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Augmenting Spring Wheat Productivity Through Seed Priming Under Late-Sown Condition in Bangladesh

Bangladeş'te Geç Ekim Koşullarında Yazlık Buğday Verimliliğinin Tohum Ön İşlemesi Yoluyla Artırılması

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ABSTRACT

The sowing of wheat can be delayed in Bangladesh because of the late harvesting of previous crops. Under late-sown conditions, heat stress results in poor development of wheat, which may be avoided by seed priming techniques. The purpose of this study was to assess the effectiveness of several seed priming methods for boosting wheat growth and yield when sown late. In this regard, from December 2019 to March 2020, a field investigation was carried out at the Agronomy Field Laboratory of Bangladesh Agricultural University. The experiment comprised three factors, Factor A: wheat variety namely, BARI Gom-27 and BARI Gom-33; Factor B: sowing dates such as 01 December 2019, 15 December 2019, and 30 December 2019; Factor C: Method of seed priming namely, control (no priming), priming with 20,000 ppm calcium chloride and priming with 20,000 ppm potassium chloride. With three replications, the experiment was set up using a split–split plot design. Research revealed that seed priming was generally effective in promoting plant growth, spikes number m^{-2}, grains $spike^{-1}$, thousand-grain weight, and grain yield. Both potassium chloride and calcium chloride performed significantly similar. As BARI Gom-33 is more resistant to heat stress, it outperformed BARI Gom-27 in terms of spike length and grains $spike^{-1}$. However, BARI Gom-27 and BARI Gom-33 performed quite similarly and wheat yield decreased gradually with the delay of sowing due to temperature stress. A clear advantage of seed priming was found in increasing grain yield at all sowing dates. Therefore, it is recommended to sow wheat by 15 November following seed priming and in case of delay sowing seed priming is a must to mitigate the temperature stress to some extent.

Keywords: Growth, heat stress, seed invigoration, sowing time, wheat, yield

ÖZ

Bangladeş'te önceki ürünlerin geç hasat edilmesi nedeniyle buğday ekimi geciktirilebilmektedir. Geç ekim koşullarında, sıcaklık stresi buğdayın zayıf gelişmesine neden olur ve bu durum tohum ön işleme teknikleri kullanılarak önlenebilmektedir. Bu çalışmanın amacı, geç ekim yapıldığında tohum ön işleme yöntemlerinin buğday büyümesini ve verimini artırmada etkinliğini değerlendirmektir. Bu amaçla, araştırmamız Aralık 2019'dan Mart 2020'ye kadar, Bangladeş Tarım Üniversitesi Zirai Araştırma arazilerinde gerçekleştirilmiştir. Araştırma, Faktör A - BARI Gom-27 ve BARI Gom-33 olmak üzere iki farklı buğday çeşidi; Faktör B - 01 Aralık 2019, 15 Aralık 2019 ve 30 Aralık 2019 olmak üzere üç farklı ekim tarihi; ve Faktör C - kontrol grubu (ön işlem yapılmamış tohumlar), 20000 ppm CaCl2 ve 20000 ppm KCl ile ön işlem yapılmış tohumlar olmak üzere üç faktörden oluşmuştur. Deneme bölünen bölünmüş parseller deneme desenine göre üç tekerrürlü olarak kurulmuştur. Araştırma, tohum öncesi işlemenin bitki büyümesini, metrekaredeki başak sayısını, başaktaki tane sayısını, bin tane ağırlığı ve tane verimini artırmada genel olarak etkili olduğunu göstermiştir. Hem KCl hem de CaCl2 ön işleme uygulamaları, önemli ölçüde benzer bir performans sergilemiştir. BARI Gom-33 çeşidi, sıcaklık stresi ile mücadele konusunda daha dirençli olduğu için, başak uzunluğu ve başaktaki tane sayısı açısından BARI Gom-27'den daha iyi sonuçlar göstermiştir. Ancak, BARI Gom-27 ve BARI Gom-33 çeşitlerinde ekim geciktikçe benzer sonuçlar göstererek sıcaklık stresi nedeniyle buğday verimi azalmıştır. Tüm ekim tarihlerinde tane verimini artırmada tohum öncesi işlemin önemi açık bir şekilde görülmüştür. Bu nedenle, tohum ön işlemesi yapıldıktan sonra buğdayın 15 Kasım'a kadar ekilmesi önerilir ve ekimin gecikmesi durumunda, sıcaklık stresini bir dereceye kadar azaltmak için tohum ön işlemesi şarttır.

Anahtar Kelimeler: Büyüme, sıcaklık stresi, tohum güçlendirme, ekim zamanı, buğday, verim

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Introduction

One of the most popular cereal grains consumed worldwide is wheat (*Triticum aestivum* L.). Wheat is the second most significant cereal crop in Bangladesh after rice (Jahan et al., 2021), and consumption of grain is rising steadily as a result of its affordable cost of production, favorable market price, and high nutritional content. Due to the country's shifting dietary preferences, wheat has now a prominent place in agricultural policies in Bangladesh and has become one of the most important grain crops. Bangladesh now produces 1.09 million tons of wheat covering a 0.34 m ha area, yielding an average of 3.3 t ha^{-1} (BBS, 2021). The average amount of wheat produced in Bangladesh is relatively low when compared to several other countries that grow wheat. Also, due to several biotic and abiotic causes, the yield of Bangladeshi wheat in farmers' fields is much lower than rice and maize (2.0 t ha^{-1}) when compared to research fields (Ahmed et al., 2019; Kamrozzaman et al., 2016; Shabi et al., 2018). The date of sowing and variety choice are of the highest importance when considering the various factors influencing the nation's poor yield of wheat.

The right sowing date can help with the specific environmental conditions that each crop variety needs to thrive to its full potential. In Bangladesh, the best period to sow wheat is from mid-November through the first week of December. However, late harvesting of kharif crops, notably T. aman rice, causes wheat sowing to be delayed. Additionally, there may not be enough irrigation water available, and occasionally there may be too much moisture and water logging due to excessive rainfall, which can also delay wheat sowing. When wheat is sown early, it encounters higher temperature resulting in inadequate root development and poor growth of plants (Kamrozzaman et al., 2016). Delay planting affects germination, growth, grain development, and eventually suppresses yield (Tahir et al., 2009). Timely planting extends the tillering phase and produces a sufficient number of tillers, spikes, grains $spike^{-1}$, and grain weight, which ultimately improves grain and straw output (Qasim et al., 2008). With each week of delayed sowing, Braun et al. (2010) found that grain output dropped, with a loss of 200–250 kg grain ha^{-1}. Wheat yields in Bangladesh are poor mostly due to environmental constraints brought on by late planting and a short winter (Islam et al., 1993).

High temperatures is the most major environmental stressor, although others such as poor soil moisture, low light intensity, and others can have an adverse effect on wheat development and yield (Modarresi et al., 2010; Trnka et al., 2004). There are two types of heat stress that wheat normally encounters: continual and terminal. The phrase "continual heat stress" refers to the heat stress that persists from sowing to maturity stages and "terminal heat stress" refers to heat stress that begins during reproductive development phases, notably from heading to maturity stages (Reynolds et al., 2001). As per an investigation by Karim et al. (1999), in Bangladesh, the wheat yield might drop by roughly 68% with a 4°C increase in temperature. According to Wiegard & Cellular (1981), for each 1.0°C increase in the mean daily air temperature, the grain filling period for wheat was delayed by 3 days. However, according to the projected future climate, unless the right cultivars and crop management strategies are used, rising temperatures would result in a considerable decrease in wheat output (Ortiz et al., 2008). The detrimental impact of high temperatures on wheat output can be mitigated by using special agronomic management strategies.

