The Pharma Innovation Journal 2023; 12(8): 569-573

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(8): 569-573

www.thepharmajournal.com
Received: 28-05-2023
Accepted: 30-06-2023

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Effect of seed priming on the seed quality of carrot (*Daucus carota* L.)

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Abstract
Successful crop establishment in direct seeded vegetables such as carrot depends on the uniform seed germination and seedling emergence. However, the major constraints to successful crop production in carrot are poor seed germination and delayed crop establishment. To accelerate the germination and seedling emergence in carrot, a laboratory trial was conducted to study the effect of different priming agents on the seed quality of carrot. Seeds of two carrot cultivars i.e., Country Red and Black Wonder were primed with fourteen priming agents for 24 hours, whereas in control, priming was not done. The seeds were removed after priming and then dried at room temperature till their initial weight. Seed testing was performed to determine germination percentage; length of root, shoot and leaf; weight of fresh and dried seedling; seedling vigour index-I and seedling vigour index-II. It was observed that use of priming agents positively affected the seed quality of both the carrot cultivars as compared to control. Seed priming with cow urine and Panchagavya enhanced the carrot seed germination and seedling vigour therefore, 5% cow urine and 5% Panchagavya can be used for seed priming to improve the overall seed quality of carrot.

Keywords: *Daucus carota* L., seed priming, germination, seedling vigour, cow urine

Introduction

Rapid and uniform seed germination are the essential pre-requisites to increase the overall yield and quality of direct seeded vegetables like carrot. Seeds of high quality are crucial for enhancing the crop yield. Uniform crop establishment and high seedling vigour are considered key elements for most of the crops, as these promote consistent plant growth and maturity, superior weed competition and high productivity (Finch-Savage and Bassel, 2016) [5]. Germination is an important stage in a crop's life cycle, and the first step towards effective growth. Poor or delayed germination of seeds is often encountered in carrot. The main cause of this has been suggested to be the seeds with rudimentary embryos. Germination and crop establishment of carrot seeds are often slow and irregular, especially under stress conditions (Kumar *et al.*, 2021b) [9]. Carrot seeds are small in size and poor-quality seeds cause low and asynchronous germination and more abnormal seedlings. Seed vigour varies greatly during storage by species or variety and even among the seed lots. In this context, priming carrot seeds is considered a better option to improve the vigour of the seeds.

Thus, seed priming, a pre-sowing treatment can lead to quick and synchronous germination and improve overall growth of the plant. It is a controlled hydration of seeds in water or a solution which permits only the initial germination processes but prevents the emergence of radicle. Priming induces biochemical changes in the seeds and encourages seed germination. Additionally, it also increases seed vigour, which in turn promotes early and uniform emergence as well as strong crop establishment. The beneficial effects of seed priming have also been reported in various vegetables including carrot. Therefore, keeping in view the above stated problems, the research work was conducted to examine the effect of seed priming on the quality of carrot seeds.

Materials and Methods

Laboratory experiment was carried out in the Horticulture Lab, School of Agriculture, Lovely Professional University, Punjab, India during November, 2022. The trial comprised two factors with three replications in a 2-Factorial Complete Randomized Design. The first factor consisted fifteen priming agents and the second factor consisted two-coloured varieties of carrot, namely Country Red and Black Wonder. The priming agents used were $ZnSO_4$ @ 1%, GA_3 @ 50 ppm, GA_3 @ 100 ppm, Cinnamon @ 10%, Cinnamon @ 15%, Coconut water @

5%, Coconut water @ 12.5%, Panchagavya @ 3%, Panchagavya @ 5%, KNO_3 @ 0.5%, KCl @ 1%, Cow urine @ 2%, Cow urine @ 5% and water for each replication. Unprimed seeds were used as control.
The seeds of two carrot varieties i.e., Country Red and Black Wonder were weighed and soaked in double the volume of all the seed priming agents at room temperature for 24 hours. After priming, the seeds were dried in ambient condition till the initial weight of the seeds was retained. Germination towel papers were collected and immersed in a tray filled with water in order to provide appropriate moisture content to the seeds. To avoid fungal growth, 0.15% of Bavistin was added to the water. 100 seeds from each treatment were placed on a pre-soaked germination towel paper and then covered with another pre-soaked germination towel paper, followed by rolling of the towel paper and tying with a rubber band, for each treatment. Each treatment was replicated thrice. The sheets were then kept treatment wise inside the germination chamber at a temperature of 26° C and 75% relative humidity. The germination of seeds was monitored on a regular basis for 14 days. The seeds of each treatment were subjected to the tests *viz.*, germination percentage, shoot length, root length, leaf length, seedling fresh weight, seedling dry weight, seedling vigour index-I and seedling vigour index-II. After seven and fourteen days, the germinated seeds were counted for seedling emergence and the results recorded were expressed as mean percentage of normal seedlings. The OPSTAT software was used for the analysis of data.

