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Seed Priming with Potassium Nitrate Impacts on Germination and Physiological Performance in Carrot

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Introduction: In order to energize the seeds, accelerate the germination process and lessen environmental stress, a range of physiological and non-physiological treatments are available. Seed priming is one of these. It's an inexpensive, effective hydration technique that speeds up germination by increasing the pre-germinative metabolic process through controlled drying and hydration.
Aims: The main aim was to evaluate effect of halo-priming with KNO_3 on germination and vigour of seed.
Materials and Methods: In the present study, which was conducted with three carrot genotypes and varying halo-priming concentrations and durations were employed. A completely randomized design with three replications was used. Three genotypes were Carrot Florence (G_1), Deb Kuroda-1 (G_2) and Deb Kuroda-3 (G_3) with various concentrations and duration of KNO_3 for halo priming viz. 2% for 24 H (T_2), 2% for 18 H (T_3), 3% for 24 H (T_4), 3% for 18 H (T_5), 4% for 24 H (T_6), 4% for 18

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H (T_7) and non-primed seeds (T_1). The different seed quality parameters such as time to 50% germination, mean germination time (MGT), germination index, germination Energy (%), root length, shoot length, fresh weight, dry weight, germination percentage and vigor index were recorded.

Results and Discussion: Seed priming is a practical and affordable way to guarantee consistent seed development in field crops. It improves germination, vigour, nutrient uptake, water use efficiency, and the release of photo- and thermo-dormancy.

Conclusion: Deb Kuroda-3 was the best genotype over all treatments. Consequently, 3% KNO_3 pre-sowing treatment for 24 H is advised for carrot seed in order to improve seedling establishment and vigour.

Keywords: Germination; potassium nitrate; priming; vigour.

1. INTRODUCTION

Carrots (*Daucus carota* L.) are one of India's most important cool season vegetable crops (2n=18). This plant belongs to the Apiaceae family and is biannual. Its rich nutritional content and several health advantages make it extremely popular. Seed is an essential part of crop production as a successful stand establishment requires optimal seed germination. But, these days, a number of abiotic and environmental stressors have a detrimental effect on the seed germination, seedling emergence, and vigour of seedlings, which ultimately results in low agricultural output. Therefore, a variety of physiological and non-physiological treatments are available to invigorate the seeds, speed up the germination process and reduce environmental stress. Among these is seed priming. It's a low-cost, efficient hydration method that uses regulated drying and hydration to boost the pre-germinative metabolic process and promote quick germination. The theory of seed priming was proposed by Heydecker in 1973. According to Basu (1976) and Chakraborty and Bordolui (2021a), seed priming can expedite germination, shorten germination times, and enhance vegetable crop performance under stress. Halo priming involves seeds which are immersed in different salt solutions, which facilitate the process of seed germination and subsequent seedling emergence even under adverse environmental conditions. During this pre-germinative phase, critical enzymes are activated, DNA repair starts, and antioxidants accumulate. This primes the seed to germinate more quickly and uniformly once it's sown. The salt solution creates a mild osmotic stress, prompting the seed to adjust by accumulating compatible solutes (like proline or sugars). This prepares the seed for better stress tolerance after planting. This also can improve ion transport mechanisms and membrane stability. For small seeds, seed priming works very well. Seed priming is a practical and affordable technique used to achieve consistent seed development in field crops. It has positive effects on crop yield, maturity and release of photo- and thermo-dormancy, nutrient uptake, and water use efficiency. In light of the aforementioned considerations, the current study examined the effects of KNO_3 seed priming on vigour status, seedling growth, and germination in a laboratory setting at varying doses and times, using dry seeds as a control.

2. MATERIALS AND METHODS

The present investigation was conducted with three carrot genotypes viz, Carrot Florence (G_1), Deb Kuroda-1 (G_2) and Deb Kuroda-3 (G_3) with various concentrations and duration of KNO_3 for halo priming viz. 2% for 24 H (T_2), 2% for 18 H (T_3), 3% for 24 H (T_4), 3% for 18 H (T_5), 4% for 24 H (T_6), 4% for 18 H (T_7) and non-primed seeds (T_1) at Seed Testing Laboratory, Department of Seed Science and Technology, BCKV, Mohanpur, Nadia, West Bengal during, 2021-22. The seeds were collected from AICRP on Vegetable.

