Effect of Different Seed Priming Methods on Plant Performance of Wheat (*triticum aestivum* l.) Crop

Abstract

The present research was carried out at the agriculture research farm and laboratories of Department of Seed Science & Technology, SKD University, Rajasthan to evaluate the effect of seed priming treatment on seed yield, quality and its storability in wheat (*Triticum astivum*). The material comprised of a variety "HD-2851" which was grown in the research farm of Department of Seed Science & Technology with twelve treatment combinations of inorganic salt and PGR. Among the priming treatments, Halopriming-Soaking in KNO3 (@0.3%) solution recommended dose of nitrogen exhibited better performance in terms of growth and yield attributes as compared to control. The results revealed that seed priming significantly influenced all the observed parameters. Among the treatments, halo-priming with KNO_3 @ 0.3% (T_9) proved most effective, recording the earliest 50% flowering (58 days) compared to the control (87.67 days). The same treatment also resulted in maximum plant height (95.24 cm), spike length (10.77 cm), number of tillers per plant (9.07), spikes per plant (8.75), and seeds per spike (21.57). Consequently, the highest seed yield per plant (11.17 g) was obtained under KNO_3 priming, while the untreated control produced the lowest yield (8.83 g). Other treatments such as $ZnSO_4$ and $CaSO_4$ priming also showed significant improvement over the control but were inferior to KNO_3 priming. The enhanced performance under seed priming may be attributed to improved metabolic activity, nutrient availability, early seedling vigor, and efficient assimilate translocation. Overall, halo-priming with KNO_3 @ 0.3% is a simple and effective technique to enhance wheat productivity.

Keywords- Wheat, Seed priming, Growth and Yield, nutrient availability

Introduction

Wheat (*Triticum aestivum* L.), a member of the family Gramineae, is among the most important cereal crops contributing to global food and nutritional security. It ranks second worldwide in total grain production after maize, followed by rice, and serves as a primary staple food for a substantial proportion of the global population across more than forty countries. China is the leading wheat-producing nation, with India occupying the second position, followed by countries such as the Russian Federation, the United States, France, Australia, and Canada. The widespread demand for wheat is largely attributed to the presence of gluten proteins in its flour, which impart unique viscoelastic and binding properties essential for baking and food processing industries. From a nutritional standpoint, wheat grains are rich in carbohydrates and contain approximately 13% protein, which is higher than many other cereals, although the protein is relatively deficient in certain essential amino acids. In India, bread wheat predominates, contributing nearly 87% of total wheat production, followed by durum wheat (about 12%) and dicoccum wheat (around 1%).

According to recent FAO estimates, global wheat production reached approximately 787 million tonnes in 2024, reflecting a slight decline compared to the previous year, while production is projected to increase to nearly 796 million tonnes in 2025. India produced about 113.3 million tonnes of wheat in 2024, with expectations of achieving a record output of 115.4 million tonnes in 2025, driven mainly by favourable policy support and higher minimum support prices. Wheat continues to rank as the third most important cereal crop globally after maize and rice. Projections from the OECD-FAO Agricultural Outlook (2025-2034) indicate that global wheat consumption is likely to increase by nearly 11% by 2034, primarily due to rising food demand in Asia, particularly in India and China. These projections emphasize the continued importance of wheat and the urgent need to enhance its productivity to meet future food requirements.

Seed priming has emerged as an efficient pre-sowing technique to improve germination and early seedling establishment in wheat. The process involves controlled hydration of seeds to initiate metabolic activity without allowing radicle emergence, followed by drying before sowing. This results in faster and more uniform germination under field conditions, leading to improved crop stand establishment. Various priming techniques such as hydropriming, osmopriming, and hormone priming have proven effective in wheat. Hydropriming, which entails soaking seeds in water for 8-12 hours and then drying them, enhances early seedling vigor and uniformity. Osmopriming with agents like KNO_3 or polyethylene glycol (PEG-6000) improves tolerance to abiotic stresses such as drought and salinity, while hormonal priming with gibberellic acid (GA_3) accelerates germination and early growth.

Overall, seed priming technologies offer a practical approach to improving germination synchrony, seed vigor, and crop performance, ultimately contributing to higher yields. Priming stimulates metabolic and catabolic processes, delays seed aging, promotes rapid germination, and enhances resistance to various stresses. A wide range of priming strategies, including hydropriming, halo-priming, osmo-priming, matrix priming, osmo-hardening, hormone priming, nutripriming, bio-priming, nanoparticle priming, and farmer-level on-farm priming, have been extensively studied. Recent advances have led to the concept of bio-nanopriming, which integrates plant growth-promoting rhizobacteria with nano-fertilizers to further enhance plant

UNDER PEER REVIEW

growth and productivity, highlighting the evolving potential of seed priming in sustainable wheat production.

