

Seed Germination Performance of Four Sugarbeet Genotypes (*Beta vulgaris* L.) under Laboratory and Open Field Conditions

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Abstract: The standard germination test serves as a measure of seed quality, utilized to forecast field emergence under nearly optimal conditions. Healthy seeds result in robust seedlings, ultimately contributing to improved crop yields. Two germination experiments were conducted at the same time in laboratory and open field conditions in December 2025 following a similar procedure to study the seed performance of four sugar beet genotypes. Four genotypes were namely, Danicia, Allanya, Serenada and Gregoria, collected from the Bangladesh Sugarcrop Research Institute (BSRI). Seeds were used to determine viability percentage, germination percentage and vigor based on seedling length, seedling fresh weight and germination speed index. Significant variation was observed in the studied parameters of sugarbeet genotypes. Higher to lower values of viability, germination, seedling length, seedling fresh weight and germination speed index were found in the Allanya, Gregoria, Danicia and Serenada genotype seeds, respectively. The germination results (>80%) indicated that the Allanya and Gregoria genotypes seeds of sugarbeet, respectively, were better under laboratory and open-field conditions.

Keywords: Tropical sugarbeet, Variety, Germination, Seedling growth, Seed vigor

INTRODUCTION

Crop yields and quality would be greatly affected without a steady supply of high-quality seed (Douglas, 2019). Seed is a basic input in agriculture and quality seed plays an important role in sustainable crop production (Shubha *et al.*, 2017). Healthy seeds mean healthy seedlings that finally lead to better production. Good seed of any crop ensures quality. Seedling length, fresh weight and seed vigor index are major components of standard germination, which can be taken into consideration to improve plant population through increasing germination percent, ultimately resulting in higher seed yield (Manjeet *et al.*, 2020). Seed is one of the important basis components for crop production. More healthy seedlings guarantee more crop stands in the field and, thus, a higher yield (Devi *et al.*, 2022). Vigor is usually measured by the speed of germination, expressed as the number of seeds sprouting per day, or by their performance in stress conditions. Many environmental stresses could reduce the field germination rate of seed below the germination rate predicted by the test (Than, 1987).

Sugar beet (*Beta vulgaris* L.) belongs to the family Amaranthaceae, which is considered to be the second most

important sugar crop in the world after sugarcane in terms of world sugar production. Sugar serves as an important source of nutrients for humans. Sugarcane and sugar beet have become the main sources of sugar production (Rajacifar *et al.*, 2019). It is grown commercially for sugar production, mostly in temperate countries. Sugar beet has potential in the subtropical sugar sector, particularly in Bangladesh (Paul *et al.*, 2018). In Bangladesh, sugar beet is a newly introduced crop which has been successfully grown with some challenges (Bithy *et al.*, 2020).

The genotypes of tropical sugar beets can be cultivated in Bangladesh with general cultivable soil conditions (Jahan *et al.*, 2025). Sugar beet is a short-duration crop, having a growth period of about half of sugarcane with high sucrose content (Syngenta, 2004). Its productivity per unit time is higher than sugarcane. Beet root is a good source of minerals, carbohydrates, protein, and it has high levels of vitamin B₁ and micro-nutrients. Considered as a vegetable, beet root may have many positive influences on human health (Cerne and Vrhovnik, 1999). Beetroot juice is today advocated as a stimulant for the immune system, as well as cancer prevention, and it has long been considered beneficial to the blood, heart and the digestive system (Nottingham, 2004). Europe remains at the top regarding

sugar beet production. Russia is at the top with a production of 42.07 t ha⁻¹ (FAO, 2019). Sugar beets provide nearly 30% of sugar production in the world and the taproot of sugar beet contains 13-22% sugar (Mahapatra *et al.*, 2020). In this regard, sugar beet might be an excellent alternative to sugarcane if processing facilities are developed in the sugar mills. Agronomic practices such as variety and location are important for the appreciable root yield and quality of tropical sugar beet. Seed and root characteristics are crucial factors for selecting suitable sugar beet genotypes (Bayomi and Khaled, 2024). Feasibility of sugar beet cultivation in Bangladesh is under trial although some people are growing low sucrose containing genotype as salad and vegetable purposes (Paul *et al.*, 2018). Sugar beet seems to be an encouraging sugar crop due to its short duration, less requirement of water, higher yield and high

sucrose content compared to sugarcane (Bithy *et al.*, 2021). The objective of this study is to observe the seed germination performance of four introduced genotypes by BSRI of sugar beet in a laboratory and open-field environment.

