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Growth and yield of carrot (*Daucus carota* L.) as influenced by seed priming

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ABSTRACT

The research work was conducted at the Horticulture Farm of the School of Agriculture, Lovely Professional University, Phagwara, Punjab, from October 2021 to February 2022 to examine the influence of seed priming on the growth and yield of carrots in the Punjab region. The experiment was conducted using a two-factorial randomized block design replicated thrice. The first factor consisted of fourteen priming agents (T_1- Zinc ($ZnSO_4$ at 1%), T_2- GA_3 (50 ppm), T_3- GA_3 (100 ppm), T_4- Cinnamon (10%), T_5- Cinnamon (15%), T_6- Coconut water (5%), T_7- Coconut water (12.5%), T_8- *Panchagavya* (3%), T_9- *Panchagavya* (5%), T_{10}- KNO_3 (0.5%), T_{11}- KCl (1%), T_{12}- Cow urine (2%), T_{13}- Cow urine (5%), T_{14}- Water) and one control (T_{15}- Unprimed seeds). The second factor comprised two commercial cultivars, namely, V_1- Carrot Deep Red and V_2- Black Wonder. Results revealed that the application of 100 ppm GA_3, *Panchagavya* (5%), cow urine (2%), and coconut water (5%) as priming agents in carrots had better growth and yield as compared to the remaining treatments. Therefore, priming carrot seeds could be recommended as an effective method to improve the performance of the plants in terms of both growth and yield attributes.

1. INTRODUCTION

Carrot, scientifically known as *Daucus carota* L., belongs to the *Apiaceae* family with a chromosome number of 2n= 2x= 18. Afghanistan, located in Western Asia, is its center of origin, with maximum diversity. The black and red varieties might have been brought from Afghanistan, Persia, and Southern Russia [1]. The area and production under carrot cultivation in India are 0.097 m ha and 1.648 m tonnes, respectively [2]. It is rich in antioxidants, that is, carotenoids and anthocyanins, and also contains a fair amount of Vitamins C and K, thiamine (B1), riboflavin (B2), pyridoxine (B6), and folates (B9) [3]. It is a cool-season crop that can also tolerate high temperatures early in the season. Temperatures between 18°C and 21°C are beneficial to achieve good color in the roots [4].

Seed is a crucial tool for agricultural production and a carrier for the application of modern agricultural technologies, as good-quality seed is the most important input for improving the overall yield. An important problem faced during carrot cultivation is the poor germination of seeds. For conducting the study, low cost and locally available seed priming agents like cinnamon, coconut water, Panchagavya and cow urine have been used for comparing their effectiveness by including two commonly used priming agents [6,7]. It increases seed performance, improves homogeneity and plant establishment, maximizes yield in different conditions, increases resistance to many environmental stresses, and facilitates the seed to overcome dormancy [5]. Positive effects of seed priming have been reported in different crops, including carrot, using GA_3 [6], KNO_3 [7], and KCl; however, limited information is available on the effect of organic formulations (cinnamon, coconut water, *panchagavya,* and cow urine) as priming agents for carrot. Therefore, the present study was undertaken to examine the effect of organic and inorganic compounds as priming agents on the growth and yield of two commercial cultivars of carrot under the Punjab conditions.

2. MATERIALS AND METHODS

An experiment was carried out at the Horticulture Farm, School of Agriculture, Lovely Professional University, Phagwara, under Punjab conditions from October 2021 to February 2022 to evaluate the response of seed priming on the growth and yield attributes of carrot. The experiment was laid out in a two-factorial randomized block design (first factor: 14 priming agents and one control; second factor: seeds of two varieties) with three replications. Seeds of two carrot cultivars, that is, V_1 (Carrot Deep Red) and V_2 (Black Wonder), were soaked in fourteen priming agents, namely, zinc ($ZnSO_4$ at 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 24 h at room temperature in the Horticulture laboratory after recording their weight and were then air dried to their original moisture content at room temperature using

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blotting papers. The air-dried seeds were then sown in the field. After emergence, five plants were selected randomly from each treatment and each replication and tagged for recording the observations on growth and yield parameters. Data were recorded for the growth parameters, namely, plant height at 30, 60, and 90 days after sowing and number of leaves at 30, 60, and 90 days after sowing; and yield parameters, that is, average root weight, average root length, average root diameter, and total yield per hectare. The statistical analysis for two factorial randomized block designs was carried out for each observed character using the OPSTAT Analysis software system developed by HAU, Hisar, Haryana [8].

