J Bangladesh Agril Univ 24(2): 129–136, 2026 https://doi.org/10.3329/jbau.v24i2.91302

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Evaluation of Seed Germination Capacity and Seedling Behaviour in Diverse Carrot (*Daucus carota* L.) Germplasm

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ARTICLE INFO

Article history
Received: 24 April 2026
Accepted: 25 June 2026
Published: 30 June 2026

Keywords
Germplasm,
Carrot,
Germination,
Seedling characteristics

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ABSTRACT

An experiment was conducted at the Postgraduate Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh, during August-September 2025 to evaluate seed germination capacity and early seedling behavior of 50 carrot germplasm. The single-factor experiment was laid out in a Completely Randomized Design with two replications. Significant variation was observed among the germplasm for all measured traits. Seven germplasm, namely Jiyang, Acrya, Spring Maki, PI 652143, Pusa Kesar, Koyogo Koyo No. 2 and Nantes Supreme, exhibited 100% germination, whereas ten germplasm, namely PI 226043, PI 249535, PI 261650, PI 279776, PI 294090, PI 289700, PI 232073, PI 341204, PI 419084 and PI 451759, failed to germinate throughout the observation period. Among the germinated entries, R5 demonstrated superior seedling growth, with the highest radicle length (5.63 cm), plumule length (4.11 cm), seedling height (9.74 cm) and number of leaves seedling–1 (4.0) at the final stage of data recording (19 days after seed placement in Petri dishes), followed by Autumn King 2 and Honku (Red). Overall, the results indicate that Jiyang, Acrya and Spring Maki, followed by Pusa Kesar, Koyogo Koyo No. 2 and Nantes Supreme, are highly promising for rapid and uniform germination, while R5, Autumn King 2 and Honku (Red) are particularly suitable for vigorous seedling growth. This germplasm may therefore be recommended for use in carrot improvement programs and quality seedling production.

Introduction

Carrot (*Daucus carota* L.) is an important root vegetable crop cultivated worldwide for its high nutritional value, particularly β-carotene, vitamins and antioxidants (Rubatzky et al., 1999). It is a highly nutritious cool-season vegetable crop belonging to the family Apiaceae (previously Umbelliferae) and is considered to have originated in the Mediterranean region (Mehedi, 2012). It is extensively cultivated in Europe, Asia, North Africa, and North and South America (Thompson and Kelly, 1957). Carrot is one of the most ancient vegetables grown throughout temperate regions in spring, summer and autumn. In tropical and subtropical regions, carrots are mainly grown during winter. In Bangladesh, carrot is grown successfully during the Rabi season, and early November to early December is considered the best sowing period for satisfactory yield (Sultana, 2012).

Carrots are valuable because of their high nutritional content, versatility in cooking and storage potential. They contain appreciable amounts of carotene (10 mg 100 g–1), thiamine (0.04 mg 100 g–1), riboflavin (0.05 mg 100 g–1) (Sharfuddin and Siddique, 1985), carbohydrates (10.6%), protein (0.9 g 100 g–1), fat (0.2 g 100 g–1) and vitamin C (3 mg 100 g–1) (Jahan et al., 2019). Carrot is also a rich source of vitamin A. This vital nutrient functions as an antioxidant that protects cells and may help reduce the risk of measles, cancer and age-related macular degeneration. Deficiency of vitamin A can cause xerophthalmia, a disorder that may impair normal vision and cause night blindness (NIH, 2022). Carrot is used in salads, cooked vegetables, soups, stews, curries, pickles, jam and sweet foods (Kabir et al., 2000; Rashid et al., 2024).

