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Silver Nanoparticles –mediate Seed priming Improves Germination and Physiological Performance in Carrot

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ABSTRACT: Present investigation was carried out with three carrot *viz*., Carrot Florence (G_1), Deb Kuroda-1 (G_2), Deb Kuroda-3 (G_3) and different concentration and durations of Ag-Nanoparticles were 20 ppm for 12 hrs (T_2), 20 ppm for 6 hrs (T_3), 15 ppm for 12 hrs (T_4), 15 ppm for 6 hrs (T_5), 10 ppm for 12 hrs (T_6), 10 ppm for 6 hrs (T_7), non-primed seeds (T_0) with the objectives for enhancing the germination and vigour. Seed priming is a pre-sowing treatment which results in a physiological condition that allows seed to germinate more efficient. The laboratory experiment was carried out in seed testing laboratory, Department of Seed science and Technology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India. From the experiment, it can be concluded that treatments over genotypes, Ag-Nanoparticles 20 ppm for soaking 6 hrs showed best performer as seeds treated with Ag-Nanoparticles 20 ppm for soaking 6 hrs observed the significant higher potential than other priming concentrations and durations. Genotypes over treatments Deb Kuroda-3 was the best genotypes. Ag-Nanoparticles 20 ppm for soaking 6 hrs showed significantly highest performance for seed quality parameter like germination percentage (95.244), germination energy (53.167), seedling vigour Index-I (854.722), and germination index (6.778). Therefore, as pre-sowing treatment Ag-Nanoparticles 20 ppm with a duration of 6 hrs is recommended for treating carrot seed for better seedling establishment.

Keywords: Ag-Nanoparticles, germination, priming, vigour.

INTRODUCTION

Carrot (*Daucus carota* L.) (2n=18) is one of the most important vegetable crop in India. The carrot is a biennial plant in the Apiaceae family. Optimum seed germination is a prime condition in good stand establishment as seed is a fundamental factor in crop production. Nowadays, due to different environmental and abiotic stress, the percentage of seed germination, emergence, and vigour of seedling has been adversely affected, which ultimately results in poor crop yield. To enhance the seed germination process various physiological and non-physiological techniques are available for enhancing seed performance as well as to combat environmental constraints. Seed priming is a low-cost effective hydration technique to stimulate seed germination. During priming, seeds go through a physiological process, i.e. controlled hydration and drying which results in enhanced and improved pre-germinative metabolic process for rapid germination . Seed priming can synchronize seed germination, and increase emergence. The theory of seed priming was proposed by Heydecker (1973). Seed priming is an effective technology to enhance rapid and uniform emergence and to achieve high vigour, leading to better stand establishment and yield. So to invigorate the seeds, accelerate the germination process, and alleviate the environmental stress, different seed priming methods have been developed including Osmo-priming, Nano-priming, Halo-priming.

Nano-priming is an efficient process that can change seed metabolism and signalling pathways, affecting not only germination and seedling establishment but also the entire plant lifecycle. Studies have shown various benefits of using seed nano-priming, such as improved plant growth and development, increased productivity, and a better nutritional quality of food. Seed priming can decrease the time of germination, increase the rate of germination and improve the performance of the crop in stress condition. It also leads the seedling emerge from the soil faster and uniform. Seed priming is highly suitable for small sized seeds. To obtain uniform seed development in different crops, seed priming is used, which is an economical and feasible technology (Pradhan *et al*., 2022). It has beneficial effects such as nutrient uptake, water use efficiency, release photo- and thermo-dormancy, maturity, and crop yield.

So, our objective was to determination of appropriate concentration and duration of Ag-Nanoparticles, essential for priming of carrot seed. Keeping the above points, the present investigation was carried out after

seed prime with Ag-Nanoparticles in different concentrations and durations, and dry seeds as control in laboratory condition on germination, seedling growth and vigour status.