Results and Discussion

The analysis of variance presented in Table 1 exhibited significant differences among the treatments, varieties, and their interaction for seed germination percentage, root length and leaf length, while for shoot length it showed significant differences among the treatments, and non-significant variation among the varieties and their interaction.

Seed germination (%)

Maximum seed germination was observed in T_{13}: cow urine @ 5% (84.00%) which was *at par* with T_2: GA_3 @ 50 ppm (82.33%) and was statistically significant over the remaining treatments. Interaction among the treatments and varieties revealed that maximum seed germination percentage (84.67%) was observed in $T_{13}V_2$ i.e., Black Wonder variety primed with 5% cow urine which was *at par* with T_2V_2 (84.33%) i.e., Black Wonder variety primed with 50 ppm GA_3, followed by $T_{13}V_1$ (83.33%) i.e., Country Red variety primed with 5% cow urine, while the minimum germination (53.33%) was observed in T_1V_2 i.e., Black Wonder variety primed with 1% $ZnSO_4$. Seed germination was found to be maximum by using cow urine as a priming agent which might be because of the reason that it contains about 95% water, 2.5% urea, 2.5% phosphorus, potash, ammonia, etc. (Sadhukan *et al.*, 2018) [15]. In addition to macronutrients, the presence of enzymes, calcium, chlorine, manganese, salt, sulphur and sodium makes cow urine essential for sustainable agriculture (Devasena and Sangeetha, 2022) [4]. Similarly, higher germination percentage (92.40%) was reported by priming custard apple with 400 ppm GA_3 and 15% cow urine (Yadav *et al.*, 2018) [21]. Sheferie (2023) [16] also reported higher germination in okra primed with 200 ppm GA_3, and concluded that cow urine can be used as a cost-effective seed priming agent alternative to GA_3.

Table 1: Effect of priming agents, varieties and their interaction on the seed germination (%), shoot length (cm), root length (cm), and leaf length (cm)

S. N.	Treatments	Seed germination (%)			Shoot length (cm)			Root length (cm)			Leaf length (cm)		
		V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
1.	T1: Zinc Sulphate ($ZnSO_4$ @ 1%)	58.00	53.33	55.67	6.03	5.96	5.99	6.25	8.04	7.15	2.77	4.40	3.58
2.	T2: Gibberellic acid (GA_3 @ 50 ppm)	80.33	84.33	82.33	6.94	6.75	6.94	8.80	10.53	9.66	4.43	3.90	4.17
3.	T3: Gibberellic acid (GA_3 @ 100 ppm)	66.67	74.33	70.50	7.05	7.48	7.27	9.10	13.73	11.45	4.20	3.80	4.00
4.	T4: Cinnamon (10%)	72.00	82.00	77.00	7.85	7.86	7.86	7.37	7.51	7.44	3.93	4.50	4.22
5.	T5: Cinnamon (15%)	58.00	80.67	69.33	8.24	7.49	7.87	9.09	12.25	10.67	3.27	4.93	4.10
6.	T6: Coconut water (5%)	59.67	65.67	62.67	7.37	6.62	6.99	8.46	10.92	9.69	3.50	4.03	3.77
7.	T7: Coconut water (12.5%)	70.67	60.33	65.50	8.23	7.40	7.82	8.18	8.95	8.56	3.70	4.70	4.20
8.	T8: Panchagavya (3%)	64.67	54.33	59.50	7.96	7.76	7.86	7.83	9.04	8.43	4.30	4.00	4.15
9.	T9: Panchagavya (5%)	72.00	76.67	74.33	8.19	8.04	8.11	8.25	12.00	10.12	3.37	4.70	4.03
10.	T10: KNO_3 (0.5%)	57.67	56.00	56.83	7.98	8.15	8.06	8.87	13.00	10.94	3.67	4.10	3.88
11.	T11: KCl (1%)	57.00	68.67	62.83	7.80	7.75	7.78	9.16	13.63	11.40	3.70	3.77	3.73
12.	T12: Cow urine (2%)	71.00	81.67	76.33	8.20	8.58	8.39	11.04	12.00	11.52	4.93	5.40	5.17
13.	T13: Cow urine (5%)	83.33	84.67	84.00	8.14	7.78	7.96	8.83	10.41	9.62	4.13	4.90	4.52
14.	T14: Water	69.67	80.00	74.83	8.31	8.09	8.20	8.26	8.87	8.57	5.07	4.67	4.87
15.	T15: Unprimed	61.67	55.67	58.67	5.93	7.50	6.37	7.45	7.98	7.71	4.13	4.17	4.15
Mean		66.82	70.56		7.62	7.50		8.47	10.59		3.94	4.40	
		T	V	T x V	T	V	T x V	T	V	T x V	T	V	T x V
C. D.		3.00	1.09	4.24	0.46	N/A	0.65	0.61	0.30	0.22	0.37	0.14	0.52
SE (d)		1.49	0.55	2.11	0.23	0.08	0.33	0.22	0.11	0.08	0.18	0.07	0.26
SE (m)		1.06	0.39	1.49	0.16	0.06	0.23	0.86	0.43	0.30	0.13	0.05	0.18