2.1 Time to 50% Germination

The number of seeds that sprouted each day was recorded using the AOSA method. Time of 50% germination (T_{50}) was shown using the following formula of Coolbear *et al.* (1984), which Farooq *et al.* (2005) modified.

$$T_{50} = t_i + \frac{\left(\frac{N}{2} - n_i\right)(t_j - t_i)}{(n_j - n_i)}$$

Where ni, nj, and N are the total number of seeds germinated by adjacent counts at times ti and tj when ni< N/2 <nj, and N is the final number of germination.

2.2 Mean Germination Time (MGT)

The mean germination time was determined using the Ellis and Roberts (1981) equation.

$$\mathrm{MGT} = \frac{\sum \mathrm{Dn}}{\sum \mathrm{n}}$$

Where n is the number of seeds that germinated on day D and D is the number of days measured from the starting of germination.

2.3 Germination Index (GI)

This formula was used to determine the germination index (GI), per AOSA (1990).

$$\mathrm{GI} = \frac{\text{Number of germinated seeds}}{\text{Day of first count}} + - - - - - + \frac{\text{Number of germinated seeds}}{\text{Day of last count}}$$

2.4 Germination Energy

The germination energy (GE) was recorded on the fourth day following the actual planting. It is the proportion of seeds that germinated four days after planting, relative to the total number of seeds tested (Ruan *et al.*, 2002).

2.5 Germination Percentage

There was blotting paper on the cotton after it had been submerged in the petridish. Distilled water was then used to wet it. Following preparation, the seeds were placed on the blotting paper and sealed with a lid. For every genotype and lot, eight petridish pairs were maintained in the germinator. After fourteen days, the petridishes were taken out of the seed germinator, and the quantity of healthy seedlings was tallied. Germination = number of normal seedlings X 100/ total seedlings.

2.6 Seedling Parameters

A scale and graph paper were used to measure the root and shoot lengths of ten seedlings using the glass plate method in the lab at 14 days after germination. The average length was then calculated and expressed in centimeters (cm). Ten seedlings were measured for fresh weight using a digital balance. The seedlings were dried for two hours at 60 to 70 degrees Celsius in a hot air oven before being weighed with a digital balance. The seedlings' fresh and dry weights were expressed in grams (g).

2.7 Vigour Index

The formula recommended by Abdul-Baki and Anderson (1973) was used to calculate the Vigour Index (VI). VI= G X L Where, 'G' stands for germination percentage and 'L' denotes average seedling length (cm).

3. RESULTS AND DISCUSSION

3.1 Time of 50% Germination (Days)

Time of 50% germination was observed lowest in T_4 over genotypes, preceded by T_5 and T_6, whereas maximum was in T_1 (7.383) followed by T_7, T_2, and T_3. Lee *et al.* (1997) reported reduction in time of 50% germination of capsicum when KNO_3 was used to prime seeds. A similar outcome was observed in carrots primed with Ag-nano particles by Kundu and Bordolui (2023). Over the treatments, G_1 had the highest mean germination time (6.983), and G_3 had lowest mean germination time (6.319). Though G_2 and G_3 over treatment were non-significantly differ. The interaction between genotypes and treatments were non-significant variation (Kundu and Bordolui, 2023).

3.2 Mean Germination Time (Days)

In treatment over genotypes T_4 observed the lowest mean germination time preceded by T_5 and T_6 whereas T_1 (8.840) took the highest mean germination time, followed by T_7, T_2, and T_3. El-Sanatawy *et al.* (2021) found that halo priming with KNO_3 improve the mean germination time in maize. Similar findings were made by Ray and Bordolui (2022a) in tomatoes. Over the treatments, G_3 (8.444) had taken the lowest mean germination time and G_1 had highest mean germination time (7.775).

Table 1. Effect of halo-priming on time of 50% germination (days) of carrot genotypes

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	7.950	7.300	6.967	6.100	6.300	6.633	7.633	6.983
G_2	7.333	6.433	6.350	5.267	6.167	6.253	6.700	6.358
G_3	6.867	6.567	6.267	5.633	5.900	6.167	6.833	6.319
Mean G	7.383	6.767	6.528	5.667	6.122	6.351	7.056	
		G	**T**	**GXT**				
SEm (±)		**0.068**	**0.103**	**0.179**				
LSD (0.05)		**0.194**	**0.296**	**NS**				

Where: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
T = Treatment, **T_1 =** Control, T_2= 2% KNO_3 for 24 H, T_3= 2% KNO_3 for 18 H, T_4= 3% KNO_3 for 24 H, T_5=3% KNO_3 for 18 H, T_6= 4% KNO_3 for 24 H and T_7= 4% KNO_3 for 18 H.

