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ORIGINAL RESEARCH ARTICLE

CrossMark

Seed priming influences on yield and protein content of wheat sown at different time

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ABSTRACT

The aim of this field experiment conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, was to investigate the impact of different seed priming techniques and sowing dates on the yield and quality of wheat. The study aimed to identify the most effective seed priming technique and optimal sowing date to enhance wheat productivity and minimize yield reduction. The experiment employed a split plot design with two factors: seed priming techniques (no priming, hydropriming with distilled water, osmopriming with PEG, and halopriming with $CaCl_2$) and sowing dates (November 20, December 05, and December 20). The trial was conducted from November 2019 to April 2020 at the research field. The study consisted of three replications for each treatment combination. Osmopriming exhibited the most favorable results among all priming techniques, showing significantly higher values for effective tillers hill^{-1} (3.91), number of grains spike^{-1} (43.82), number of spikelets spike^{-1} (16.16), grain yield (3.87 tons hectare^{-1}), biological yield (6.02 t ha^{-1}), and harvest index (39.03%). No priming condition resulted in the highest protein content (12.11%), while osmopriming had the lowest protein content (11.77%). The sowing conducted on November 20 yielded the highest number of effective tillers hill^{-1} (3.57), number of grains spike^{-1} (42.49), number of spikelets spike^{-1} (15.75), grain yield (3.71 t ha^{-1}), biological yield (9.70 t ha^{-1}), and lowest protein content (11.74%). Sowing on December 20 resulted in the highest protein content (12.20%). Based on the study's findings, it can be concluded that the osmopriming technique, combined with sowing on November 20, offers the most promising approach to mitigate the yield reduction of wheat. This combination demonstrated the highest grain yield (4.23 t ha^{-1}) compared to other treatments. Therefore, farmers and agricultural practitioners are recommended to adopt the osmopriming technique with a sowing date of November 20 for optimizing wheat production and enhancing overall crop quality.

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INTRODUCTION

More than any other cereal, wheat (*Triticum aestivum* L.), an important crop of the Poaceae family, provides the majority of the world's staple foods (Wato *et al.*, 2020). The crop is grown under different climatic conditions in humid to arid, subtropical to temperate zones, and at elevations ranging from a few meters to more than 3600 meters (Hannan *et al.*, 2021;

Hoque *et al.*, 2021). The position of Bangladesh in a subtropical area of South Asia makes it the best place for the crop. It is Bangladesh's second-most significant staple crop after rice, which accounts for more than 20% of all dietary calories (Rahman and Hasan, 2009; Afsana *et al.*, 2020). According to projections, global cereal demand would rise by 56% in 2050 compared to the base year of 2000, with wheat accounting for 26% of this rise (Hubert *et al.*, 2010). Wheat output should be expanded to reduce the burden on rice and provide food security. The statistics of (BBS, 2020) state that wheat was cultivated on 816,000 acres in Bangladesh, producing 10,16,000 metric tons annually, or 1220 kg per acre in terms of yield. The production of wheat is constrained by a variety of biotic (diseases, insect pests, and weeds) and abiotic (drought, high temperatures, salinity, flooding, freezing, strong radiation, nutrient shortage, or toxicity) variables (Hannan *et al.*, 2021). Among the abiotic factors, high temperature is the most important environmental factors for limiting the production of wheat in the world (Kumaraswamy and Shetty, 2016). Early wheat planting improves the number of tillers meter^{-1} square, the number of grains spike^{-1}, and the grain weight of wheat, all of which boost yield (Qasim, 2008). Wheat is frequently sown in November to encourage good crop development and avoid excessive temperatures. When wheat is planted in the field after that, it will be subjected to a wide variety of temperatures that will have an impact on its development, growth, and potential yield. Photosynthesis in wheat is maximum between 22°C to 25°C and decreases sharply above 32°C during anthesis stage (Djanaguiraman *et al.*, 2020).

