**Combating Heat Stress in Late Sown Wheat through Pre-Sowing Seed Priming**

**Abstract**

The goal of the current study was to assess the effectiveness of various seed priming methods for boosting wheat growth and yield when sown late. Therefore, a field experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh following a Split-plot design with three replications. The experiment comprised two factors, Factor A: wheat sowing date viz., (i) 30 November; (ii) 15 December; (iii) 30 December; Factor B: seed priming agent namely, (i) control (no priming); (ii) hydro priming; (iii) priming with 20000 ppm CaCl2; (iv) priming with 20000 ppm KCl; (v) priming with 15000 ppm KNO3; and (vi) priming with 40000 ppm Mannitol. The study discovered that BARI Gom-33's grain yield was highest (3.06 t ha-1) when sown on 30 November which was lowered by 39.87% and 64.37%, respectively, by late and very late sowing. Grain yield was significantly increased by seed priming, especially with CaCl2, by 0.66 t ha-1 when compared to the control. Moreover, when CaCl2 priming was used on November 30, the highest grain yield was obtained (3.37 t ha-1), when no priming was used on 30 December, the lowest yield (1.11 t ha-1) was obtained. Consequently, in order to reduce the effects of high temperatures, wheat should be sown by November 30th, ideally with 20,000 ppm of CaCl2.

**Keywords:** Seed priming;High temperature stress; Late sown wheat; Grain yield

**Introduction**

Wheat, a cereal grain, has been a cornerstone of human civilization for millennia. Its importance goes beyond basic survival because it is intricately linked to history, culture, and international economies. The domestication of wheat 10,000 years ago, represents wheat as a major turning point in human civilization and is therefore a historically significant staple crop (Singh *et al.* 2023). A notable source of vegetable protein in human diets, wheat contributes roughly 13% of its protein content. It is primarily composed of gluten, which makes up 75–80% of the protein in wheat. Wheat also contributes significantly to carbohydrates (71%). Whole grains, like wheat, are a good source of dietary fiber and other nutrients (Srivastava *et al.* 2023). Bangladesh's agricultural policies now place a strong emphasis on wheat, because of the realization that crop diversification is essential for ensuring food security. Currently, Bangladesh cultivates 1.23 million tons of wheat on 0.34 million hectares of land, producing 3.63 t ha-1 on average (BBS 2022)**.** Bangladesh's modest size and lack of climatic diversity make it a less diversified tropical nation than other countries with more varied climates or temperate climates. As a result, Bangladesh produces less wheat on average compared to other diversified climatic or temperate countries (Islam *et al.* 2023). Stresses from the environment, like low soil moisture, high temperatures, and lack of light, can negatively impact wheat growth and yield. Of these, high temperature is the most important (Modarresi *et al.* 2010; Trnka *et al.* 2004). Heat stress affects over 50 countries that annually import more than 20 million tons of wheat. This stress is characterized by a mean daily temperature exceeding 17.5 °C during the coolest month of the season and persists throughout the entire wheat growth cycle (Modarresi *et al.* 2010). When taking into account the different factors influencing the country's low wheat yield, the date of sowing holds the greatest significance.

The precise environmental conditions that every crop variety requires to reach its maximum potential can be helped by choosing the appropriate sowing date. The best time to plant wheat in Bangladesh is from the middle of November to the first week of December. There are a number of indications why the sowing date of wheat is delayed, including inadequate irrigation water, excessive moisture or water logging conditions from flooding, and the late harvesting of Kharif crops, particularly transplant aman rice. Crucial stages for increasing wheat yield are root development, germination, and grain development. Nevertheless, early sowing severely hinders root development because plants suffer from drought stress at that time, and late sowing hinders germination and grain development because of foggy conditions and dew drops which affects the development of germination and grain development of wheat (Tahir *et al.* 2009). Maximizing grain and straw output hinges on prioritizing the tillering phase. This critical stage directly influences tiller count, spike formation, grains per spike, and individual grain weight. Furthermore, timely planting remains a non-negotiable factor in achieving optimal results (Qasim *et al.* 2008). Wheat production in Bangladesh faces challenges primarily due to environmental limitations arising from delayed planting and a brief winter season (Ahmed *et al.* 2019).