MATERIALS AND METHODS

The present investigation entitled was conducted with three carrot genotypes and different concentration and durations of nano priming at Seed Testing Laboratory, Department of Seed Science and Technology, F/Ag., BCKV, Mohanpur, Nadia, West Bengal during, 2021-22 following Complete Randomized Design with three replications. Three carrot genotypes were Carrot Florence (G_1), Deb Kuroda-1 (G_2), Deb Kuroda-3 (G_3). Different concentration and durations of Ag-Nanoparticles were 20 ppm for 12 hrs (T_2), 20 ppm for 6 hrs (T_3), 15 ppm for 12 hrs (T_4), 15 ppm for 6 hrs (T_5), 10 ppm for 12 hrs (T_6) and 10 ppm for 6 hrs (T_7). Non-primed seeds were the control (T0). The seeds were collected from Pahuja Seeds Pvt. Ltd. The collected seed were examined in Seed Testing Laboratory.

Germination potential

Time to 50% germination

According to the AOSA approach, the number of seeds that germinated each day was recorded. The following formulas from Coolbear *et al.* (1984), as modified by Farooq *et al.* (2005), were used to determine the time to achieve 50% germination (T50):

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

Where, N stands for final number of germination and n_i, n_j are cumulative number of seeds germinated by adjacent counts at times t_i and t_j when $n_i < N/2 < n_j$.

Mean germination time (MGT)

The Ellis and Roberts (1981) equation was used to compute the mean germination time (MGT):

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

Where, n indicates the number of seeds, which were germinated on day D, and D is the number of days counted from the beginning of germination.

Germination percentage

Germination percentage (G) is calculated as:

$$G = \frac{X}{Y} \times 100$$

Where Y is the total number of seeds taken for germination and X represents the number of normal seedlings produced (ISTA, 1996). It is outlined as a percentage.

Germination index (GI). According to AOSA (1990), the germination index (GI) was computed using the following formula:

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

Germination Energy. On the fourth day after planting, the energy of germination (GE) was measured. In relation to the total number of seeds tested, it is the percentage of seeds that germinated 4 days after planting (Ruan *et al*., 2002).

Germination percentage. Cotton was placed in the petridish, and then the blotting paper was placed on it. After that it was wetted by distilled water. The treated seeds were placed on the blotting paper and covered it with lid. Such eight pairs of petridish as were kept in the germinator for each genotype and lot. After fourteen days, the petridish as were taken out from seed germinator and numbers of germinated and ungerminated seeds were counted.

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds}} \times 100$$

Calculation:

Seedling parameters: Root lengths and shoot lengths of ten seedlings were measured at 14 days after germination by glass plate method in the laboratory with the help of a scale and graph paper and average was made out, expressed in centimetre (cm). Fresh weight of ten seedlings was measured with the help of a digital balance. Then seedlings were dried at 60-70°C for two hours in hot air oven and weighed in a digital balance. Both seedling fresh weight and dry weight were expressed in gram (g).

Vigour index: Vigour index (VI) was calculated by using the formula suggested by Abdul Baki and Anderson (1973): VI = G × L, Where 'G' indicates germination percentage and 'L'
denotes average seedling length (cm)

RESULTS AND DISCUSSION

Enhancement of physiological activity of carrot seed by Nano-priming

Time of 50% Germination (Days). Significant influence of treatments over genotypes in time of 50% germination could be noticed in carrot and it was lowest after treating with T_3 than other treatments. It was the best as it was taken less time to germinate. Highest was observed in control. Performance of G_3 (3.396 days) average over treatments was best as it was taken less time (Table 1). On the other hand, the trend in performance of individual genotypes was almost similar after individual treatments. When the interaction effect of genotypes and seed treatments was taken into consideration, G_1T_1 showed highest value (7.767 days) for this parameter. Statistically non-significant was observed in some interaction like G_1T_5, G_2T_5; G_1T_3, G_2T_3; G_1T_7, G_2T_6.

