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Research Article

Evaluation of Seed Germination and Seedling Behaviour of Carrot Cultivars (*Daucus carota* L.)

Monira Mamotaj, Md. Harun Ar Rashid* and Md. Golam Rabbani

Department of Horticulture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.

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Correspondence
Md. Harun Ar Rashid
✉: harun_hort@bau.edu.bd

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ABSTRACT

An experiment was conducted in the Postgraduate Laboratory of the Department of Horticulture from 01 November, 2025 to 16 November, 2025 to determine the impact of carrot genotypes on different parameters during carrot seed germination. The single-factor experiment was laid out following a Completely Randomized Design (CRD) with three replications. The experiment included eight carrot genotypes namely- King Kuroda, Kuroda Improved, Pusha Keshor, Bankim Keshor, Brasilia 2007, BAU Gazor 5, Brasilia Agroflora and Prima Agroflora. Results revealed that BAU Gazor 5 took the minimum time for the emergence of the radicle (24 hrs) and plumule (46 hrs) while Prima Agroflora took the maximum time for radicle emergence (28 hrs) and Kuroda Improved took maximum time for plumule emergence (72 hrs). Again, BAU Gazor 5 also showed the highest plumule (2.55 cm) and radicle lengths (2.12 cm) at different days after sowing. In case of fungal infection maximum found in Brasilia Agroflora and Prima Agroflora where BAU Gazor 5 didn't show any fungal infection. Brasilia Agroflora also showed maximum seed rotting. However, the maximum germination percentage (86.67%) was also obtained from BAU Gazor 5. Overall, it can be concluded from the findings that BAU Gazor 5 showed better performance during carrot seed germination and seedling growth.

Introduction

Carrots (*Daucus carota* L.) are one of the most widely consumed root vegetables globally. They are the most common vegetable after potatoes and are considered an economically important crop (Silva and Supriana, 2020). It belongs to the Apiaceae family with 2n=18 (Peirce, 1987). They are appreciated not only for its sweet taste and versatility in cooking but also for its rich nutritional profile. Carrot contains carotenoids (β-carotene, α-carotene, lutein, lycopene) which are essential for vitamin A production, eye health, antioxidant activity, cancer risk reduction (Ikram *et al.*, 2024; Boadi *et al.,* 2021; Khomich *et al.*, 2020; Ahmad *et al*., 2019). β-carotene is the precursor of vitamin A and helps prevent -"night blindness". As the demand for high-quality carrots continues to rise, optimizing their production processes has become a focal point for agricultural scientists and farmers. Among the many factors that contribute to successful carrot cultivation, seed germination is one of the most crucial. Germination is the first step in the growth cycle, directly influencing the plant establishment, growth rate, and ultimately, yield. However, seed germination is a complex process influenced by multiple factors, including environmental conditions such as temperature, light, and moisture. Increasingly, research has revealed that the genetic makeup of carrot seeds, or genotype, also plays a pivotal role in determining germination success, germination rates, and overall seed vigor.

Understanding the role of genotype in seed germination is vital, as it helps elucidate the genetic factors that contribute to variations in seed performance. Carrot seed germination is known to be a highly sensitive process specially in drought (Nijabat *et al*., 2023), with successful sprouting requiring a precise balance of genetic predisposition and favorable environmental conditions. However, despite these conditions, germination rates can vary significantly among different carrot varieties, even when grown under identical environmental circumstances. This

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variation is largely attributable to genetic factors, which affect several aspects of the germination process, including the seed's ability to break dormancy, its responsiveness to environmental cues, and its rate of germination under specific conditions (Finch-Savage and Leubner-Metzger, 2006).

Genotype influences seed germination through a variety of mechanisms, such as seed coat characteristics, enzyme activity, hormone production, and the regulation of metabolic pathways. For instance, some genotypes may exhibit stronger dormancy traits, requiring specific environmental conditions or pre-treatment (such as stratification) to overcome this dormancy and trigger germination. Other genotypes may have an enhanced ability to germinate in suboptimal conditions, making them more resilient to environmental stressors like temperature fluctuations or drought. Under non-stress conditions, genotypes differ significantly in final germination percentage and speed (Nowicki *et al*., 2025). Moreover, genotypic differences can result in variations in seedling vigor and overall plant health, which have downstream effects on yield quality and quantity. These differences are particularly important when breeding new carrot varieties adapted to specific climatic regions or farming practices. The role of genotype in seed germination is not only of academic interest but also has significant practical implications for carrot growers and breeders. Selecting genotypes with faster or more uniform germination patterns can lead to stronger, more consistent stands of carrots. This experiment explores the impact of different genotypes on carrot seed germination, aiming to provide insights into how genetic diversity can be harnessed to enhance germination success and ultimately improve crop yield.