Wheat typically experiences two distinct types of heat stress: continuous and terminal. “Continuous heat stress” persists throughout the entire wheat growth season, from sowing to maturity. In contrast, “terminal heat stress” occurs during the reproductive growth stages, specifically from heading to maturity (Reynolds *et al.* 2001). Elevated temperatures accelerate the spike's development and decrease the number of grains and spikelets within each spike (Farooq *et al.* 2011). The worldwide effect of heat stress on wheat is estimated to be 36 million hectares, with 40% of the crop dealing with terminal heat stress (Kumar *et al.* 2023; Reynolds *et al.* 2010,). In tropical and subtropical regions, however, 25–30 million hectares of wheat are vulnerable to yield loss due to heat stress (including China, Bangladesh, Nepal, India, Pakistan, Ethiopia, Sudan, Egypt, and North Africa). Global warming projections and current trends indicate that this area would significantly increase. According to reports, the yield drop caused by high temperatures in developing countries is approximately 29%. According to the climate scenario for the future, wheat output will significantly decline as a result of rising temperatures (Ortiz *et al.* 2008). Bangladesh's wheat yield would drop by 68% with every 4 °C increase in temperature (Acharjee and Shariot-Ullah 2021). Moreover, a doubling of temperature and atmospheric CO2 concentration would result in a 31% decline in wheat yield worldwide. Under terminal heat stress, the lengthening of the grain-filling period results in smaller grains and a lower grain spike-1 than in a suitable planting crop (Farhad *et al.* 2023).

Utilizing a variety of agronomic management strategies can lessen the detrimental effects of high temperatures on wheat yield. Nonetheless, wheat's sensitivity to high temperatures could be reduced by a variety of physiological techniques. One of these low-cost techniques for encouraging crop stand establishment is seed priming (Farooq *et al.* 2006). The technique known as "seed priming" involves controlling the hydration process inside seeds, re-drying them, triggering numerous physiological processes related to the initial stages of germination, and getting them ready for radical protrusion, which suspends the seeds in the lag phase (Paparella *et al.* 2015). Prior to distributing seeds, seed priming treatment is carried out. This means that seeds must be adequately hydrated to permit the occurrence of metabolic processes prior to germination while inhibiting the formation of radicles (Rehman *et al.* 2011; Nascimento *et al.* 2013). Prime seeds may germinate more quickly due to a variety of factors, including increased activity of degrading enzymes like amylase, RNA and DNA synthesis, the amount of ATP, and the presence of mitochondria (Afzal *et al.* 2002). Due to their many benefits, primed seeds are also more beneficial. Increased metabolic events can trigger the germination of dormant seeds (Soleimanzadeh 2013), allowing for early flowering and maturity, early reproductive organ growth, and improved resistance to abiotic stresses (Maasoumeh and Mohammad 2014) and soil-borne pathogens like *Rhizoctonia solani, Fusarium spp*., and *Sclerotium rolfsii* (Rafi *et al.* 2015).

Considering that Bangladesh's population is growing rapidly and that the nation needs wheat on a daily basis. Further research endeavors should concentrate more on augmenting wheat yield under heat stress conditions by developing heat-tolerant cultivars and efficient techniques such as seed priming. In-depth research on how different seed priming techniques affect wheat development and yield under late-sown conditions has not been done very often. Keeping this in view, this present research work was designed to recognize the most suitable priming technique for increasing growth and yield of late sown wheat under high temperature stress.

**Materials and Methods**

**Experimental sites**

A field trial was carried out at the Agronomy Field Laboratory of Bangladesh Agricultural University (24°43'12"N 90°25'37"E and 18.6 m above sea level) from November 2022 to March 2023. The area belongs to the non-calcareous dark gray floodplain soil of the Old Brahmaputra Floodplain agro ecological zone (AEZ 9). The land was silty-loam in texture, medium-high, and well-drained. At pH 6.65, with 1.21% of organic matter, 0.12% of total nitrogen, 26.07 ppm of available phosphorus, 0.15 me % of exchangeable potassium, and a moderate overall fertility level, the soil in the experimental field was essentially neutral in reaction. The experimental site is located in a humid, sub-tropical monsoon climate. Table 1 provides information on the pattern of rainfall, sunlight hours, fluctuation of temperature, and relative humidity over the research period, and also show the maximum, minimum and average temperature during the experimental period.