Table 1: Effect of Nano-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	7.767	3.173	3.040	3.316	3.101	3.705	3.458	3.937
G_2	6.503	3.247	3.053	3.291	3.146	3.496	3.367	3.729
G_3	5.463	3.050	2.945	3.065	3.000	3.164	3.086	3.396
Mean G	6.578	3.157	3.013	3.224	3.082	3.455	3.303	
		G	**T**	**G × T**				
SEm (±)		**0.022**	**0.033**	**0.057**				
LSD (0.05)		**0.062**	**0.94**	**0.163**				

Note: G = Genotypes, **G_1** = Carrot Florence, **G_2** = Deb Kuroda-1, **G_3** = Deb Kuroda-3
T = Treatment, **T_1** = Control, **T_2** = 20 ppm AgNP for 12 hrs, **T_3** = 20 ppm AgNP for 6 hrs, **T_4** = 15 ppm AgNP for 12 hrs, **T_5** = 15 ppm AgNP for 6 hrs, **T_6** = 10 ppm AgNP for 12 hrs, **T_7** = 10 ppm AgNP for 6 hrs

Mean Germination Time (days). In case of treatments over genotypes T_1 showed highest mean germination time followed by T_6, T_7, and T_4, whereas T_3 observed the lowest mean germination time, preceded by T_5 and T_2. Similar type of result was found by Ray and Bordolui (2022a) in tomato. Over the treatments, G_1 had the highest mean germination time (5.314), and G_3 had lowest mean germination time. When the interaction effect of genotypes and seed treatments were taken into consideration, G_1T_1 showed highest value (9.143) for this parameter. Here, G_1T_2, G_2T_4, G_2T_7; G_2T_3, G_3T_3; G_1T_5 and G_2T_5 were statistically at per.

Germination index. Greater influence was in T_3 (6.778) over that genotypes, followed by T_5, T_2 and T_4; while it was of lowest germination index for T_1 (control) preceded by T_6 and T_7. Chakraborty and Bordolui (2021) found that, nano priming by AgNP improve the germination index of green gram. Highest germination index (6.132) was observed for G_2 and lowest germination index (4.645) was recognized for G_1, over treatments. When the interaction effect of genotypes and seed treatments were taken into consideration, G_3T_3 showed highest value (7.600) for this parameter. Some interactions were statistically at per G_1T_1, G_2T_1; G_3T_1; G_1T_6, G_1T_7 and G_3T_6, G_3T_7.

Table 2: Effect of Nano-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	9.143	4.550	4.417	4.692	4.477	5.082	4.835	5.314
G_2	7.880	4.624	4.430	4.667	4.523	4.873	4.743	5.106
G_3	6.840	4.426	4.322	4.441	4.377	4.540	4.462	4.773
Mean G	7.954	4.533	4.389	4.600	4.459	4.832	4.680	
		G	**T**	**G × T**				
SEm (±)		**0.022**	**0.034**	**0.059**				
LSD (0.05)		**0.064**	**0.098**	**0.169**				

Note: G = Genotypes, **G_1** = Carrot Florence, **G_2** = Deb Kuroda-1, **G_3** = Deb Kuroda-3
T = Treatment, **T_1** = Control, **T_2** = 20 ppm AgNP for 12 hrs, **T_3** = 20 ppm AgNP for 6 hrs, **T_4** = 15 ppm AgNP for 12 hrs, **T_5** = 15 ppm AgNP for 6 hrs, **T_6** = 10 ppm AgNP for 12 hrs, **T_7** = 10 ppm AgNP for 6 hrs

Table 3: Effect of Nano -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	2.150	5.233	6.000	4.833	5.500	4.333	4.467	4.645
G_2	2.160	6.233	6.733	6.033	6.567	5.400	5.733	5.551
G_3	2.190	6.700	7.600	6.553	7.133	6.333	6.417	6.132
Mean G	2.167	6.056	6.778	5.807	6.400	5.356	5.539	
		G	**T**	**G × T**				
SEm (±)		**0.030**	**0.046**	**0.080**				
LSD (0.05)		**0.087**	**0.133**	**0.230**				