MATERIALS AND METHODS

A laboratory and an open field experiment were conducted following the same procedure during winter (1–15 December 2025) at Bangladesh Open University main campus located at Board bazar under Gacha union of Gazipur Sadar upazila. The geographical location of the experimental site with the coordinates of latitude 23.9443°N and longitude 90.3819°E (Fig. 1).

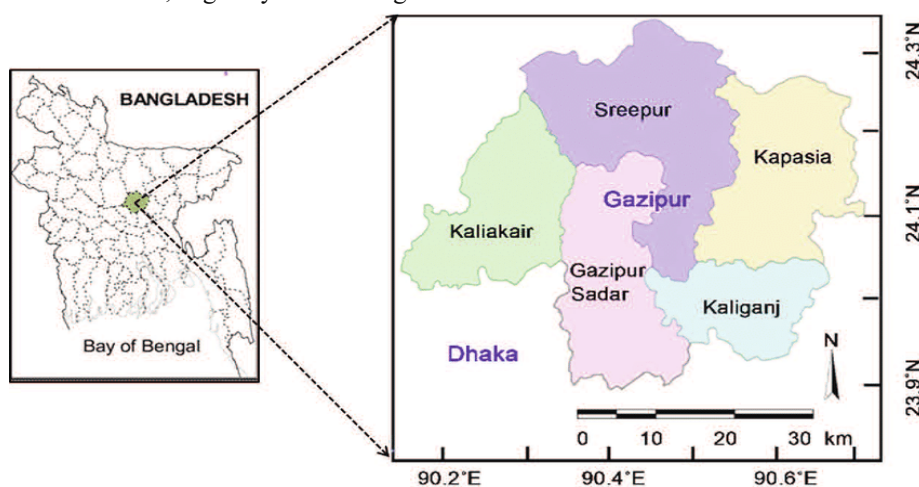


Figure 1. Location map of Gazipur District, Bangladesh (Rony *et al.*, 2021)

The objective of both experiments was to evaluate seed quality of four selected sugarbeet genotypes, namely, Danicia, Allanya, Serenada and Gregoria. Both laboratory and open field germination tests were arranged in a Complete Randomized Design (CRD) with four replications. Seeds were collected from the Breeding Division of Bangladesh Sugar crop Research Institute (BSRI), Bangladesh. Seeds were used to determine viability percentage, germination percentage and seed vigor based on seedling length, seedling fresh weight and germination speed index following standard procedure. The experimental area belongs to the Madhupur Tract Agroecological Zone (AEZ-28) (UNDP and FAO, 1988). The average daily temperature and relative humidity of the open experimental site were observed between 17.2 to 21.5°C and 68–83%, respectively. Whereas, the laboratory temperature was between 20.5 to 23.2°C and relative humidity was 55–68%.

The emergence of seedlings is a major problem affecting standard establishment in sugar beet production.

The sand laboratory procedures for measuring seedlings' emergence of sugarbeet were highly correlated with field emergence, whereas standard germination was not a reliable indicator of emergence potential (Akeson and Widner, 1980). The germination test was conducted following the standard procedure (ISTA, 2013). Four replicates, 50 seeds of each genotype, were sown in wet sand in each 30 cm-diameter plastic plate for germination under laboratory and field conditions on 01 December 2025. Intensive care was taken up to 14 days from seed placement to maintain an optimum germination environment. The plates were monitored daily, counted and recorded for the sprouted seeds for determination of percentage germination rate in each replication.