(V1: Country Red variety, V2: Black Wonder variety, T: treatments, V: varieties, T x V: interaction among the treatments and two varieties)

Shoot length (cm)

Shoot length was found to be maximum in seeds primed with 2% cow urine (8.39 cm) which was *at par* with T_{14}: water (8.20 cm), whereas the minimum shoot length was observed in T_1: $ZnSO_4$ @ 1% (5.99 cm). Cow urine enhances the plant growth due to the presence of triacontane and 4-(p-methoxyphenyl)-3-buten-2-one, which might have led to increased shoot length in fenugreek (31.8 cm) @ 5% concentration (Gottimukkala *et al.*, 2019) [6]. Hydro priming helped in the maintenance of tissue water content, increased the antioxidant activities, and metabolism of carbohydrates which might have increased the shoot length. Higher shoot growth in hydro-primed seeds might be due to their better efficiency for water absorption from growing media (Singh *et al.*, 2018) [17]. Similar findings were also recorded in okra with hydro-priming by Tania *et al.* (2020) [20] and in brinjal var. PKM1 (6.2 cm) with 2% cow urine by Bhavyashree and Vinothini (2019) [1].

Root length (cm)

The root length was maximum in T_{12}: cow urine @ 2% (11.52 cm) which was *at par* with T_3: GA_3 @ 100 ppm (11.45 cm), while the lowest value was observed in T_1: Z_nSO_4 @ 1% (7.15). Interaction among the treatments and varieties exhibited maximum root length in T_3V_2 (13.73 cm) i.e., Black Wonder variety primed with 100 ppm GA_3 which was *at par* with $T_{11}V_2$ (13.643 cm) i.e., Black Wonder variety primed with 1% KCl, while the minimum root length was reported in T_1V_1 (6.25 cm) i.e., Country Red variety primed with 1% $ZnSO_4$. Cow urine contains macronutrients and this resulted in increased phosphate levels and root development. Increased root length was reported in custard apple primed with 400 ppm GA_3 and 15% cow urine (Yadav *et al.*, 2018) [21]. GA_3 enhances metabolic activities in the primed seeds and, higher metabolic activity results in effective food mobilization during the initial stage of germination, which might have increased the shoot and root length (Brar *et al.*, 2020) [2]. Similar results were also reported in chilli primed with 50 ppm GA_3 (Kabilan *et al.*, 2022 and Debbarma *et al.*, 2018) [7, 3], in carrot (6.87 cm) with GA_3 @ 100 ppm (Sowmeya *et al.*, 2018) [19], and in fenugreek (9.2 cm) with 5% cow urine (Gottimukkala *et al.*, 2019) [6].

Leaf length (cm)

The maximum leaf length was observed in T_{12}: 2% cow urine (5.17 cm) which was *at par* with T_{14}: water (4.87 cm), followed by T_{13}: cow urine @ 5% (4.52 cm), while the minimum leaf length was observed in T_1: 1% $ZnSO_4$ (3.58 cm). Interaction among the fifteen treatments and two varieties reported the maximum leaf length in $T_{12}V_2$ (5.40 cm) i.e., Black Wonder variety primed with 2% cow urine which was *at par* with $T_{14}V_1$ (5.07 cm) i.e., Country Red variety primed with water, while the minimum leaf length was reported in T_1V_1 (2.77 cm) i.e., Country Red variety primed with 1% $ZnSO_4$. Priming of seeds with cow urine speeds up several elements of growth in a variety of crops viz., mustard, lettuce, etc. Similar findings were also recorded by Yadav *et al.*, 2018 [21] in custard apple with 400 ppm GA_3 and 15% cow urine.

The analysis of variance presented in Table 2 revealed significant differences among the treatments, varieties, and their interaction for seedling fresh weight, seedling dry weight, seedling vigour index-I and seedling vigour index-II.