**Table 1.** Weather data from November 2022 to March 2023 at the experimental site during the growing season of wheat

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Month and year** | **Air temperature (o C)** | **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.

**Treatments and design**

Two factors were involved in the experiment, Factor A: sowing date and Factor B: priming agents. Three dates were selected for sowing *viz.,* D1: optimum sowing (30 November), D2: late sowing (15 December), and D3: very late sowing (30 December). The experiment employed only laboratory-grade priming agents manufactured in MERCK, India. Six conditions were created by using five priming agents such as a) no priming (P1) (b) hydro priming(P2) (c) priming with 20000 ppm CaCl2 (P3) (d) priming with 20000 ppm KCl (P4) (e) priming with 15000 ppm KNO3 (P5) and (f) priming with 40000 ppm Mannitol (C6H14O6) (P6). Split-plot design with three replications was used to set up the experiment, resulting in a total of 54 (18×3) plots. The date of sowing was assigned in the main plots, while seed priming practices was assigned in the sub-plots. Plot dimensions were 2.5 m × 2.0 m. The distances between plots and blocks were 0.5 and 1.0 meters, respectively.

**Plant material**

BARI Gom-33 is a Zn-enriched and wheat blast resistant variety with weaker glaoucosity in spike, released by Wheat Research Centre, Bangladesh Agricultural Research Institute (BARI), Dinajpur in 2017 [this research center currently renamed as Bangladesh Wheat and Maize Research Institute (BWMRI)]. The variety has a dark green stem and leaf. It needs roughly 60–65 days for heading and 110–115 days for physiological maturation. Tillers are semi-erect during heading, and the flag leaf is broad and droopy. A well-managed crop can yield 4-5 t ha-1 of grain.

**Crop husbandry**

After collecting BARI Gom-33, seeds were soaked in priming agent solution in the ratio of seed weight to solution volume 1:5 (g mL-1) for 6 hours and washed thoroughly to remove the chemical particles properly and after maintaining the moisture content, it stored in refrigerator for sowing. Following the implementation of appropriate management practices, the land was prepared. Subsequently, fertilizers were applied at the following rates: 240, 150,110, 120, and 8 kg ha-1 of urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP), Gypsum and Boric acid, respectively. The treated seeds were planted in the plot at a rate of 120 kg seeds ha-1 in rows 20 cm apart in accordance with the predetermined sowing dates. Following the right intercultural practices, such as irrigation and weeding, the crop eventually reached maturity. When the crop reached full maturity, it was first harvested individually, plot-wise, on 16, 23, and 31 March 2023, for the first, second, and third sowing dates, respectively.

**Data collection procedure**

Prior to harvesting, ten randomly chosen hills from each plot were removed. Plot-wise data on grain and straw yields were obtained using a 14% moisture basis, and the results were expressed as t ha-1. Plant height, spikes m-2, spikelets spikes-1, grains spikelet-1 were measured by selecting 10 plants randomly from each plot and then averaged. Weight of 1000 grains was collected after the entire plot was harvested. Then grain yield and straw yield were calculated after proper sun drying, and the biological yield was the sum of grain and straw yield. Finally, harvest index was calculated through = (Grain yield/Straw yield) ×100.

**Statistical analysis**

For statistical analysis, the recorded data were collated and tabulated. The software program MSTAT was used to perform an analysis of variance at the 5% probability level. Duncan's Multiple Range Test (DMRT) was used to determine the mean differences between the treatments.