Materials and Methods

The laboratory-experiment was carried out at the Postgraduate Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh from 01 November, 2025 to 16 November, 2025. The single-factor experiment included eight carrot genotypes namely King Kuroda, Kuroda Improved, Pusha Keshor, Bankim Keshor, Brasilia 2007, BAU Gazor 5, Brasilia Agroflora and Prima Agroflora and was conducted following Completely Randomized Design (CRD) with three replications. The required materials included carrot seeds, Petridishes, filter paper, distilled water, a ruler and a laboratory notebook.

Seed sorting was performed to select a uniform batch of seeds. The Petridishes were prepared by placing a layer of filter paper at the bottom. The paper was moistened with a small amount of distilled water. 10 seeds were placed in each petri dish. Thereafter each petri dish was then covered with its lid. The laboratory condition was recorded everyday and humidity was around 90% and temperature around 24°C were maintained. Higher temperatures (35–36 °C) sharply reduce germination and seedling vigor (Pereira *et al*., 2008). According to silva *et al*. (2011) temperatures of 15°C and 35°C reduce germination and vigor compared with 20 °C. Laboratory germination was done on moist filter paper in closed dishes or trays to maintain humidity. In the germination process, the radicle emerges first and a seed is scored as germinated when the radicle emerges or reaches approximately half the seed length or >1 mm (Sun *et al*., 2025; Nijabat *et al.,* 2023; Bolton and Simon, 2019). The germination procedure was monitored daily and the number of seeds that germinated was recorded. Other parameters- such as plumule and radicle emergence time recorded in hours, plumule length, radicle length etc. were measured every 4 days. Five seeds from each petri dish were sampled, and individual data were recorded. Data were statistically analyzed, and means were calculated using an F-variance test. The significance of differences among the treatment means was evaluated by the Least Significant Difference (LSD) test at 5 and 1% levels of probability (Gomez and Gomez, 1984).

Results and Discussion

Weight of thousand seed

Different genotypes showed significant effect on weight of thousand seed. Maximum weight of 1000 seed was found (2.44 g) from Dc_6 subsequently it decreases (2.42 g) in case of Dc_4 and minimum (1.16 g) was found from Dc_7 (Table 1). Thousand seed weight indicates the size and quality of carrot seeds. Carrot seeds with higher weight generally have more stored food reserves. These reserves help in faster and more uniform germination. Heavier carrot seeds often show higher and faster germination (Vandelook *et al.,* 2024). Larger and heavier seeds produce more vigorous seedlings (Corbineau *et al.,* 1995; Gross, 1984). Seeds with low weight may have poor viability. Such seeds may germinate slowly or unevenly. Higher seed weight is linked with better seedling establishment. Thus, thousand seed weight positively influences carrot seed germination under suitable conditions.

Radicle emergence time

Genotype strongly influences radicle emergence in carrot seed germination. Genotype Prima Agroflora took maximum time (28 hour) and BAU Gazor 5 took minimum time (24 hour) for emergence of radicle (Table 1). Different carrot genotypes vary in the speed and uniformity of radicle protrusion. These differences arise from genetic control of embryo vigor and reserve mobilization. Carrot accessions shows variation in emergence timing in uniformity even when grown under the same conditions (Loarca *et al.,* 2024). Variation in seed coat structure among genotypes affects water uptake and radicle emergence. Hormonal regulation (gibberellin and abscisic acid balance) also differs by genotype. Thus, genotype plays key role in radicle emergence of carrot.