Table 2. Effect of halo-priming on mean germination time (days) of carrot genotypes

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	9.407	8.757	8.390	7.557	7.783	8.090	9.127	8.444
G_2	8.790	7.923	7.807	6.767	7.623	7.710	8.200	7.831
G_3	8.323	8.020	7.723	7.107	7.357	7.623	8.270	7.775
Mean G	8.840	8.233	7.973	7.143	7.588	7.808	8.532	
		G	**T**	**GXT**				
SEm (±)		**0.070**	**0.107**	**0.186**				
LSD (0.05)		**0.201**	**0.307**	**NS**				

Where: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
T = Treatment, **T_1 =** Control, T_2= 2% KNO_3 for 24 H, T_3= 2% KNO_3 for 18 H, T_4= 3% KNO_3 for 24 H, T_5=3% KNO_3 for 18 H, T_6= 4% KNO_3 for 24 H and T_7= 4% KNO_3 for 18 H.

3.3 Germination Index

T_4 produced the highest germination index (6.468) over genotypes, followed by T_5, T_6, and T_3, whereas T_1 had the least germination index, preceded by T_2 and T_3. El-Sanatawy *et al.* (2021) found that halo priming with KNO_3 improve the germination index in maize. Over the treatments, G_3 showed the highest germination index (5.910), and G_1 noted the lowest germination index (5.139). When the interaction effect of genotypes and seed treatments were taken into consideration, G_3T_4 showed highest value (6.650) for this parameter. Here, G_1T_1, G_2T_1; G_2T_5, G_2T_6 and G_3T_5, G_3T_6 were statistically at per.

3.4 Germination Energy (%)

Over genotypes, T_4 (39.000) produced the shoots with the highest germination energy followed by T_5, T_6, and T_3, whereas T_1 had the least length, preceded by T_2 and T_3. Over the treatments, similar type of result was observed like germination index.

Table 3. Effect of halo-priming on Germination index of carrot genotypes

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	2.187	5.250	5.433	6.287	6.000	5.600	5.217	5.139
G_2	2.240	6.227	6.273	6.467	6.433	6.353	6.173	5.738
G_3	2.500	6.367	6.467	6.650	6.597	6.563	6.227	5.910
Mean G	2.309	5.948	6.058	6.468	6.343	6.172	5.872	
		G	**T**	**GXT**				
SEm (±)		**0.014**	**0.021**	**0.037**				
LSD (0.05)		**0.040**	**0.061**	**0.106**				

Where: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
T = Treatment, **T_1 =** Control, T_2= 2% KNO_3 for 24 H, T_3= 2% KNO_3 for 18 H, T_4= 3% KNO_3 for 24 H, T_5=3% KNO_3 for 18 H, T_6= 4% KNO_3 for 24 H and T_7= 4% KNO_3 for 18 H.

Table 4. Effect of halo-priming on germination energy (%) of carrot genotypes

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	21.000 (27.260)	35.367 (36.476)	34.500 (35.956)	37.333 (37.647)	36.840 (37.355)	36.200 (36.974)	33.367 (35.064)	33.515 (35.277)
G_2	22.000 (27.960)	36.450 (37.123)	35.473 (36.540)	39.167 (38.727)	37.367 (37.667)	36.717 (37.282)	34.680 (36.064)	34.550 (35.909)
G_3	23.167 (28.760)	37.900 (37.982)	37.200 (37.982)	40.500 (39.508)	39.333 (38.825)	38.573 (37.379)	36.567 (37.193)	36.177 (36.888)
Mean G	22.056 (27.993)	36.572 (37.194)	35.724 (36.688)	39.000 (38.627)	37.847 (37.949)	37.163 (37.545)	34.871 (36.888)	
		G	**T**	**GXT**				
SEm (±)		**0.062**	**0.095**	**0.165**				
LSD (0.05)		**0.178**	**0.273**	**NS**				

Where: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
T = Treatment, **T_1 =** Control, T_2= 2% KNO_3 for 24 H, T_3= 2% KNO_3 for 18 H, T_4= 3% KNO_3 for 24 H, T_5=3% KNO_3 for 18 H, T_6= 4% KNO_3 for 24 H and T_7= 4% KNO_3 for 18 H.