Figure 2. Sugarbeet seeds germinated on a plate under laboratory (Left) and open-field (Right) conditions

All sprouted seeds are counted to calculate the viability percentage, but only normal seedlings were counted for germination results at the time of the final count. The final count for germination was recorded on the 14th day. Seedling length and seedling fresh weight of 10 randomly selected seedlings from each replication were measured on a centimeter scale and digital balance and expressed in centimeters and milligrams, respectively. Individual mean seedling length (cm) and fresh weight (g) are directly related to calculation of seed vigor. Elongation of root and shoot is an expression of seedling length. Speed of germination expresses the rate of germination in terms of the total number of seeds that germinate in a time interval. Germination speed index was calculated by following the standard formula (Maguire, 1968). The germination index is the result of the sum of the number of new seeds germinated each day divided by the number of days. The values mentioned in the table under the germination speed

index were calculated based on each replication (50 seeds). Data on various parameters were statistically analyzed using an R software and Duncan's Multiple Range Test (DMRT) adjusted the means (Gomez and Gomez, 1984).

RESULTS

The seed quality of four sugarbeet varieties was evaluated under laboratory and open-field conditions. The measured seed quality parameters showed significant variations in both experiments (Table 1, 2 and Fig. 2).

Laboratory Experiment

The effect of sugarbeet variety on viability was found statistically significant (Table 1). Higher viability (92.25%) was found in the Allanya variety (V_2) that was statically similar to Gregoria (V_4). The lowest viability (67.25%) was found in Serenada (V_3).

Table 1. Effect of sugarbeet genotypes on the seed quality parameters under laboratory conditions

Variety	Seed quality parameters			
	Viability (%)	Seedling length (cm)	Seedling fresh weight (mg)	Germination speed index
Dancia (V_1)	79.50b	9.01bc	74.29c	9.70c
Allanya (V_2)	92.25a	9.88a	87.97a	13.57a
Serenada (V_3)	67.25c	8.60c	65.54d	7.78d
Gregoria (V_4)	85.50ab	9.56ab	83.35b	11.52b
Level of sig.	***	**	***	***
CV (%)	6.42	4.23	2.89	2.18

In a column with a similar letter(s) are statistically similar and those with a dissimilar letter(s) differ significantly at a 5% probability level. ***=Significant at 0.1% level of probability, **=Significant at 1% level of probability.

A higher seedling length (9.88 cm) was found in Allanya (V_2) and the lowest seedling length (8.60 cm) in Serenada, which measured at 14 days after sowing (DAS).

Fresh seedling weight was found statistically significant due to variety. Higher fresh seedling weight (87.97g) was found in the Allanya variety (V_2) and the lowest fresh

seedling weight (65.54g) was found in Serenada (V₃). Gregoria and Danicia are in 2nd (83.85 mg) and 3rd (74.29 mg) positions in respect of individual seedling fresh weight. The germination speed index of four seed samples of sugarbeet varieties varied from 7.78 to 13.57. Allanya (V₂), a variety of sugarbeet, showed a higher germination speed index value (13.57), which was greater than Gregoria (11.52), Danicia (9.70) and Serenada (7.78). The

germination percentage of four sugarbeet varieties varied from 64.25 to 85.50%. A higher germination rate (85.50%) was found in the Allanya variety (V₂), which was statistically similar to Gregoria (V₄). Lowest germination percentage (64.25%) was observed in Serenada (V₃). Danicia (V₁) showed 3rd position in respect of viability (79.50%) and germination rate (75.25%) under laboratory conditions (Fig. 2).