Wheat's high-temperature stress can be lessened by using a variety of physiological techniques. Seed priming is one of these methods, which is a safe and affordable strategy to improve wheat development (Farooq et al., 2006a). "Seed priming" seeks to control the germination process by regulating the temperature and moisture level of the seeds. It is a useful physiological pre-germination technique that enhances seed performance and promotes coordinated germination of seed quickly (Matsushima & Sakagami, 2013) by imposing stress conditions on the seed before germination, which provides improved resistance to forthcoming stresses (Anwar et al., 2021b; Yadav et al., 2011). Plants that have been grown from primed seed, develop more quickly and completely, with early blooming, maturity, and larger yields as well as decreased likelihood of crop failure. Various sorts of priming methods are hydro-priming with water, osmo-priming with organic osmotic solution, halo-priming by inorganic salt solutions, thermo-priming by low or high temperatures depending on species, bio-priming with biological compounds, and solid matrix priming with solid matrices (Ashraf & Foolad, 2005). Greater germination percentage, synchronized germination, and speedier seedling emergence are advantages of seed priming, and these qualities are directly related to crop development and yield (Anwar et al., 2012; Farooq et al., 2007; Mim et al., 2021).

Although applying seed priming techniques in controlled environments has been shown to promote germination and seedling growth (Anwar et al., 2020; Basra et al., 2005; Farooq et al., 2009b) and also some achievements (Du & Tuong, 2002) in boosting the performance of crops have been confirmed, but there has not been much detailed study done to evaluate the impact of various seed priming procedures to boost wheat development and yield in late-sown conditions. Given the foregoing, the goal of the current experiment was to determine how well various seed priming strategies increased wheat growth and yield when it was seeded late in the season.

Methods

A field trial was carried out at the Agronomy Field Laboratory of Bangladesh Agricultural University from December 2019 to March 2020 to determine the effectiveness of various seed priming procedures to boost the growth and yield of wheat under late-sown conditions. Geographically, the region was situated at 24°75′ N latitude and 90°50′ E longitude, with an altitude of 18 m above sea level. This region is a part of the Old Brahmaputra Floodplain (AEZ 9), which has non-calcareous dark gray floodplain soil under the Sonatola series. The land was medium-high and well drained with a silty-loam texture. The soil of the experimental field was more or less neutral in reaction (pH: 6.65), organic matter content (1.21%), total nitrogen (0.12%), available phosphorous (26.07 ppm), exchangeable potassium (0.15 me %), and the general fertility level of the soil was moderate. The experimental site belongs to a subtropical monsoon climate with a humid environment. Table 1 provides information on the pattern of rainfall, sunlight hours, temperature swings, and relative humidity over the research period, and Figure 1 depicts the weekly averages for maximum, minimum, and mean temperatures.

The experiment comprised three different sowing dates viz. 01 December 2019 (D_1), 15 December 2019 (D_2), and 30 December 2019 (D_3); two seed priming agents with control treatment viz. no priming (P_0), priming with 20,000 ppm $CaCl_2$ (P_{Ca}), priming with

Table 1.
Weather Data From November 2019 to March 2020 at the Experimental Site During the Growing Season of Wheat

Month and Year	Air Temperature (°C)			Rainfall (mm)	Relative Humidity (%)	Sunshine (Hours)
	Maximum	Minimum	Average			
December 2019	25.4	13.5	19.8	17.7	80.2	201.3
January 2020	24.02	12.15	19.22	0.00	84.35	227.2
February 2020	26.8	15.54	21.28	1.17	83.00	164.8
March 2020	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.

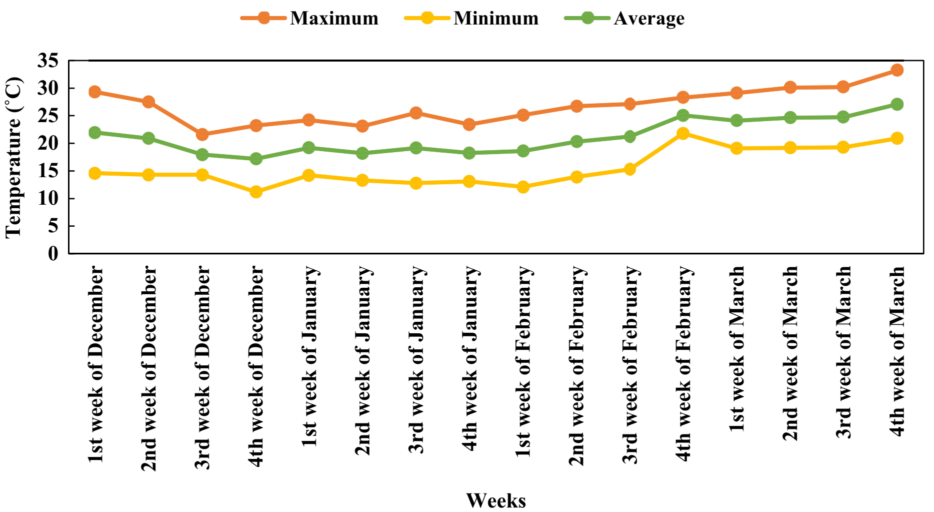

Figure 1.
Weekly Average Maximum, Minimum, and Mean Temperature From December 2019 to March 2020.

20,000 ppm KCl (P_K); and two wheat varieties viz. BARI Gom-27 (V_1) and BARI Gom-33 (V_2). The experiment employed laboratory-grade two priming agents made at MERCK, India: potassium chloride (KCl) and calcium chloride ($CaCl_2$). A split–split plot design with three replications was used to set up the experiment. Sowing dates were assigned to the main plots, seed priming techniques to the subplots, and variety was allocated to the sub-subplots. There were 54 plots overall, each measuring 10 m^2 (2.5 m × 4.0 m).

The land was prepared in the third week of November 2019. A power tiller was used to repeatedly plow the ground. The land was cleared of weeds and the remnants of the previous crop. Following leveling, the experimental plots were set up in accordance with the chosen treatments and layout. At the time of the final land preparation, one-third of recommended urea dose and the full amount of Tripple Super Phosphate (TSP), Muriate of Potash (MoP), gypsum, and boric acid were applied at 180, 50, 120, and 7.5 kg ha^{-1}, respectively. On days 20 and 55 following sowing, the remaining two-thirds of urea were top-dressed in two equal portions. Both wheat varieties' seeds were steeped for 6 hours at room temperature (25 ± 2°C) in various priming agent solutions that had been previously made using distilled water. The seed weight to solution volume ratio was 1:5 (w:v). The seeds were then taken out of the priming solution and thoroughly washed with distilled water to eliminate any remaining chemical residues. Forced air was then used to dry the seeds to their original moisture level. Dry seeds were placed in polythene bags and kept in a refrigerator at 5°C until needed. After sprouting, the seeds were sown in the plot at 110 g seeds per plot, spaced 20 cm apart. Three distinct date–1 December, 15 December, and 30 December 2019–were chosen for the sowing of the seeds. The optimum period to sow was thought to be on 1 December; 15 December and 30 December were deemed late and extremely late, respectively. So, at various stages, seedlings are subject to heat stress. After sowing, the seeds were kept safe from birds. Three irrigations were given, the first irrigation was given at 20 days after sowing (DAS) at the crown root initiation stage, the second one at the heading stage (60 DAS), and the third one at the grain filling stage (80 DAS). To ensure the crop's proper development, intercultural activities like weeding were carried out.

The cultivars were harvested individually and according to a plot after they were fully mature on 15 March, 21 March, and 29 March 2020, respectively, 1st, 2nd, and 3rd sowing dates. At harvest, data on the height of the plant; number of spikes m^{-2}; spike length, number of spikelets $spike^{-1}$; grains $spike^{-1}$; grains $spikelet^{-1}$; 1000-grain weight; grain, straw, and biological yield; and harvest index were documented. The yields of grain and straw were calculated plot-wise on a basis of 14% moisture and represented as t ha^{-1}.

The data were collected, tabulated, and statistically analyzed. Using the computer program MSTAT, an analysis of variance was performed with a 5% level of probability. Duncan's Multiple Range Test was used to determine the average differences between the treatments.