3. RESULTS AND DISCUSSION

3.1. Growth Parameters

Results revealed that different priming agents significantly influenced the growth of carrots, namely, the number of leaves and plant height [Table 1]. Among all the treatments, priming seeds with 100 ppm GA_3 significantly increased the number of leaves and plant height (cm) as compared to the remaining treatments.

3.1.1. Plant height (cm)

Among the various treatments, the mean value of plant height at 90 DAS ranged from 46.02 cm (T_{15}: control) to 61.83 cm (T_3: gibberellic acid at 100 ppm). Priming with gibberellic acid at 100 ppm recorded the maximum mean plant height at 30, 60, and 90 DAS (61.83 cm), followed by T_{12}: cow urine at 2% (57.47 cm), whereas the minimum plant height was observed in control (46.02 cm). Among the two varieties, that is, V_1-Carrot Deep Red and V_2-Black Wonder, the maximum mean value for plant height at 90 DAS was recorded in Black Wonder (53.48 cm) and the minimum in Carrot Deep Red (51.65 cm). Interaction among the fifteen treatments and two varieties revealed that the highest plant height at 90 DAS was reported in T_3V_1 (64.80 cm), i.e., the Carrot Deep Red variety primed with gibberellic acid at 100 ppm, followed by T_3V_2 (58.56 cm), i.e., the Black Wonder variety primed with GA_3 at 100 ppm, whereas the lowest plant height at 90 DAS was recorded in T_9V_1 (42.73 cm), i.e., the Carrot Deep Red variety primed with *Panchagavya* (5%). Similarly, the highest plant height was observed in cucumber using 200 ppm GA_3 [9], in chickpea by using 225 ppm GA_3 [10], and in soyabean by using 100 ppm GA_3 [11].

3.1.2. Number of leaves

Among the various treatments, the mean value for the number of leaves at 90 DAS ranged from 14.77 (T_{15}: control) to 24.87 (T_3: gibberellic acid at 100 ppm). The highest number of leaves at 30, 60, and 90 DAS were reported in T_3, i.e., GA_3 at 100 ppm (24.87), which was statistically significant over the remaining treatments, followed by T_9: *Panchagavya* at 5% (19.17). Interaction among the 15 treatments and two varieties revealed that the highest number of leaves at 90 DAS were reported in T_3V_2 (26.18) i.e., Black Wonder variety primed with gibberellic acid at 100 ppm, followed by T_3V_1 (23.57) that is, Carrot Deep Red primed with gibberellic acid at 100 ppm, while the lowest number of leaves at 90 DAS were recorded in T_6V_1, that is, (14.45) Carrot Deep Red variety primed with coconut water at 5%. Similarly, the highest number of leaves was observed using 100 ppm in onion [12], and soyabean [11], and sponge gourd [13].

3.2. Yield Parameters

Among all the treatments, T_3: GA_3 at 100 ppm significantly revealed superior results with respect to average root weight (g), average root length (cm), average root diameter (cm), and total yield (q/ha) [Table 2].

3.2.1. Average root weight (g)

Maximum average root weight was observed with the use of 100 ppm GA_3 (159.83 g), followed by T_{12}: 2% cow urine (130.91 g), whereas the minimum mean root weight was observed in T_{15}: control (104.06 g). The maximum average root weight was recorded in the Black Wonder variety (125.42 g), while the minimum average root weight was observed in Carrot Deep Red (119.10 g). Interaction among the fifteen treatments and two varieties revealed that the maximum root weight was reported in T_3V_2 (160.30 g), that is, the Black Wonder variety primed with gibberellic acid at 100 ppm, followed by T_3V_1 (159.37 g), i.e., the Carrot Deep Red variety primed with GA_3 at 100 ppm, while the minimum root weight was recorded in $T_{15}V_1$ (101.64 g), the unprimed Carrot Deep Red variety.

