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Effect of Different Seed Priming Treatments on Seed Quality Components of Barley (*Hordeum vulgare* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. 'All authors read and approved the final manuscript.

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ABSTRACT

The effects of different seed priming treatments, namely tap water, KNO_3 @ 2.5%, Thiourea @ 1000 ppm, $CaCl_2$ @ 2%, $NaCl_2$ @ 2%, $ZnSO_4$ @ 1%, KH_2PO_4 @ 1% and Salicylic acid @ 100 ppm solutions, on seed quality parameters of Barley cv. K-1055 and K-409 in Factorial Completely

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Randomized Block Design with four replications were investigated during 2022-23 and 2023-24 at the laboratory of Department of Seed Science and Technology, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. Analysis of variance revealed that the all recorded seed quality parameters were significantly affected by various seed priming treatments. Priming with KNO_3 @ 2.5 % showed maximum 1000 seed weight, standard germination %, seedling length, seedling root length, seedling shoot length, seedling dry weight, seed vigour index-I and seed vigour index-II.

Keywords: Barley; priming; KNO_3; seed quality.

1. INTRODUCTION

After wheat, rice, and maize in terms of area and production, barley (*Hordeum vulgare* L.) is a versatile cereal grain that is grown around the world [1]. Barley is a member of the Triticeae tribe, the family Poaceae, and the genus Hordeum, which together contain over 350 species. Of these, roughly 32 species both wild and domestic are found in the Hordeum. Barley is a diploid with 2n=14 chromosomes. Global barley production had been estimated to be 142.22 million metric tons.

The top four nations in the world for barley production are the UK, Australia, Canada, and Russia. Russia produces 19.03 million metric tons of barley annually over an area of 9 million hectares, accounting for 13% of global output. Australia produces 11.5 million metric tons of barley annually on 3.2 million hectares, approximately 8% of the world's total. With an area of 2.7 million hectares and a yield of 9.6 million metric tons, Canada contributes 6% of the global barley production [1].

Barley is use as a source of fermentable material for beer and certain distilled beverages and as a component of various health foods. Barley grains are commonly made into malt in a traditional and ancient method of preparation. In general, barley is mainly classified as six-rowed and two-rowed barleys based on arrangement of kernels. Seed is an important component and the quality seed plays a crucial role in agricultural production as well as in the national economy. Seed quality plays a significant role in determining the productivity and sustainability of agricultural practices. The quality of seeds can greatly affect the overall success of a crop. High-quality seeds are essential for ensuring a healthy and vigorous crop that is able to gives better growth and yield.

Seeds that are of poor quality may lead to low germination rates, weak plants, and reduced yields. Seed deterioration starts once the seed attains physiological maturity in the field. The quality of seed deteriorate due to some of physiological changes like drop of germinability, decrease in mean germination time and loss of vigour.

Priming offers several advantages, including rapid and uniform germination, increased nutrient uptake, relief from phytochrome-induced photo- and thermo-dormancy, expanded germination temperature range, improved water use efficiency, and synchronous crop maturity. By reducing imbibitions time [2] and promoting metabolite production and pre-germinative enzyme activation [3], seed priming ensures uniform germination and enhances crop establishment. Seed priming has also been investigated as a pre-sowing or mid-storage treatment for seed batches that have lost vigour due to insufficient storage conditions [4].

Various studies have been carried out on seed priming and have shown positive results over non-primed seeds, though the methods are not widely used. The behavior of seed with different priming treatments depends on various physiological and biochemical factors. There is ample scope for investigating mechanism involved behind the beneficial and adverse effect impacts of seed priming on seed quality.