Table 1. Effect of genotype on weight of thousand seed, emergence time of radicle and plumule duringcarrot seed germination

Genotype	Weight of thousand seed (g)	Radicle emergence time (hour)	Plumule emergence time (hour)
Dc_1	1.95	25.00	48.00
Dc_2	1.22	26.00	72.00
Dc_3	1.87	27.00	69.00
Dc_4	2.42	27.00	65.00
Dc_5	1.46	25.00	49.00
Dc_6	2.44	24.00	46.00
Dc_7	1.16	25.00	49.00
Dc_8	2.05	28.00	51.00
$LSD_{0.01}$	0.12	2.70	5.66
Level of significance	**	**	**

** = Significant at 1% level of probability. Dc_1= King Kuroda, Dc_2= Kuroda Improved, Dc_3= Pusha Keshor, Dc_4= Bankim Keshor, Dc_5= Brasillia 2007, Dc_6= BAU Gazor 5, Dc_7= Brasilia Agroflora, Dc_8= Prima Agroflora.

Plumule emergence time

Genotype has a significant impact on plumule emergence of carrot seed. BAU Gazor 5 took minimum time (46 hour) for plumule emergence while Kuroda Improved took maximum time (72 hour) (Table 1). Different carrot genotypes vary in the timing and rate of plumule emergence.

These differences are linked to genetic variation in seedling vigor and growth potential. According to Loarca *et al.* (2024) carrot genotypes differ meaningfully plumule emergence time; this variation is strongly heritable and associated with early vigor. Genotype influences the efficiency of reserve utilization after radicle emergence. Variations in hormonal balance affect shoot elongation and plumule appearance. Some genotypes show faster plumule emergence and better early seedling growth.

Plumule length

Different genotypes showed significant effect on plumule length at different days. At 16 days after seed sowing maximum plumule length was 2.55 cm that was obtained by BAU Gazor 5 followed by King Kuroda (2.54 cm) (Table 2). Different carrot genotypes show wide variation in early shoot elongation. These differences are governed by genetic control of seedling vigor. According to Rashid *et al.* (2024) genotypes show significant variation in plumule length. Genotype influences the rate of cell division and elongation in the plumule. Seedling length and related traits are recognized as relevant proxies for vigor and stand establishment in carrot and other crops (Loarca *et al*., 2024). Genetic variability for shoot traits supports a strong genetic component in early shoot development (Kumar *et al*., 2022; Meghashree *et al*., 2018). Efficient mobilization of seed reserves contributes to longer plumules in some genotypes. Hormonal regulation, especially gibberellin activity varies among genotypes. Again, improved genotypes often exhibit greater plumule length than traditional varieties. Longer plumules indicate stronger early seedling establishment. So, plumule length is a genotype-dependent trait in carrot seed germination.

Radicle length

Genotype showed statistically significant influences on radicle length during carrot seed germination. At 16 days after seed sowing BAU Gazor 5 showed maximum radicle length (2.12 cm) while Brasilia 2007 showed minimum (2.03 cm) (Table 3). Different carrot genotypes show variation in early root elongation. This result matched with Rashid *et al.* (2024). This variation is due to genetic control of seedling vigor and cell elongation. Again, high genotypic coefficients of variation and heritability for root length and related parameters support early root development (Singh *et al*., 2022; Meghashree *et al*., 2018). Some genotypes produce longer radicles, enhancing early water and nutrient uptake. Thus, radicle length is a genotype-dependent trait in carrot seed germination.

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Table 2. Effect of genotype on plumule length during carrot seed germination

Genotype	Plumule length (cm) at different days after sowing			
	4	8	12	16
Dc_1	0.55	1.28	2.42	2.54
Dc_2	0.45	1.20	2.31	2.51
Dc_3	0.43	1.25	2.21	2.52
Dc_4	0.51	1.21	1.98	2.51
Dc_5	0.44	1.19	2.28	2.47
Dc_6	0.55	1.32	2.42	2.55
Dc_7	0.51	1.27	1.89	2.50
Dc_8	0.42	1.23	2.29	2.49
$LSD_{0.01}$	0.05	0.04	0.48	0.05
Level of significance	**	**	**	**

** = Significant at 1% level of probability. Dc_1= King Kuroda, Dc_2= Kuroda Improved, Dc_3= Pusha Keshor, Dc_4= Bankim Keshor, Dc_5= Brasillia 2007, Dc_6= BAU Gazor 5, Dc_7= Brasilia Agroflora, Dc_8= Prima Agroflora.