Carrots are becoming increasingly popular, particularly in urban areas of Bangladesh. In 2022-2023, Bangladesh produced 46,192 tons of carrots from 4,410 hectares, with an average yield of 11.16 t ha–1, which is much lower than the world average productivity of 38.02 t ha–1 (FAOSTAT, 2024). The major carrot-growing regions of Bangladesh include Dhaka, Manikganj

Cite This Article
Awal,M.A., Rashid,M.H.A., Rabbani, M.G., and Hossain, M.A. 2026. Evaluation of Seed Germination Capacity and Seedling Behaviour in Diverse Carrot (*Daucus carota* L.) Germplasm. *Journal of Bangladesh Agricultural University,* 24(2): 129-136. https://doi.org/10.3329/jbau.v24i2.91302

, Pabna, Rajshahi, Bogura, Dinajpur, Gaibandha, Rangpur and Panchagarh (Rashid et al., 2024). Successful crop establishment in carrot largely depends on seed germination and early seedling growth, as the crop is highly sensitive during its initial growth stages (Nascimento et al., 2011). Seed germination is a complex physiological process influenced by genetic makeup and environmental conditions (Bewley et al., 2013). Poor germination and weak seedling growth often result in uneven plant stands and yield reduction in carrot cultivation (Finch-Savage and Bassel, 2016). Therefore, assessment of seed quality and early seedling traits is essential for identifying superior germplasm. Genetic variability among carrot germplasm provides opportunities for selection of genotypes with improved germination capacity and seedling vigour (Simon et al., 2008). Laboratory-based germination tests offer a reliable and rapid method to evaluate early growth behavior under controlled conditions (ISTA, 2019). The present study aimed to assess the germination capacity and seedling behavior of 50 carrot germplasm to identify promising genotypes for future breeding and cultivation. The germplasm was chosen to represent a broad spectrum of genetic diversity, ensuring a comprehensive assessment of their adaptability and performance. By examining key traits such as germination percentage, number of leaves, radicle length, plumule length and seedling height, this research aims to identify superior genotypes that can contribute to the improvement of carrot cultivation. Furthermore, the study provides a basis for future breeding programs focused on improving seedling establishment, early growth and overall yield potential of carrot germplasm.

Materials and methods

Experimental site

The experiment was carried out at the Postgraduate Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from August-September 2025.

Experimental treatments

The experiment was conducted using seeds of 50 carrot germplasm viz. G1 = Brasilia (Embrapa), G2 = PI 226043, G3 = PI 249535, G4 = PI 261650, G5 = PI 279776, G6 = PI 294090, G7 = BAU Gajor 5, G8 = Koyogo Koyo No. 2, G9 = PI 289700, G10 = Love Heart, G11 = PI 232073, G12 = Cosmos, G13 = King Kuroda, G14 = L1408, G15 = Tokita, G16 = T Summer, G17 = PI 163238, G18 = PI 652143, G19 = PI 652259, G20 = PI 652243, G21 = Long Imperator, G22 = Nantes 3, G23 = PI 341204, G24 = Nantes Supreme, G25 = Amsterdam 2, G26 = Kosun, G27 = Sweet Enrich, G28 = Shin Kuroda, G29 = Jiyang, G30 = Acrya, G31 = PI 419084, G32 = Royal Kuroda, G33 = Orange Grand, G34 = Pusa Kesar, G35 = Bankim Keshor, G36 = Tkimatting, G37 = PI 451759, G38 = Kuroda Gosunto, G39 = Sweet Salad People, G40 = Okonomi, G41 = P7262, G42 = Sidur, G43 = Athalia, G44 = R4, G45 = R5, G46 = Piccolo, G47 = Diamond, G48 = Autumn King 2, G49 = Spring Maki and G50 = Honku (Red). The carrot seeds were collected from the USA, UK, Japan and different local sources. Healthy, uniform and disease-free seeds were selected for the study.

Experimental Design and Conditions

The laboratory experiment was laid out in a Completely Randomized Design (CRD) with two replications.

Experimental setup

The filter papers were first cut according to the size of the Petri dishes and placed properly in the dishes. For each germplasm, 10 seeds were placed in a Petri dish lined with moist filter paper. The Petri dishes were kept at room temperature (25 ± 2°C), and moisture was maintained by adding distilled water as required.