Seedling fresh weight (mg)

The maximum seedling fresh weight was obtained in T_{12}: cow urine @ 2% (357.66 mg) which was *at par* with T_6: coconut water @ 5% (317.31 mg), followed by T_2: GA_3 @ 50 ppm (315.64 mg), while the minimum value was observed in T_{15} (220.03 mg) i.e., unprimed seeds. Interaction among the fifteen treatments and two varieties reported maximum seedling fresh weight in $T_{12}V_2$ (368.49 mg) i.e., Black Wonder variety primed with 2% cow urine which was *at par* with $T_{12}V_1$ (346.83 mg) i.e., Country Red variety primed with 2% cow urine. Cow urine contains urea, uric acid, oestrogen, progesterone, etc., which have an impact on inducing seed growth. Coconut water contains a variety of phytohormones, primarily sugar and minerals, and also auxins (IAA and IBA), gibberellins, and zeatin (cytokinin). Similar findings were reported in karonda (3.24 g) primed with 25% cow urine (Pal *et al.*, 2020) [12], in okra primed with 20% coconut water (Lakmali and Seran, 2022) [11] and in papaya primed with cow urine for 24 hours (Singh *et al.*, 2020) [18].

Table 2: Effect of priming agents, varieties and their interaction on the seedling fresh weight (mg), seedling dry weight (mg), seedling vigour index-I, and seedling vigour index-II

S. N.	Treatments	Seedling fresh weight (mg)			Seedling dry weight (mg)			Seedling vigour index-I			Seedling vigour index-II		
		V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
1.	T1: Zinc Sulphate ($ZnSO_4$ @ 1%)	225.06	304.66	264.86	16.23	16.11	16.17	712.70	746.67	729.69	961.06	841.71	901.39
2.	T2: Gibberellic acid (GA_3 @ 50ppm)	315.41	315.87	315.64	17.70	18.48	18.09	1264.22	1456.95	1360.59	1422.53	1558.78	1490.66
3.	T3: Gibberellic acid (GA_3 @ 100ppm)	212.52	246.32	229.42	24.06	21.69	22.87	1063.49	1592.98	1328.24	1557.43	1585.03	1571.23
4.	T4: Cinnamon (10%)	284.10	330.94	307.52	18.44	17.51	17.98	1095.21	1259.33	1177.27	1326.30	1422.05	1374.17
5.	T5: Cinnamon (15%)	281.40	273.45	277.42	19.03	17.92	18.47	1010.68	1592.83	1301.76	1092.94	1447.99	1270.46
6.	T6: Coconut water (5%)	311.04	323.57	317.31	20.43	20.77	20.60	945.00	1152.98	1048.99	1218.32	1364.06	1291.19
7.	T7: Coconut water (12.5%)	254.94	267.84	261.39	22.93	19.17	21.05	1159.74	1005.21	1082.48	1528.21	1156.77	1342.49
8.	T8: Panchagavya (3%)	310.32	236.20	273.26	21.25	19.48	20.39	1072.46	864.04	968.52	1375.04	1091.10	1233.07
9.	T9: Panchagavya (5%)	255.37	341.75	298.56	22.97	24.02	23.49	1184.29	1486.15	1335.22	1654.09	1906.48	1780.28
10.	T10: KNO_3 (0.5%)	308.97	309.20	309.09	20.08	19.98	20.03	940.53	1185.56	1063.04	1158.08	1135.91	1147.00
11.	T11: KCl (1%)	287.91	278.39	283.15	20.87	19.11	19.99	973.27	1468.59	1220.93	1172.17	1319.55	1245.87
12.	T12: Cow urine (2%)	346.83	368.49	357.66	20.97	18.35	19.66	1367.38	1681.28	1524.33	1514.18	1714.59	1614.39
13.	T13: Cow urine (5%)	281.35	280.07	280.71	18.88	18.46	18.67	1415.39	1539.23	1477.31	1573.12	1596.99	1585.06
14.	T14: Water	306.18	283.35	294.77	20.12	19.04	19.58	1165.26	1357.59	1261.43	1402.77	1543.87	1473.32
15.	T15: Unprimed	217.46	222.59	220.03	17.34	16.26	16.80	825.42	786.04	805.73	1070.26	923.52	996.89
Mean		279.92	292.18		20.09	19.09		1079.67	1278.36		1335.10	1373.89	
		T	V	T x V	T	V	T x V	T	V	T x V	T	V	T x V
C. D.		22.78	8.32	32.21	0.54	0.20	0.77	90.11	32.90	127.43	105.80	38.63	149.63
SE (d)		11.35	4.14	16.05	0.27	0.10	0.38	44.90	16.40	63.50	52.72	19.25	74.56
SE (m)		8.03	2.93	11.35	0.19	0.07	0.27	13.75	11.59	44.90	37.28	13.61	52.72