3.5 Shoot Length (cm)

The longest magnitude of shoot length was recorded in T_4 (3.317) over genotypes, followed by T_6, T_5, and T_2, whereas T_1 had the least length, preceded by T_3 and T_7. Over the treatments, G_3 (3.302) had the highest shoot length and G_1 (2.771 cm) had the smallest shoot length. Though over treatment G_1 and G_2 were non-significantly differ with each other. When the interaction effect of genotypes and seed treatments were taken into consideration, G_3T_4 (3.583 cm) showed highest value for this parameter. Here, G_2T_1, G_1T_7; G_2T_2, G_2T_1 and G_2T_5, G_2T_6 were statistically at par. Using sodium molybdate (Na_2MoO_4) nutri-priming to lengthen shoots, Choudhury and Bordolui (2022a) observed similar results in Bengal gram.

3.6 Root Length (cm)

The longest root length over genotypes was observed to produce by T_4 (3.002) on an average followed by T_6, T_5, and T_2 whereas T_1 had the least length, preceded by T_3 and T_7. El-Choudhury and Bordolui (2022b) found that halo priming with KNO_3 improve the root length in chickpea. Highest root length (2.872 cm) was observed for G_3 and shortest root length was recognized for G_1 (2.554 cm) over treatments.

3.7 Seedling Length (cm)

T_1 (4.372 cm) generated seedlings with the shortest lengths over genotypes, which were preceded by T_3 and T_7 while T_4 (6.319 cm) produced seedlings with highest length of, followed by T_6, T_5, and T_2. Similar type of result was noted by Shaban *et al*., 2018 and Kumar *et al*., 2023. G_3 (6.174 cm) had the longest seedlings and G_1 (5.326 cm) had the shortest seedlings over treatments. Here, G_2 and G_3 were non- significantly differ. When the interaction effect of genotypes and seed treatments were taken into consideration, G_3T_4 showed highest value (6.757 cm) for this parameter. Here, G_2T_5, G_2T_6; G_1T_5, G_1T_5; G_3T_7, G_3T_4 were statistically at par.

Table 5. Effect of halo-priming on shoot length (cm) of carrot genotypes

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	2.133	2.867	2.633	3.133	2.900	2.933	2.800	2.771
G_2	2.287	3.133	2.267	3.233	3.100	3.150	2.963	2.876
G_3	2.380	3.483	3.367	3.583	3.483	3.517	3.300	3.302
Mean G	2.267	3.161	2.756	3.317	3.161	3.200	3.021	
		G	**T**	**GXT**				
SEm (±)		**0.018**	**0.027**	**0.046**				
LSD (0.05)		**0.050**	**0.077**	**0.133**				

Where: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
T = Treatment, **T_1 =** Control, T_2= 2% KNO_3 for 24 H, T_3= 2% KNO_3 for 18 H, T_4= 3% KNO_3 for 24 H, T_5=3% KNO_3 for 18 H, T_6= 4% KNO_3 for 24 H and T_7= 4% KNO_3 for 18 H.

Table 6. Effect of halo-priming on Root length (cm) of carrot genotypes

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	1.833	2.557	2.453	2.867	2.733	2.760	2.677	2.554
G_2	2.200	2.720	2.620	2.967	2.833	2.813	2.697	2.693
G_3	2.283	2.857	2.750	3.173	3.067	3.103	2.870	2.872
Mean G	2.106	2.711	2.608	3.002	2.878	2.892	2.748	
		G	**T**	**GXT**				
SEm (±)		**0.018**	**0.027**	**0.047**				
LSD (0.05)		**0.051**	**0.077**	**NS**				

Where: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
T = Treatment, **T_1 =** Control, T_2= 2% KNO_3 for 24 H, T_3= 2% KNO_3 for 18 H, T_4= 3% KNO_3 for 24 H, T_5=3% KNO_3 for 18 H, T_6= 4% KNO_3 for 24 H and T_7= 4% KNO_3 for 18 H.