Parameters measured

Data were recorded on seed germination percentage, radicle length, plumule length, number of leaves and seedling height at 10, 13, 16 and 19 days after seed placement in Petri dishes. The number of germinated seeds was counted at three-day intervals and converted into percent germination.

Seed germination (%) = (Number of seeds germinated / Total number of seeds) × 100

Radicle length, plumule length and seedling height were measured using a scale and expressed in centimeters (cm). The mean value of five randomly selected seedlings from each Petri dish was calculated and expressed in centimeters.

Statistical analysis

The data on different parameters were statistically analyzed using the MSTAT computer program. The mean values for all parameters were calculated, and analysis of variance (ANOVA) was performed using the F-test. The significance of differences between pairs of means was tested by the Least Significant Difference (LSD) test at 5% and 1% levels of probability (Gomez and Gomez, 1984).

Results

Seed germination

The germination percentage varied significantly among the 50 genotypes. Ten genotypes, namely PI 226043, PI 249535, PI 261650, PI 279776, PI 294090, PI 289700, PI 232073, PI 341204, PI 419084 and PI 451759, showed no germination up to 19 days after seed placement in Petri dishes (Table 1). However, R4 showed no

germination up to 13 days, but 55% germination was recorded at 16 days and increased to 80% at 19 days after seed placement in Petri dishes. Among the remaining genotypes, Jiyang, Acrya and Spring Maki reached 100% germination by 13 days; PI 652143 and Pusa Kesar reached 100% by 16 days; and Koyogo Koyo No. 2 and Nantes Supreme reached 100% by 19 days after seed placement in Petri dishes. All other genotypes showed incomplete germination during the observation period (Table 1).

Radicle length

Radicle length also varied significantly among the genotypes. R5 had the longest radicle (3.55, 4.33, 5.02 and 5.63 cm) at 10, 13, 16 and 19 days after seed placement in Petri dishes, respectively, followed by Autumn King 2 (2.10, 2.52, 2.94 and 3.36 cm, respectively). However, PI 226043, PI 249535, PI 261650, PI 279776, PI 294090, PI 289700, PI 232073, PI 341204, PI 419084 and PI 451759 did not show any germination, and no seedlings were visible during the observation period. Cosmos did not show any visible radicle at 10 and 13 days and recorded the shortest radicle among the germinated genotypes at 16 (0.60 cm) and 19 (0.72 cm) days after seed placement (Table 1).

Plumule length

Plumule length was significantly affected by carrot genotypes. R5 showed the highest plumule length (3.50, 3.60, 4.00 and 4.11 cm) at 10, 13, 16 and 19 days, respectively, followed by Honku (Red) (3.40, 3.60, 3.60 and 3.65 cm, respectively). Cosmos produced the shortest plumule length (0.89 and 1.45 cm) at 16 and 19 days, respectively, and did not produce visible seedlings at 10 and 13 days after seed placement in Petri dishes. Among the germinated seedlings, Kosun showed the lowest plumule length at 10 days (0.83 cm), while Koyogo Koyo No. 2 and Tokita recorded the same lowest plumule length (1.00 cm) at 13 days. The ten non-germinated genotypes, namely PI 226043, PI 249535, PI 261650, PI 279776, PI 294090, PI 289700, PI 232073, PI 341204, PI 419084 and PI 451759, did not produce any plumule (Table 2).

Seedling length

Seedling length at different days after seed placement in Petri dishes also varied significantly among the 50 genotypes. The ten genotypes, namely PI 226043, PI 249535, PI 261650, PI 279776, PI 294090, PI 289700, PI 232073, PI 341204, PI 419084 and PI 451759, did not produce seedlings because they failed to germinate. Among the germinated genotypes, R5 produced the longest seedlings (7.05, 7.93, 9.02 and 9.74 cm), followed by Autumn King 2 (4.90, 5.32, 6.06 and 6.72 cm) and Honku (Red) (4.77, 5.32, 5.91 and 6.40 cm) at 10, 13, 16 and 19 days after seed placement, respectively (Table 2). Kosun produced the shortest seedlings (1.35 and 1.71 cm) at 10 and 13 days, whereas Cosmos produced the shortest seedlings (1.49 and 2.17 cm) at 16 and 19 days after seed placement among the germinated entries (Table 2).