Results

Main Effect

Sowing date

With the exception of spike length and grains spikelet^{-1}, the sowing date had a substantial impact on the growth, yield-contributing characteristics, and yield of wheat. The delay in planting led to a reduction in wheat plant height. The highest plant height (95.38 cm) was found when sowing was done on 01 December. At very late sowing (30 December), the plant (88.80 cm) was shortened by 7 cm compared to the optimum sowing date (1 December). Number of spikes m^{-2} also followed a similar trend where the highest value (146.38) was obtained with early sowing (1 December). Apart from the sowing on 30 December (139.80), the remaining two dates produced statistically equivalent numbers of spikes m^{-2}. The performance of the 30 December sowing was the worst in terms of spikelets spike^{-1} (12.77). A clear advantage of sowing date in increasing spikelets spike^{-1} was evident on 01 December (15.85) and 15 December (14.92) sowing, but not thereafter. In terms of grains spike^{-1} of wheat, 1 December sowing showed maximum grains spike^{-1} (47.66), whereas 30 December sowing exhibited minimum grains spike^{-1} (38.50). From Table 2, it is clear that up to 15 December sowing the number of grains spike^{-1} of wheat was considerable. With the delay in sowing, wheat's thousand-grain weight dropped. The sowing that took place on 1 December produced the maximum weight of 1000 grains (43.52 g), while the sowing that took place on 30 December produced the lowest weight of 1000 grains (31.04 g). With the postponement of sowing, wheat grain yield was also reduced. Wheat sowing on 1 December resulted in the maximum grain yield (2.99 t ha^{-1}). Wheat grain yield (1.67 t ha^{-1}) was lowered by 44% as a result of the very late sowing (30 December). Also, early sowing led to the maximum straw yield (3.54 t ha^{-1}) and when sown very late, the straw yield was recorded as being the lowest. The highest harvest index (45.79%) of wheat was found when sowing was done on 01 December. With the delay of sowing, harvest index was gradually decreased (Table 2).

Seed priming

Seed priming had a significant influence on all yield parameters and yield except spike length, spikelets spike^{-1}, and grains spikelet^{-1}. When compared to non-primed seeds, it was shown that priming the seeds enhanced wheat plant stature. Seed priming performed significantly better than the control (90.03 cm), but there were no significant differences between calcium (94.17 cm) and potassium (94.81) priming. From Table 3, it is clear that on average due to seed priming plant height was increased by 5 cm. As a result of seed priming, there were more wheat spikes m^{-2} than there were under control. With KCl priming, the greatest number of spikes m^{-2} (145.81) was produced which was

Table 2.
Effect of Sowing Date on Plant Characters, Yield Parameters, and Yield of Wheat

Sowing Date	Plant Height (cm)	Spikes m^{-2} (no.)	Spike Length (cm)	Spikelets Spike^{-1} (no.)	Grains Spike^{-1} (no.)	Grains Spikelet^{-1} (no.)	1000-Grain Weight (g)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Harvest index (%)
01 December	95.38a	146.38a	12.08	15.85a	47.66a	3.02	43.52a	2.99a	3.54a	45.79a
15 December	94.82a	145.82a	12.20	14.92a	44.88a	3.03	41.07b	2.69b	3.32a	44.73a
30 December	88.80b	139.80b	12.03	12.77b	38.50b	3.04	31.04c	1.67c	2.71b	38.11ab
$S\bar{x}$	27.41	27.41	0.14	2.66	22.11	0.27	2.66	0.07	0.10	22.35
Level of significance	**	**	NS	**	**	NS	**	**	**	**
CV (%)	5.6	3.6	3.1	11.2	10.8	17.2	4.2	10.9	10.2	11.0

Note: NS = Not significant.
Means with the same letters or without letters within the same column do not differ significantly.
**Significant at 1% level of probability.

Table 3.
Effect of Seed Priming on Plant Characters, Yield Parameters, and Yield of Wheat

Seed Priming	Plant Height (cm)	Spikes m^{-2} (no.)	Spike Length (cm)	Spikelets Spike^{-1} (no.)	Grains 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	90.03b	141.03b	12.21	13.87	41.50b	3.02	37.11b	2.21b	3.02b	41.70b
$CaCl_2$ priming	94.17a	145.17a	12.05	14.85	44.66a	3.01	38.96a	2.55a	3.28a	43.17a
KCl priming	94.81a	145.81a	12.05	14.8	44.88a	3.06	39.57a	2.59a	3.27a	43.76a
$S\bar{x}$	15.58	25.70	0.36	2.07	7.99	0.08	1.30	0.02	0.09	3.38
Level of significance	*	*	NS	NS	*	NS	**	**	*	*
CV (%)	4.2	2.7	5.0	9.9	6.5	9.5	3.0	6.4	9.9	4.3

Note: NS = Not significant.
Means with the same letters or without letters within the same column do not differ significantly.
**Significant at 1% level of probability.
*Significant at 5 % level of probability.

Table 4.
Effect of Variety on Plant Characters, Yield Parameters, and Yield of Wheat

Variety	Plant Height (cm)	Spikes m^{-2} (no.)	Spike Length (cm)	Spikelets $Spike^{-1}$ (no.)	Grains $Spike^{-1}$ (no.)	Grains $Spikelet^{-1}$ (no.)	1000-Grain Weight (g)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Harvest Index (%)
BARI Gom-27	92.22	143.22	10.32b	14.17	42.70b	3.03	37.79	2.35	3.13b	42.45
BARI Gom-33	93.78	143.22	13.89a	14.86	44.66a	3.03	39.30	2.55	3.25a	43.30
$S\bar{x}$	25.70	25.70	0.36	1.28	0.07	0.08	20.10	0.17	0.01	21.65
Level of significance	NS	NS	**	NS	**	NS	NS	NS	**	NS
CV (%)	5.5	3.5	5.0	7.8	0.6	9.8	11.6	16.9	0.9	10.9

Note: NS = Not significant.
Means with the same letters or without letters within the same column do not differ significantly.
**Significant at 1% level of probability.

statistically similar to $CaCl_2$ priming (145.17) and the lowest was registered with no priming (141.03). When compared to the control, seed priming greatly outperformed it in terms of number of grains spike^{-1} (41.50), but there was no significant difference between calcium (44.66) and potassium (44.88) priming and on average due to seed priming wheat grains spike^{-1} was increased by 7%. As compared to the control, priming boosted 1000-grain weight by roughly 5.5%. Seed priming demonstrated higher effectiveness in this regard. The maximal 1000-grain weight (39.57 g) obtained by KCl seed priming was comparable to $CaCl_2$ priming (38.96 g). Using KCl priming, the best grain yield was attained (2.59 t ha^{-1}) which was statistically equivalent to $CaCl_2$ priming (2.55 t ha^{-1}). Seed priming outperformed the control by a large margin and boosted yield. When compared to non-primed seeds, it was shown that priming the seeds enhanced the yield of wheat straw. The performance of seed priming was much better than the control, but there was no noticeable difference between calcium (3.28 t ha^{-1}) and potassium (3.27 t ha^{-1}) priming. The harvest index for seeds primed with KCL was greatest (43.76%), followed by seeds primed with $CaCl_2$ (43.17). Due to seed priming, the harvest index rose by 2% on average (Table 3).

Variety

In wheat varieties, a significant varietal effect was seen in the spike length, grains spike^{-1}, and straw yield. Between the two varieties, the performance of BARI Gom-33 was better in terms of length of spike (13.89 cm), number of grains spike^{-1} (44.66), and straw yield (3.25 t ha^{-1}) of wheat. BARI Gom-27, on the other hand, generated 10.31 cm long spikes, 42.70 grains spike^{-1}, and 3.13 straw t ha^{-1}. (Table 4).