Note: G = Genotypes, **G_1** = Carrot Florence, **G_2** = Deb Kuroda-1, **G_3** = Deb Kuroda-3
T = Treatment, **T_1** = Control, **T_2** = 20 ppm AgNP for 12 hrs, **T_3** = 20 ppm AgNP for 6 hrs, **T_4** = 15 ppm AgNP for 12 hrs, **T_5** = 15 ppm AgNP for 6 hrs, **T_6** = 10 ppm AgNP for 12 hrs, **T_7** = 10 ppm AgNP for 6 hrs

Germination Energy (%). The highest germination energy over genotypes was observed to produce by T_3 (53.167) on an average followed by T_5, T_2 and T_4; while it was for T_1 (control) preceded by T_6 and T_7. Similar type of result was found by Chakraborty and Bordolui (2021) in green gram by using AgNP. Highest germination energy was observed for G_2 (6.132) and lowest germination energy was recognized for G_1 (4.645), over treatments. G_3T_3 showed highest value (54.833) for this parameter when the interaction between genotypes and seed treatments taken into consideration. Here, G_1T_2, G_1T_5; G_1T_4, G_2T_7; G_2T_2, G_3T_4 were statistically at per.

Table 4: Effect of Nano -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	19.000 (25.827)	49.300 (44.581)	51.167 (45.650)	47.967 (43.817)	49.600 (44.753)	45.500 (42.401)	46.500 (42.976)	44.862 (41.928)
G_2	21.667 (27.721)	50.250 (45.125)	53.500 (46.988)	48.500 (44.123)	52.500 (46.414)	46.167 (42.784)	47.833 (43.740)	45.774 (42.414)
G_3	24.000 (29.321)	51.800 (46.013)	54.833 (47.755)	50.667 (45.364)	53.933 (47.237)	48.833 (44.314)	50.667 (45.364)	47.105 (43.125)
Mean G	21.556 (27.623)	50.450 (45.240)	53.167 (46.798)	49.044 (44.434)	52.011 (44.753)	46.833 (43.166)	48.333 (41.928)	
		G	T	G × T				
SEm (±)		0.100	0.153	0.264				
LSD (0.05)		0.286	0.437	0.757				

Note: G = Genotypes, G_1 = Carrot Florence, G_2 = Deb Kuroda-1, G_3 = Deb Kuroda-3
T = Treatment, T_1 = Control, T_2 = 20 ppm AgNP for 12 hrs, T_3 = 20 ppm AgNP for 6 hrs, T_4 = 15 ppm AgNP for 12 hrs, T_5 = 15 ppm AgNP for 6 hrs, T_6 = 10 ppm AgNP for 12 hrs, T_7 = 10 ppm AgNP for 6 hrs

Shoot Length (cm). The longest shoot length over genotypes was observed to produce by T_3 (5.073) on an average followed by T_5, T_4 and T_2; while it was of shortest length for T_1 preceded by T_6 and T_7. Choudhury and Bordolui (2022a) observed similar result in bengal gram by using sodium molybdate (Na_2MoO_4) nutri-priming improve the shoot length. Highest shoot length (4.666 cm) was observed for G_3 and shortest shoot length (4.467 cm) was recognized for G_1, over treatments (Table 4.02.05). Though G_1 and G_3 over treatment were non-significantly differ. When the interaction effect of genotypes and seed treatments were taken into consideration, G_3T_5 showed highest value (4.392 cm) for this parameter.

Root length (cm). T_3 (3.900 cm) produced the roots with the longest length over genotypes, followed by T_2, T_5, and T_7, whereas T_1 had the least length, preceded by T_6 and T_4. Similar type of result was observed by Choudhury and Bordolui (2022b) in bengal gram by using potassium nitrate. Over the treatments, G_3 had the highest root length (3.656 cm), and G_1 had the smallest root length (3.497 cm). When the interaction effect of genotypes and seed treatments were taken into consideration, G_3T_3 showed highest value (3.997 cm) for this parameter.