Table 7. Effect of halo-priming on seedling length (cm) of carrot genotypes

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	3.967	5.423	5.087	6.000	5.633	5.693	5.477	5.326
G_2	4.487	5.853	4.887	6.200	5.933	5.963	5.660	5.569
G_3	4.663	6.340	6.117	6.757	6.550	6.620	6.170	6.174
Mean G	4.372	5.872	5.363	6.319	6.039	6.092	5.769	
		G	**T**	**GXT**				
SEm (±)		**0.031**	**0.047**	**0.081**				
LSD (0.05)		**0.088**	**0.135**	**0.233**				

Where: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
T = Treatment, **T_1 =** Control, T_2= 2% KNO_3 for 24 H, T_3= 2% KNO_3 for 18 H, T_4= 3% KNO_3 for 24 H, T_5=3% KNO_3 for 18 H, T_6= 4% KNO_3 for 24 H and T_7= 4% KNO_3 for 18 H.

3.8 Germination Percentage

The highest germination percentage over genotypes was observed to produce by T_4 (89.430) on an average followed by T_5, T_6, and T_7, whereas T_1 had the least length, preceded by T_3 and T_2. An analogous result was found in tomatoes by Ray and Bordolui (2022b). Highest germination percentage (87.838) was observed for G_2 and lowest germination percentage (85.969) was recognized for G_1 over treatments. Though G_1 and G_3 over treatment were non-significantly differ.

Table 8. Effect of halo-priming on Germination percentage (tr value) of carrot genotypes

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	81.927	85.703	85.187	88.667	87.633	86.670	85.993	85.969
	(64.817)	(67.761)	(67.337)	(70.306)	(69.388)	(68.559)	(67.995)	(68.023)
G_2	84.033	87.000	87.383	90.640	89.333	88.833	87.640	87.838
	(66.422)	(68.847)	(69.168)	(72.159)	(70.911)	(70.451)	(69.402)	(69.623)
G_3	82.733	87.350	86.723	88.983	88.067	87.667	86.767	86.899
	(65.423)	(69.139)	(68.604)	(70.596)	(69.772)	(69.415)	(68.645)	(68.799)
Mean G	82.898	86.684	86.431	89.430	88.344	87.723	86.800	
	(65.554)	(68.582)	(68.370)	(71.020)	(70.024)	(69.475)	(68.680)	
		G	**T**	**GXT**				
SEm (±)		**0.119**	**0.182**	**0.315**				
LSD (0.05)		**0.341**	**0.521**	**NS**				

Where: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
T = Treatment, **T_1 =** Control, T_2= 2% KNO_3 for 24 H, T_3= 2% KNO_3 for 18 H, T_4= 3% KNO_3 for 24 H, T_5=3% KNO_3 for 18 H, T_6= 4% KNO_3 for 24 H and T_7= 4% KNO_3 for 18 H.

3.9 Vigour Index-I

Considering vigour index-I over genotypes, maximum value was calculated for T_4, i.e., 554.172 followed by T_5, T_6, and T_3; minimum vigour index was noted for T_1, i.e., 409.564 preceded by T_2 and T_3. Over the treatments, G_3 (543.886) recorded the highest vigour index and G_1 showed the lowest vigour index (461.719). Though G_1 and G_3 over treatment were non-significantly differ.

3.10 Fresh weight (mg) of Seedlings

Over genotypes T_4 (106.444) produced the highest fresh weight of ten seedlings T_6, T_5 and T_2; in contrast, T_1 (control) produced the lowest fresh weight preceded by T_3 and T_7. El-Sanatawy *et al.* (2021) found that halo priming with KNO_3 improve the fresh weight in maize. Comparing Ag nano priming to other treatments, Chakraborty and Bordolui (2021b) found that it increased the fresh weight of green grams seedlings. Genotype over treatments, G_3 showed the highest fresh weight (97.476) and G_1 (89.476) had the lowest fresh weight. When seed treatments and genotype interactions were taken into account, G_3T_4 (109.000) displayed the highest value for this parameter.