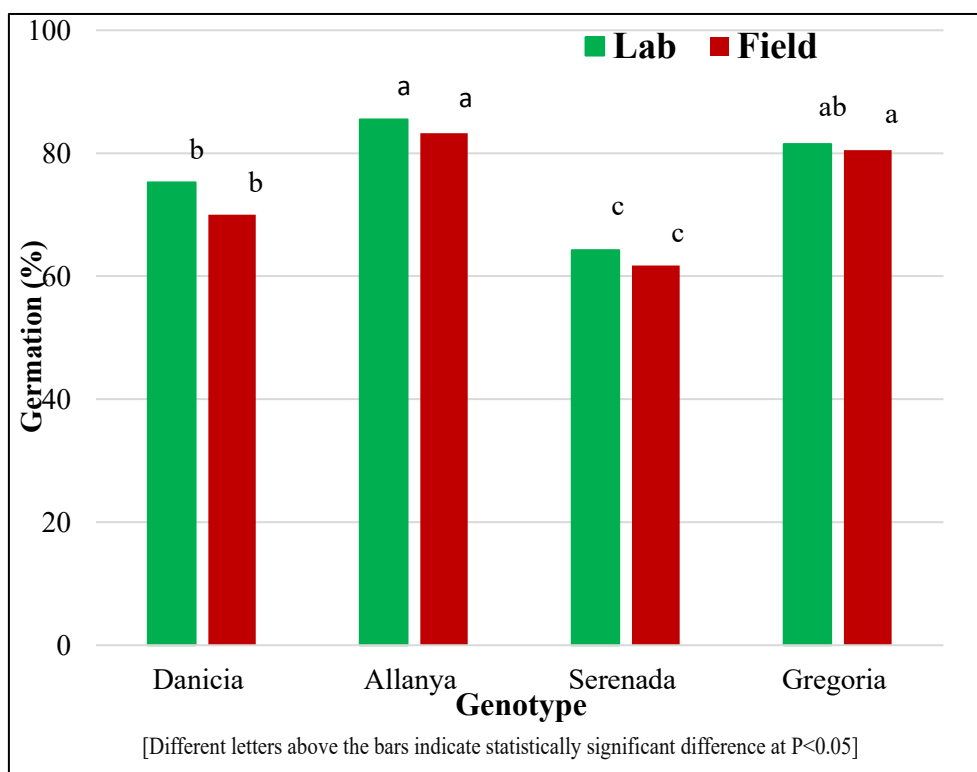


Figure 3. Germination (%) of four sugarbeet genotypes under laboratory and open field conditions

The results indicated that Allanya had higher vigor with a higher germination rate. Seedling vigor as expressed in terms of seedling length, fresh seedling weight and germination speed. Germination speed index values indicate the early seed sprouting of seeds which are capable of producing more normal seedlings. This means the Allanya seeds of sugarbeet have more potential than the Gregoria, Danicia and Serenada varieties, respectively. This might be due to more food reserve and dry matter accumulation in Allanya seeds.

Open field experiment

The effect of sugarbeet variety on viability was found statistically significant (Table 2). A higher viability rate (89.75%) was found in the Allanya variety (V₂) that was statically similar to Gregoria (V₄) under open field environmental conditions. The lowest viability (59.25%) was found in Serenada (V₃). A higher germination rate (83.25%) was found in the Allanya variety (V₂), which was statistically similar to Gregoria (V₄). Lowest germination

percentage (61.75%) was observed in Serenada (V₃). Danicia (V₁) showed 3rd position in respect of germination rate (70.00%) under open field conditions (Fig. 2). A higher seedling length (11.94 cm) was found in Allanya (V₁), which was statistically similar to Gregoria (V₃), which was measured at the end of the test (14 days after sowing). Higher seedling fresh weight (108.55 mg) was found in the Allanya variety (V₂) and the lowest seedling fresh weight (74.57 mg) was found in Serenada (V₃). Gregoria (V₄) and Danicia (V₁) are in 2nd and 4th positions in respect of individual seedling fresh weight. Allanya (V₁), a variety of sugarbeet, showed a higher germination speed index value (12.52) than other tested varieties. Gregoria (12.52), Danicia (9.70) and Serenada (7.78) held 2nd, 3rd and 4th positions in respect of the germination speed index. Seedling length was observed to be higher in all cases under open field conditions than in laboratory conditions (Table 1 and Table 2), especially root growth was found higher in open field conditions (Plate 1-4).

Table 2. Effect of sugarbeet genotypes on the seed quality parameters under field conditions

Variety	Seed quality parameters			
	Viability (%)	Seedling length (cm)	Seedling fresh weight (mg)	Germination speed index
Dancia (V ₁)	75.00b	10.28b	85.04c	9.32c
Allanya (V ₂)	89.75a	11.94a	108.55a	12.52a
Serenada (V ₃)	59.25c	9.66b	74.57d	7.43d
Gregoria (V ₄)	82.75ab	11.31a	100.99b	10.36b
Level of sig.	***	***	***	***
CV (%)	6.98	4.19	3.42	2.37

In a column with a similar letter(s) are statistically similar and those with a dissimilar letter(s) differ significantly at a 5% probability level. ***=Significant at 0.1% level of probability.