3.2.2. Average root length (cm)

The maximum mean root length was recorded in T_3: GA_3 at 100 ppm (8.75 cm), followed by T_6: coconut water (5%) (8.51 cm), while the minimum mean root length was observed in T_{15}: Control (6.79 cm). Among the two varieties, the maximum mean value for root length was recorded in Black Wonder (8.15 cm), followed by Carrot Deep Red (7.73 cm). Interaction among the 15 treatments and two varieties revealed that maximum root length was reported in T_3V_1 (8.96 cm), that is, the Carrot Deep Red variety primed with gibberellic acid at 100 ppm, followed by $T_{14}V_2$ (8.76 cm), that is, the Black Wonder variety primed with water, while the lowest root length was recorded in $T_{15}V_2$, that is, the (6.49 cm) Black Wonder variety, which was the control.

3.2.3. Average root diameter (cm)

The maximum mean root diameter was recorded in T_3: GA_3 at 100 ppm (5.74 cm), followed by T_7: 12.5% coconut water (4.49 cm), while the minimum root diameter was found in T_9: 5% *Panchagavya* (2.92 cm). Among the two varieties, the maximum mean value for root diameter was recorded in Black Wonder (4.03 cm) and the minimum in Carrot Deep Red (3.65 cm). Interaction among the 15 treatments and two varieties revealed that the highest root diameter was reported in T_3V_2 (6.21 cm), that is, the Black Wonder variety primed with gibberellic acid at 100 ppm, followed by T_3V_1 (5.38 cm), that is, the Carrot Deep Red variety primed with 100 ppm GA_3, while the lowest root diameter was recorded in T_9V_1 (2.67 cm), that is, the Carrot Deep Red variety primed with *Panchagavya* at 5%.

3.2.4. Total yield (q/ha)

The maximum mean total yield was recorded in T_3: GA_3 at 100 ppm (230.88 q/ha), followed by T_{12}: 2% cow urine (189.10 q/ha), while the minimum yield was found in T_{15}: Control (150.33 q/ha). Among the two varieties, the maximum mean value for total yield was recorded in Black Wonder (181.18 q/ha) and the minimum in Carrot Deep Red (172.03 q/ha). Interaction among the 15 treatments and two varieties revealed that the highest total yield was reported in T_3V_2 (231.57 q/ha), that is, the Black Wonder variety primed with gibberellic acid at 100 ppm, followed by T_3V_1 (230.20 q/ha), that is, the Carrot Deep Red variety primed with 100 ppm GA_3, while the lowest yield was recorded in $T_{15}V_1$ (146.83 q/ha), the Carrot Deep Red variety, which was the control.

It was observed that priming carrot seeds with GA_3, cow urine, *Panchagavya,* and coconut water enhanced both the growth and yield attributes of both cultivars of carrot. Similar findings were reported by the use of 100 ppm GA_3, which increased the yield in cowpea [14], resulted in maximum pod length, pod diameter, and pod yield per hectare in okra [15], helped in achieving the highest average bulb weight, average bulb diameter, and total bulb yield (q/ha) in onion [12], and increased the seed yield in sunflower [16]. Among the four