Materials and Methods

The present research was carried out at the agriculture research farm and laboratories of Department of Seed Science & Technology, SKD University, Rajasthan to evaluate the effect of seed priming treatment on seed yield, quality and its storability in wheat (*Triticum astivum*). The material comprised of a variety "HD-2851" which was grown in the research farm of Department of Seed Science & Technology with twelve treatment combinations of inorganic salt and PGR. Days to 50% flowering represents the time taken by wheat to reach the reproductive stage and serves as an important indicator of crop maturity and duration. It is influenced by genetic makeup, environmental factors, and seed vigor, with seed priming treatments often promoting earlier flowering through improved germination and early growth. Plant height reflects vegetative vigor and biomass accumulation, and priming enhances nutrient uptake and enzymatic activity, leading to better growth while maintaining an optimum height to avoid lodging. Spike length is a key reproductive trait associated with the number of spikelets and grains per spike; seed priming improves assimilate partitioning and spike development, resulting in longer spikes and higher yield potential. The number of spikes per plant, determined by fertile tillers, indicates a plant’s productivity, which is generally higher in primed seeds due to improved emergence and root growth. Similarly, the number of tillers per plant, including both productive and non-productive tillers, is enhanced by priming through improved seedling vigor and root development. Seed number per spike reflects reproductive efficiency and grain-setting ability, which is positively influenced by priming through better photosynthesis, nutrient translocation, and enzyme activity. Overall, these growth and yield attributes collectively demonstrate the beneficial role of seed priming in improving wheat performance under the agro-climatic conditions of Hanumangarh.

Results and discussion

Days to 50% Flowering

Details regarding mean performance analysis of days to 50 per cent flowering in response to inorganic salt and PGR are given in the Table 1. The days to 50% flowering were significantly affected by various treatment combinations. The lowest number of days (58.00) required for 50% flowering was observed under Halopriming-Soaking treatment in KNO_3 (@0.3%) solution and drying(T_9) which was statistically at par T_5 (59.17) with the Halo-priming-Soaking in $ZnSO_4$ (@0.5%) solution and drying, while maximum number of days (87.67) Control (untreated) $T_1$was recorded during the year 2022-23, and 2023-24 on pooled basis. The present investigation clearly demonstrated that seed priming treatments, particularly

UNDER PEER REVIEW

halo priming with KNO_3 @ 0.3% (T_9), significantly influenced growth, phenological, yield-attributing, and yield traits of wheat. The earliest attainment of 50% flowering (58 days) was recorded under T_9, which was statistically at par with $ZnSO_4$ priming (T_5). This advancement in flowering may be attributed to improved metabolic activation, osmotic regulation, and hormonal balance induced by nitrate ions during priming, leading to rapid vegetative growth and early reproductive transition. Uniform emergence, better canopy development, and synchronized flowering under halo priming further contributed to improved crop performance (Tiwari *et al.,* 2025).

Plant Height (cm)

The perusal of data in Table 2 revealed that mean performance of different treatments for plant height ranged from 85.46 to 95.24. The plant height differed significantly due to different treatments. Significantly highest plant height (95.24) was recorded in treatment Halopriming-Soaking in KNO3(@0.3%) solution and drying (T9) which was statistically at par with T5 (94.14) with the Halo-priming-Soaking in ZnSo4 (@0.5%) followed by Halopriming $CaSO_4$ (@0.5%) solution and drying. (T11: 92.65) whereas the lowest plant height (85.46) T1 was recorded in control during the year 2022-23 and 2023-24 on pooled basis. The results indicate that halo-priming significantly enhanced plant height compared to the control. KNO_4 priming proved most effective, likely due to improved nutrient availability and early seedling vigor, while micronutrient priming with $ZnSO_4$ and $CaSO_4$ also showed comparable positive effects (Chakraborty *et al.,* 2017; Singh *et al.,* 2023).

UNDER PEER REVIEW

Table No. 1: Effect of seed priming treatment on Days of 50% flowering in wheat varieties HD-2851.