Table 5: Effect of Nano -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	2.500	4.833	5.000	4.750	4.833	4.653	4.700	4.467
G_2	2.567	5.000	5.100	4.933	5.087	4.763	4.843	4.613
G_3	2.583	5.033	5.120	5.100	5.177	4.800	4.850	4.666
Mean G	2.550	4.956	5.073	4.928	5.032	4.739	4.798	
		G	T	G × T				
SEm (±)		0.016	0.024	0.042				
LSD (0.05)		0.046	0.70	NS				

Note: G = Genotypes, G_1 = Carrot Florence, G_2 = Deb Kuroda-1, G_3 = Deb Kuroda-3
T = Treatment, T_1 = Control, T_2 = 20 ppm AgNP for 12 hrs, T_3 = 20 ppm AgNP for 6 hrs, T_4 = 15 ppm AgNP for 12 hrs, T_5 = 15 ppm AgNP for 6 hrs, T_6 = 10 ppm AgNP for 12 hrs, T_7 = 10 ppm AgNP for 6 hrs

Table 6: Effect of Nano -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	2.400	3.743	3.800	3.617	3.683	3.600	3.637	3.497
G_2	2.417	3.843	3.903	3.700	3.780	3.667	3.727	3.577
G_3	2.517	3.883	3.997	3.783	3.853	3.747	3.813	3.656
Mean G	2.444	3.823	3.900	3.700	3.772	3.671	3.726	
		G	T	G × T				
SEm (±)		0.018	0.028	0.048				
LSD (0.05)		0.052	0.080	NS				

Note: G = Genotypes, G_1 = Carrot Florence, G_2 = Deb Kuroda-1, G_3 = Deb Kuroda-3
T = Treatment, T_1 = Control, T_2 = 20 ppm AgNP for 12 hrs, T_3 = 20 ppm AgNP for 6 hrs, T_4 = 15 ppm AgNP for 12 hrs, T_5 = 15 ppm AgNP for 6 hrs, T_6 = 10 ppm AgNP for 12 hrs, T_7 = 10 ppm AgNP for 6 hrs

Seedling length (cm). Seedling length was maximum (8.937cm) in T_3 followed by T_5, T_2 and T_4; it was of shortest length (4.994cm) for T_1 preceded by T_6 and T_7 (Table 4.02.07). Chakraborty and Bordolui, (2021) found that, nano priming by AgNP improve the seedling length of green gram. Among the genotypes over treatments G_3 became able to produce seedlings with longest length i.e., (8.237 cm) and G_1 had the shortest shoots over treatments (7.964 cm). When the interaction effect of genotypes and seed treatments

were taken into consideration, G_3T_3 showed highest value (9.117 cm) for this parameter.

Table 7: Effect of Nano -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	4.900	8.577	8.800	8.367	8.517	8.253	8.337	7.964
G_2	4.983	8.843	9.003	8.633	8.867	7.747	8.570	8.092
G_3	5.100	8.917	9.117	8.883	9.030	7.950	8.663	8.237
Mean G	4.994	8.779	8.973	8.628	8.804	7.983	8.523	
		G	T	G × T				
SEm (±)		0.046	0.070	0.122				
LSD (0.05)		0.132	0.201	NS				

Note: G = Genotypes, G_1 = Carrot Florence, G_2 = Deb Kuroda-1, G_3 = Deb Kuroda-3
T = Treatment, T_1 = Control, T_2 = 20 ppm AgNP for 12 hrs, T_3 = 20 ppm AgNP for 6 hrs, T_4 = 15 ppm AgNP for 12 hrs, T_5 = 15 ppm AgNP for 6 hrs, T_6 = 10 ppm AgNP for 12 hrs, T_7 = 10 ppm AgNP for 6 hrs

Germination percentage. The highest germination percentage (95.244) over genotypes was observed for T_3 followed by T_2, T_5 and T_4 where T_1 (control) showed lowest magnitude preceded by T_6 and T_7. Similar type of result was found by Ray and Bordolui (2022b) in tomato. Over the treatments, G_1 had the lowest germination percentage while G_2 showed the highest value. The interaction effect of genotypes and seed treatments G_3T_3 showed highest value (95.233) for this parameter.