Interaction Effect

Variety and seed priming

With the exception of spikelets spike^{-1}, grains spikelet^{-1}, and harvest index, interaction between variety and seed priming had a substantial impact on all yield parameters and yield of wheat. Apart from the interaction between BARI Gom-27 and control, which exhibited reduced plant height (89.48 cm) of wheat, other interactions of variety and seed priming resulted in statistically identical plant height. BARI Gom-33 with KCL priming had the tallest plant (95.65 cm). When the seeds of BARI Gom-33 were primed with KCL, the maximum number of spikes m^{-2} (146.65) was generated which was statistically equivalent to other interactions except BARI Gom-27 with control which resulted in lower spikes m^{-2} (140.48). The BARI Gom-33 with control treatment had the longest spike (14.09 cm), which was statistically equal to the BARI Gom-33 with $CaCl_2$ priming (13.83 cm) and BARI Gom-33 with KCl priming (13.75 cm), but the BARI Gom-27 with $CaCl_2$ priming had the smallest spike (10.27 cm). Similar to this, BARI Gom-33 with KCL priming generated the most grains spike^{-1} (46.44), whereas BARI Gom-27 with control treatment produced the least (40.77). BARI Gom-33 with KCL priming also generated the maximum 1000-grain weight (40.66 g), whereas BARI Gom-27 with control treatment produced the minimum (36.70 g). Grain yield was found highest (2.72 t ha^{-1}) in BARI Gom-33 with KCL and all other interactions produced significantly similar grain yield of wheat except BARI Gom-27 with control treatment (2.14 t ha^{-1}) and BARI Gom-33 with control treatment (2.28 t ha^{-1}) (Figure 2). In the case of interaction between variety and seed priming except for BARI Gom-27 with control (2.93 t ha^{-1}), all other interactions produced a significantly similar straw yield and the highest was noticed in BARI Gom-33 with KCL priming (3.34 t ha^{-1}) (Table 5).

Variety and sowing date

Two varieties performed well irrespective of the sowing date in the situation of variety and sowing date interaction. Irrespective of varieties, the performance of the 30 December sowing was the worst. Tallest plant (96.38 cm), maximum number of spikes m^{-2} (147.38), spikelets spike^{-1} (16.47), grains spike^{-1} (49.00), 1000-grain weight (44.42 g), grain yield (2.46 t ha^{-1}), straw yield (3.60 t ha^{-1}), and harvest index (46.32 %) were documented in BARI Gom-33 when sown on 1 December (Figure 3, Table 6). All of these parameters were gradually decreased with the delay of sowing for both varieties. Though the spike length of BARI Gom-27 followed this trend spike length of BARI Gom-33 did not, where the highest spike length (14.04 cm) was obtained with BARI Gom-33 when sown on 15 December. Most of the parameters were found lowest in BARI Gom-27 sown on 30 December, but the lowest spike length was found in BARI Gom-33 sown on 30 December (Table 6).

Seed priming and sowing date

Length of spike and grains spikelets^{-1} were not significantly varied when seed priming and sowing date interacted with each other. The tallest plant (97.26 cm) and highest number of spikes m^{-2} (148.26) were noticed in $CaCl_2$ priming and 15 December sowing. A clear advantage of priming in increasing plant height and spikes m^{-2} was evident up to 15 December sowing, but not thereafter. The highest number of spikelets spike^{-1} (16.40), grains spike^{-1} (49.33), highest 1000-grain weight (44.95 g), and grain yield (3.16 t ha^{-1}) was observed in KCl priming and 1 December sowing (Figure 4, Table 7). Table 7 indicates that up to the 15 December sowing, the benefit of priming in improving these

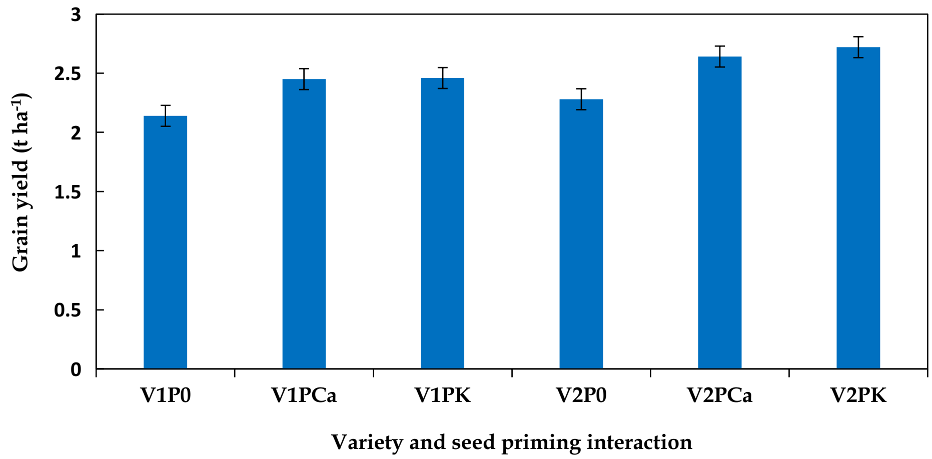

Figure 2.
Grain Yield of Wheat as Influenced by the Interaction Between Variety and Seed Priming. Bar Represents Standard Error of Means. Here, V_1 = BARI Gom-27, V_2 = BARI Gom-33; P_0 = No priming, P_{Ca} = $CaCl_2$ priming, P_k = KCl priming.

Table 5.
Interaction Effect of Variety and Seed Priming on Plant Characters, Yield Parameters, and Yield of Wheat

Variety × Seed Priming		Plant Height (cm)	Spikes m^{-2} (no.)	Spike Length (cm)	Spikelets $Spike^{-1}$ (no.)	Grains $Spike^{-1}$ (no.)	Grains $Spikelet^{-1}$ (no.)	1000-Grain Weight (g)	Straw Yield (t ha^{-1})	Harvest Index (%)
	No priming	89.48b	140.48b	10.34b	13.51	40.77b	3.05	36.70d	2.93b	41.82
BARI Gom-27	$CaCl_2$ priming	93.23ab	144.23ab	10.27b	14.61	44.00ab	3.02	38.18b–d	3.25ab	42.49
	KCl priming	93.96ab	144.96ab	10.36b	14.38	43.33ab	3.03	38.48bc	3.21ab	43.05
	No priming	90.57ab	141.57ab	14.09a	14.23	42.22ab	2.99	37.52cd	3.12ab	41.58
BARI Gom-33	$CaCl_2$ priming	95.12a	146.12a	13.83a	15.08	45.33ab	3.01	39.73ab	3.31a	43.86
	KCl priming	95.65a	146.65a	13.75a	15.27	46.44a	3.09	40.66a	3.34a	44.47
$S\bar{x}$		27.41	27.41	0.14	2.66	22.11	0.27	2.66	0.10	22.35
Level of significance		**	**	**	NS	**	NS	**	*	NS
CV (%)		4.2	2.7	5.0	9.9	6.5	9.5	3.0	9.9	4.3

Note: NS = Not significant.
Means with the same letters or without letters within the same column do not differ significantly.
**Significant at 1% level of probability.
*Significant at 5% level of probability.