Symb.	Treatments	Days of 50% flowering		
		2023	2024	Pooled
T1	Control (Untreated)	64.00	63.33	63.67
T2	Hydro-priming- Soaking in water for 8h at 25^0Cand air drying at 25^0C for 48h	63.67	60.67	62.17
T3	Halopriming-Soaking in Salicylic acid(@75ppm) solution and drying	62.33	62.00	62.17
T4	Halopriming-Soaking in GA_3(@100ppm) solution and drying	62.67	62.33	62.50
T5	Halopriming-Soaking in ZnSO4(@0.3%) solution and drying.	59.33	59.00	59.17
T6	Halopriming-Soaking in NaCl (@0.5%) solution and drying	62.00	61.00	61.50

T7	Halopriming-Soaking in $CaCl_2$(@0.5%) solution and drying	61.67	62.00	61.83
T8	Halopriming-Soaking in $FeSo_4$(@0.5%) solution and drying	63.00	62.00	62.50
T9	Halopriming-Soaking in KNO3(@0.3%) solution and drying	58.67	57.33	58.00
T10	Halo priming-Soaking in KCL (@0.3%) solution and drying	61.33	61.00	61.17
T11	Halopriming $CaSo_4$ (@0.5%) solution and drying.	61.67	61.67	61.67
T12	Halopriming-Soaking in Na_4NO_3(@0.5%) solution and drying	62.33	62.33	62.33
	Mean	61.89	61.22	61.56
	SE(m) ±	0.75	0.71	0.67
	C.D. at 5%	2.22	2.10	1.97
	CV (%)	2.10	2.01	1.88

Spike Length (cm)

It is evident the perusal of data in Table 3 revealed that mean performance of different treatments for spike length ranged from 8.59 to 10.77. The spike length differed significantly due to different treatments. Significantly highest spike length (10.77) was recorded in treatment Halopriming-Soaking in KNO3(@0.3%) solution and drying (T9) which was statistically at par with T5 (10.38) with the Halo-priming-Soaking in $ZnSO_4$ (@0.5%) followed by Halopriming CaSo4 (@ 0.5%) solution and drying. T11 (10.32) whereas the

Table No. 2. Effect of seed priming treatment on Plant height (cm) in wheat varieties HD-2851.

Symb	Treatments	Plant height (cm)		
		2023	**2024**	**Pooled**
T1	Control (Untreated)	85.19	85.72	85.46
T2	Hydro-priming- Soaking in water for 8h at 25^0Cand air drying at 25^0C for 48h	87.20	88.07	87.63
T3	Halopriming-Soaking in Salicylic acid(@75ppm) solution and drying	89.42	90.27	89.85
T4	Halopriming-Soaking in GA_3(@100ppm) solution and drying	88.52	89.06	88.79
T5	Halopriming-Soaking in ZnSo4(@0.3%) solution and drying.	93.89	94.42	94.14
T6	Halopriming-Soaking in NaCl(@0.5%) solution and drying	90.03	90.26	90.15

UNDER PEER REVIEW

T7	Halopriming-Soaking in $CaCl_2$(@0.5%) solution and drying	89.15	90.12	89.63
T8	Halopriming-Soaking in $FeSo_4$(@0.5%) solution and drying	91.46	92.23	91.85
T9	Halopriming-Soaking in KNO3(@0.3%) solution and drying	94.69	95.79	95.24
T10	Halo priming-Soaking in KCl (@0.3%) solution and drying	89.82	90.37	90.10
T11	Halopriming $CaSo_4$ (@0.5%) solution and drying.	92.46	92.83	92.65
T12	Halopriming-Soaking in Na_4NO_3(@0.5%) solution and drying	91.07	91.63	91.35
	Mean	90.24	90.90	90.57
	SE(m) ±	0.54	0.72	0.58
	C.D. at 5%	1.61	2.14	1.72
	CV (%)	1.04	1.38	1.11

lowest spike length (8.61) T1 was recorded in control during the year 2022-23, and 2023-24 on pooled basis. The significant improvement in spike length under halo-priming treatments may be attributed to enhanced seed metabolic activity, improved nutrient uptake, and better early crop establishment. KNO_4 priming was most effective, while $ZnSO_4$ and $CaSO_4$ priming also promoted spike development compared to the untreated control (Iqbal *et al.,* 2020; Singh *et al.,* 2017; Rehman *et al.,* 2020).

Table No. 3 Effect of seed priming treatment on Spike length (cm) in wheat varieties HD-2851.