Table 1: Effect of different priming agents on the growth of carrot

Treatments	Plant height at 30 DAS (cm)			Plant height at 60 DAS (cm)			Plant height at 90 DAS (cm)			Number of leaves at 30 DAS			Number of leaves at 60 DAS			Number of leaves at 90 DAS		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1	13.03	11.42	12.22	36.42	24.86	30.64	46.70	48.64	47.67	4.23	4.36	4.29	7.48	10.51	8.99	16.79	16.62	16.70
T_2	13.17	13.86	13.52	34.76	25.28	30.02	49.07	50.14	49.60	4.34	4.46	4.40	7.48	11.53	9.50	14.86	18.62	16.74
T_3	14.40	15.32	14.86	41.65	33.97	37.81	64.80	58.86	61.83	5.32	5.54	5.43	11.02	16.27	13.64	23.57	26.18	24.87
T_4	13.07	12.05	12.56	40.10	29.04	34.57	60.12	51.43	55.77	4.44	4.73	4.58	8.81	10.09	9.45	19.48	18.60	19.04
T_5	12.05	13.25	12.65	30.27	29.79	30.03	43.40	54.86	49.13	4.47	3.54	4.14	9.31	8.65	8.98	17.02	15.83	16.42
T_6	13.25	12.60	12.92	39.74	28.25	33.99	4084	56.73	48.78	4.05	3.00	3.52	8.90	8.54	8.72	14.45	19.40	16.92
T_7	13.50	13.30	13.40	32.86	30.20	31.53	50.24	52.83	51.53	4.04	4.12	4.08	8.380	12.46	10.42	15.44	15.89	15.66
T_8	12.24	14.01	13.13	32.01	30.64	31.32	48.01	54.01	51.01	4.10	5.27	4.68	10.42	8.81	9.62	19.17	14.59	16.88
T_9	12.56	14.18	13.37	34.40	30.74	32.57	42.73	51.2	46.96	4.10	4.64	4.37	9.22	8.69	8.95	20.13	18.22	19.17
T_{10}	13.26	13.85	13.55	38.59	31.6	35.12	51.63	56.56	54.09	3.74	4.31	4.02	7.49	9.40	8.44	15.80	15.78	15.79
T_{11}	12.18	15.12	13.65	38.67	30.44	34.56	51.47	57.90	54.68	4.53	4.74	4.63	7.53	8.81	8.17	15.52	18.87	17.19
T_{12}	13.49	13.26	13.37	40.01	29.48	34.74	60.10	57.84	58.37	4.14	5.26	4.70	7.96	8.54	8.25	20.48	15.01	17.74
T_{13}	12.70	12.37	12.53	39.06	29.34	34.20	60.04	51.02	55.53	4.23	4.04	4.13	7.86	12.33	10.10	21.39	16.34	18.86
T_{14}	12.60	13.28	12.94	38.90	30.14	34.52	61.20	55.54	57.47	4.15	4.58	4.36	8.74	11.37	10.05	19.80	14.78	17.29
T_{15}	11.25	10.43	10.84	29.88	23.67	26.77	44.41	47.64	46.02	3.14	3.55	3.34	7.31	8.15	7.73	15.03	14.51	14.77
Mean	12.85	13.22		36.49	29.17		51.65	53.48		4.22	4.41		8.53	10.28		17.93	17.28	
	T	V	T×V	T	V	T×V	T	V	T×V	T	V	T×V	T	V	T×V	T	V	T×V
S. Em. ±	0.162	0.059	14.403	0.328	0.120	36.881	0.523	0.191	60.348	0.059	0.022	5.267	0.175	0.064	13.151	0.272	0.099	24.107
CD at 5%	0.459	0.168	13.053	0.931	0.340	36.15	1.485	0.740	52.741	0.168	0.061	4.351	0.496	0.181	10.099	0.771	0.282	17.65
CV (%)		3.120			2.449			2.437			3.355			4.551			3.779	

T_1: Zinc ($ZnSO_4$ at 1%), T_2: GA_3 (50 ppm), T_3: GA_3 (100 ppm), T_4: Cinnamon (10%), T_5: Cinnamon (15%), T_6: Coconut water (5%), T_7: Coconut water (12.5%), T_8: Panchagavya (3%), T9: Panchagavya (5%), T_{10}: KNO_3 (0.5%), T_{11}: KCl (1%), T_{12}: Cow urine (2%), T_{13}: Cow urine (5%), T_{14}: Water; T_{15}: Control, V_1: Carrot Deep Red, V_2: Black Wonder