Table 3. Effect of genotype on radicle length during carrot seed germination

Genotype	Radicle length (cm) at different days after sowing			
	4	8	12	16
Dc_1	0.62	1.18	1.89	2.11
Dc_2	0.58	1.23	1.85	2.05
Dc_3	0.57	1.16	1.84	2.05
Dc_4	0.61	1.21	1.84	2.04
Dc_5	0.60	1.10	1.88	2.03
Dc_6	0.62	1.25	1.87	2.12
Dc_7	0.56	1.20	1.83	2.11
Dc_8	0.55	1.11	1.92	2.12
$LSD_{0.05}$	0.03	0.05	0.05	0.05
$LSD_{0.01}$	0.05	0.07	0.08	0.08
Level of significance	**	**	*	**

** = Significant at 1% level of probability. * = Significant at 5% level of probability. Dc_1= King Kuroda, Dc_2= Kuroda Improved, Dc_3= Pusha Keshor, Dc_4= Bankim Keshor, Dc_5= Brasillia 2007, Dc_6= BAU Gazor 5, Dc_7= Brasilia Agroflora, Dc_8= Prima Agroflora.

Germination percentage

Impact of genotype was statistically significant on germination percentage. Maximum germination was obtained from Dc_6 (86.67%) and lowest germination percentage was obtained from Dc_2 (60.00%) (Table 4). Genotype plays a crucial role in determining the germination percentage of carrot seeds. According to Accogli *et al*. (2025) seed quality character germination rates for the "Polignano" and "Tiggiano" carrot seeds were 79.7 and 85.8%, respectively. Carrot seed germination is strongly genotype dependent (Nijabat *et al*., 2023). Under optimal lab conditions, mean germination is often high (≈80%), but individual accessions range from about 50% to 100% (Bolton and Simon, 2019). As different carrot varieties exhibit varying levels of seed viability, with some genotypes showing higher germination rates than others. Genetic factors influence the seed's ability to absorb water, initiate metabolic processes, and successfully sprout. Certain genotypes may have naturally stronger seed coats or better stress tolerance, leading to higher germination percentages. Environmental factors, such as temperature and moisture, can also interact with genetic traits, either promoting or limiting seed germination.

Table 4. Effect of genotype on fungal infection, seed rotting and germination percentage during carrot seed germination

Genotype	Germination (%)	Seed rotting (%)	Fungal infection (%)
Dc_1	76.67	0.00	0.00
Dc_2	60.00	20.00	40.00
Dc_3	63.33	0.00	0.00
Dc_4	78.33	0.00	0.00
Dc_5	75.00	10.00	0.00
Dc_6	86.67	0.00	0.00
Dc_7	71.67	30.00	50.00
Dc_8	78.33	0.00	50.00
$LSD_{0.01}$	4.94	4.80	9.88
Level of significance	**	**	**

** = Significant at 1% level of probability. Dc_1= King Kuroda, Dc_2= Kuroda Improved, Dc_3= Pusha Keshor, Dc_4= Bankim Keshor, Dc_5= Brasillia 2007, Dc_6= BAU Gazor 5, Dc_7= Brasilia Agroflora, Dc_8= Prima Agroflora

Seed sowing Emergence of radicle Emergence of plumule

Plate 1: Different stage during carrot seed germination

Seed rotting

The impact of genotype on seed rotting during carrot seed germination is significant. Only 3 genotype showed seed rotting where Brasilia Agroflora showed maximum percentage (30) followed by Kuroda Improved (20%) (Table 4). Seed borne fungi like *Alternaria, Fusarium* etc. cause seed rot and cause lower germination and abnormal seedling (Rosińska *et al*., 2023; Szopińska and Dorna, 2021). Different carrot genotypes show varying susceptibility to pathogens, affecting the extent of seed rot. Some genotypes possess inherent resistance traits, reducing fungal colonization and decay. Others may be more susceptible, leading to higher seed loss. Environmental conditions often interact with genetic traits, influencing the severity of rotting. Seed coat properties and biochemical defenses also vary with genotype and influences seed rotting.