**Results and Discussion**

**Effect of sowing date on wheat**

Sowing dates had a significant impact on all the plant characters, yield contributing characters and yield of wheat. Planting later than the optimum time resulted in shorter wheat plants because it created unfavorable conditions for wheat plants. When sowing was completed on November 30, the highest plant height (87.51 cm) was discovered. In comparison to the ideal sowing date of November 30, the plant (73.96 cm) was 13.55 cm shorter at the extremely late sowing date of December 30. The number of spikes m-2 exhibited a similar pattern, with the highest value (186.79) being attained on November 30, the day of optimal sowing. Unfortunately, only 66.87 spikes m-2 were obtained from the very late sowing date of 30 December, that amount is less than half of the optimum sowing date obtained. In terms of spikelets spike-1, 30 December sowing yielded the lowest results 6.20 (Table 2). When seeds were sown on November 30 (14.21) and December 15 (9.28) there was a definite benefit to the sowing date in terms of increasing spikelets spike-1, but not after that. When it came to wheat grains spikelet-1, the sowing on November 30 displayed the highest number of grains spikelet-1 (2.84), while the sowing on December 30 displayed the lowest number of grains spikelet-1 (1.72) (Table 2). Moreover, it is evident that until 15 December sowing time, the number of grains spikelet-1 (2.20) of wheat was tolerable (Table 2). The weight of 1000-grain drastically falls according to the delay of sowing time. When the sowing date was 30 November, it produced the highest weight of 1000-grain accounting for 40.50gm, however, when the sowing date became 30 December the weight of 1000-grain (25.97gm) dropped by almost 15gm compared to the optimum sowing date (30 November) (Table 2). The retarded sowing also resulted in a lower wheat grain yield. The sowing date that took place on 30 November resulted in utmost grain yield (3.06 t ha-1). Due to the extremely late sowing (30 December) and late sowing (15 December), wheat grain yield (1.19 t ha-1, 1.84 t ha-1) was reduced by 64.37% and 39.87% respectively. Furthermore, the highest straw yield (3.78 t ha-1) was obtained from early sowing, while the lowest straw yield (1.77 t ha-1) was found from very late sowing. When the wheat was sown on November 30, it had the greatest harvest index (44.42%). Harvest index steadily diminished as sowing was postponed (Table 2). High temperatures caused late-sown wheat cv BARI Gom-33 to produce fewer spikes per m-2, which could potentially negatively impact grain yield plant-1 and 1000-grain weight. According to research by Nawaz *et al.* (2013) and Farooq *et al.* (2011), high temperatures reduced the number of grains spike-1 and ear heads as well as hindered pollination and seed set. Better spikes m-2 and grain yield plant-1 evidence improved wheat performance following seed priming treatments. In the case of late-sown conditions, this lessened the harsh consequences of rising temperatures. Priming functions as a kind of immunization against impending illnesses like high temperatures (Arun *et al.* 2021; Patanè *et al.* 2009; Wahid *et al.* 2008). Zulfiqar *et al.* (2022) reported that seed priming has a correlation with seedlings' capacity to tolerate both biotic and abiotic stress. The hypothesis was that pre-sowing seed treatment could improve germination, boost germination rate, and boost seedling vigor and growth in Bangladesh, where late planting of wheat is becoming more common. In overcoming different abiotic and biotic obstacles, this may help wheat seedlings.

**Table 2:** Effect of sowing date on plant characters, yield parameters and yield of wheat cv BARI Gom-33

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sowing date** | **Plant height (cm)** | **Spikes m-2 (no.)** | **Spikelets spike-1 (no.)** | **Grains spikelet-1 (no.)** | **1000-grain weight (g)** | **Grain yield (t ha-1)** | **Straw yield (t ha-1)** | **Harvest Index (%)** |
| 30 November | 87.51a | 186.79a | 14.21a | 2.84a | 40.50a | 3.06a | 3.78a | 44.42a |
| 15 December | 78.22b | 115.68b | 9.28b | 2.20b | 35.32b | 1.84b | 2.56b | 41.92b |
| 30 December | 73.96c | 66.87c | 6.20c | 1.72c | 25.97c | 1.19c | 1.77c | 40.20c |
| Sx | 1.77 | 2.21 | 0.45 | 0.14 | 0.40 | 0.12 | 0.13 | 0.77 |
| Level of sig. | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* |
| CV (%) | 6.63 | 5.38 | 13.56 | 18.14 | 3.56 | 17.91 | 14.38 | 5.47 |

In a column, figures with same letter do not differ significantly (as per DMRT), \*\*=significant at 1% level of probability, NS=Non-significant