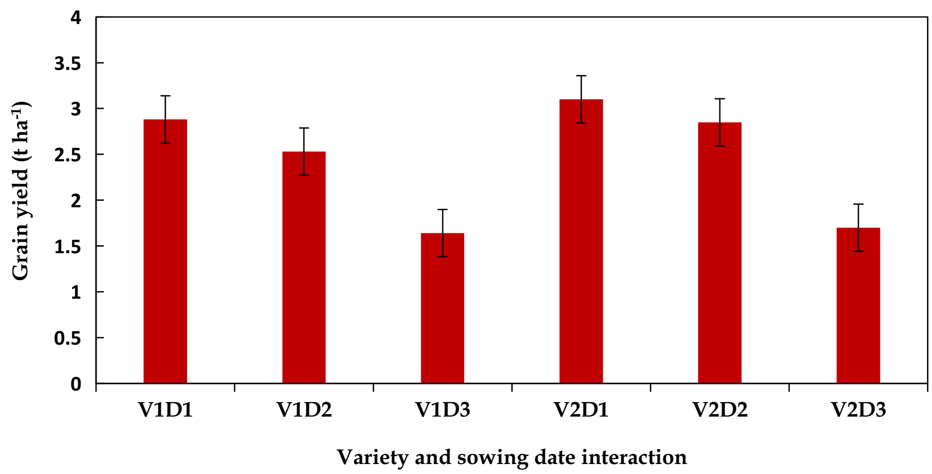

Figure 3.
Grain Yield of Wheat as Influenced by the Interaction Between Variety and Sowing Date. Bar Represents Standard Error of Means. Here, V_1 = BARI Gom-27, V_2 = BARI Gom-33, D_1 =01 December, D_2 =15 December, D_3 =30 December 2019.

Table 6.
Interaction Effect of Variety and Sowing Date on Plant Characters, Yield Parameters, and Yield of Wheat

Variety × Sowing Date		Plant Height (cm)	Spikes m^{-2} (no.)	Spike Length (cm)	Spikelets $Spike^{-1}$ (no.)	Grains $Spike^{-1}$ (no.)	Grains $Spikelet^{-1}$ (no.)	1000-Grain Weight (g)	Straw Yield (t ha^{-1})	Harvest Index (%)
	01 December	94.38ab	145.38ab	10.38b	15.22ab	46.33ab	3.05	42.63b	3.48ab	45.27a
BARI Gom-27	15 December	93.98ab	144.98ab	10.37b	14.42bc	43.66b	3.06	39.94c	3.21b	44.15a
	30 December	88.31c	139.31c	10.22b	12.86cd	38.11c	2.98	30.80d	2.70c	37.94b
	01 December	96.38a	147.38a	13.78a	16.47a	49.00a	2.99	44.42a	3.60a	46.32a
BARI Gom-33	15 December	95.66a	146.66a	14.04a	15.43ab	46.11ab	3.01	42.21b	3.44ab	45.31a
	30 December	89.30bc	140.30bc	13.84a	12.68d	38.88c	3.09	31.28d	2.73c	38.29b
$S\bar{x}$		27.41	27.41	0.14	2.66	22.11	0.27	2.66	0.10	22.35
Level of significance		**	**	**	**	**	NS	**	**	**
CV (%)		5.6	3.6	3.1	11.2	10.8	17.2	4.2	10.2	11.0

Note: NS = Not significant.
Means with the same letters or without letters within the same column do not differ significantly.
**Significant at 1% level of probability.

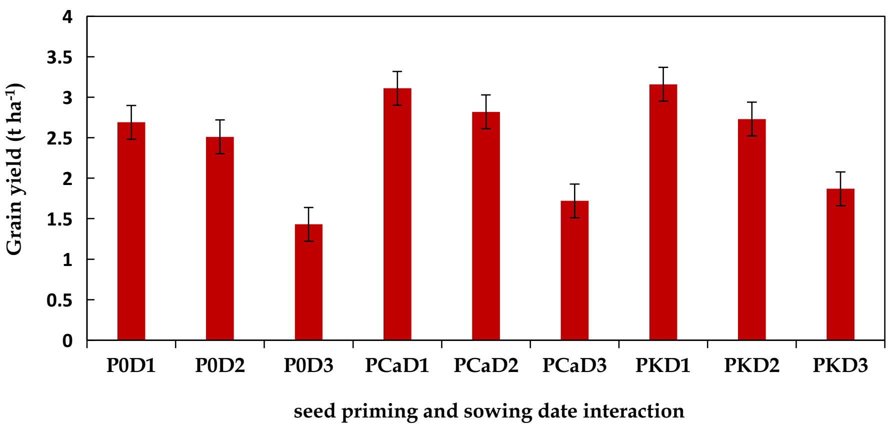

Figure 4.
Grain Yield of Wheat as Influenced by the Interaction Between Seed Priming and Sowing Date. Bar Represents Standard Error of Means. Here, P_{Ca} = $CaCl_2$ priming, P_{k} = KCl priming; D_1 = 01 December, D_2 = 15 December, D_3 = 30 December 2019, P_0 = No priming.

Table 7.
Interaction Effect of Seed Priming and Sowing Date on Plant Characters, Yield Parameters, and Yield of Wheat

Seed Priming × Sowing Date		Plant Height (cm)	Spikes m^{-2} (no.)	Spike Length (cm)	Spikelets $Spike^{-1}$ (no.)	Grains $Spike^{-1}$ (no.)	Grains $Spikelet^{-1}$ (no.)	1000-Grain Weight (g)	Straw Yield (t ha^{-1})	Harvest Index (%)
	01 December	93.38a–c	144.38a–c	12.14	14.90ab	45.00bc	3.03	41.51b	3.30ab	45.15ab
No priming	15 December	90.90b–d	141.90b–d	12.20	14.55a–c	44.00cd	3.07	40.30b	3.28ab	43.38b
	30 December	85.81d	136.81d	12.30	12.16d	35.50f	2.96	29.51d	2.50c	36.58d
	01 December	95.38a–c	146.38a–c	11.99	16.25a	48.66ab	3.01	44.11a	3.68a	45.76ab
$CaCl_2$ priming	15 December	97.26a	148.26a	12.12	15.51a	46.00a–c	2.96	41.43b	3.30ab	46.12a
	30 December	89.88cd	140.88cd	12.04	12.78cd	39.33e	3.07	31.33c	2.86bc	37.64d
	01 December	97.40a	148.40a	12.11	16.40a	49.33a	3.01	44.95a	3.65a	46.48a
KCl priming	15 December	96.31ab	147.31ab	12.29	14.71a–c	44.66bc	3.08	41.50b	3.40a	44.68ab
	30 December	90.71b–d	141.71b–d	11.76	13.38b–c	40.66de	3.09	32.28c	2.78c	40.12c
$S\bar{x}$		15.58	0.36	0.36	2.07	7.99	0.08	1.30	0.09	3.38
Level of significance		**	**	NS	**	**	NS	**	**	**
CV (%)		5.6	3.6	3.1	11.2	10.8	17.2	4.2	10.2	11.0

Note: NS = Not significant.
Means with the same letters or without letters within the same column do not differ significantly.
**Significant at 1% level of probability.

parameters was obvious. Interaction between $CaCl_2$ priming and 1 December sowing produced the highest straw yield (3.68 t ha^{-1}) and the maximum harvest index (46.12%) was recorded in $CaCl_2$ priming and 15 December sowing. All the parameters were found lowest in no priming and very late (30 December) sowing (Table 7).

Variety, seed priming, and sowing date

When variety, seed priming, and sowing date all interacted with each other they substantially impacted yield parameters and yield of wheat except grains $spikelet^{-1}$. Tallest plant (98.53 cm), number of spikes m^{-2} (149.53), spikelets $spike^{-1}$ (17.13), grains $spike^{-1}$ (51.33), 1000-grain weight (46.06 g), grain yield (3.28 t ha^{-1}), and harvest index (47.20 %) were recorded in BARI Gom-33, KCl priming and 1 December sowing (Figure 5, Table 8). The longest spike (14.36 cm) was registered with BARI Gom-33, no priming, and 30 December sowing, whereas the highest straw yield was documented in BARI Gom-33, $CaCl_2$ priming, and 1 December sowing. Most of the parameters were found lowest in BARI Gom-27, no priming, and 30 December sowing whereas the lowest spikelets $spike^{-1}$ and weight of 1000 grains were documented in BARI Gom-33, no priming, and 30 December sowing (Table 8).