Symb	**Treatments**	**Spike length (cm)**		
		2023	**2024**	**Pooled**
T1	Control (Untreated)	8.57	8.61	8.59
T2	Hydro-priming- Soaking in water for 8h at 25^0Cand air drying at 25^0C for 48h	8.85	9.05	8.95
T3	Halopriming-Soaking in Salicylic acid(@75ppm) solution and drying	9.06	9.20	9.13
T4	Halopriming-Soaking in GA_3(@100ppm) solution and drying	9.70	9.83	9.76
T5	Halopriming-Soaking in ZnSo4(@0.3%) solution and drying.	10.51	10.25	10.38
T6	Halopriming-Soaking in NaCl (@0.5%) solution and drying	9.88	10.12	10.00
T7	Halopriming-Soaking in $CaCl_2$ (@0.5%) solution and drying	10.02	10.16	10.09

UNDER PEER REVIEW

T8	Halopriming-Soaking in $FeSo_4$ (@0.5%) solution and drying	10.17	10.35	10.26
T9	Halopriming-Soaking in KNO3 (@0.3%) solution and drying	10.69	10.85	10.77
T10	Halo priming-Soaking in KCl (@0.3%) solution and drying	9.95	10.06	10.01
T11	Halopriming $CaSo_4$ (@0.5%) solution and drying.	10.54	10.09	10.32
T12	Halopriming-Soaking in Na_4NO_3(@0.5%) solution and drying	10.21	10.42	10.31
	Mean	**9.85**	**9.92**	**9.88**
	SE(m) ±	0.36	0.34	0.33
	C.D. at 5%	1.06	1.00	0.96
	CV (%)	6.30	5.92	5.71

Number of tillers per Plant

The figures on tiller no per plant appear to be influenced by seed priming treatments Table 4. However, the results indicate that the number of tillers per plant induced by seed treatment with priming was significant. Numerically the highest No. of tiller per plant (9.07) was recorded in seeds primed with halo-priming in KNO3 (@0.3%) solution and drying (T9) followed by seed halo-priming-Soaking in $ZnSO_4$ (@0.5%) T5 (8.53) while, the lowest number of tiller per plant (5.77) was recorded in control (T_1) on pooled basis. The increase in tillers under seed priming treatments may be due to improved germination, enhanced root growth, and better nutrient availability during early growth stages. Halo-priming with KNO_4 proved most effective, followed by $ZnSO_4$, while the control exhibited poor tillering due to limited early vigor (Ahmadvand *et al.,* 2012; Yadav *et al.,* 2018; Prajapati *et al.,* 2021).

Table No. 4: Effect of seed priming treatment on no. of tiller per plant in wheat varieties HD-2851.

Symb	**Treatments**	**No. of tiller per plant**		
		2023	**2024**	**Pooled**
T1	Control (Untreated)	5.73	5.80	5.77
T2	Hydro-priming- Soaking in water for 8h at 25^0Cand air drying at 25^0C for 48h	5.93	6.07	6.00
T3	Halopriming-Soaking in Salicylic acid (@75ppm) solution and drying	6.20	6.33	6.27
T4	Halopriming-Soaking in GA_3 (@100ppm) solution and drying	7.00	7.33	7.17
T5	Halopriming-Soaking in ZnSo4 (@0.3%) solution and drying.	8.73	8.33	8.53

UNDER PEER REVIEW

T6	Halopriming-Soaking in NaCl (@0.5%) solution and drying	7.13	7.20	7.17
T7	Halopriming-Soaking in $CaCl_2$(@0.5%) solution and drying	7.07	7.20	7.13
T8	Halopriming-Soaking in $FeSo_4$(@0.5%) solution and drying	7.33	7.33	7.33
T9	Halopriming-Soaking in KNO3(@0.3%) solution and drying	8.93	9.20	9.07
T10	Halo priming-Soaking in KCl(@0.3%) solution and drying	7.33	7.40	7.37
T11	Halopriming $CaSo_4$ (@0.5%) solution and drying.	8.47	8.07	8.27
T12	Halopriming-Soaking in Na_4NO_3(@0.5%) solution and drying	8.00	8.13	8.07
	Mean	7.32	7.37	7.34
	SE(m) ±	0.36	0.22	0.24
	C.D. at 5%	1.05	0.63	0.70
	CV (%)	8.39	5.05	5.60

Seed Number per Spike

The data on number of spikes per plant of wheat as influenced by different seed priming treatments have been presented in Table 5. A cursory glans over the data showed the Number of spikes per plant different significantly at the all treatment combination. Treatment of seeds primed with halo-priming in KNO3(@0.3%) solution and drying has recorded maximum number of spike per plant(T9) 8.75. which was statistically as per the treatment halo-priming in KNO3(@0.3%) solution and drying (T5) 8.43 and halo-priming CaSo4 (@0.5%) solution and drying T11(8.25) while significantly lower number of Number of spike per plant were observed in control T0 (5.25). The enhanced number of spikes per plant under seed priming treatments may be attributed to improved germination, better tiller establishment, and efficient nutrient utilization. Halo-priming with KNO_3 proved most effective, followed by $ZnSO_4$ and $CaSO_4$, whereas the control recorded fewer spikes due to poor early growth (Chauhan *et al.,* 2016; Koutu *et al.,* 2019).