According to Jafar *et al.* (2012), seed priming is a controlled hydration and re-drying process that allows pre-germination metabolic activity to start right away. It is a low-risk and efficient approach for increasing growth uniformity and germination rate, which reduces emergence time (Basra *et al.*, 2002). In order to get a good crop stand, especially early emergence, better growth and development on residual soil moisture, and mitigating the negative effects of climatic conditions, seed priming or treating seeds with different salt solutions and growth regulators prior to sowing and sowing of pre-germinated seed is advantageous. It regulates germination metabolism and physio-biochemical characteristics of wheat, resulting in great temperature tolerance (Farooq *et al.*, 2008). Given these facts, the current study was carried out to comprehend the physiological basis of seed priming, the effect of sowing date on yield, the features that contribute to yield, and the protein content of wheat.

MATERIALS AND METHODS

Collection of the germplasms and experimental location

The experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh during the period of November 2019 to April 2020 to determine the individual and combined effects of sowing date and seed priming on wheat (BARI Gom33) growth and yield contributing features. The experimental site was located at 24°75' N latitude and 90° 50' E longitude, 18 m above sea level, and was part of the Old Brahmaputra Floodplain's (AEZ-9) non-calcareous dark gray floodplain soil (UNDP and FAO, 1988). The experimental field was a medium high land with silty clay loam soil texture having pH value of 6.5.

Experimental materials and design

Wheat variety BARI Gom33 was used as test crop (Table 1). Wheat seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The experiment was set up using a split plot design with three replications, where the main plot was allocated sowing dates (factor A) from (Table 1) and the sub plot was given primed seed (factor B) from the same table. There were 36 plots in total. The plot measured 5m^2. Continuous rows were used for planting. The space between rows was 20 cm. The experiment's replication to replication and plot to plot distances were 1 m and 0.75 m, respectively. After land preparation seeds were sown in three different sowing dates. Proper intercultural operations like weeding, thinning, gap filling, irrigation and pest managements were provided as per required.

Seed priming

According to the treatment, various priming solutions were created. After that, seeds were left to soak for 12 hours at 252°C room temperature. The ratio of seed weight to solution volume was kept at 1:5 (g L^{-1}). Later, seeds were removed from the primers, lightly washed with blotting paper, and dried by forced air. Dried seeds were put in brown envelopes with tags in sealed polythene bags and stored in a refrigerator at 5±1°C until being placed for germination. While control treatment received no prior seed priming (Mim *et al.*, 2021).

Table 1. Features of the experimental material and experimental treatments.

Experimental treatments	
Factor A: Date of sowing (3)	**Factor B: Priming Techniques (4)**
20 November (S_1)	P_0 = No Priming
5 December (S_2)	P_1 = Hydropriming with distilled water
20 December (S_3)	P_2 = Halopriming with 1% $CaCl_2$ solution
	P_3 = Osmopriming with 13.5% PEG solution

Data collection and analysis

Due to the three separate seeding dates, harvesting took place at three different times when the crop was mature. The plants in a 1.0 m^2 area were harvested for yield in all cases. The plants in a 1.0 m^2 area were harvested for yield in all cases. Then sun dry weights of both the grain and straw were recorded for every plot and the weight in g $plot^{-1}$ was converted to kg ha^{-1}. Data were recorded during the crop cycle of three sowing dates; the dates of emergence, booting, heading and anthesis were recorded using the scale proposed by Zadoks *et al*. (1974). Data on various morphological traits viz. plant height (cm), number of total tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$ were determined at 20, 40, 60, 80 DAS, respectively. Yield parameter such as spike length (cm), number of spikelets $spike^{-1}$, number of sterile spikelets $spike^{-1}$, number of grains $spike^{-1}$, 1000-grain weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}), harvest index (t ha^{-1}), protein content (%) were determined following standard lab protocol. At the Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh, protein content was calculated using the Kjeldahl method in accordance with the recommended procedure by Bremner (1982). The recorded data were statistically analyzed using the "Analysis of Variance" technique and the differences among treatment means were adjudged by Duncan's New Multiple Range Test and Least Significant Difference Test whenever necessary (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of sowing date on yield contributing traits and protein content of wheat