2. MATERIALS AND METHODS

The experiment was carried out to determine the effect of various seed priming treatments on Barley seed quality parameters, during 2022-23 and 2023-24 at the laboratory of Department of seed science and Technology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, U.P. The experiment comprised of two Barley cultivars *viz,* cv. K-409 (V_1) and K-1055(V_2). Both varieties were primed with control (T_0), tap water (T_1), KNO_3 2.5% (T_2), Thiourea 1000 ppm(T_3), $CaCl_2$ 2% (T_4), $Nacl_2$ 2% (T_5), $ZnSO_4$ 1% (T_6), KH_2PO_4 1% (T_7), Salicylic acid 100 ppm (T_8) solutions. For test weight of seed

1000 seeds in four replications were counted manually from seed lot of each treatment and weight in (g) up to two decimal places with the help of the digital balance. Germination test was carried out by following the procedure out lined by ISTA rules. Four replications of 100 seeds each for every treatment were uniformly placed on moist germination paper and rolled with butter paper to prevent moisture evaporation during test period. Samples were placed in plastic tray in stand upright position and these trays were shifted to seed germinator maintained at 20±2°C temperature and 90±3 per cent relative humidity. The sample was allowed to germinate for the prescribed period. Germination percentage was recorded on 8^{th} days by counting normal seedlings. On 8^{th} day of germination, ten seedlings were selected randomly from each replication and seedling length, seedling root length and seedling shoot length was measured in cm and averaged. Randomly taken ten normal seedlings which were used for recording the seedling measurement were kept in beakers and dried for 24 hours in a hot air oven maintained at 100^{0}C temperature. These dried seedlings were removed and cooled in a desiccator for 30 minutes. Then the weight was recorded and express in grams. The seedling vigour index-I was calculated by multiplying the per cent seed germination and total seedling length (cm) of all treatments separately. The seedling vigour index-II was determined by multiplying seed germination percentage and seedling dry weight (g). Formula suggested by Abdul Baki and Anderson [5] as below.

Vigour Index-I = Germination Percentage x Seedling Length (cm)

Vigour index-II = Germination Percentage x Seedling dry weight (g)

3. RESULTS AND DISCUSSION

The data presented in Table 1 to Table 8 revealed that both varieties of Barley when treated with various seed priming treatments showed significant effects on seed quality parameters.

It is evident from Table 1 to Table 8 that the Variety K-1055 exhibited significantly greater 1000 seed weight (42.71 g), standard germination % (92.33 %), seedling length (23.74 cm), seedling root length (10.20 cm), seedling shoot length (13.54 cm), seedling dry weight (0.229 g), seed vigour index-I (2194.87 cm), seed vigour index-II (21.20 cm). as compared to variety K-409 that may be due to differential response of variety. Similar results have been reported by Afzal et al. [6], Bakht et al [7], and Siddique and Bose [8].

Pooled data of priming treatments also presented in Table-1 to Table-8 revealed that among the priming treatments, priming with KNO_3 @ 2.5% (T_2) was significantly superior in terms of 1000 seed weight (43.85 g), standard germination % (95.31%), seedling length (25.88 cm), seedling root length(11.09 cm), seedling shoot length(14.79 cm), seedling dry weight (0.239 g), seed vigour index-I (2466.52 cm), seed vigour index-II (22.82 cm) followed by priming with thiourea @ 1000 ppm (T_3) while all the seed quality characters were minimum in control (T_0). These results are in conformity with Ali et al. [9], El Tayeb [10], Naz and Shagufta [11], Khokhar et al. [12].

Table 1 to Table 8 revealed that the The interaction of barley varieties with priming treatments were showed significant improvement in 1000 seed weight, seedling length, seedling root length, seedling shoot length on pooled data basis of both years, maximum 1000 seed weight (44.46 g) was recorded in variety K-1055 with priming treatment KNO_3 @ 2.5 % ($V_2 \times T_2$) followed by variety K-1055 with priming treatment thiourea @ 1000 ppm. Maximum seedling length (26.13 cm), seedling root length (11.23 cm), seedling shoot length (14.90 cm) was recorded in variety K-1055 with priming treatment KNO_3 @ 2.5 % ($V_2 \times T_2$) followed by variety K-409 with priming treatment KNO_3 @ 2.5 % ($V_1 \times T_2$). In terms of standard germination percentage, seedling dry weight, seed vigour index-I and seed vigour index-II the interaction of barley varieties with priming treatments were showed non significant improvement. However, maximum standard germination percentage (95.75%), seedling dry weight (0.241g), seed vigour index-I (2502.38) and seed vigour index-II (23.04) were recorded in variety K-1055 with priming treatment KNO_3 @ 2.5 % ($V_2 \times T_2$) followed by variety K-409 with priming treatment KNO_3 @ 2.5 % ($V_1 \times T_2$). All the recorded seed quality parameters found minimum in variety K-409 without priming ($V_1 \times T_0$). findings are in conformity with the results of Rim Ben Youssef et al. [13], Jalal et al. [14], Murungu [15], [16-18].