DISCUSSION

The standard germination test is an indicator of seed quality, which can be used to predict field emergence of crops (Daurant and Gummerson, 1990). Allanya variety of sugarbeet showed higher viability percent, germination rate, individual seedling length, individual seedling fresh weight and germination speed index compared to Gregoria, Dancia and Serenada under both laboratory and open field conditions. Seed viability percent, germination rate and germination speed index values are higher in the laboratory. On the other hand, individual seedling length and individual seedling fresh weight were found higher in all varieties under open field conditions. Allanya and Gregoria varieties of sugarbeet were identified to have a standard germination rate (>80%), respectively, in both conditions (Fig. 2). Fast seed sprouting occurs in a laboratory after five days of sowing and then in open field conditions after seven days from sowing. Most probably, this variation happens due to the influence of environmental factors like temperature, relative humidity and light. Comparatively, a higher temperature was present in the laboratory, which could accelerate early germination of seeds than the open space atmospheric temperature in winter. Similar statements are agreed by several researchers. Germination is affected by genetics as well as environmental factors like location and time (Apostolides and Goulas, 1998).

Tests of germination at low temperatures would lead to more accurate predictions of field emergence than standard tests at 20°C. Furthermore, tests at 20°C may not give accurate estimates of potential viability (Brown 1980). The germination rate and germination index at 25°C and 30°C were significantly higher than those at lower temperatures between 15°C to 20°C (Luo *et al.*, 2022). Seed vigor is the potential of seeds for rapid and uniform emergence and development of normal seedlings under various environmental conditions (Marcos, 2015). Individual variability of different varieties might be attributed to their genetic constituents and their capacity to benefit from environmental factors (Hozayan *et al.*, 2014). Weather conditions during seed germination reduce seed vigor (Elias, 2006). Germination is one of the most important qualitative characteristics of sugar beet seed and a standard

laboratory test can be used to assess correlation with establishment in the field (Sadeghian and Yavari, 2004). The capacity for yield in sugar beet is influenced by its varietal potential, as well as the agroclimatic and edaphic conditions, in addition to management practices (Mahapatra *et al.*, 2020). Root length and abnormal seedling are good indexes for screening sugar beet genotypes (Khayamim *et al.*, 2014). Sugar beet seed germination percentage and plant establishment are mostly controlled by genetic factors (Sadeghian and Khodaii, 1998). The seed vigor levels among sugarbeet genotypes differed depending on varietal genetic character (Li *et al.*, 2022; Copeland and McDonald, 2001; Marcos, 2015; Ellis *et al.*, 1980).

Seed vigor is the sum of the properties determining the activity and performance of seed lots for acceptable germination in a wide range of environments (ISTA 2015). The difference between sugar beet germination percentage in paper and soil is related to the interactive effects of genotype and environment for germination ability (Sadeghian and Khodaii, 1998). Seed vigor index, shoot length and seedling length are major components of standard germination which can be taken into consideration to improve plant population through increasing germination percent, ultimately resulting in higher seed yield (Manjeet *et al.*, 2020). Genotypic variation in germination rate among sugar beet cultivars was observed by Jafarzadeh and Aliasgharzad (2007). Most agricultural crop seeds do not need sunlight to germinate.

The germination test is universally accepted and used as a seed quality test. Germination methods are based on optimum levels of oxygen, moisture and temperature, while field conditions are never optimum. Actual field emergence is often less than that predicted by laboratory germination (Than, 1987). Seeds need water, oxygen and temperature to germinate. Although optimum levels of these conditions give the highest germination, optimum conditions for all three are never found in nature. The ultimate value of any vigor test may be its ability to predict field performance (AOSA, 1983). Temperature is often the main environmental factor governing the rate of seed germination (Garcia-Huidobro *et al.*, 1982) and it also has a major effect

on time required for germination (Woods and McDonald, 1971).