In Table 2, the results of the analysis of variance showed that the sowing date had a statistically significant impact on all of the yield-contributing variables that were examined, in addition to wheat yield and protein content. First sowing date (20 November) produced the longest plant (98.21 cm), the highest number of tillers $plant^{-1}$ (3.57), effective tillers $plant^{-1}$ (3.37), the longest spike (13.48 cm), the highest number of spikelets $spike^{-1}$ (15.75), grains $spike^{-1}$ (42.49), 1000-grain weight (46.68 g), grain yield (3.8 t ha^{-1}), harvest index (38.13%), biological yield (9.70 t ha^{-1}) and the lowest number of non-effective tillers $plant^{-1}$ (0.15), sterile spikelets $spike^{-1}$ (1.58) compared to second (05 December) and last (20 December) sowing date (Table 3).

Due to high temperatures negatively affecting wheat's photosynthesis, the plant height may drop at late sowing. Passioura (1994) and this plant height result were comparable. $Hill^{-1}$ findings regarding the total number of tillers were consistent with those of Alam *et al*. (2013). Because plants were subjected to terminal heat stress at the late sowing stage (20 December), the number of effective tillers $hill^{-1}$ was higher in wheat planted on November 20. The crop sown on November 20 might have enjoyed longer duration for growth as compared to others and produced maximum number of grains $spike^{-1}$. The results are

Table 2. Analysis of variance (mean square) of the data for yield contributing characters and yield of wheat.

Source of variation	df	Plant height (cm)	No. of total tillers $hill^{-1}$	No. of effective tillers $hill^{-1}$	No. of non-effective tillers $hill^{-1}$	Spike length (cm)	No. of spikelets $spike^{-1}$	No. of sterile spikelets $spike^{-1}$	No. of grains $spike^{-1}$	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	1.974	0.19111	0.1433	0.07778	0.0074	0.01785	0.001036	0.0949	0.0925	0.0927	0.0049	0.0817	3.8383
Date of sowing (A)	2	37.3**	0.56444**	0.91**	0.08444*	6.5268**	0.0435*	0.026103**	1.1898*	7.9008**	1.4323**	1.7489**	6.1694**	20.4971*
Error	4	1.576	0.00444	0.0133	0.00778	0.0232	0.01668	0.000319	0.1148	0.1183	0.0378	0.0857	0.0137	1.6372
Seed priming (B)	3	51.292**	2.41481**	3.6163**	0.12593**	8.0465**	1.66872**	0.057367**	21.661**	2.7558**	1.5722**	1.0227**	4.8602**	24.9915**
A × B	6	1.438*	0.00148*	0.0285*	0.01037*	0.0997*	0.04005*	0.002892**	0.5194*	0.2475*	0.2997**	0.0148*	0.0263*	1.1381**
Error	18	0.567	0.00148	0.0167	0.00333	0.0452	0.03001	0.000225	0.288	0.0631	0.0504	0.0282	0.0081	0.2228

Table 3. Effect of date of sowing on the yield contributing characters and protein content of wheat.

Date of sowing	Plant height (cm)	No. of Total tillers hill^{-1}	No. of Effective tillers hill^{-1}	No. of Non -effective tillers hill^{-1}	Spike length (cm)	No. of Spikelets spike^{-1}	No. of Sterile spikelets spike^{-1}	No. of Grains spike^{-1}	1000 grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)	Protein content (%)
S_1	98.21a	3.57a	3.37a	0.15b	13.48a	15.75a	1.58c	42.49a	46.68a	9.70a	38.13a	11.74c
S_2	95.88b	3.37b	3.12b	0.25a	12.49b	15.66b	1.62b	42.13ab	46.43a	9.40b	37.08a	11.92b
S_3	94.75b	3.13c	2.82c	0.32a	12.04c	15.63b	1.68a	41.86b	45.17b	8.34c	35.53b	12.20a
$S\bar{x}$	1.02	0.13	0.16	0.05	0.43	0.03	0.03	0.18	0.47	0.41	0.75	0.11
Level of significance	**	**	**	*	**	*	**	*	**	**	*	**
CV (%)	1.30	2.00	3.70	6.90	1.20	0.80	1.10	0.80	0.70	1.30	3.50	3.03