**Effect of priming agents on wheat**

All yield parameters, with the exception of 1000 grain weight and straw yield, were significantly influenced by seed priming (a technique for hydrating seeds prior to sowing that promotes germination and consistent seedling emergence). It was demonstrated that priming the seeds elevated the height of the wheat plant when compared to non-primed seeds. While seed priming outperformed the control (76.46 cm) by a significant margin, hydro (79.44 cm), CaCl2 (82.53 cm), KCl (80.94 cm), KNO3 (79.81 cm), and mannitol (80.21 cm) priming did not differ significantly from one another. From Table 3, it is evident that seed priming caused an average 5 cm boost in plant height. Ali *et al.* (2013) also found that various seed priming techniques in wheat increased plant height. Farooq *et al.* (2011) reported that primed seeds generally outperform control seeds in terms of dry matter production, plant height, and root weight. For the impact of seed priming, it was observed that more spikes m-2 were obtained from primed seeds than no priming. The highest number of spikes m-2 (126.57) was produced with CaCl2 priming which was similar(statistically) to KCl (125.92), while other seed priming (hydro, KNO3, mannitol) produced statistically identical results (Table 3). The lowest number of spikes m-2 (119.56) was recorded with no priming. In terms of number of spikelets spike-1, seed priming with CaCl2 (11.34) performed significantly better than the control (8.73), however, there was no statistically significant difference between CaCl2 (11.34) and KCl (10.84) priming, while KNO3 (9.47) and hydro (8.90) priming produced statistically different results from CaCl2 and KCl priming (Table 3). Seed priming increased yield and exceeded the control by a significant margin. According to Asadujjaman *et al.* (2023), primed seed treated with KCl and CaCl2 under high temperature stress resulted in the highest plant height, number of spikes m-2, spikelets spike-1, grain yield, and straw yield of wheat compared to control. When seeds primed with CaCl2 had the highest harvest index (43.65%) among all and no priming produced the lowest harvest index of only 38.15 % (Table 3). Seed priming induced an average 5% raise in the harvest index (Table 3). In order to verify the foundation and maximize plant yield, Arun *et al.* (2021) stated that the intention of priming was to the assurance of the germination process while protecting the seed from environmental stress during the seedling stage.

**Table 3.** Effect of seed priming on plant characters, yield parameters and yield of wheat cv BARI Gom-33

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Plant height (cm)** | **Spikes m-2 (no.)** | **Spikelets spike-1 (no.)** | **Grains spikelet-1 (no.)** | **1000-grain weight (g)** | **Grain yield (t ha-1)** | **Straw yield (t ha-1)** | **Harvest Index (%)** |
| No Priming | 76.46b | 119.56b | 8.73c | 1.88c | 33.67 | 1.60b | 2.68 | 38.15b |
| Hydro Priming | 79.44ab | 121.08ab | 8.90bc | 2.02bc | 33.70 | 1.98a | 2.51 | 43.16a |
| Priming with 20000 ppm CaCl2 | 82.53a | 126.57a | 11.34a | 2.56a | 34.23 | 2.26a | 2.82 | 43.65a |
| Priming with 20000 ppm KCl | 80.94ab | 125.92a | 10.84a | 2.42a | 34.02 | 2.16a | 2.75 | 43.19a |
| Priming with 15000 ppm KNO3 | 79.81ab | 121.56ab | 9.47bc | 2.31ab | 33.95 | 2.06a | 2.64 | 42.86a |
| Priming with 40000 ppm Mannitol | 80.21ab | 124.00ab | 10.10ab | 2.33ab | 34.01 | 2.11a | 2.81 | 42.06a |
| Sx | 2.50 | 3.12 | 0.63 | 0.19 | 0.57 | 0.17 | 0.18 | 1.09 |
| Level of significance | \*\* | \*\* | \*\* | \*\* | NS | \*\* | NS | \*\* |
| CV (%) | 6.63 | 5.38 | 13.56 | 18.14 | 3.56 | 17.91 | 14.38 | 5.47 |

In a column, figures with same letter do not differ significantly (as per DMRT), \*\*=significant at 1% level of probability, NS=Non-significant

**Interaction effect of sowing date and seed priming**

All the plant characters, yield parameters and yield of wheat were significantly varied when sowing date and seed priming interacted with each other. The plants with the tallest height (90.10 cm) and the most spikes m-2 (189.8) were observed in the CaCl2 priming and sowing on November 30. On the contrary, the lowest height of plants (71.33 cm) was found in no priming and sowing on extremely late sowing (30 December).