(V1: Country Red variety, V2: Black Wonder variety, T: treatments, V: varieties, T x V: interaction among the treatments and two varieties)

Seedling dry weight (mg)

The maximum seedling dry weight was recorded in T_9: Panchagavya @ 5% (23.49 mg) which was *at par* with T_3: 100 ppm GA_3 (22.87 mg), followed by T_7: Coconut water @ 12.5% (21.05 mg). Interaction among the fifteen treatments and two varieties reported the maximum seedling dry weight in T_3V_1 (24.06 mg) i.e., Country Red variety primed with GA_3 @ 100 ppm which was *at par* with T_9V_2 (24.02 mg) i.e., Black Wonder variety primed with 5% Panchagavya. Similar findings were reported in pigeonpea (0.48 g) primed with 7% Panchagavya (Reddy *et al.*, 2021) [14], in ridge gourd (0.798 g) primed with 3% Panchagavya (Kumari *et al.*, 2021) [10], and in carrot (23.00 mg) primed with 50 ppm GA_3 (Sowmeya *et al.*, 2018) [19].

Seedling vigour index-I

The maximum seedling vigour index-I was recorded in T_{12}: cow urine @ 2% (1524.33) which was *at par* with T_{13}: cow urine @ 5% (1477.31), followed by T_2: GA_3 @ 50 ppm (1360.59) while the minimum seedling vigour index-I was reported in T_1: $ZnSO_4$ @ 1% (729.69). Interaction between fifteen treatments and two varieties reported maximum seedling vigour index-I in $T_{12}V_1$ (1681.28) i.e., Black Wonder variety primed with 2% cow urine which was *at par* with T_3V_2 (1592.98) i.e., Black Wonder variety primed with GA_3 @ 50 ppm. The minimum value was reported in T_1V_1 (712.70) i.e., Country Red variety primed with 1% $ZnSO_4$. The reason behind the better seedling vigour index-I might be the presence of physiologically active chemicals viz., growth regulators, nutrients and trace elements in cow urine. Similar findings were reported in sapota primed with 10% cow urine (Patel *et al.*, 2021) [13], in chilli (794.05) primed with 8% Panchagavya (Kumar *et al.*, 2021a) [8], and in pigeonpea (3420.70) primed with 7% Panchagavya (Reddy *et al.*, 2021) [14].

Seedling vigour index-II

The maximum seedling vigour index-II was obtained in T_9: Panchagavya @ 5% (1780.28), followed by T_{12}: cow urine @ 2% (1614.39), and the minimum value was reported in T_1: $ZnSO_4$ @ 1% (901.39). Interaction among the fifteen treatments and two varieties reported maximum seedling vigour index-II in $T_{12}V_2$ (1714.59) i.e., Black Wonder variety primed with 2% cow urine which was *at par* with T_9V_1 (1654.09) i.e., Country Red variety primed with 5% Panchagavya, and the minimum value was observed in T_1V_2 (841.71) i.e., Black Wonder variety primed with 1% $ZnSO_4$. Maximum seedling vigour index- II was recorded by priming seeds with Panchagavya. This might be due to the presence of essential macronutrients, micronutrients, and growth hormones (IAA and GA_3) in Panchagavya which enhanced the plant growth. Similar findings were observed in ridge gourd (66.220) primed with 3% Panchagavya (Kumari *et al.*, 2021) [10], in pigeonpea (42.14) primed with 7% Panchagavya (Reddy *et al.*, 2021) [14], in chilli (841.575) primed with 8% Panchagavya (Kumar *et al.*, 2021a) [8], and in sapota primed with 10% cow urine (Patel *et al.*, 2021) [13].

Conclusion

The results revealed that seeds of two different carrot cultivars exhibited different response to the agents used for priming seeds. Priming carrot seeds with cow urine and GA_3 improved the germination percentage, shoot length, root length, leaf length, seedling fresh weight, and seedling vigour index-I, whereas, priming with 5% Panchagavya improved seedling dry weight and seedling vigour index-II. It was observed from the current study that priming carrot seeds with cow urine, GA_3, and Panchagavya significantly increased the seed germination and seedling emergence. Cow urine and Panchagavya being affordable and cost effective can thus be used as priming agents to improve the seed quality and overall production but its effect also depends on the cultivar and the initial vigour of the seeds. However, further research is required in this context.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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