Means with the same letters within the same column do not differ significantly; ** = Significant at 1% level of probability, * = Significant at 5% level of probability; S_1 = 20 November, S_2 = 05 December, S_3 = 20 December.

inconsistent with those of Ali *et al.* (1982). The highest grain weight (46.68 g) in sowing date 20 November might be due to the production of a greater number of grains spike^{-1} with heavier weight. These results are similar with those of (Singh and Singh, 1991). The earlier sowing wheat resulted in better development of the grain due to longer growing period. The results of (Jashi and Singh, 1995) lend considerable credence to these conclusions. The effect of terminal heat stress caused by late sowing may be the cause of the maximum biological yield on sowing date 20 November. Sial *et al.* (2005) observed that delayed planting decreased the days to heading, days to maturity, grain filling time, and eventually revealed the reduction in yield and yield components. This result was identical to their findings. Rahman *et al.* (2014) also noted that the 20 November sowing date outperformed the other sowing dates and that the yield gradually decreased when wheat seeds were delayed in being seeded. Kumar and Singh (1998) also reported that November sowing date gave higher yields than December sowing. Early sowing always gives high yield than late sowing mainly due to longer duration of growth. Each day delay in sowing from 20th November onward decreases grain yield @ 39 kg ha^{-1} (Singh and Uttam, 1999). The highest harvest index (38.13 %) was observed on sowing date 20 November and the lowest (35.53 %) was observed on 20 December (Table 3). This might be for late sowing of wheat and face of terminal heat stress by plant. On the other hand, seeding on December 20 produced the highest number of ineffective tillers hill^{-1} and sterile spikelets hill^{-1} (Table 3). This may be due to inadequate tiller development caused by environmental discord at the tillering stage. This outcome matched what Alam *et al.* (2013) found. Additionally, he discovered a substantial variation in the number of ineffective tillers hill^{-1} in wheat cultivars. Sowing dates had a substantial impact on wheat grain quality. Compared to the rest of the sowing dates, late sowing (20 December) resulted in the highest protein content (Table 3). The protein content of the 20 December planted wheat was more (12.20%) and it was 3.91% and 2.34% higher than the first and second sowing, respectively. This might be due to heat stress related to rise in temperature during the growth period of the crop. Higher protein content was also reported by Eslami *et al.* (2014) under late sown condition. However, the outcome did not agree with Spink *et al.* (1993). They discovered that, among the planting dates, early sowing (November 15), followed by sowing on November 30 (12.96%) and December 15 (11.97%), yielded grains with greater protein levels (13.96%).

Effect of seed priming on yield traits and protein content of wheat

On all of the wheat attributes that were investigated, various seed priming procedures had a substantial impact (Table 2). The plant height results corroborated Nayyer *et al.* (1995) findings. The general theory that plants in their early phases of growth may adapt to their surroundings considerably more easily due to seed priming treatment may be linked to the highest number of effective tillers hill^{-1}. These results supported to those

Table 4. Effect of seed priming on the yield contributing characters and protein content of wheat.