Table 1. Effect of priming treatments for 6 hours on 1000 seed weight (g) in Barley varietiesK-409 and K-1055

Treatments	2022-23			2023-24			Pooled		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_0	40.12	41.02	40.57	40.78	41.21	40.99	40.45	41.12	40.78
T_1	40.80	41.47	41.14	41.12	41.69	41.41	40.96	41.58	41.27
T_2	43.11	44.05	43.58	43.37	44.87	44.12	43.24	44.46	43.85
T_3	42.51	43.80	43.16	42.58	44.27	43.72	42.54	44.03	43.28
T_4	41.74	42.24	41.99	41.87	42.64	42.26	41.81	42.44	42.12
T_5	41.15	41.72	41.43	41.26	42.23	41.74	41.20	41.97	41.59
T_6	42.34	43.18	42.76	42.67	43.46	43.06	42.50	43.32	42.91
T_7	42.19	42.28	42.23	42.14	42.61	42.37	42.16	42.44	42.30
T_8	41.95	42.64	42.29	42.46	42.87	42.66	42.20	42.75	42.48
Mean	**41.77**	**42.49**	**42.13**	**42.03**	**42.94**	**42.48**	**41.90**	**42.71**	**42.30**
Factors	**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**	
V	**0.04**	**0.08**		**0.006**	**0.012**		**0.024**	**0.048**	
T	**0.09**	**0.18**		**0.013**	**0.026**		**0.051**	**0.103**	
V×T	**0.13**	**0.25**		**0.018**	**0.037**		**0.072**	**0.145**	
CV(%)	**2.29**			**2.31**			**2.30**		

Table 2. Effect of priming treatments for 6 hours on standard germination % in Barley varietiesK-409 and K-1055

Treatments	2022-23			2023-24			Pooled		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_0	70.38	70.84	70.61	70.83	71.79	71.31	70.60	71.31	70.95
	(88.75)	(89.25)	(89.00)	(89.25)	(90.25)	(89.75)	(89.00)	(89.75)	(89.38)
T_1	71.08	71.89	71.44	71.30	72.26	71.78	71.19	72.02	71.60
	(89.50)	(90.25)	(89.88)	(89.75)	(90.75)	(90.25)	(89.63)	(90.50)	(90.06)
T_2	76.41	77.42	76.92	77.39	78.82	95.75	76.90	78.12	77.51
	(94.50)	(95.25)	(94.88)	(95.25)	(96.25)	(95.75)	(94.88)	(95.75)	(95.31)
T_3	75.52	76.12	75.82	76.10	77.39	76.74	75.81	76.75	76.28
	(93.75)	(94.25)	(94.00)	(94.25)	(95.25)	(94.75)	(94.00)	(94.75)	(94.38)
T_4	72.02	72.78	72.40	72.77	73.28	73.02	72.39	73.03	72.71
	(90.50)	(91.25)	(90.88)	(91.25)	(91.75)	(91.50)	(90.88)	(91.50)	(91.19)
T_5	71.54	72.04	71.79	72.02	72.78	72.40	71.78	72.41	72.09
	(90.00)	(90.50)	(90.25)	(90.50)	(91.25)	(90.88)	(90.25)	(90.88)	(90.56)
T_6	73.81	74.91	74.36	74.35	74.91	74.63	74.08	74.91	74.94
	(92.25)	(93.25)	(92.75)	(92.75)	(93.25)	(93.00)	(92.50)	(93.25)	(92.88)
T_7	72.28	73.28	72.78	73.28	73.81	73.54	72.78	73.54	73.16
	(90.75)	(91.75)	(91.25)	(91.75)	(92.25)	(92.00)	(91.25)	(92.00)	(91.63)
T_8	72.77	74.08	73.42	73.81	74.35	74.08	73.29	74.21	73.75
	(91.25)	(92.50)	(91.88)	(92.25)	(92.75)	(92.50)	(91.75)	(92.63)	(92.19)
Mean	**72.87**	**73.70**	**73.28**	**73.54**	**74.38**	**73.95**	**73.20**	**74.04**	**73.62**
	(91.25)	**(92.03)**	**(91.64)**	**(91.89)**	**(92.64)**	**(92.26)**	**(91.57)**	**(92.33)**	**(91.95)**
Factors	**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**	
V	**0.21**	**0.42**		**0.14**	**0.29**		**0.17**	**0.35**	
T	**0.45**	**0.90**		**0.31**	**0.62**		**0.38**	**0.76**	
V×T	**0.63**	**NS**		**0.44**	**NS**		**0.53**	**NS**	
CV(%)	**2.11**			**2.16**			**2.14**		