Table No. 5: Effect of seed priming treatment on No. of spike per plant in wheat varieties HD-2851.

Symb	Treatments	No. of spike per plant		
		2023	**2024**	**Pooled**

UNDER PEER REVIEW

T1	Control (Untreated)	5.09	5.42	5.25
T2	Hydro-priming- Soaking in water for 8h at 25^0Cand air drying at 25^0C for 48h	5.80	6.00	5.90
T3	Halopriming-Soaking in Salicylic acid (@75ppm) solution and drying	6.06	6.20	6.13
T4	Halopriming-Soaking in GA_3(@100ppm) solution and drying	6.95	7.09	7.02
T5	Halopriming-Soaking in ZnSo4 (@0.3%) solution and drying.	8.35	8.51	8.43
T6	Halopriming-Soaking in NaCl (@0.5%) solution and drying	7.33	7.46	7.40
T7	Halopriming-Soaking in $CaCl_2$ (@0.5%) solution and drying	7.01	7.07	7.04
T8	Halopriming-Soaking in $FeSo_4$ (@0.5%) solution and drying	7.89	8.06	7.97
T9	Halopriming-Soaking in KNO3 (@0.3%) solution and drying	8.56	8.93	8.75
T10	Halo priming-Soaking in KCl (@0.3%) solution and drying	7.87	8.04	7.96
T11	Halopriming $CaSo_4$ (@0.5%) solution and drying.	8.21	8.29	8.25
T12	Halopriming-Soaking in Na_4NO_3 (@0.5%) solution and drying	8.11	8.31	8.21
	Mean	**7.27**	**7.45**	**7.36**
	SE(m) ±	0.32	0.35	0.32
	C.D. at 5%	0.95	1.03	0.95
	CV (%)	7.65	8.15	7.65

Number of seed per spike

Data are shown in table 6, effect of seed priming methods on number of seeds per spike compared with different treatment @ k Blanto 3 (0.3 %) has also performed respectively maximum number of seed per spike (21.57), which was found at par with halo-priming $CaSO_4$ (@ 0. 5%) solution (T_5 :20.33) with halo-priming CaSo4 (@ 0. 5%) solution (T_{11}: 20.13). and minimum seed per spike T_1 (14.50) on pooled basis. The increase in seeds per spike under halo-priming treatments may be attributed to improved spike fertility, better nutrient availability, and enhanced assimilate translocation. KNO_3 priming recorded the maximum seeds per spike, while $CaSO_4$ priming showed comparable performance. The control produced fewer seeds due to suboptimal growth conditions (Kesharwani *et al.,* 2018).

Table No. 6: Effect of seed priming treatment on no. of seeds per spike in wheat varieties HD-2851.

Symb	**Treatments**	**No. of seeds per spike**		
		2023	**2024**	**Pooled**

UNDER PEER REVIEW

T1	Control (Untreated)	14.00	15.00	14.50
T2	Hydro-priming- Soaking in water for 8h at 25^{0}Cand air drying at 25^{0}C for 48h	15.73	17.73	16.73
T3	Halopriming- Salicylic acid(@75ppm) solution and drying	15.40	16.13	15.77
T4	Halopriming-Soaking in GA_3(@100ppm) solution and drying	16.93	15.73	16.33
T5	Halopriming-Soaking in ZnSo4(@0.3%) solution and drying.	20.07	20.60	20.33
T6	Halopriming-Soaking in NaCl(@0.5%) solution and drying	18.47	19.40	18.93
T7	Halopriming-Soaking in $CaCl_2$(@0.5%) solution and drying	19.47	19.33	19.40
T8	Halopriming-Soaking in $FeSo_4$(@0.5%) solution and drying	19.53	19.87	19.70
T9	Halopriming-Soaking in KNO3(@0.3%) solution and drying	21.33	21.80	21.57
T10	Halo priming-Soaking in KCl(@0.3%) solution and drying	19.40	20.27	19.83
T11	Halopriming $CaSo_4$ (@0.5%) solution and drying.	20.20	20.07	20.13
T12	Halopriming-Soaking in Na_4NO_3(@0.5%) solution and drying	18.73	19.33	19.03
	Mean	18.27	18.77	18.52
	SE(m) ±	0.63	0.51	0.39
	C.D. at 5%	1.86	1.52	1.15
	CV (%)	5.97	4.74	3.65