Seed priming	Plant height (cm)	No. of Total tillers hill^{-1}	No. of Effective tillers hill^{-1}	No. of Non-effective tillers hill^{-1}	Spike length (cm)	No. of Spikelets spike^{-1}	No. of Sterile spikelets spike^{-1}	No. of Grains spike^{-1}	1000 grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)	Protein content (%)
P_0	93.90c	2.87d	2.47d	0.40a	11.59d	15.14d	1.73a	40.22d	45.52b	8.17d	35.47c	12.11a
P_1	94.86c	3.07 c	2.76c	0.24b	12.31c	15.59c	1.64b	41.83c	45.76b	9.06c	35.69c	12.05a
P_2	97.14b	3.44b	3.27b	0.18b	12.98b	15.84b	1.58c	42.77b	46.36a	9.47b	37.45b	11.87ab
P_3	99.22a	4.04a	3.91a	0.13b	13.81a	16.16a	1.55d	43.82a	46.73a	9.89a	39.03a	11.77b
$S\bar{x}$	1.19	0.26	0.32	0.06	0.47	0.22	0.04	0.76	0.28	0.37	0.83	0.10
Level of significance	**	**	**	**	**	**	**	**	**	**	**	*
CV (%)	0.80	1.10	4.20	4.16	1.70	1.10	0.90	1.30	0.50	1.00	1.30	2.87

Means with the same letters within the same column do not differ significantly; ** = Significant at 1% level of probability; P_0 = No priming; P_1 = Seed priming with water; P_2 = Seed priming with $CaCl_2$; P_3 = Seed priming with PEG.

Table 5. Interaction effect of date of sowing and seed priming on the yield contributing characters and protein content of wheat.

Date of sowing : Seed priming	Plant height (cm)	No. of Total tillers hill^{-1}	No. of Effective tillers hill^{-1}	No. of Non-effective tillers hill^{-1}	Spike length (cm)	No. of Spikelets spike^{-1}	No. of Sterile spikelets spike^{-1}	No of Grains spike^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)	Protein content (%)
S_1:P_0	94.97fg	3.07h	2.80e	0.27cd	12.48de	15.26ef	1.65cd	40.81fg	46.23cd	3.15e	5.52e	8.66g	36.31d	11.71d
S_1:P_1	96.33de	3.27f	2.87e	0.20de	13.23c	15.64d	1.61ef	42.07de	46.47b-d	3.47d	6.07bc	9.54d	36.33d	11.85c
S_1:P_2	99.57b	3.67d	3.53c	0.13e	13.83b	15.84b-d	1.55h	42.85b-d	46.87ab	4.00b	6.14ab	10.14b	39.43b	11.77c
S_1:P_3	101.97a	4.27a	4.27a	0.00f	14.39a	16.26a	1.51i	44.23a	47.17a	4.23a	6.23a	10.46a	40.44a	11.61d
S_2:P_0	93.80g-i	2.87i	2.47f	0.40b	11.23fg	15.20f	1.71b	40.47g	46.00de	3.03ef	5.39f	8.43hi	36.00de	12.05bc
S_2:P_1	94.67f-h	3.07h	2.87e	0.20de	12.23e	15.60d	1.64de	41.88de	46.27cd	3.34d	5.98c	9.32e	35.83de	12.10bc
S_2:P_2	96.67d	3.47e	3.27d	0.20de	12.77d	15.71cd	1.59fg	42.38c-e	46.57bc	3.67c	6.08bc	9.74c	37.62c	11.82c
S_2:P_3	98.40bc	4.07b	3.87b	0.20de	13.74b	16.14ab	1.55h	43.79ab	46.87ab	3.93b	6.19a	10.12b	38.86b	11.72d
S_3:P_0	92.93i	2.67j	2.13g	0.53a	11.07g	14.96f	1.83a	39.37h	44.33f	2.53g	4.89g	7.42j	34.11g	12.58a
S_3:P_1	93.57hi	2.87i	2.53f	0.33bc	11.47f	15.52de	1.67c	41.55ef	44.53f	2.91f	5.42f	8.33i	34.91fg	12.21ab
S_3:P_2	95.20ef	3.20g	3.00e	0.20de	12.33e	15.97a-c	1.61ef	43.08bc	45.63e	3.01f	5.51e	8.52gh	35.31ef	12.03bc
S_3:P_3	97.30cd	3.80c	3.60c	0.20de	13.30c	16.07ab	1.58g	43.45ab	46.17cd	3.43d	5.65d	9.09f	37.78c	11.98bc
$S\bar{x}$	0.77	0.15	0.18	0.04	0.31	0.12	0.02	0.42	0.25	0.14	0.12	0.26	0.56	0.18
Level of significance	*	*	*	*	*	*	**	*	*	**	*	*	**	*
CV (%)	0.80	1.10	4.20	4.16	1.70	1.10	0.90	1.30	0.50	2.10	0.90	1.00	1.30	2.87