(The data presented in parentheses indicate transformed back values)

Table 3. Effect of priming treatments for 6 hours on seedling length (cm) in Barley varietiesK-409 and K-1055

Treatments	2022-23			2023-24			Pooled		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_0	20.87	21.52	21.19	21.20	21.92	21.56	21.04	21.72	21.38
T_1	21.69	22.11	21.90	22.28	22.64	22.46	21.99	22.37	22.18
T_2	25.25	25.82	25.53	25.99	26.45	26.22	25.62	26.13	25.88
T_3	24.07	24.72	24.40	24.94	25.56	25.25	24.51	25.14	24.82
T_4	22.27	23.06	22.66	22.90	23.62	23.26	22.58	23.34	22.96
T_5	21.87	22.36	22.11	22.50	23.02	22.76	22.18	22.69	22.44
T_6	23.69	24.24	23.96	24.50	25.06	24.78	24.10	24.65	24.37
T_7	22.65	23.39	23.02	23.56	23.84	23.70	23.11	23.61	23.36
T_8	23.05	23.65	23.35	24.11	24.38	24.24	23.58	24.01	23.80
Mean	**22.82**	**23.43**	**23.12**	**23.55**	**24.05**	**23.80**	**23.19**	**23.74**	**23.46**
Factors	**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**	
V	**0.011**	**0.022**		**0.006**	**0.013**		**0.009**	**0.018**	
T	**0.023**	**0.047**		**0.014**	**0.027**		**0.019**	**0.037**	
V×T	**0.03**	**0.066**		**0.019**	**0.039**		**0.026**	**0.053**	
CV(%)	**5.85**			**6.18**			**6.02**		

Table 4. Effect of priming treatments for 6 hours on seedling root length (cm) in Barley varietiesK-409 and K-1055

Treatments	2022-23			2023-24			Pooled		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_0	8.55	9.01	8.78	8.73	9.16	8.94	8.64	9.08	8.86
T_1	9.12	9.37	9.24	9.56	9.67	9.61	9.34	9.52	9.43
T_2	10.69	10.98	10.83	11.21	11.48	11.35	10.95	11.23	11.09
T_3	10.16	10.60	10.38	10.83	11.14	10.98	10.50	10.87	10.68
T_4	9.42	9.89	9.66	9.78	10.24	10.01	9.60	10.07	9.83
T_5	9.27	9.64	9.45	9.63	9.87	9.75	9.45	9.76	9.60
T_6	10.09	10.39	10.24	10.64	10.89	10.77	10.37	10.64	10.50
T_7	9.62	10.11	9.86	10.14	10.35	10.24	9.88	10.23	10.05
T_8	9.83	10.23	10.03	10.46	10.61	10.54	10.14	10.42	10.28
Mean	**9.64**	**10.02**	**9.83**	**10.11**	**10.38**	**10.24**	**9.87**	**10.20**	**10.04**
Factors	**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**	
V	**0.008**	**0.016**		**0.008**	**0.016**		**0.008**	**0.016**	
T	**0.017**	**0.035**		**0.017**	**0.035**		**0.017**	**0.035**	
V×T	**0.025**	**0.049**		**0.025**	**0.049**		**0.025**	**0.049**	
CV(%)	**6.36**			**7.32**			**6.84**		