Fungal Infection

Genotype has a significant impact on fungal infection during carrot seed germination. Maximum fungal infection was found in both genotype Brasilia agroflora and Prima Agroflora followed by Kuroda Improved (Table 4). It is an important seed quality character that helps in germination. Plant population is primarily dependent on seed quality (Noor *et al*., 2020; Oliva *et al.,* 1988) that control the number of populations. Seed-borne fungi specially *Alternaria*, *Fusarium* etc. are common on carrot seed and are a major cause of reduced germination and weak seedlings (Rosińska and Gato, 2025; Zhang *et al*., 2020). Different carrot genotypes vary in their susceptibility to seed-borne and soil-borne fungi. Fungal infection strongly associated with abnormal seedlings, damping-off and seed decay, lowering effective germination and emergence (Szopińska *et al*., 2010; Tylkowska and Bulk, 2001). Genetic differences in seed coat structure influence fungal penetration. Some genotypes contain higher levels of natural antifungal compounds. Genotype affects the rate of germination, reducing the window for fungal attack. More vigorous genotypes establish seedlings faster and resist infection better. Variation in moisture absorption among genotypes also influences fungal growth.

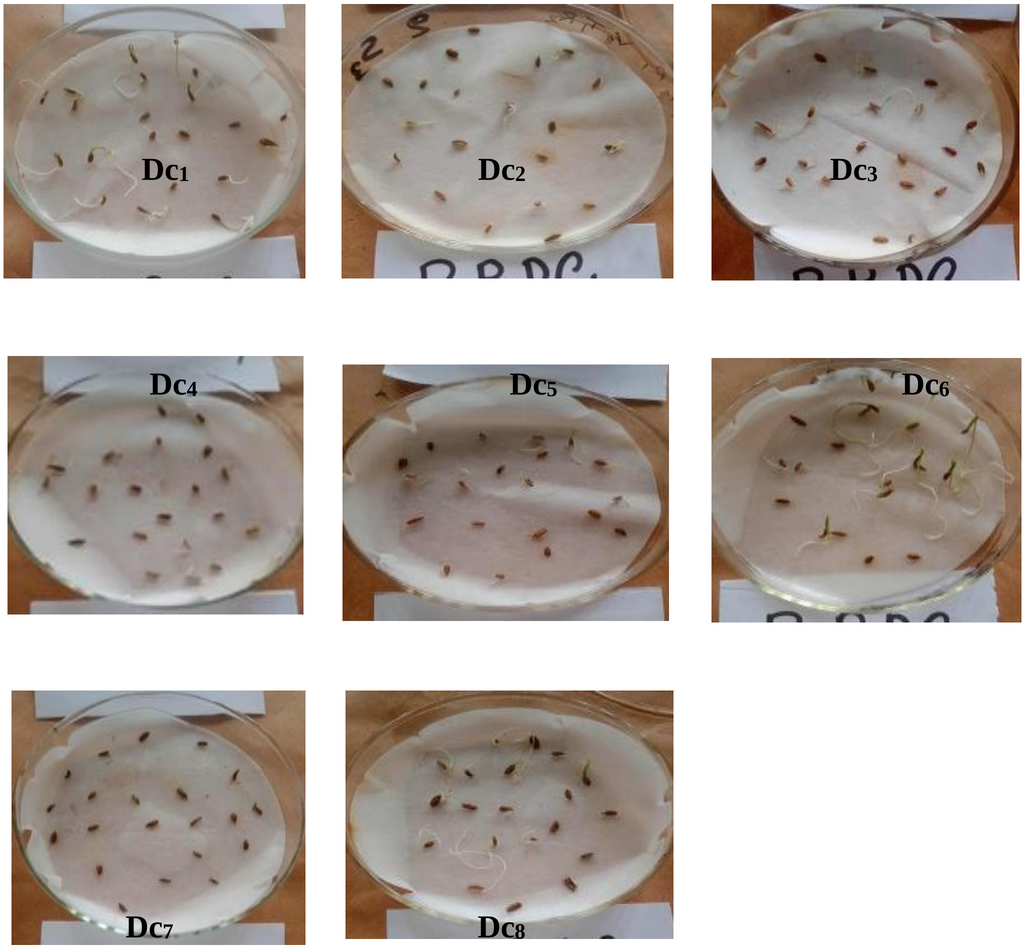

Plate 2: Photograph showing germination test of different carrot genotype

Dc_1= King Kuroda, Dc_2= Kuroda Improved, Dc_3= Pusha Keshor, Dc_4= Bankim Keshor, Dc_5= Brasillia 2007, Dc_6= BAU Gazor 5, Dc_7= Brasilia Agroflora, Dc_8= Prima Agroflora.