Means with the same letters within the same column do not differ significantly; ** = Significant at 1% level of probability, * = Significant at 5% level of probability.

S_1 = 20 November
S_2 = 05 December
S_3 = 20 December

P_0 = No priming
P_1 = Seed priming with water
P_2 = Seed priming with $Cacl_2$
P_3 = Seed priming with PEG

reported by Singh and Singh (1991). The findings for number of grains spike^{-1} confirmed the results of Singh and Singh (191) that treated seeds gave a greater number of grains spike^{-1} than untreated seeds. Seed priming of wheat seed prior to planting might have an impact on grain filling stage thus produces higher grain weight. Sarkar (2012) also found that priming had positive effects on yield. This might be due to the effect of seed priming which minimized the stress of temperature in late sown wheat.

In contrast, no priming approach produced the maximum levels of ineffective tillers hill^{-1} (0.40), sterile spikelets spike^{-1} (1.73), and protein (12.11%) (Table 4). Non-effective tillers might be due to the lowest viability and vigor of seedling in absence of seed priming techniques. High protein content in no priming condition might be due to the highest up taking capability of N through root. But Sallam (1992) reported that water-soaked seeds significantly gave highest protein content as compared to un-soaked and $NaHCO_3$ soaked seeds.

Interaction effect of sowing date and seed priming on yield traits and protein content of wheat

The interaction of the seed priming and sowing dates had a statistically significant impact on the wheat protein content, yield, and all of the yield contributing characteristics (Table 2).

The tallest plant (101.97 cm), highest (4.27) number of tillers, highest (4.27) number of effective tillers hill^{-1}, highest spike length (14.39 cm), highest number of spikelets spike^{-1} (16.26), highest grain number (44.23), highest 1000-grain weight (47.17 g), highest (10.46 t ha^{-1}) biological yield, highest harvest index (40.44%) were found on 20 November from osmopriming technique (Table 5) in contrast with lowest values in no priming technique on 20 December (Table 5). On the other hand, on December 20 in the absence of priming, the highest number of ineffective tillers (0.53), highest number of sterile spikelets spike^{-1}, and highest protein content (12.58%) were discovered (Table 5). Early wheat planting may result in nutritious grains spike^{-1} that are hefty. These findings concur with Singh and Singh (1991) findings. Higher grain yield in osmopriming technique from 20 November sowing might be due to the inception of higher solar radiation by leaf and higher nutrient uptake by root. Keskitalo *et al.* (2005) also found the same. Additionally, late sowing of wheat is constantly prone to changeable temperate regimes that extra-accelerate crop development, resulting in crop plants using less solar radiation and producing a lower final yield (Namakka *et al*., 2008).