A high index value indicates a faster germination rate than a low index value. environmental stresses reduce the germination of low vigor seeds more than that of high vigor seeds (Than, 1987). High seedling emergence rates and subsequent seedling growth are facilitated by using seeds with desirable vigor. Various seedling traits are key determinants of seed vigor and quality in sugar beet (Mirzaei, 2025). Laboratory tests using ISTA standards provide ideal temperatures (20–30°C range), constant moisture, and sometimes light, whereas field conditions can vary dramatically, causing lower, staggered germination. Conversely, in open outdoor tests, sugarbeet germination is influenced by unpredictable environmental stressors such as moisture stress and cold temperatures. The time of seedling emergence is a complex physiological process that is affected by genetic and environmental factors (Asgarpour *et al.*, 2015). It is affected by light, light quality, temperature, and other environmental factors (Jeremi and Jacek 2015; Cornea-Cipcigan *et al.*, 2020; Liu *et al.*, 2019). Temperature is crucial because it governs the greatest germination percentage and germination rate (Phartyal *et al.*, 2003). Plants with fast emergence can initiate their growth earlier in the growing season and reach maximum yield (Rimaz *et al.*, 2020).

It may be concluded that seedling vigor, as expressed in terms of germination speed index, was significantly affected by variety. Germination speed index values indicate the early seed sprouting of seeds which are capable of producing more normal seedlings. This means the Allanya variety of sugarbeet is a more potential variety than the Gregoria, Danicia and Serenada varieties, respectively, in both laboratory and open field conditions.

CONCLUSION

In the research, seed viability percentage, germination rate, and germination speed index values of four sugarbeet genotypes were found higher in the laboratory experiment and open field experiment. Allanya and Gregoria varieties of sugarbeet were identified to have a standard germination rate (>80%) and vigor, respectively, in both conditions. The seeds of the Allanya sugarbeet variety performed better than Gregoria, Danicia and Serenada, considering higher germination rate and speed of germination in both laboratory and open-field conditions. It is needed to continue varietal evaluation of sugarbeet seeds from different sources under laboratory and field conditions in Bangladesh.

Appendix



Plate 1. Uprooted seedlings of sugarbeet (V₁) at lab (Left) & field (Right) conditions (14 DAS)



Plate 2. Uprooted seedlings of sugarbeet (V₂) at lab (Left) & field (Right) conditions (14 DAS)



Plate 3. Uprooted seedlings of sugarbeet (V_3) at lab (Left) & field (Right) conditions (14 DAS)



Plate 4. Uprooted seedlings of sugarbeet (V_4) at lab (Left) & field (Right) conditions (14 DAS)

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Conflict of Interest

The authors indicate no conflict of interest in this work.

REFERENCES

- Akeson, W.R. and Widner, J.N. 1980. Laboratory Packed Sand Test for Measuring Vigor of Sugarbeet Seed. *Crop Science*. 20 (5): 641-644.
- AOSA. 1983. Association of Official Seed Analysts. Seed vigor testing handbook. Contrib. 32. Handb. Seed Testing Assoc. Off. Seed Anal.
- Apostolides, G. and Goulas, C. 1998. Seed Crop Environment and Processing Effects on Sugar Beet (*Beta vulgaris* L.) Certified by Hybrid Variety Seed Quality. *Seed Sci. Tech*. 26: 223-235.
- Asgarpour R., Ghorbani, R., Khajeh-Hosseini, M., Mohammadv and, E. and Chauhan, B.S. 2015. Germination of spotted spurge (*Chamaesyce maculata*) seeds in response to different environmental factors. *Weed Sci*. 63(2):502-510.
- Bayomi, Khaled M. 2024. Seed and root traits of some sugar beet genotypes under Egyptian conditions. *Egyptian J. Desert Res*. 74(2): 387-396.
- Bithy S., Mahapatra, C.K., Sarkar, S.K., Hossain, M.S., Sarkar, M.A.R. and Paul, S.K. 2021. Growth traits and beet weight of tropical sugar beet responses to foliar application of boron. *Res. Agric. Livest. Fish*. 8 (2): 181-191.
- Bithy S., Paul, S.K., Kader, M.A., Sarkar, S.K., Mahapatra, C.K. and Islam, A.K.M.R. 2020. Foliar application of boron boosts the performance of tropical sugar beet. *Journal of Bangladesh Agricultural University*. 18(3): 537-544.
- Brown, S.J. 1980. Variation in germination and seedling emergence of sugar beet at sub-optimal temperatures. *Annals of Applied Biology*. 95 (1):143-150.
- Cerne, M. and Vrhovnik, I. 1999. Effect of nitrogen fertilization on quality and yield of red beet. *Agricultural Institute of Slovenia, Slovenia*.
- Copeland, L.O. and McDonald, M.B. 2001. *Principles of Seed Science and Technology*, 4th Ed.; Springer: New York, NY, USA.
- Cornea-Cipcigan, M., Pamfil, D., Sisea, C.R. and Mărgăoan, R. 2020. Gibberellic acid can Improve seed germination and ornamental quality of selected *Cyclamen* species grown under short and long days. *Agronomy*. 10(4):516.
- Devi, R.M., Kalaiselvi, P., Parameswari, E., Babu-Rajendra, V.P and Maheswari, M. 2022. Laboratory