Seed yield

A glimpse of data table 7 revealed that seed yield might be varied significantly due to different treatment combination among all treatment combination halo- priming in KNO3 (@0.3%) solution (T9) has recorded maximum yield (11.17) g/plant followed by halo-priming CaSo4 (@ 0.5%) solution (T5 :10.83) and Halo-priming-Soaking in Na4NO3 (@0.5%) (T11: 10.70) and significantly minimum seed yield (8.83) was observed in control (T1) where no treatment were applied. The significant increase in seed yield under seed priming treatments may be attributed to improved germination, enhanced early vigor, and better utilization of nutrients, resulting in superior yield attributes. Halo-priming with KNO_3 was most effective, followed by $CaSO_4$ and $NaNO_3$, whereas the control recorded the lowest yield due to poor crop establishment (Golezani *et al*., 2010; Kumar *et al.,* 2024; Varinda *et al.,* 2025).

Table No. 7: Effect of seed priming treatment on seed yield in wheat varieties HD-2851.

Symb	**Treatments**	**Yield (g/plant)**		
		2023	**2024**	**Pooled**
T1	Control (Untreated)	8.75	8.92	8.83

UNDER PEER REVIEW

T2	Hydro-priming- Soaking in water for 8h at 25^{0}Cand air drying at 25^{0}C for 48h	9.57	9.81	9.69
T3	Halopriming- Salicylic acid(@75ppm) solution and drying	10.02	10.32	10.17
T4	Halopriming-Soaking in GA_3(@100ppm) solution and drying	10.03	10.29	10.16
T5	Halopriming-Soaking in ZnSo4(@0.3%) solution and drying.	10.77	10.89	10.83
T6	Halopriming-Soaking in NaCl(@0.5%) solution and drying	10.38	10.70	10.54
T7	Halopriming-Soaking in $CaCl_2$(@0.5%) solution and drying	10.09	10.75	10.42
T8	Halopriming-Soaking in $FeSo_4$(@0.5%) solution and drying	10.46	10.82	10.64
T9	Halopriming-Soaking in KNO3(@0.3%) solution and drying	11.06	11.28	11.17
T10	Halo priming-Soaking in KCl(@0.3%) solution and drying	10.18	10.39	10.28
T11	Halopriming $CaSo_4$ (@0.5%) solution and drying.	10.12	10.62	10.37
T12	Halopriming-Soaking in Na_4NO_3(@0.5%) solution and drying	10.59	10.81	10.70
	Mean	**10.17**	**10.47**	**10.32**
	SE(m) ±	0.36	0.32	0.31
	C.D. at 5%	1.07	0.94	0.92
	CV (%)	6.15	5.28	5.23

Conclusion

The present investigation conclusively demonstrated that seed priming treatments, particularly halo-priming with inorganic salts, exerted a pronounced and consistent influence on phenological development, growth attributes, yield components, and final seed yield of wheat over the pooled data of 2022-23 and 2023-24. Among all treatments, halo-priming with KNO_3 @ 0.3% (T_9) proved to be the most effective, as evidenced by earlier attainment of 50% flowering, greater plant height, longer spike length, higher number of tillers and spikes per plant, increased number of seeds per spike, and ultimately superior seed yield per plant. The beneficial effects of KNO_3 priming may be attributed to enhanced metabolic activation, improved osmotic adjustment, better nutrient availability, and efficient assimilate partitioning, which collectively promoted vigorous vegetative growth and improved reproductive efficiency. Other priming treatments such as $ZnSO_4$ and $CaSO_4$ also showed significant improvement over the control, indicating their positive role in micronutrient supply and physiological enhancement, though their performance remained slightly inferior to KNO_3 priming. In contrast, the untreated control consistently recorded the poorest performance across all

UNDER PEER REVIEW

parameters, highlighting the importance of seed priming in wheat cultivation. Overall, halo-priming with KNO_3 @ 0.3% emerges as a simple, cost-effective, and efficient seed enhancement technique for improving wheat productivity and can be recommended for adoption under similar agro-climatic conditions.

Disclaimer (Artificial intelligence)

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

UNDER PEER REVIEW

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