Conclusion

From the findings considering the genotypic impact on carrot seed germination, and seedling growth BAU Gazor 5 showed better performance during carrot seed germination.

Author's Contribution

M.M.: 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.

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Conflict of interest

The authors did this research and wrote the article and there is no conflict of interest with others.

References

Accogli, R., Cazzato, E., Bellomo, D., Santamaria, P., and Renna, M. 2025: Morphological profile and seed yield ability of polignano and tiggiano carrot landraces: steps toward registration as conservation varieties. *Horticulturae* 11(2) 199.

Ahmad, T., Cawood, M., Iqbal, Q., Ariño, A., Batool, A., Tariq, RMS., and Akhtar, S. 2019. Phytochemicals in Daucus carota and their health benefits. *Foods*, 8(9), 424.

Boadi, N. O., Badu, M., Kortei, N. K., Saah, S. A., Annor, B., Mensah, M. B., and Fiebor, A. 2021. Nutritional composition and antioxidant properties of three varieties of carrot (Daucus carota). *Scientific African*, 12, e00801.

Bolton, A., and Simon, P. 2019. Variation for Salinity Tolerance During Seed Germination in Diverse Carrot [*Daucus carota* (L.)] Germplasm. *HortScience*. https://doi.org/10.21273/hortsci13333-18.

Corbineau, F., Picard, M., Bonnet, A., and Côme, D. 1995. Effects of production factors on germination responses of carrot seeds to temperature and oxygen. *Seed Science Research*, 5, 129 - 135.