So, to get the highest plant height and number of spikes m-2 wheat should be planted on 30 November with CaCl2 priming. Upon combining CaCl2 priming with 30 November sowing, the greatest number of spikelets spike-1 (15.73), grains spikelet-1 (3.16), highest 1000-grain weight (40.76 g), and highest grain yield (3.37 g) were observed (Table 4, Figure 1). On the contrary, lowest number of grains spikelet-1 (1.23), weight of 1000 grains (25.86 gm) found in the combination of no priming and 30 December. The highest straw yield (4.09 t ha-1) was produced by the interaction of mannitol priming and 30 November sowing, while the maximum harvest index (47.22%) was observed in the combination of CaCl2 and 30 November sowing. Prior to December 15th sowing, priming was clearly advantageous in raising the harvest index, but not after that.

This study shows how late-sown wheat can perform better when seed priming techniques are used. The occurrence of low temperatures during sowing of wheat cv BARI Gom-33 leads to poor seed germination, establishment, and vigor of seedlings when seeded too late. Due to inadequate stand establishment, a lack of spikes m-2 subsequently results in lower grain production, straw yield, and harvest index. Seed priming improved tiller counts, emergence, stand establishment, grain and straw yields, and harvest index in late-sown wheat (Farooq *et al.* 2008). Numerous seed priming techniques improved the yields of viable tillers, plant height, 1000-grain weight, yield, and grain and biological components in wheat (Ali *et al.* 2013). In a similar vein, Toklu *et al.* (2015) demonstrated that hydro-priming, PEG, and KCl treatments increased wheat grain yield relative to the control. Additionally, seed priming in wheat produced a noticeably higher grain yield (17%) compared to the non-primed control, according to Ramamurthy *et al.* (2015).

The highest plant height, spike m-2, 1000-grain weight, grain yield, and straw yield of wheat cv. BARI Gom-33 under high temperature stress were obtained in this study using primed seed, particularly CaCl2. Other priming agents, in addition to CaCl2, also outperformed the control. Similarly, Suryakant *et al.* (2000) found that the highest yields of wheat grain, straw, and biological material were obtained from sprouted seeds, which were then followed by priming treatments with KCl, water, and ZnSO4, and the lowest yields from dry seed sowing (control).

The current study demonstrates that seed priming, when applied later in the growing season, can effectively boost wheat plant growth and yield even in the face of heat stress. Without a doubt, seed priming with CaCl2 proved to be the most effective priming agent. However, wheat cv BARI Gom-33's growth and yield were also enhanced by additional priming agents. These results will open up new possibilities for improving seed priming to protect late-sown wheat from heat stress, especially during the reproductive stage.

**Table 4.** Interaction effect of seed priming and sowing date on plant characters, yield parameters and yield of wheat cv BARI Gom-33