- Germination Experiment for Assessing the Phytotoxic Effect of Arsenic on the Growth Attribute of Different Crops. *International Journal of Environment and Climate Change*. 12(11): 79-88.
- Douglas, J.E. 2019. Successful seed programs: A planning and management guide. CRC Press.
- Durrant, M.J. and Gummerson, R.J. 1990. Factors associated with germination of Sugar beet seed in the standard test establishment in the field. *Seed Sci. and Technology*. 18:1-10.
- Ellis, R.H. and Roberts, E.H. 1980. Towards a rational basis for testing seed quality. In *Seed Production* (ed. P.D. Hebblethwaite), Butterworths, London. 605-645.
- FAO. 2019. Food and Agricultural Organization. Statistical yearbook 2019, Rome, Italy.
- Garcia-Huidobro, J. et al. 1982. Time, temperature and germination of pearl millet (*Pennisetum typhoides*). *J. Exp. Bot.* 33: 288-296.
- Gomez, K. A. and Gomez, A. A. 1984. Statistical procedures for agricultural research (2nd ed.). New York: Wiley, P. 272–356.
- Hozayn, M., Korayem, A.M., El-Hashash, E.E., Abd El-Monem, A.A., Abd El-Lateef, E.M., Hassanein, M.S. and Elwa, T.A. 2014. Evaluation of ten exotic sugar beet varieties under different locations in Egypt. *Middle East J. Agric. Res.* 3(4): 1145-1154.
- ISTA. 2013. International Rules for Seed Testing. International Seed Testing Association, Bassorsdorf, Switzerland. 27.
- ISTA. 2015. International Rules for Seed Testing, Vol. 215, Introduction, i-1-6 (10). The International Seed Testing Association, Bassersdorf, Switzerland.
- Jafarzadeh, A. and Aliasgharad, N. 2007. Salinity and salt composition effects on seed germination and root length of four sugar beet cultivars. *Biologia*. 62(5): 562-564.
- Jahan, N., Solaiman, A.H.M., Islam, N. and Choudhury, S. 2025. Evaluation of Morphological, Yield and Quality Performance of Sugar Beet Genotypes under Different Soil pH Levels. *Asian Journal of Agricultural and Horticultural Research*. 12(4): 50-61.
- Jeremi K and Jacek P. 2015. Effect of environmental factors on germination and emergence of invasive *Rumex confertus* in Central Europe. *Sci World J.* 5:170176.
- Khayamim, S., Afshari, S.T., Sadeghian, S.Y., Poustini, K., Rouzbeh, F. and Abbasi, Z. 2014. Seed Germination, Plant Establishment, and Yield of Sugar Beet Genotypes under Salinity Stress. *J. Agr. Sci. Tech.* 16: 779-790
- Li, Z., Zhang, T., Zhu, M., Li, C., Li, B., Lu, X., Wang, J., Jia, L. Qi, H. and Wang, X. 2022. High-vigor seeds associated with seed hardness and water absorption rate in rice (*Oryza sativa* L.). *Agriculture*. 12(5):712.
- Liu, Q.Q., Huang, Z. J, Guo, S., Wang, D.Y., Wang, C.H., Wang, Z.N., Ma, X.Q., Liu, B. 2019. Responses of seed germination and seedling growth of *Cunninghamia lanceolata* and *Schima superba* to different light intensities. *J Appl Ecol.* 30(9):2955–2963.
- Luo, Y., Cheng, J., Yan, X., Zhang, J. and Zhang, J. 2022. Germination of Seeds Subjected to Temperature and Water Availability: Implications for Ecological Restoration. *Forests*. 13 (11), 1854.
- Mahapatra, C.K., Bhadra, T. and Paul, S.K. 2020. Nutrient management in sugar beet: A review. *PSA*. 35(2): 31-44.