https://doi.org/10.1017/s0960258500002749.
Finch-Savage, W., and Leubner-Metzger, G. 2006. Seed dormancy and the control of germination. *The New phytologist, 171 3*, 501-23 . https://doi.org/10.1111/j.1469-8137.2006.01787.x.
Gomez, K.A., and Gomez, A.A. 1984. *Statistical procedures for agricultural research*. John Wiley & Sons.
Gross, K. 1984. Effects of seed size and growth form on seedling establishment of six monocarpic perennial plants. *Journal of Ecology*, 72, 369-387. https://doi.org/10.2307/2260053.
Ikram, A., Rasheed, A., Ahmad Khan, A., Khan, R., Ahmad, M., Bashir, R., and Hassan Mohamed, M. 2024. Exploring the health benefits and utility of carrots and carrot pomace: a systematic review. *International Journal of Food Properties*, 27(1), 180-193.
Khomich, L. M., Perova, I. B., and Eller, K. I. 2020. Carrot juice nutritional profile. *Voprosy Pitaniia,* 89(1), 86-95.
Kumar, N., Nigam, A., and Pathak, A. 2022. Assessment of genetic variability and path analysis in carrot (Daucus carota L.) genotypes. *International Journal of Horticulture and Food Science.* https://doi.org/10.33545/26631067.2022.v4.i1a.77.
Loarca, J., Liou, M., Dawson, J., and Simon, P. 2024. Evaluation of shoot-growth variation in diverse carrot (*Daucus carota* L.) germplasm for genetic improvement of stand establishment. *Frontiers in Plant Science*, 15. https://doi.org/10.3389/fpls.2024.1342512.
Meghashree, J., Hanchinamani, C., Hadimani, H., Nishani, S., Ramanagouda, S., and Kamble, C. 2018. Genetic variability studies for different attributes in Carrot Genotypes (*Daucus carota* L.) under Kharif Season. *International Journal of Current Microbiology and Applied Sciences*. https://doi.org/10.20546/ijcmas.2018.712.391.
Nijabat, A., Manzoor, S., Faiz, S., Naveed, N., Bolton, A., Khan, B., Ali, A., and Simon, P. 2023. Variation in seed germination and amylase activity of diverse Carrot [*Daucus carota* (L.)] Germplasm under Simulated Drought Stress. *HortScience*. https://doi.org/10.21273/hortsci16806-22.
Noor, A., Ziaf, K., Ghani, M. A., Ayub, C. M., Ahmad, I., and Amjad, M. 2020. 35. Plant spacing effects on seed yield and quality of carrot genotype *T-29. Pure and Applied Biology* 9(4) 2563-2570.
Nowicki, M., Nowakowska, M., Nowak, K., Szczechura, W., and Kamiński, P. 2025. Seed priming and abiotic stress tolerance in carrot: Unraveling the mechanisms of improved germination. *PLOS ONE*, 20. https://doi.org/10.1371/journal.pone.0318753.
Oliva, R., Tissaoui, T., and Bradford, K. 1988: Relationships of plant density and harvest index to seed yield and quality in carrot. *Journal of the American Society for Horticultural Science,*113 (4),532-537.
Peirce, L. C. 1987. *Vegetables. Characteristics, production, and marketing* (p. 433pp).
Pereira, R., Nascimento, W., and Vieira, J. 2008. Carrot seed germination and vigor in response to temperature and umbel orders. *Scientia Agricola*, 65, 145-150. https://doi.org/10.1590/s0103-90162008000200006.
Rashid, M., Zahura, M., Suchi, K., Anjum, N., Tasmim, M., and Simon, P. 2024. Effects of salinity stress on the seed germination and seedling characters of carrots (*Daucus carota* L.). *Fundamental and Applied Agriculture*. https://doi.org/10.5455/faa.201891.
Rosińska, A., and Gato, R. 2025. The effect of true cinnamon tree and peppermint hydrolates on germination and seed health of carrot seeds. *Notula Botanicae Horti Agrobotanici Cluj-Napoca*. https://doi.org/10.15835/nbha53214553.
Rosińska, A., Andrzejak, R., and Kakkerla, V. 2023. Effect of osmopriming with melatonin on germination, vigor and health of *Daucus carota* L. Seeds. *Agriculture*. https://doi.org/10.3390/agriculture13040749.
Silva Jr, A. A. D., and Supriana, T. 2020. Analysis of farmer's revenue and factors which affect carrot production in Surbakti Village. In *IOP Conference Series: Earth and Environmental Science* (Vol. 454, No. 1, p. 012028). IOP Publishing.
Silva, M., Medeiros, A., Dias, D., Alvarenga, E., Coelho, F., and Braun, H. 2011. Effect of heat and water stress on germination and vigour of carrot seeds. *Idesia*, 29(3), 39-44.
Singh, D., Dhillon, T., Javed, T., Singh, R., Dobaria, J., Dhankhar, S., Kianersi, F., Ali, B., Poczai, P., and Kumar, U. 2022. Exploring the genetic diversity of carrot genotypes through phenotypically and genetically detailed germplasm collection. *Agronomy*. https://doi.org/10.3390/agronomy12081921.
Sun, Y., Yin, Y., Wang, G., Han, X., Lan, Y., Huang, D., and Zhao, S. 2025. Hydro-electro hybrid priming synchronizes cell wall remodeling to accelerate carrot (*Daucus carota* L.) Seed Germination. *Agronomy*, 15(5),1147. https://doi.org/10.3390/agronomy15051147.
Szopińska, D., and Dorna, H. 2021. The effect of microwave treatment on germination and health of carrot (*Daucus carota* L.) seeds. *Agronomy.* https://doi.org/10.3390/agronomy11122571.
Szopińska, D., Jensen, B., Knudsen, I., Tylkowska, K., and Dorna, H. 2010. Non-chemical methods for controlling seedborne fungi in carrot with special reference to Alternaria radicina. *Journal of Plant Protection Research*, 50, 184-192. https://doi.org/10.2478/v10045-010-0031-3.
Tylkowska, K., and Bulk, R. 2001. Effects of osmo- and hydropriming on fungal infestation levels and germination of carrot (*Daucus carota* L.) seeds contaminated with Alternaria spp. Seed *Science and Technology*, 29, 365-375.
Vandelook, F., Van De Vyver, A., and Soltani, E. 2024. Intra-specific variation in relative embryo length and germination of wild Daucus carota across climate gradients in North America and Europe. *Seed Science Research.* https://doi.org/10.1017/s0960258524000230.
Zhang, X., Wang, R., Ning, H., Li, W., Bai, Y., and Li, Y. 2020. Evaluation and management of fungal-infected carrot seeds. *Scientific Reports*, 10. https://doi.org/10.1038/s41598-020-67907-5.