Number of leaves seedling^{-1}

The number of leaves seedling–1 was counted at 13, 16 and 19 days after seed placement. Acrya produced significantly the lowest number of leaves seedling–1 (0.33) at 13 days, while Acrya and Orange Grand recorded the same lowest number of leaves seedling–1 (1.00) at both 16 and 19 days after seed placement (Table 2). Orange Grand did not produce leaves at 13 days. In contrast, Athaliaand R5 produced the highest number of leaves seedling–1 (3.33, 4.00 and 4.00) at 13, 16 and 19 days after seed placement, respectively, compared with the other genotypes (Table 2).

Table 1. Effect of carrot germplasm on seed germination percentage and radicle length at different days after seed placement in Petri dishes

Germplasm		Seed germination (%) at different days				Radicle length (cm) at different days after seed placement			
		10	13	16	19	10	13	16	19
G1	Brasilia (Embrapa)	55.00	70.00	85.00	90.00	0.64	0.78	0.84	1.08
G2	PI 226043	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G3	PI 249535	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G4	PI 261650	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G5	PI 279776	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G6	PI 294090	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G7	BAU Gajor 5	50.00	75.00	80.00	80.00	1.00	1.20	1.35	1.65
G8	Koyogo Koyo No. 2	70.00	80.00	95.00	100.00	0.84	1.05	1.20	1.38
G9	PI 289700	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G10	Love Heart	40.00	45.00	55.00	70.00	0.95	1.15	1.28	1.49
G11	PI 232073	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G12	Cosmos	0.00	15.00	50.00	70.00	0.00	0.00	0.60	0.72
G13	King Kuroda	25.00	50.00	55.00	60.00	0.99	1.22	1.49	1.74
G14	L1408	40.00	55.00	65.00	80.00	1.25	1.47	1.72	1.96
G15	Tokita	55.00	65.00	80.00	80.00	1.11	1.26	1.45	1.85
G16	T Summer	55.00	70.00	75.00	75.00	0.73	1.05	1.24	1.40
G17	PI 163238	50.00	70.00	70.00	75.00	0.85	1.02	1.19	1.36
G18	PI 652143	45.00	85.00	100.00	100.00	1.10	1.36	1.63	1.75
G19	PI 652259	65.00	90.00	90.00	90.00	0.97	1.16	1.36	1.55
G20	PI 652243	50.00	75.00	80.00	90.00	1.86	2.23	2.60	3.04
G21	Long Imperator	15.00	45.00	55.00	60.00	0.92	1.07	1.25	1.48
G22	Nantes 3	60.00	90.00	90.00	90.00	1.00	1.20	1.40	1.70
G23	PI 341204	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G24	Nantes Supreme	45.00	90.00	95.00	100.00	0.80	0.98	1.12	1.44
G25	Amsterdam 2	5.00	35.00	80.00	80.00	0.90	1.04	1.26	1.50
G26	Kosun	65.00	85.00	90.00	90.00	0.52	0.61	0.68	1.04
G27	Sweet Enrich	75.00	95.00	100.00	100.00	0.92	1.07	1.26	1.69
G28	Shin Kuroda	20.00	40.00	60.00	70.00	1.25	1.50	1.75	2.07
G29	Jiyang	60.00	100.00	100.00	100.00	1.50	1.91	2.24	2.51
G30	Acrya	75.00	100.00	100.00	100.00	1.59	1.90	2.38	2.70
G31	PI 419084	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G32	Royal Kuroda	65.00	80.00	80.00	90.00	1.72	2.02	2.38	2.80
G33	Orange Grand	70.00	90.00	90.00	90.00	1.12	1.25	1.40	1.60
G34	Pusa Kesar	70.00	90.00	100.00	100.00	0.88	1.34	1.81	2.10
G35	Bankim Keshor	65.00	75.00	75.00	75.00	1.35	1.63	1.90	2.36
G36	Tkimatting	65.00	80.00	80.00	80.00	1.57	1.95	2.56	2.83
G37	PI 451759	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G38	Kuroda Gosunto	60.00	75.00	90.00	90.00	0.71	0.96	1.29	1.59
G39	Sweet Salad People	55.00	80.00	90.00	90.00	1.45	1.96	2.35	2.78
G40	Okonomi	75.00	90.00	90.00	90.00	0.97	1.30	1.57	2.10
G41	P7262	55.00	75.00	75.00	75.00	1.00	1.20	1.40	1.60
G42	Sidur	85.00	90.00	90.00	90.00	1.00	1.16	1.26	1.42
G43	Athalia	85.00	90.00	90.00	90.00	1.27	1.54	1.86	2.27
G44	R4	0.00	0.00	55.00	80.00	0.62	0.82	0.94	1.13
G45	R5	70.00	75.00	80.00	90.00	3.55	4.33	5.02	5.63
G46	Piccolo	65.00	90.00	90.00	90.00	1.25	1.77	2.05	2.52
G47	Diamond	80.00	90.00	90.00	90.00	1.66	2.13	2.33	2.68
G48	Autumn King 2	80.00	90.00	90.00	90.00	2.10	2.52	2.94	3.36
G49	Spring Maki	75.00	100.00	100.00	100.00	1.78	2.32	2.44	2.52
G50	Honku (Red)	80.00	85.00	90.00	90.00	1.37	1.72	2.31	2.75
$LSD_{0.05}$		14.29	11.43	6.70	4.04	0.18	0.24	0.43	0.62
$LSD_{0.01}$		19.12	15.30	8.97	5.41	0.24	0.33	0.58	0.84
Level of significance		**	**	**	**	**	**	**	**