Discussion

Throughout the life cycle, plants often experience a period of abiotic stress in their natural settings, which can affect their normal development and growth. Previous studies (Arun et al., 2022; Patanè et al., 2009; Wahid et al., 2008) have shown that priming seed is a previous exposure to a certain stress which provides plants better resistance to future stress. Therefore, it was proposed that seed treatment prior to sowing would aid in quicker and higher seed germination, improved survival, enhanced growth, and greater vigor in wheat seedlings. Compared to unprimed seeds, plants grown from primed seeds frequently develop more quickly (Anwar et al., 2021a).

The sowing dates in this study had a substantial impact on plant height. When the sowing date was delayed, plants' height dramatically fell. The shortened growth period in late sowings caused the plants' height to decline. It may be possible that early-sown crops benefited from improved climatic circumstances, particularly in terms of temperature and solar radiation, which led to the tallest plants. These results are consistent with Akram et al. (2007), who claimed that sowing dates significantly influenced plant height and also, they documented taller plants in early-sown rice than in late-sown rice. But in contrast to plants without priming, seed priming dramatically raised the height of wheat cultivars produced under the same conditions. In some crop species, seed priming significantly improved stand, establishment, and early vigor (Harris et al., 1999), which lead to accelerated growth and greater plant height. According to Farooq et al., (2011), primed seeds often produce more dry matter and grow plants with higher plant heights and root weights than untreated seeds. Additionally, Ali et al. (2013) provided evidence that several seed priming techniques increased the plant height of wheat. A further finding made by Anwar et al. (2012) was that the seed priming technique had a positive effect on the plant height of direct-seeded aerobic rice. The current study reveals the same results as earlier ones.

It was shown that high temperatures caused a significant drop in spikes m^{-2} and spikelets spike in late-sown wheat, which may have also decreased grains $spike^{-1}$, weight of 1000 grains, and grain yield. If seeds are sown too early, low temperature may impact germination, and if seeds are sown too late, high temperature may diminish crop output. Thus, it is essential to sow seeds at the proper time. If wheat is sown later, low temperatures that are common during late sowing will negatively affect the germination process of seed, emergence of seedling and seedling vigor that led to fewer spikes m^{-2} and ultimately reduces yield and harvest index. Impaired pollination and seed set (Farooq et al., 2011), a drop in the number of ear heads, and a reduction in the quantity of grains $spike^{-1}$ (Nawaz et al., 2013) may be related to the obvious deleterious consequences of high temperatures. The findings of the study reveal that seed priming increased the number of spikes m^{-2} and spikelets $spike^{-1}$. As demonstrated by several studies (Patanè et al., 2009; Wahid et al., 2008), seed priming gives plants a higher resistance to stress, As a result, it was anticipated that seed treatment before sowing may assist

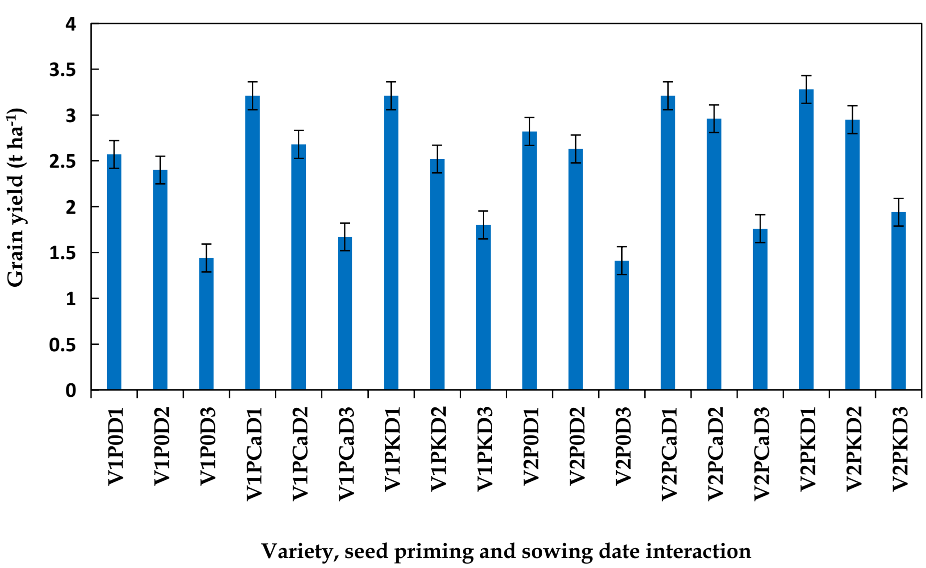

Figure 5.
Grain Yield of Wheat as Influenced by the Interaction Among Variety, Seed Priming, and Sowing Date. Bar Represents Standard Error of Means. Here, V_1 = BARI Gom-27, V_2 = BARI Gom-33, D_1 =01 December, D_2 = 15 December, D_3 = 30 December 2019, P_0 = No priming, P_{Ca} = $CaCl_2$ priming, P_k = KCl priming.

Table 8.
Interaction Effect of Variety, Seed Priming, and Sowing Date on Plant Characters, Yield Parameters, and Yield of Wheat

Variety × Seed Priming × Sowing Date			Plant Height (cm)	Spikes m^{-2} (no.)	Spike Length (cm)	Spikelets $Spike^{-1}$ (no.)	Grains $Spike^{-1}$ (no.)	Grains $Spikelet^{-1}$ (no.)	1000-Grain Weight (g)	Straw Yield (t ha^{-1})	Harvest Index (%)
		01 December	92.26a–c	143.26a–c	10.44c	15.06a–d	43.66a–e	3.08	41.00bc	3.20a–d	44.78a–c
	No priming	15 December	90.46a–c	141.46a–c	10.34c	14.03a–d	43.33a–e	3.12	39.10c	3.13a–e	43.44a–c
		30 December	85.73c	136.73c	10.24c	12.30cd	35.33e	2.95	30.00de	2.46f	37.25bc
		01 December	94.63a–c	145.63a–c	10.18c	15.80ab	48.00a–c	3.06	43.06ab	3.63a	45.28ab
BARI Gom-27	$CaCl_2$ priming	15 December	96.20ab	147.20ab	10.17c	15.13a–d	44.66a–d	2.95	40.83bc	3.23a–d	45.30ab
		30 December	88.86a–c	139.86a–c	10.51c	12.90b–d	39.33c–e	3.04	30.66de	2.90b–f	36.90bc
		01 December	96.26ab	147.26ab	10.51c	15.66ab	47.33a–c	3.02	43.83ab	3.63a	45.75ab
	KCl priming	15 December	95.30a–c	146.30a–c	10.61c	14.10a–d	43.00a–e	3.12	39.90c	3.26a–d	43.71a–c
		30 December	91.10a–c	141.33a–c	9.96c	13.40b–d	39.66c–e	2.95	31.73de	2.73d–f	39.68a–c
		01 December	94.50a–c	145.50a–c	13.84ab	15.60ab	46.33a–c	2.99	42.03bc	3.40a–c	45.52ab
	No priming	15 December	91.33a–c	142.33a–c	14.07ab	15.06a–d	44.66a–d	3.02	41.50bc	3.43a–c	43.32a–c
		30 December	85.90bc	136.90bc	14.36a	12.03d	35.66de	2.96	29.03e	2.53ef	35.91c
		01 December	96.13ab	147.20ab	13.80ab	16.70a	49.33ab	2.96	45.16a	3.73a	46.24ab
BARI Gom-33	$CaCl_2$ priming	15 December	98.33a	149.33a	14.07ab	15.90ab	47.33a–c	2.97	42.03bc	3.36a–d	46.94a
		30 December	90.90a–c	142.10a–c	13.62b	12.66b–d	39.33c–e	3.09	32.00de	2.83c–f	39.68a–c
		01 December	98.53a	149.53a	13.71ab	17.13a	51.33a	3.01	46.06a	3.66a	47.20a
	KCl priming	15 December	97.33a	149.33a	13.97ab	15.33a–c	46.33a–c	3.03	43.10ab	3.53ab	45.66ab
		30 December	97.33a–c	142.10a–c	13.55b	13.36b–d	41.66b–e	3.22	32.83d	2.83c–f	40.55a–c
$S\bar{x}$			27.41	27.41	0.14	2.66	22.11	0.27	2.66	0.10	22.35
Level of significance			**	**	**	**	**	NS	**	**	**
CV (%)			5.6	3.6	3.1	11.2	10.8	17.2	4.2	10.2	11.0

Note: NS = Not significant.
Means with the same letters or without letters within the same column do not differ significantly.
**Significant at 1% level of probability.

wheat seedlings combat various abiotic challenges under late-sown conditions (Mim et al., 2021).