Vigour Index. Treatments over genotypes highest vigour index (854.722) was observed in T_3 followed by T_5, T_2 and T_4; while it was minimum for T_1 preceded by T_6 and T_7. Chakraborty and Bordolui (2021) observed that nano priming by AgNP improve the vigour index of green gram. Genotypes over treatments, the highest vigour index (770.607) was observed for G_2 and lowest (738.503) was recognized for G_1. Though G_2 and G_3 over treatment were non-significantly differ. Interaction effect of genotypes and seed treatments non-significantly differ with each other but G_3T_3 showed highest value (868.233) for this parameter.

Table 8: Effect of Nano -priming on Germination percentage of carrot genotypes.

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	85.583 (67.661)	93.833 (75.593)	94.533 (76.459)	93.267 (74.932)	93.767 (75.514)	92.000 (73.545)	93.000 (74.629)	92.283 (74.048)
G_2	88.133 (69.823)	95.533 (77.778)	95.967 (78.384)	94.767 (76.747)	95.200 (77.316)	93.633 (75.356)	93.933 (75.711)	93.881 (75.874)
G_3	86.967 (68.818)	94.600 (76.542)	95.233 (77.361)	94.333 (76.202)	94.800 (76.790)	92.470 (74.047)	93.470 (74.169)	93.125 (74.990)
Mean G	86.894 (68.767)	94.656 (76.638)	95.244 (77.401)	94.122 (75.960)	94.589 (76.540)	92.701 (74.316)	93.468 (75.169)	
		G	T	G × T				
SEm (±)		0.097	0.148	0.256				
LSD (0.05)		0.277	0.424	NS				

Note: G = Genotypes, G_1 = Carrot Florence, G_2 = Deb Kuroda-1, G_3 = Deb Kuroda-3
T = Treatment, T_1 = Control, T_2 = 20 ppm AgNP for 12 hrs, T_3 = 20 ppm AgNP for 6 hrs, T_4 = 15 ppm AgNP for 12 hrs, T_5 = 15 ppm AgNP for 6 hrs, T_6 = 10 ppm AgNP for 12 hrs, T_7 = 10 ppm AgNP for 6 hrs

Table 9: Effect of Nano -priming on Vigour Index of carrot genotypes.

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	419.300	804.767	831.897	780.330	798.593	759.320	775.313	738.503
G_2	439.243	844.843	864.037	818.147	844.110	725.467	805.003	762.979
G_3	443.563	843.530	868.233	837.997	856.033	735.140	809.750	770.607
Mean G	434.036	831.047	854.722	812.158	832.912	739.976	796.689	
		G	T	G × T				
SEm (±)		4.451	6.798	11.775				
LSD (0.05)		12.746	19.471	NS				

Note: G = Genotypes, G_1 = Carrot Florence, G_2 = Deb Kuroda-1, G_3 = Deb Kuroda-3
T = Treatment, T_1 = Control, T_2 = 20 ppm AgNP for 12 hrs, T_3 = 20 ppm AgNP for 6 hrs, T_4 = 15 ppm AgNP for 12 hrs, T_5 = 15 ppm AgNP for 6 hrs, T_6 = 10 ppm AgNP for 12 hrs, T_7 = 10 ppm AgNP for 6 hrs

Seedling Fresh weight (mg) of 10 seedlings. The highest fresh weight over genotypes (119.056 mg) was observed to produce by T_3 on an average followed by T_2, T_4 and T_5 ; while it was of lowest fresh weight for T_1 (control) preceded by T_6 and T_7. Similar type of result was found by Ray and Bordolui (2022b) in tomato. Highest fresh weight (109.895 mg) was observed for G_3 and shortest fresh weight (107.633 mg) was recognized for G_1 over treatments. Though G_1 and G_2 over treatment were non-significantly differ. When

the interaction effect of genotypes and seed treatments were taken into consideration, they were non-significantly vary. G_3T_3 showed highest value (120.167 mg) for this parameter.