Table 5. Effect of priming treatments for 6 hours on seedling shoot length (cm) in Barley varietiesK-409 and K-1055

Treatments	2022-23			2023-24			Pooled		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_0	12.32	12.51	12.41	12.47	12.76	12.61	12.39	12.63	12.51
T_1	12.57	12.74	12.65	12.73	12.97	12.85	12.65	12.85	12.75
T_2	14.56	14.84	14.70	14.78	14.97	14.87	14.67	14.90	14.79
T_3	13.91	14.12	14.01	14.11	14.43	14.27	14.01	14.27	14.14
T_4	12.85	13.17	13.01	13.12	13.38	13.25	12.98	13.28	13.13
T_5	12.61	12.72	12.66	12.87	13.15	13.01	12.74	12.93	12.83
T_6	13.61	13.85	13.73	13.86	14.17	14.01	13.73	14.01	13.87
T_7	13.04	13.28	13.16	13.42	13.49	13.45	13.23	13.38	13.30
T_8	13.23	13.42	13.32	13.64	13.77	13.70	13.43	13.59	13.51
Mean	**13.19**	**13.40**	**13.29**	**13.44**	**13.67**	**13.56**	**13.31**	**13.54**	**13.43**
Factors	**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**	
V	**0.003**	**0.006**		**0.003**	**0.006**		**0.003**	**0.006**	
T	**0.007**	**0.014**		**0.006**	**0.013**		**0.007**	**0.014**	
V×T	**0.010**	**0.019**		**0.009**	**0.018**		**0.010**	**0.019**	
CV(%)	**5.56**			**5.39**			**5.48**		

Table 6. Effect of priming treatments for 6 hours on seedling dry weight (g) in Barley varieties K-409 and K-1055

Treatments	2022-23			2023-24			Pooled		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_0	0.216	0.218	0.217	0.217	0.219	0.218	0.216	0.219	0.218
T_1	0.219	0.221	0.220	0.221	0.222	0.222	0.220	0.221	0.221
T_2	0.238	0.240	0.239	0.239	0.241	0.240	0.238	0.241	0.239
T_3	0.235	0.237	0.236	0.237	0.239	0.238	0.236	0.238	0.237
T_4	0.224	0.225	0.225	0.225	0.226	0.226	0.225	0.226	0.225
T_5	0.222	0.223	0.222	0.223	0.225	0.224	0.223	0.224	0.223
T_6	0.231	0.233	0.232	0.234	0.236	0.235	0.232	0.234	0.233
T_7	0.226	0.229	0.228	0.228	0.231	0.229	0.227	0.230	0.228
T_8	0.229	0.231	0.230	0.231	0.234	0.232	0.230	0.233	0.231
Mean	**0.227**	**0.229**	**0.228**	**0.228**	**0.230**	**0.229**	**0.227**	**0.229**	**0.228**
Factors	**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**	
V	**0.001**	**0.001**		**0.001**	**0.001**		**0.001**	**0.001**	
T	**0.002**	**0.003**		**0.001**	**0.002**		**0.002**	**0.003**	
V×T	**0.002**	**NS**		**0.002**	**NS**		**0.002**	**NS**	
CV(%)	**3.24**			**3.27**			**3.26**		

Table 7. Effect of priming treatments for 6 hours on vigour index-I in Barley varieties K-409 and K-1055