3.11 Dry Weight (mg) Seedlings

The highest dry weight over genotypes was observed to produce by T_4 (11.826) followed by T_6, T_5 and T_2; while it was of lowest dry weight in T_1 (control) preceded by T_3 and T_7. Kundu and Bordolui (2025) found a similar result in carrots after osmo-priming. Highest dry weight (10.831) was observed for G_3 and lowest dry weight (9.941) was recognized for G_1, Though G_2 and G_3 over treatment were non-significantly differ. The interaction between genotypes and seed treatments G_3T_4 (12.110) showed highest value for this parameter but G_1T_2, G_2T_7 and G_2T_6, G_2T_5 were statistically at par.

Table 9. Effect of halo-priming on Vigour Index-I of carrot genotypes

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	376.942	454.719	463.274	517.267	495.613	487.659	436.561	461.719
G_2	419.037	478.763	476.347	551.439	527.113	522.345	462.354	491.057
G_3	432.713	545.381	554.988	593.810	576.872	568.067	535.373	543.886
Mean G	409.564	492.954	498.203	554.172	533.200	526.023	478.096	
		G	**T**	**GXT**				
SEm (±)		**9.141**	**13.964**	**24.186**				
LSD (0.05)		**26.225**	**40.059**	**NS**				

Note: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
Where: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
T = Treatment, **T_1 =** Control, T_2= 2% KNO_3 for 24 H, T_3= 2% KNO_3 for 18 H, T_4= 3% KNO_3 for 24 H, T_5=3% KNO_3 for 18 H, T_6= 4% KNO_3 for 24 H and T_7= 4% KNO_3 for 18 H.

Table 10. Effect of halo-priming on seedling fresh weight (mg) of carrot genotypes

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	62.333	92.333	85.667	102.333	95.000	99.667	89.000	89.476
G_2	66.000	97.000	90.000	108.000	100.333	104.333	93.000	94.095
G_3	68.333	101.667	95.333	109.000	103.333	106.000	98.667	97.476
Mean G	65.556	97.000	90.333	106.444	99.556	103.333	93.556	
		G	**T**	**GXT**				
SEm (±)		**0.233**	**0.356**	**0.617**				
LSD (0.05)		**0.668**	**1.021**	**1.768**				

Where: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
T = Treatment, **T_1 =** Control, T_2= 2% KNO_3 for 24 H, T_3= 2% KNO_3 for 18 H, T_4= 3% KNO_3 for 24 H, T_5=3% KNO_3 for 18 H, T_6= 4% KNO_3 for 24 H and T_7= 4% KNO_3 for 18 H.

Table 11. Effect of halo-priming on Seedling Dry Weight (mg) of carrot genotypes

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	6.927	10.257	9.517	11.367	10.557	11.073	9.890	9.941
G_2	7.330	10.780	10.000	12.000	11.147	11.597	10.333	10.455
G_3	7.593	11.293	10.597	12.110	11.480	11.780	10.963	10.831
Mean G	7.283	10.777	10.038	11.826	11.061	11.483	10.396	
		G	**T**	**GXT**				
SEm (±)		**0.026**	**0.040**	**0.069**				
LSD (0.05)		**0.074**	**0.114**	**0.197**				

Where: G = Genotypes, **G_1 =** Carrot Florence, **G_2 =** Deb Kuroda-1, **G_3 =** Deb Kuroda-3
T = Treatment, **T_1 =** Control, T_2= 2% KNO_3 for 24 H, T_3= 2% KNO_3 for 18 H, T_4= 3% KNO_3 for 24 H, T_5=3% KNO_3 for 18 H, T_6= 4% KNO_3 for 24 H and T_7= 4% KNO_3 for 18 H.

4. CONCLUSIONS

Carrot seeds treated with 3% KNO_3 for 24H duration had better seed quality than the control. In comparison to other priming concentration and duration, 3% KNO_3 for 24H was the most effective treatment over genotypes. Significantly highest germination index, germination energy, highest seedling length, fresh weight, dry weight and vigour index and lowest mean germination time were noted for Deb Kuroda-3 (G_3) while only highest germination percentage, was observed for Deb Kuroda-1(G_2). So, Deb Kuroda-3 is best considering the all parameters. Consequently, 3% KNO_3 for 24H duration is advised as a pre-sowing treatment for carrot seeds in order to improve seedling establishment.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors hereby affirm that no generative AI tools, including text-to-image generators and large language models (ChatGPT, COPILOT, etc.), were used in the composition or editing of this work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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