- Manjeet, Mahavir, Anu, Vivek, K. Singh, P.K. and Verma. 2020. Character association and path analysis for seed vigor traits in sesame (*Sesamum indicum* L.). *Journal of Experimental Biology and Agricultural Sciences*. 8(2):111-114.
- Marcos, F.J. 2015. Seed vigor testing: An overview of the past, present and future perspective. *Sci. Agric.* 72:363-374.
- Maguire, J.D. 1962. Speed of germination-aid in selection and evaluation for seedling emergence and vigor. *Crop Sci.* 2: 176-177.
- Mirzaei, M.R. 2025. Studying the effect of seed production environment and genotype on germination and seedling traits of different sugar beet (*Beta vulgaris*) single crosses. *Iranian J. Seed Res.* 11(2): 95-110.
- Nottingham, S. 2004. Beetroot. 2004. [http://www.stephennottingham.co.uk/beetroot.htm 2012].
- Rajaeifar M.A., Sadeghzadeh Hemayati S., Tabatabaei M., Aghbashlo M., Mahmoudi S.B. 2019: A review on beet sugar industry with a focus on implementation of waste-to-energy strategy for power supply. *Renewable Sustainable Energy Reviews*. 103: 423–442.
- Than, M.1987. Effect of Seed Deterioration on Germination of Wheat under Environmental Stresses. MS thesis in Crop Science. Oregon State University.
- Paul, S.K., Paul, S.C., Sarkar, M.A.R. and Hossain, M.S. 2018: Influence of integrated nutrient management on the growth, yield and sugar content of tropical sugarbeet (*Beta vulgaris* L.). *Pak. Sugar J.* 33 (2):11-22.
- Phartyal, S.S., Thapliyal, R.C., Nayal, J.S., Rawat, M.M.S. and Joshi, G. 2003. The Influences of temperatures on seed germination rate in Himalayan elm (*Ulmus wallichiana*) *Seed Sci. Technol.* 31:83–93.
- Rimaz, H.R., Zand-Parsa, S., Taghvaei, M., Kamgar-Haghighi, A.A. 2020. Predicting the seedling emergence time of sugar beet (*Beta vulgaris*) using beta models. *Physiology and Molecular Biology of Plants*. 26(12):2329-2338.
- Rony, S.A., Islam, M.A., Anisuzzaman and Alam, M.Z. 2021. Small-scale farmers' perception and practice on coccidiosis management in broiler farm at Gazipur, Bangladesh. *Annals of Parasitology*. 67(1): 85-94.

- Sadeghian, S. Y. and Khodaii, A. 1998. Diallel Cross Analysis of Seed Germination Traits in Sugar Beet. *Euphytica*. 103: 259-263.
- Sadeghian, S. Y. and Yavari, N. 2004. Effect of Water Deficit Stress on Germination and Early Seedling Growth in Sugar Beet. *J. Agron. Crop Sci.* 190: 138-144.
- Shubha, K., Mukherjee, A., Kumari, M., Tiwari, K. and Meena, V.S. 2017. Bio-stimulants: an approach towards the sustainable vegetable production. In: agriculturally important microbes for sustainable agriculture, Springer, Singapore, PP. 259-277.
- Syngenta. 2004. Syngenta Bangladesh Ltd. Sugar.
- UNDP and FAO. 1988. Land Resources Appraisal of Bangladesh for Agricultural Report No. 2. Agro-Ecological Region of Bangladesh. United Nations Development Program in Food and Agriculture Organization. PP. 212-221.
- Woods, L.E., and McDonald, H.A. 1971. The effects of temperature and osmotic moisture stress on the germination of *Lotus corniculatus*. *J. Exp. Bot.* 22:575-585.