Table 10: Effect of Nano -priming on Seedling Fresh weight (mg) of carrot genotypes (10 seedlings).

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	63.333	117.100	118.167	115.667	115.167	111.500	113.500	107.633
G_2	65.333	118.100	118.833	116.167	116.000	113.267	113.833	108.648
G_3	67.667	119.167	120.167	117.167	116.333	114.600	115.167	109.895
Mean G	65.444	118.122	119.056	116.333	115.833	113.122	114.167	
		G	T	GXT				
SEm (±)		0.257	0.393	0.681				
LSD (0.05)		0.737	1.125	NS				

Note: G = Genotypes, G_1 = Carrot Florence, G_2 = Deb Kuroda-1, G_3 = Deb Kuroda-3
T = Treatment, T_1 = Control, T_2 = 20 ppm AgNP for 12 hrs, T_3 = 20 ppm AgNP for 6 hrs, T_4 = 15 ppm AgNP for 12 hrs, T_5 = 15 ppm AgNP for 6 hrs, T_6 = 10 ppm AgNP for 12 hrs, T_7 = 10 ppm AgNP for 6 hrs

Table 11: Effect of Nano -priming on Seedling Dry Weight (mg) of carrot genotypes (10 seedlings).

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean T
G_1	6.690	10.433	10.833	9.833	10.433	8.667	9.280	9.453
G_2	6.733	10.933	11.900	10.733	11.167	8.833	9.667	9.995
G_3	7.000	12.100	12.483	11.600	12.233	9.833	10.833	10.869
Mean G	6.808	11.156	11.739	10.722	11.278	9.111	9.927	
		G	T	GXT				
SEm (±)		0.085	0.129	0.224				
LSD (0.05)		0.243	0.371	NS				

Note: G = Genotypes, G_1 = Carrot Florence, G_2 = Deb Kuroda-1, G_3 = Deb Kuroda-3
T = Treatment, T_1 = Control, T_2 = 20 ppm AgNP for 12 hrs, T_3 = 20 ppm AgNP for 6 hrs, T_4 = 15 ppm AgNP for 12 hrs, T_5 = 15 ppm AgNP for 6 hrs, T_6 = 10 ppm AgNP for 12 hrs, T_7 = 10 ppm AgNP for 6 hrs

Seedling Dry Weight (mg) of 10 seedlings. T_3 produced the highest dry weight over the genotypes (10.869 mg), which was followed by T_2, T_5, and T_4; in contrast, T_1 (control) produced the lowest dry weight, which was preceded by T_6 and T_7. Chakraborty and Bordolui (2021) found that, nano priming by AgNP improve the dry weight of green gram over treatments, G_3 had the highest dry weight (10.869 mg) and G_1 had the lowest dry weight (9.453 mg). Treatments and genotype interactions were non-significantly differ; G_3T_3 displayed the highest value (12.483 mg) for this parameter.

CONCLUSIONS

Carrot seeds were treated with various concentration and duration of Ag-Nanoparticles recorded higher seed quality than control. So, it can be concluded that treatments over genotypes, Ag-Nanoparticles 20 ppm for soaking 6 hrs was best compared to other treatments. Genotypes over treatments Deb Kuroda-3 was the best genotypes. Treatments over genotypes, Ag-Nanoparticles 20 ppm for soaking 6 hrs observed the significantly best than other priming concentrations and durations. Ag-Nanoparticles 20 ppm for soaking 6 hrs showed significantly highest performance for seed quality parameter like germination percentage (95.244), germination energy (53.167), seedling vigour Index-I (854.722), and germination index (6.778). Therefore, as pre-sowing treatment Ag-Nanoparticles 20 ppm with a duration of 6 hrs is recommended for treating carrot seed for better seedling establishment.

FUTURE SCOPE

There is a scope to study Ag-Nanoparticles effect in the field on yield in carrot.

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