seed rates. *Sarhad Journal of Agriculture*, 27(2), 177-183.

Lloveras, J., Manent, J., Viudas, J., López, A., & Santiveri, P. (2004). Seeding rate influence on yield and yield components of irrigated winter wheat in a mediterranean climate. *Journal of Agronomy,* 96, 1258-1265.

Nazir, M. S., Hossain, A., Ali, G. & Shahi, R. H. (1987). Conventional versus new geometry of planting wheat. *Pakistan Journal of Agricultural Research*, 8(2), 125-129.

Neumann, K., Verburg, P. H., Stehfest, E., & Müller, C. (2010). The yield gap of global grain production: a spatial analysis. *Agricultural System,* 103(5), 316–326.

Oliveira, E. F. D., & Bego, A. (1983). Effect of spacing and plant density of wheat (Triticum aestivum) on yield and some agronomic characteristics. *Organizacao das cooperation do estado de parana 187-197.*

Ozturk, A., Caglar, O., & Bulut, S. (2006). Growth and yield response of facultative wheat to winter sowing, freezing sowing and spring sowing at different seeding rates. *Journal of Agronomy of Crop Science*, 192, 10-16.

Peter, J., Cerny, V., & Huska, L. (1988). Development in crop science (13). *Yield formation in the main field crops*. Elsevier Science Publishing Company, inc., New York, USA. 336.

Pukridge, D. W. & Donald, C. M. (1967). Competition among wheat plants sown at a wide range of densities. *Australian Journal of Agricultural Research*, 18, 193–211.

Rafique, S. M., Rashid, M., Akram, M. M., Alumad, J., Hussain, R., & Razzaq, A. (2010). Optimum seed rate of wheat in available soil moisture under rainted conditions. *Journal of Agricultural Research,* 47(2), 170-189.

Raj-Singh, S., Diwan, S., Rao, V. U., Singh, R., & Singh, D. (1992). Effect of date of sowing and row spacing on the yield of wheat (Triticum aestivum). *Indian Journal of Agronomy,* 39(3), 403-405.

Razzaque, M. A., Sattar, M. A., Amin, M. S., Qayum, M. A., & Alam, M. S. (2000). Krishi Projukti Hathoi (Handbook on Agro-technology), 2nd Ed. Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh. p.464.

Rickman, R. W., Klepper, B. L., & Peterson, C. M. (1983). Time distributions for describing appearance of specific culms of winter wheat. *Journal of Agronomy*, 75, 551-556.

Said, S., Gul, H., Saeed, B., Haleema, B., Badshah, N. L., & Parveen, L. (2012). Response of wheat to different planting dates and seeding rates for yield and yield components, *Journal of Agricultural and Biological* *Science*, 7(2), 138-140.

Singh, V. P. M., & Uttam, S. K. (1995). Effect of seed rate and inter-row spacing on yield of wheat variety HD1981 (Pratap) under rainfed condition of Central Uttar Pradesh. *Agrilcultural Science Digest,* 13(3-4), 117-121.

Slafer, G. A., & Satorre, E. H. (Editors) (1999). An introduction to the physiological ecological analysis of wheat yield. In Wheat Ecology and Physiology of Yield Determination. The Haworth Press, New York. pp. 3-12.

Thiry, D. E., Sears, R. G., Shroyer, J. P., & Paulsen, G. M. (2002). Relationship between tillering and grain yield of kansas wheat varieties. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Manhattan, Kansas, 66, 134.

Vukadinovic, Curbra, V. M., Calo, S., & Zuher, F. (1986). Multiple of factor affecting wheat crop production. *Archive fur Aciur and pfanzenbau and Bodenkunde, Bernbury, German*, 56, 321-332.

Zhang, J., Wang, J. A., Dang, J. Y., & Zhang, D. Y. (2010). Difference of grain yield and quality between the main stems and tillers of wheat. *Journal of Triticeae Crops,* 30, 526–528.

Zheng, T., Fan, G. Q., Chen, Y., Li, J.G., Rong, X. J., & Li, G.R. (2013). Effect of number and interspace of planting rows on population and individual quality of strip-drilling wheat. *Acta Agronomica Sinica,* 39(5), 885-895.