Table 2: Effect of different priming agents on the yield of carrot

Treatments	Average root weight (g)			Average root length (cm)			Average root diameter (cm)			Total yield (q/ha)		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
T_1	103.52	115.70	109.61	8.40	8.45	8.44	3.37	3.47	3.41	149.53	167.13	158.33
T_2	106.19	126.67	116.43	8.34	8.15	8.24	3.35	4.31	3.83	153.37	182.97	168.17
T_3	159.37	160.30	159.83	8.96	8.54	8.75	5.28	6.21	5.74	230.20	231.57	230.88
T_4	106.84	127.29	117.07	7.34	8.04	7.69	2.70	3.22	2.96	154.30	183.83	169.07
T_5	113.16	124.51	118.83	8.10	7.81	7.95	4.34	3.36	3.85	163.47	179.87	171.67
T_6	111.40	113.44	122.42	8.61	8.42	8.51	3.13	3.71	3.42	160.90	192.73	176.82
T_7	103.55	112.80	113.21	7.71	8.77	8.24	4.24	4.55	4.39	149.57	177.50	163.53
T_8	123.72	120.11	121.92	6.90	8.81	7.85	3.44	5.01	4.23	178.70	173.53	176.12
T_9	121.54	136.14	128.84	7.31	8.10	7.70	2.67	3.17	2.92	175.57	196.67	186.12
T_{10}	125.23	113.43	119.33	7.24	8.27	7.75	3.12	4.50	3.81	180.87	163.87	172.37
T_{11}	133.51	120.93	127.22	7.56	7.59	7.57	4.07	3.21	3.64	192.83	174.70	183.77
T_{12}	138.06	123.77	130.91	6.96	7.38	7.17	4.08	4.65	4.36	199.40	178.80	189.10
T_{13}	131.41	123.81	127.61	7.35	8.69	8.02	3.82	3.97	3.90	189.83	178.83	184.33
T_{14}	107.31	125.85	116.58	8.04	8.76	8.40	4.03	4.03	4.03	155.03	181.80	168.42
T_{15}	101.64	106.48	104.06	7.10	6.49	6.79	3.08	3.13	3.10	146.83	153.83	150.33
Mean												
	T	V	T×V	T	V	T×V	T	V	T×V	T	V	T×V
S. Em. ±	0.808	0.295	157.544	0.121	0.044	8.407	0.125	0.046	5.389	0.117	0.043	22.757
CD at 5%	2.293	0.837	124.587	0.343	0.125	8.027	0.356	0.130	3.906	0.331	0.121	17.997
CV (%)		1.546			2.575			7.996			1.617	

T_1: Zinc ($ZnSO_4$ at 1%), T_2: GA_3 (50 ppm), T_3: GA_3 (100 ppm), T_4: Cinnamon (10%), T_5: Cinnamon (15%), T_6: Coconut water (5%), T_7: Coconut water (12.5%), T_8: Panchagavya (3%), T_9: Panchagavya (5%), T_{10}: KNO_3 (0.5%), T_{11}: KCl (1%), T_{12}: Cow urine (2%), T_{13}: Cow urine (5%), T_{14}: Water; T_{15}: Control, V_1: Carrot Deep Red, V_2: Black Wonder

concentrations of GA_3 (75 ppm, 150 ppm, 225 ppm, and 300 ppm) used in chickpeas, 225 ppm GA_3 resulted in a superior yield [10]. It also increased the plant height and yield even under saline conditions in wheat [17].

GA_3, being an effective plant growth regulator, enhances metabolism and photosynthate accumulation [18], thereby overcoming seed dormancy and ensuring rapid seed germination [19], which might have increased the number of leaves. It increases cell division in the cambial zone, increases internodal length, which eventually enhances the morphological characters [20], also governs other major growth and developmental processes occurring in the plants such as seed germination, elongation, and expansion of hypocotyl [21], and helps to improve the petiole length, which ultimately increases the plant height [17] and number of leaves. Seed priming with 5% *Panchagavya* also resulted in the maximum number of leaves at 90 DAS, which might be due to the presence of beneficial microorganisms, thus improving the microbial activity around the root zone, which might have increased the number of leaves [22]. Though the use of GA3 was found to be much better, but based on the above results, it was found that using locally available inputs like cow urine and Panchagavya as a seed priming agent improved the growth and yield of carrot as compared to the remaining priming agents.

4. CONCLUSION

The results obtained from this experiment clearly suggested that priming improved the growth and yield parameters in both cultivars of carrot. Among all the priming agents, 100 ppm GA_3 revealed significantly superior results for both growth and yield as compared to other treatments. It was found that the locally available farm inputs positively increased the growth and yield of red coloured carrot cultivar (Carrot Deep Red), which suggests that these can be used as suitable priming agents for getting better yield in red coloured carrot cultivars. Therefore, it can be concluded that, being one of the simplest and easiest techniques, seed priming can be adopted to enhance the growth and yield attributes of carrots. However, further research is required in this context.

5. AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work. All the authors are eligible to be authors as per the International Committee of Medical Journal Editors (ICMJE) requirements and guidelines.

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7. CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

8. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

9. DATA AVAILABILITY

All the data is available with the authors and shall be provided upon request.

10. USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declares that they have not used artificial intelligence (AI)-tools for writing and editing of the manuscript, and no images were manipulated using AI.

11. PUBLISHER'S NOTE

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