In this study, seed priming increased the number of grains spike^{-1} and 1000-grain weight, which ultimately boosted yield. Under high-temperature stress, seed priming can boost the grain and straw yield of wheat. According to Farooq et al. (2008), in late-sown wheat, seed priming improved seed emergence, stand establishment, grain and straw yields, and the harvest index. Seed priming significantly enhanced grain output (17%) as compared to non-primed wheat seed Ramamurthy et al. (2015). Ali et al. (2013) also noted that various seed priming methods improved the number of viable tillers, the weight of one thousand grains, grain yield, and the biological yield of wheat. Higher grain output from primed seed may be the result of well-established, vigorous seedlings that acquire resources more quickly (Anwar et al., 2012; Harris et al., 1999; Mahajan et al. 2011). Additionally, Farooq et al. (2009a) claimed that the quick and controlled synthesis of emergent metabolites in primed seeds resulted in more robust and healthy seedlings that improved growth and increased yield. Anwar et al. (2012) stated that primed stands may produce more grain due to greater numbers of panicle-bearing tillers resulting from less seedling mortality. The stronger seedlings from primed seeds produced more grain because they were able to gather resources quicker and more successfully than seedlings from unprimed seeds (Farooq et al., 2009a).

In this study, the influence of wheat variety on spike length, grain spike^{-1}, and straw production was significant. Two varieties (BARI Gom-27 and BARI Gom-33) responded differently to different sowing dates and it was noticed that early-sown wheat performed well than late sown and this nature was observed in both varieties. Though BARI Gom-33 performed marginally better than BARI Gom-27, overall, the results show that both types performed almost equally well and the grain yield of these kinds steadily declines with the delaying of sowing. For all sowing dates, BARI Gom-27 and BARI Gom-33's grain yield increased, which is a definite benefit of seed priming. The purpose of seed priming was to speed up germination and shield the seed from environmental stress throughout the crucial stage of seedling growth in order to ensure consistent establishment and higher yields (Arun et al., 2021).

The priming agents employed in this experiment, KCl and $CaCl_2$, performed nearly similarly. However, there were other instances when KCl priming outperformed $CaCl_2$ priming only marginally. Farooq et al. (2006b) found that increasing rice yield under dry direct sowing conditions looked to be possible with KCl and $CaCl_2$ priming. According to Toklu et al. (2015), in contrast to the control, PEG, KCl, and hydro-priming treatments increased wheat grain output. Suryakant et al. (2000) reported that the priming treatment with IAA, KCl, water, and $ZnSO_4$ followed by sowing of sprouted produced the highest grain, straw, and biological yields of wheat, whereas the dry seed sowing method produced the lowest yields. Anwar et al. (2012) also determined that the best way to promote seed germination and seedling vigor was to prime seeds with KCl or $CaCl_2$. According to Anwar et al. (2021a), winter rice can be benefitted from priming with KCl or $CaCl_2$ (20,000 ppm) to increase seed germination, seedling growth, and seedling survival when exposed to cold stress.

Conclusions and Recommendation

Finally, current research supports that both of the varieties performed fairly similar and grain yield decreases gradually with the delay of sowing due to temperature stress. At all planting dates, boosting grain yield was demonstrated to be a definite benefit of seed priming. Therefore, it is recommended to sow wheat by 15 November following seed priming and in case of delay sowing seed priming is a must to mitigate the temperature stress to some extent. With the intention of opening up new possibilities for improving seed priming to reduce heat stress in late-sown wheat, particularly at the reproductive stage, KCl and $CaCl_2$ emerged as the best priming agents. Consequently, it can be asserted that seed priming is a viable technique for at least somewhat lowering the effect of temperature stress in the event of a delay. But more investigations should be done throughout the world to strengthen this recommendation.

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References

Ahmed, S., Alam, M. J., Awan, T. H., & Islam, A. K. M. M. (2019). Herbicidal weed control in drill sown spring wheat under Bangladesh condition. *Fundamental and Applied Agriculture*, *4*(2), 839–848. [CrossRef]

Akram, H. M., Ali, A., Nadeem, M. A., & Iqbal, M. S. (2007). Yield and yield components of rice varieties as affected by transplanting dates. *Pakistan Journal of Agricultural Science*, *45*(2), 105–111.

Ali, H., Iqbal, N., Shahzad, A. N., Sarwar, N., Ahmad, S., & Mehmood, A. (2013). Seed priming improves irrigation water use efficiency, yield and yield components of late-sown wheat under limited water conditions. *Turkish Journal of Agriculture*, *37*, 534–544. [CrossRef]

Anwar, M. P., Ahmed, M. K., Islam, A. K. M. M., Hossain, M. D., & Uddin, F. M. J. (2020). Improvement of weed competitiveness and yield performance of dry direct seeded rice through seed priming. *Turkish Journal of Weed Science*, *23*(1), 15–23.

Anwar, M. P., Jahan, R., Rahman, M. R., Islam, A. K. M. M., & Uddin, F. M. J. (2021a). Seed priming for increased seed germination and enhanced seedling vigor of winter rice. *IOP Conference Series: Earth and Environmental Science*, *756*(1), 012047. [CrossRef]

Anwar, M. P., Khalid, M.A.I., Islam, A.K.M.M., Yeasmin, S., Ahmed, S., Hadifa, A., Ismail, I. A., Hossain, A., & Sabagh, A. E. (2021b). Potentiality of different seed priming agents to mitigate cold stress of winter rice seedlings. *PHYTON-International Journal of Experimental Botany*, *90*(5), 1491–1506. [CrossRef]

Anwar, M. P., Juraimi, A. S., Puteh, A., Selamat, A., Rahman, M. M., & Samedani, B. (2012). Seed priming influences weed competitiveness and productivity of aerobic rice. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science*, *62*(6), 499–509. [CrossRef]

Arun, M. N., Hebbar, S.S., Bhanuprakash, B., Senthivel, T. A. K., Nair, A. K., Padmavathi, G., Pandey, P. & Singh, A. (2021). Seed Priming: The Way Forward to Mitigate Abiotic Stress in Crops. In M. Hasanuzzaman, & K. Nahar (Eds.), Plant Stress Physiology - Perspectives in Agriculture. *Intech Open*. [CrossRef]

Ashraf, M., & Foolad, M. R. (2005). Pre-sowing seed treatment-a shotgun approach to improve germination, plant growth, and crop yield under saline and non-saline conditions. *Advances in Agronomy*, *88*, 223–271. [CrossRef]

Basra, S. M. A., Farooq, M., & Tabassum, R. (2005). Physiological and biochemical aspects of seed vigor enhancement treatments in fine rice (*Oryza sativa* L.). *Seed Science and Technology*, *33*(3), 623–628. [CrossRef]

BBS (Bangladesh Bureau of Statistics) (2021). *Statistical yearbook of Bangladesh* (pp. 39–42). Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

Braun, H. J., Atlin, G., & Payene, T. (2010). Multi-location testing as a tool to identify plant response to global climate change. *Climate Change and Crop Production*, *1*, 115–138. [CrossRef]

Du, L. V., & Tuong, T. P. (2002). Enhancing the performance of dry-seeded rice: Effects of seed priming, seedling rate, and time of seeding. *Direct Seeding*, 241–256.