Conclusion

Sowing date, seed priming, and their interaction had similar effects on yield and yield-contributing traits, as well as protein content of wheat. The first sowing date (20 November) and seed priming with PEG (osmopriming) or their interaction resulted in the most favorable outcomes. These treatments produced wheat plants with longer stature, higher number of tillers plant^{-1}, longer spikes, increased spikelets spike^{-1}, grains spike^{-1}, 1000-grain weight, harvest index, and biological yield. Additionally, they exhibited the lowest number of non-effective tillers plant^{-1} and sterile spikelets spike^{-1}. In the late sowing condition (20 December), osmopriming, halopriming, and hydropriming techniques yielded grain yields of 3.43 t ha^{-1}, 3.01 t ha^{-1}, 2.91 t ha^{-1}, and 2.53 t ha^{-1}, respectively, which were significantly higher compared to the control. These treatments increased grain yield by 35.6%, 18.9%, and 15% compared to the control, respectively. Overall, the optimum sowing date of 20 November combined with seed treated with PEG (osmopriming) resulted in the highest grain yield (4.41 t ha^{-1}) compared to other sowing dates and seed treatments. However, in adverse conditions where wheat is sown late (on 5 December and 20 December), osmopriming, halopriming, and hydropriming techniques can be recommended as they significantly increased grain yield by 29.7%, 21.1%, and 10.2% on 5 December sowing, and 35.6%, 18.9%, and 15% on 20 December sowing, respectively. Based on these findings, it can be concluded that osmopriming with PEG-treated seeds, particularly in the optimal sowing date of 20 November, is recommended for achieving higher grain yield in wheat. However, in late sowing conditions, the use of osmopriming, halopriming, and hydropriming techniques can still enhance grain yield and its components, providing a strategy to mitigate the reduction in yield associated with late sowing.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

REFERENCES

Afsana, H., Mukidul, I., Muhammad, S. R., Najmol, H., & Sagor, G. H. M. (2020). Morpho-genetic evaluation of rice genotypes (*Oryza sativa* L.) including some varieties and advanced lines based on yield and its attributes. *Journal of the Bangladesh Agricultural University*, *18*(4), 923-933.

Alam, M. P., Kumar, S., Ali, N., Manjhi, R. P., Kumari, N., Lakra, R. K., & Izhar, T. (2013). Performance of wheat varieties under different sowing dates in Jharkhand. *Journal of Wheat Research*, *5*(2), 61-64.

Ali, G., Iqbal, Z., & Nazir, M. S. (1982). Grain yield and protein content of some short duration wheat genotypes in relation to degree of late sowing. *Journal of Agricultural Research*.

Basra, S. M. A., Zia, M. N., Mehmood, T., Afzal, I., & Khaliq, A. (2002). Comparison of different invigoration techniques in wheat (*Triticum aestivum* L.) seeds. *Pakistan Journal of Arid Agriculture*, 5(2), 11-16.

BBS (2020). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division. Ministry of Planning. Government of the People's Republic of Bangladesh, Dhaka.

Bremner, J. M. (1982). Total nitrogen. *Methods of soil analysis*, 595-624.

Djanaguiraman, M., Narayanan, S., Erdayani, E., & Prasad, P. V. (2020). Effects of high temperature stress during anthesis and grain filling periods on photosynthesis, lipids and grain yield in wheat. *BMC Plant Biology*, *20*, 1-12.

Eslami, H., Hadi, S. M., & Arabi, M. K. (2014). Effect of planting date on protein content of wheat varieties. *International Journal of Farming and Allied Sciences*, *3*, 362-364.

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 chilling tolerance. *Journal of Agronomy and Crop Science*, *194*(1), 55-60.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John wiley & sons.

Hannan, A., Hoque, M. N., Hassan, L., & Robin, A. H. K. (2021). *Drought affected wheat production in Bangladesh and breeding strategies for drought tolerance*. London, UK: IntechOpen.

Hoque, M. N., Tuz-zohra, F., Seen, M. M. H., Biswas, R., Hosen, A., & Hannan, A. (2021). Current status of salt tolerant indigenous rice genotypes, problems and feasibility at farmers' level in the coastal areas of Bangladesh. *Fundamental and Applied Agriculture*, *6*(2), 172-182.

Hubert, B., Rosegrant, M., Van Boekel, M. A., & Ortiz, R. (2010). The future of food: scenarios for 2050. *Crop Science*, *50*, S-33.