** = Significant at 1% level of probability

Table 2. Effect of carrot germplasm on plumule length, seedling length and number of leaves seedling–1 at different days after seed placement in Petri dishes

Germplasm		Plumule length (cm) at different days after seed placement				Seedling length (cm) at different days after seed placement				No. of leaves seedling–1 at different days after seed placement		
		10	13	16	19	10	13	16	19	13	16	19
G1	Brasilia (Embrapa)	1.43	1.50	2.00	2.46	2.07	2.28	2.84	3.54	1.00	1.67	2.17
G2	PI 226043	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G3	PI 249535	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G4	PI 261650	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G5	PI 279776	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G6	PI 294090	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G7	BAU Gajor 5	1.80	1.85	2.32	2.45	2.80	3.05	3.67	4.10	2.17	3.00	3.00
G8	Koyogo Koyo No. 2	0.85	1.00	1.65	2.10	1.69	2.05	2.85	3.48	1.17	2.50	2.50
G9	PI 289700	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G10	Love Heart	0.95	1.30	1.73	2.00	1.90	2.45	3.01	3.49	2.84	3.34	3.34
G11	PI 232073	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G12	Cosmos	0.00	0.00	0.89	1.45	0.00	0.00	1.49	2.17	0.00	0.00	0.67
G13	King Kuroda	1.20	1.60	2.00	2.50	2.19	2.82	3.49	4.24	1.33	1.84	2.34
G14	L1408	1.00	1.40	1.97	2.43	2.25	2.87	3.69	4.39	0.83	1.50	1.84
G15	Tokita	0.98	1.00	1.78	2.00	2.09	2.26	3.23	3.85	2.50	3.00	3.17
G16	T Summer	1.00	1.20	1.96	2.24	1.73	2.25	3.20	3.64	0.67	2.00	2.00
G17	PI 163238	1.10	1.50	2.00	2.00	1.95	2.52	3.19	3.36	1.84	2.17	2.17
G18	PI 652143	1.40	1.70	2.12	2.25	2.50	3.06	3.75	4.00	1.00	2.67	3.00
G19	PI 652259	1.40	1.50	2.34	2.40	2.37	2.66	3.70	3.95	1.33	1.67	2.00
G20	PI 652243	2.00	2.10	2.56	3.00	3.86	4.33	5.16	6.04	1.00	1.67	2.33
G21	Long Imperator	0.98	1.20	1.68	2.30	1.90	2.27	2.93	3.78	1.33	2.33	2.33
G22	Nantes 3	1.30	1.60	1.93	2.33	2.30	2.80	3.33	4.03	1.33	2.33	2.33
G23	PI 341204	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G24	Nantes Supreme	1.00	1.24	2.00	2.15	1.80	2.22	3.12	3.59	3.00	3.67	3.67