Farooq, M., Basra, S. M. A., Ahmad, N., & Murtaza, G. (2009a). Enhancing the performance of transplanted course rice by seed priming. *Paddy and Water Environment*, *7*(1), 55–63. [CrossRef]

Farooq, M., Basra, S. M. A., & Hafeez, K. (2006b). Seed invigoration by osmohardening in coarse and fine rice. *Seed Science and Technology*, *34*(1), 181–187. [CrossRef]

Farooq, M., Basra, S. M. A., Khalid, M., Tabassum, R., & Mahmood, T. (2006a). Nutrient homeostasis, reserves metabolism and seedling vigor as affected by seed priming in coarse rice. *Canadian Journal of Botany*, *84*(8), 1196–1202. [CrossRef]

Farooq, M., Basra, S. M. A., & Khan, M. B. (2007). Seed priming improves growth of nursery seedlings and yield of transplanted rice. *Archives of Agronomy and Soil Science*, *53*(3), 315–326. [CrossRef]

Farooq, M., Basra, S. M. A., Rehman, H., & Saleem, B. A. (2008). Seed priming enhances the performance of late sown wheat (*Triticum aestivum* L.) by improving the chilling tolerance. *Journal of Agronomy and Crop Science*, *194*(1), 55–60. [CrossRef]

Farooq, M., Basra, S. M. A., & Ur-Rehman, H. U. (2009b). Seed priming enhances emergence, yield and quality of direct-seeded rice. *International Rice Research Notes*, *31*(2), 42–44. [CrossRef]

Farooq, M., Bramley, H., Palta, J. A., & Siddique, K. H. M. (2011). Heat stress in wheat during reproductive and grain filling phases. *Critical Reviews in Plant Sciences*, *30*(6), 491–507. [CrossRef]

Harris, D., Joshi, A., Khan, P. A., Gothkar, P., & Sodhi, P. S. (1999). On-farm seed priming in semiarid agriculture development and evaluation in maize, rice and chickpea in India using participatory methods. *Experimental Agriculture*, *35*(1), 15–29. [CrossRef]

Islam, N., Ahmed, S. M., Razzaque, M. A., Sufian, A., & Hossain, M. A. (1993). A study on the effect of seedling dates on the yield of wheat varieties. *Bangladesh Journal of Agricultural Research*, *18*(1), 102–107.

Jahan, M. A. H. S., Hossain, A., & Hoque, M. A. (2021). Evaluation of economically viable and environmentally friendly weed control methods for wheat (*Triticum aestivum* L.). *Gesunde Pflanz.*, *73*, 209–218. [CrossRef]

Kamrozzaman, M. M., Khan, M. A. H., Ahmed, S., & Sultana, N. (2016). Growth and yield of wheat at different dates of sowing under Charland ecosystem of Bangladesh. *Journal of the Bangladesh Agricultural University*, *14*(2), 147–154. [CrossRef]

Karim, Z., Hussain, S. G., & Ahmed, M. (1999). Assessing impacts of climate variations on food grain production in Bangladesh. *Water, Air, and Soil Pollution*, *92*, 53–62. [CrossRef]

Mahajan, G., Sarlach, R. S., Japinder, S., & Gill, M. S. (2011). Seed priming effects on germination, growth and yield of dry direct-seeded rice. *Journal of Crop Improvement*, *25*(4), 409–417. [CrossRef]

Matsushima, K. I., & Sakagami, J. I. (2013). Effects of seed hydropriming on germination and seedling vigor during emergence of rice under different soil moisture conditions. *American Journal of Plant Sciences*, *04*(8), 1584–1593. [CrossRef]

Mim, T. F., Anwar, M. P., Ahmed, M., Sriti, N., Moni, E. H., Hasan, A. K., & Yeasmin, S. (2021). Competence of different priming agents for increasing seed germination, seedling growth and vigor of wheat. *Fundamental and Applied Agriculture*, *6*(4), 444–459. [CrossRef]

Modarresi, M., Mohammadi, V., Zali, A., & Mardi, M. (2010). Response of wheat yield and yield related traits to high temperature. *Cereal Research Communications*, *38*(1), 23–31. [CrossRef]

Nawaz, A., Farooq, M., Sardar, A., Alam, S., & Wahid, A. (2013). Differential response of wheat cultivars to terminal heat stress. *International Journal of Agricultural Biology*, *15*, 1354–1358.

Ortiz, R., Sayre, K. D., Govaerts, B., Gupta, R., Subbarao, G. V., Ban, T., Hodson, D., Dixon, J. M., Iván Ortiz-Monasterio, J., & Reynolds, M. (2008). Climate change: Can wheat beat the heat? *Agriculture, Ecosystems and Environment*, *126*(1–2), 46–58. [CrossRef]

Patanè, C., Cavallaro, V., & Cosentino., S. L. (2009). Germination and radicle growth in unprimed and primed seed of sweet sorghum as affected by reduced water potential in NaCl at different temperatures. *Industrial Crops and Products*, *30*(1), 1–8. [CrossRef]

Qasim, M., Qamer, M., Faridullah, & Alam, M. (2008). Sowing dates effect on yield and yield components of different wheat varieties. *Journal of Agricultural Research*, *46*(2), 135–140.

Ramamurthy, V., Venugopalan, M. V., Parhad, V. N., & Prasad, J. (2015). Effect of seed priming on emergence and yield of late sown wheat (*Triticum aestivum* L.) on Typic Haplusterts of Central India. *Indian Journal of Agricultural Research*, *49*(3), 245. [CrossRef]

Reynolds, M. P., Nagarajan, S., Razzaque, M. A., & Ageeb, O. A. A. (2001). Breeding for adaptation to environmental factors: Heat tolerance. In M. P. Reynolds, J. I. Ortiz-Monasterio & A. McNab (Eds.). *Application of physiology in wheat breeding* (pp. 124–135). Cimmyt.

Shabi, T. H., Islam, A. K. M. M., Hasan, A. K., Juraimi, A. S., & Anwar, M. P. (2018). Differential weed suppression ability in selected wheat varieties of Bangladesh. *Acta Scientifica Malaysia*, *2*(2), 01–07. [CrossRef]

Suryakant, S. S., Pahuja, & Verma, S. S. (2000). Productivity of late sown wheat (*Triticum aestivum*) as influenced by different seed priming treatments. *Haryana Journal of Agronomy*, *16*(1,2), 35–39.

Tahir, M., Ali, A., Nadeem, M. A., Hussain, A., & Khalid, F. (2009). Effect of different sowing dates on growth and yield of wheat varieties in district Jhang, Pakistan. *Pakistan Journal of Life and Social Science*, *7*(7), 66–69.

Toklu, F., Baloch, F. S., Karaköy, T., & Özkan, H. (2015). Effects of different priming applications on seed germination and some agro morphological characteristics of bread wheat (*Triticum aestivum* L.). *Turkish Journal of Agriculture*, *39*, 1005–1013. [CrossRef]

Trnka, M., Dubrovský, M., Semerádová, D., & Žalud, Z. (2004). Projections of uncertainties in climate change scenarios into expected winter wheat yields. *Theoretical and Applied Climatology*, *77*(3–4), 229–249. [CrossRef]

Wahid, A., Noreen, A., Basra, S. M. A., Gelani, S., & Farooq, M. (2008). Priming induced metabolic changes in sunflower achenes improve germination and seedling growth. *Botanical Studies*, *49*, 343–350.

Wiegand, C. L., & Cuellar, J. A. (1981) Duration of grain filling and kernel weight of wheat as affected by temparature. *Crop Science*, *21*(1), 95–101. [CrossRef]

Yadav, P. V., Kumari, M., & Ahmed, Z. (2011). Seed priming mediated germination improvement and tolerance to subsequent exposure to cold and salt stress in capsicum. *Research Journal of Seed Science*, *4*(3), 125–136. [CrossRef]