Jafar, M. Z., Farooq, M., Cheema, M. A., Afzal, I., Basra, S. M. A., Wahid, M. A., & Shahid, M. (2012). Improving the performance of wheat by seed priming under saline conditions. *Journal of Agronomy and Crop Science*, *198*(1), 38-45.

Jashi, S. N. L., & Singh, H. G. (1995). Performance of wheat varieties under different sowing dates of semi-arid land. *Indian Journal of Agronomy*, *28*(1), 54-58.

Keskitalo, J., Bergquist, G., Gardestrom, P., & Jansson, S. (2005). A cellular timetable of autumn senescence. *Plant Physiology*, *139*(4), 1635-1648.

Kumar, R., & Singh, S. (1998). Effect of sowing date on wheat (*Triticum aestivum*) varieties under late sown irrigated condition. *International journal of tropical agriculture*, *16*(1-4), 165-166.

Kumaraswamy, S., & Shetty, P. K. (2016). Critical abiotic factors affecting implementation of technological innovations in rice and wheat production: A review. *Agricultural reviews*, *37*(4), 268-278.

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.

Namakka, A., Abubakar, I. U., Sadik, I. A., Sharifai, A. I., & Hassas, A. H. (2008). Effect of sowing date and nitrogen level on yield and yield components of two extra early maize varieties (*Zea mays* L.) in Sudan savanna of Nigeria. *Journal of Agricultural and Biological Science*, *3*(2), 1-5.

Passioura, J. B. (1994). The yield of crops in relation to drought. *Physiology and Determination of Crop Yield*, 343-359.

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

Rahman, M., Begum, M., Mandal, M. S. H., Mehraj, H., Roy, T. S., & Amin, A. R. (2014). Influence of sowing date on the growth and yield of wheat varieties (Doctoral Dissertation, Department of Agronomy).

Rahman, S., & Hasan, M. K. (2009). Wheat in Bangladesh: Yield growth, production performance and determinants. *Soybean and Wheat Crops: Growth, Fertilization and Yield. Nova Science Publishers.*

Sallam, H. A. (1992). Zinc seed-hardening of some wheat cultivars in relation to growth behavior and some biochemical constituents under saline conditions. *Annals of Agricultural Science*, *30*(3), 1249-1257.

Sarkar, R. K. (2012). Seed priming improves agronomic trait performance under flooding and non-flooding conditions in rice with QTL SUB1. *Rice Science*, *19* (4), 286-294.

Sial, M. A., Arain, M. A., Khanzada, S. H. A. M. A. D. A. D., Naqvi, M. H., Dahot, M. U., & Nizamani, N. A. (2005). Yield and quality parameters of wheat genotypes as affected by sowing dates and high temperature stress. *Pakistan Journal of Botany*, *37*(3), 575.

Singh, S. P., & Singh, H. B. (1991). Productivity of late-sown wheat (*Triticum aestivum*) as influenced by seed condition and varieties. *Indian Journal of Agronomy*, *36*, 38-40.

Singh, V. P. N., & Uttam, S. K. (1999). Influence of sowing dates on yield of wheat cultivars under saline sodic conditions in Central Utter Pradesh. *Indian Journal of Agriculture*, *38*(1), 64-68.

Spink, J. H., Clare, R. W., & Kilpatrick, J. B. (1993). Grain quality of milling wheats at eight different sowing dates. *Aspects of Applied Biology*, *36*, 231-240.

UNDP & FAO (1988). Land Resources Appraisal of Bangladesh for Agriculture Development. Report number 2 Agroecological Regions of Bangladesh. United Nations Development Program and Food and Agricultural Organization of United Nations, pp. 212-221.

Wato, T., Amare, M., & Bonga, E. (2020). Review on the Response of Wheat (*Triticum aestivum* L.) Grain Yield to Different Planting Methods in Ethiopia.

Zadoks, J. C., Chang, T. T., & Konzak, C. F. (1974). A decimal code for the growth stages of cereals. *Weed research*, *14*(6), 415-421.