Treatments	2022-23			2023-24			Pooled		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_0	1852.06	1920.11	1886.09	1892.46	1977.79	1935.12	1872.26	1948.95	1910.60
T_1	1940.78	1995.03	1967.90	1999.68	2054.15	2026.91	1970.23	2024.59	1997.41
T_2	2385.94	2458.95	2422.44	2475.37	2545.82	2510.59	2430.65	2502.38	2466.52
T_3	2255.97	2329.94	2292.95	2350.62	2434.76	2392.69	2303.29	2382.35	2342.82
T_4	2015.18	2104.68	2059.93	2089.17	2167.39	2128.28	2052.17	2136.04	2094.10
T_5	1968.26	2022.77	1995.51	2036.05	2100.29	2068.17	2002.15	2061.53	2031.84
T_6	2185.08	2259.76	2222.42	2272.63	2336.80	2304.71	2228.85	2298.28	2263.57
T_7	2055.53	2146.42	2100.98	2161.13	2204.66	2182.90	2108.33	2175.54	2141.94
T_8	2103.37	2187.26	2145.32	2223.55	2261.08	2242.32	2163.46	2224.17	2193.82
Mean	**2084.68**	**2158.32**	**2121.50**	**2166.74**	**2231.41**	**2199.08**	**2125.71**	**2194.87**	**2160.29**
Factors	**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**	
V	**11.94**	**24.05**		**7.64**	**15.370**		**9.79**	**19.71**	
T	**25.34**	**51.02**		**16.22**	**32.610**		**20.78**	**41.81**	
V×T	**35.83**	**NS**		**22.94**	**NS**		**29.38**	**NS**	
CV(%)	**7.98**			**8.34**			**8.16**		

Table 8. Effect of priming treatments for 6 hours on vigour index-II in Barley varieties K-409 and K-1055

Treatments	2022-23			2023-24			Pooled		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_0	19.15	19.48	19.31	19.34	19.79	19.57	19.25	19.63	19.44
T_1	19.58	19.92	19.75	19.84	20.15	19.99	19.71	20.04	19.87
T_2	22.47	22.89	22.68	22.74	23.20	22.97	22.60	23.04	22.82
T_3	22.01	22.36	22.19	22.29	22.74	22.52	22.15	22.55	22.35
T_4	20.25	20.55	20.40	20.55	20.71	20.63	20.40	20.63	20.52
T_5	20.00	20.13	20.07	20.16	20.51	20.33	20.08	20.32	20.20
T_6	21.33	21.73	21.53	21.66	21.98	21.82	21.50	21.86	21.68
T_7	20.51	21.03	20.77	20.90	21.34	21.12	20.70	21.19	20.95
T_8	20.85	21.39	21.12	21.27	21.68	21.47	21.06	21.54	21.30
Mean	**20.68**	**21.05**	**20.87**	**20.97**	**21.34**	**21.16**	**20.83**	**21.20**	**21.01**
Factors	**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**		**SE(d)**	**CD 5%**	
V	**0.011**	**0.23**		**0.084**	**0.17**		**0.048**	**0.20**	
T	**0.24**	**0.51**		**0.17**	**0.36**		**0.20**	**0.43**	
V×T	**0.35**	**NS**		**0.25**	**NS**		**0.30**	**NS**	
CV(%)	**5.36**			**5.41**			**5.39**		

4. CONCLUSION

The research conducted has led us to conclude that by priming the seeds with KNO_3 at a concentration of 2.5% for a duration of 6 hours, there is a notable enhancement in the seed quality parameters of Barley. This method has shown significant improvements in the all recorded seed quality parameters., which are crucial factors in achieving successful crop production. Furthermore, among the varieties analyzed, it was observed that variety K-1055 displayed superior performance compared to the other. On the basis of above conclusion it may be recommended that the priming the seeds with KNO_3 at a concentration of 2.5% for a duration of 6 hours and variety K-1055 have potential, for practical utility at the farmer level.

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 writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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