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sowing date × seed priming** | **Plant height (cm)** | **Spikes m-2 (no.)** | **Spikelets spike-1 (no.)** | **Grains spikelet-1 (no.)** | **1000-grain weight g)** | **Straw yield (t ha-1)** | **Harvest Index (%)** |
| D1P1 | 84.10a-d | 183.33a | 12.90bc | 2.53a-e | 40.16a | 3.67a | 36.92f |
| D1P2 | 86.20abc | 185.07a | 13.06bc | 2.66a-d | 40.23a | 3.60a | 46.69ab |
| D1P3 | 90.10a | 189.80a | 15.73a | 3.16a | 40.76a | 3.77a | 47.22a |
| D1P4 | 89.23ab | 189.10a | 15.10ab | 3.03ab | 40.60a | 3.82a | 45.85abc |
| D1P5 | 87.20abc | 186.17a | 13.73ab | 2.83abc | 40.73a | 3.71a | 46.36abc |
| D1P6 | 88.23ab | 187.27a | 14.73ab | 2.83abc | 40.50a | 4.09a | 43.44a-e |
| D2P1 | 73.96ef | 110.17b | 7.80fgh | 1.90e-h | 35.00b | 2.73b | 37.30f |
| D2P2 | 76.93def | 112.00b | 8.16fgh | 2.03d-g | 35.06b | 2.31bcd | 41.61de |
| D2P3 | 81.16b-e | 120.17b | 11.10cd | 2.46b-f | 35.56b | 2.79b | 43.46a-e |
| D2P4 | 79.23c-f | 119.33b | 10.63de | 2.20c-f | 35.36b | 2.57b | 43.54a-d |
| D2P5 | 79.00c-f | 115.23b | 8.63efg | 2.26c-f | 35.43b | 2.43bcd | 42.55cde |
| D2P6 | 79.06c-f | 117.20b | 9.36def | 2.36b-f | 35.50b | 2.53bc | 43.04b-e |
| D3P1 | 71.33f | 65.17c | 5.50i | 1.23h | 25.86c | 1.65e | 40.23def |
| D3P2 | 75.20ef | 66.17c | 5.46i | 1.36gh | 25.80c | 1.61e | 41.19de |
| D3P3 | 76.33def | 69.73c | 7.20f-i | 2.06def | 26.36c | 1.89cde | 40.26def |
| D3P4 | 74.36ef | 69.33c | 6.80ghi | 2.03d-g | 26.10c | 1.87de | 40.18def |
| D3P5 | 73.23ef | 63.27c | 6.06hi | 1.83fgh | 25.70c | 1.79de | 39.67ef |
| D3P6 | 73.33ef | 67.53c | 6.20hi | 1.80fgh | 26.03c | 1.80de | 39.69ef |
| Sx | 4.33 | 5.40 | 1.10 | 0.33 | 0.99 | 0.32 | 1.88 |
| Level of sig. | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* |
| CV (%) | 6.63 | 5.38 | 13.56 | 18.14 | 3.56 | 14.38 | 5.47 |

In a column, figures with same letter do not differ significantly (as per DMRT), \*\*=significant at 1 % level of probability. D1= 30 November, D2= 15 December, D3= 30 December. P1= No Priming, P2= Hydro Priming, P3= Priming with 20000 ppm CaCl2, P4= Priming with 20000 ppm KCl, P5= Priming with 15000 ppm KNO3, P6= Priming with 40000 ppm mannitol.



**Figure 1.** Grain yield of wheat cv BARI Gom-33 as influenced by the interaction between seed priming and sowing date. Bar represents standard error of means. Here, D1=30 November, D2= 15 December, D3= 30 December P1= No Priming, P2= Hydro Priming, P3= Priming with 20000 ppm Cacl2, P4= Priming with 20000 ppm KCl, P5= Priming with 15000 ppm KNO3, P6= Priming with 40000 ppm mannitol

**Conclusion**

The study found that the sowing date, priming agent, and their interaction significantly impacted the plant height, spikes m-2, spikelets panicle-1, grains spike-1, and grain yield of wheat. Seed priming showed a positive effect on plant characteristics, yield parameters, and yield of wheat cv BARI Gom-33. The grain yield of BARI Gom-33 decreased with delay in sowing, with the highest yield (3.06 t ha-1) found when sowing on 30 November. Seed priming with CaCl2 resulted in the highest grain yield (2.26 t ha-1), while no priming produced the lowest yield of 1.60 t ha-1. On average, seed priming increased grain yield by 0.66 t ha-1 compared to the control. Delay in sowing caused poor crop stand and growth, but seed priming improved stand establishment and growth, resulting in a substantial increase in grain yield. Thus, it is advised to sow wheat by November 30 after seed priming, ideally with 20,000 ppm CaCl2. If sowing is delayed, seed priming is essential to partially alleviate temperature stress. However, this research is conducted in a single year and location, hence, multi-location and especially multi-year trials should be conducted based on these preliminary results before draw a final conclusion.

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**Ethics Statement:** Not Applicable

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