G25	Amsterdam 2	0.86	1.10	1.82	2.00	1.76	2.14	3.08	3.50	1.66	2.00	2.67
G26	Kosun	0.83	1.10	1.59	1.80	1.35	1.71	2.27	2.84	1.66	2.00	2.67
G27	Sweet Enrich	1.24	1.60	1.99	2.25	2.16	2.67	3.25	3.94	2.00	2.33	2.67
G28	Shin Kuroda	1.60	1.70	2.11	2.43	2.85	3.20	3.86	4.50	0.33	1.33	1.33
G29	Jiyang	1.90	2.00	2.64	3.00	3.40	3.91	4.88	5.51	1.00	1.33	1.33
G30	Acrya	2.00	2.12	2.83	2.85	3.59	4.02	5.21	5.55	0.33	1.00	1.00
G31	PI 419084	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G32	Royal Kuroda	2.00	2.13	2.68	2.80	3.72	4.15	5.06	5.60	1.00	1.67	2.00
G33	Orange Grand	1.50	1.70	2.23	2.56	2.62	2.95	3.63	4.16	0.00	1.00	1.00
G34	Pusa Kesar	2.76	3.00	3.45	3.65	3.64	4.34	5.26	5.75	3.00	3.67	3.67
G35	Bankim Keshor	1.90	1.98	2.37	2.45	3.25	3.61	4.27	4.81	1.00	2.67	2.67
G36	Tkimatting	1.60	1.86	2.42	2.50	3.17	3.81	4.98	5.33	2.67	3.00	3.00
G37	PI 451759	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G38	Kuroda Gosunto	2.13	2.16	2.61	2.80	2.84	3.12	3.90	4.39	1.00	2.67	3.00
G39	Sweet Salad People	1.68	1.83	2.23	2.30	3.13	3.79	4.58	5.08	1.33	1.67	2.00
G40	Okonomi	2.26	2.30	2.54	2.55	3.23	3.60	4.11	4.65	1.00	1.67	2.33
G41	P7262	1.40	1.50	1.67	2.30	2.40	2.70	3.07	3.90	1.33	2.33	2.33
G42	Sidur	3.00	3.13	3.36	3.50	4.00	4.29	4.62	4.92	1.33	2.33	2.33
G43	Athalia	2.50	2.70	2.94	3.25	3.77	4.24	4.80	5.52	3.33	4.00	4.00
G44	R4	1.46	1.47	1.64	2.00	2.08	2.29	2.58	3.13	0.33	1.33	1.33
G45	R5	3.50	3.60	4.00	4.11	7.05	7.93	9.02	9.74	3.33	4.00	4.00
G46	Piccolo	2.00	2.22	2.57	2.97	3.25	3.99	4.62	5.49	3.00	3.67	3.67
G47	Diamond	2.75	2.80	3.00	3.24	4.41	4.93	5.33	5.92	1.66	2.00	2.67
G48	Autumn King 2	2.80	2.80	3.12	3.36	4.90	5.32	6.06	6.72	1.66	2.00	2.67
G49	Spring Maki	2.06	2.12	2.16	2.45	3.84	4.44	4.60	4.97	2.00	2.33	2.67
G50	Honku (Red)	3.40	3.60	3.60	3.65	4.77	5.32	5.91	6.40	1.66	2.67	3.00
$LSD_{0.05}$		0.32	0.15	0.13	0.26	0.18	0.24	0.43	0.62	0.65	0.63	0.68
$LSD_{0.01}$		0.43	0.20	0.18	0.35	0.24	0.33	0.58	0.84	0.87	0.85	0.91
Level of significance		**	**	**	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability

Photographs:

Plate 1. Photograph showing the setting up of the experiment in the laboratory

Plate 2. Photograph showing seed germination (left), radicle length measurement (middle) and plumule length + leaves seedling–1 (right)

Discussion

The results for germination percentage clearly showed that the different germplasm differed in their germination behavior. Jiyang, Acrya, Spring Maki, PI 652143, Pusa Kesar, Koyogo Koyo No. 2 and Nantes Supreme exhibited 100% germination, indicating strong genetic potential and better adaptability to the laboratory germination conditions. The relatively poor germination observed in some carrot germplasm may be attributed to inherent seed-related factors, including genetic variability and physiological dormancy. Carrot seeds are known to show variable germination because of differences in embryo maturity and endogenous inhibitor levels. In addition, sensitivity of carrot seeds to environmental conditions such as temperature and moisture may have contributed to reduced germination performance. Similar findings were reported by Bolton and Simon (2019), who stated that variation in seed germination may be associated with the genetic characteristics of different carrot varieties. Although seed viability testing was not performed, the use of uniform, freshly sourced carrot seeds and the assessment of germination and seedling emergence provided sufficient indication of seed viability for the objectives of this study.

Pandey and Sharma (2017) also found significant variation in radicle length of carrot plants due to differences in genetic make-up among varieties. Therefore, the variation in radicle length observed in the present study may also be associated with genetic differences among the germplasm.

The variation in plumule length observed in the present study is in agreement with Pandey and Sharma (2017), who reported significant variation in carrot plumule length due to differences in the genetic make-up of varieties.

The significant variation in seedling length among the 50 genotypes may be due to genetic differences among the germplasm. The results are in agreement with Pandey and Sharma (2017), who reported that Early Nantes recorded significantly higher plant height than New Kuroda at every growth stage and that plant height increased with the advancement of growth. They also reported that varietal genetic make-up contributed to variation in plant height.

The variation in leaf production in the present study may be attributed to genetic differences among the germplasm and differences in adaptability under the experimental conditions. A similar result was reported by Rana et al. (2016), who stated that number of leaves seedling–1 varied significantly among carrot varieties.

Conclusion

The present study revealed significant variation among the 50-carrot germplasm for seed germination and early seedling growth traits. Jiyang, Acrya, Spring Maki, PI 652143, Pusa Kesar, Koyogo Koyo No. 2 and Nantes Supreme showed 100% germination, indicating their potential for rapid and uniform crop establishment. In contrast, PI 226043, PI 249535, PI 261650, PI 279776, PI 294090, PI 289700, PI 232073, PI 341204, PI 419084 and PI 451759 did not germinate within the observation period. For seedling growth, R5 showed the best overall performance, recording the highest radicle length, plumule length, seedling height and number of leaves seedling–1 at 19 days after seed placement, followed by Autumn King 2 and Honku (Red). Therefore, the germplasm with high germination capacity may be useful for improving seed establishment, while R5, Autumn King 2 and Honku (Red) may be valuable for selecting vigorous seedling traits. This promising germplasm can be considered for future carrot improvement programs and quality seedling production. Further evaluation under field conditions is recommended to confirm their adaptability, growth performance and yield potential.

Acknowledgements

The authors are pleased to thank BAS-USDA Endowment Program (Project No. 2025/4/BAS) for funding this research.

Author's Contribution

M.A.A.: Performing the field and lab experiments, collection and analysis of data. M.H.A.R.: Design, formulation and supervision of experiment. M.G.R: Co-supervision of experiment and review of manuscript, M.A.H.: Co-supervision of experiment and review of manuscript.

Conflict of interest:

The authors declare that there is no conflict of interest.

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