Biological Forum
an International Journal 17(3): 40-48(2025)
ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Morphological Evaluation of Gerbera Genotypes in Different Environments under Western Himalayan Conditions

Romika Thakur, Mohar Singh, Niketa Yadav, Ramesh Chauhan, Bhavya Bhargava, Satbeer Singh and Sanatsujat Singh*
Division of Agrotechnology, Council of Scientific and Industrial Research, Institute of Himalayan Bioresource Technology, Palampur (Himachal Pradesh), India.

(Corresponding author: Sanatsujat Singh)*
(Received: 22 December 2024; Revised: 25 January 2025; Accepted: 14 February 2025; Published online: 10 March 2025)
(Published by Research Trend)

ABSTRACT: Gerbera is one of the most important cut flowers and present attempt was made to evaluate the mean performance and stability parameters of gerbera genotypes. Eight genotypes of gerbera were evaluated over four different environments in Western Himalayan during 2020 and 2021 by using a randomized complete block design. Data were recorded on flower diameter (cm), number of leaves per plant, number of flowers per plant, and stalk length (cm). Highly significant differences ($p \leq 0.05$) were observed for floral and morphological traits among the genotypes. The pooled analysis of variance showed a significant difference ($p \leq 0.05$) among genotypes, environments, and genotype-environment interaction for flower diameter. A significant G×E interaction was observed for yield-contributing trait like flower diameter, indicating the difference in genotype performance over the environments. Flower diameter is of economically important parameter in gerbera. The mean performance of genotypes revealed that genotype CSIR-IHBT-MS-12 had performed superior for flower diameter (cm). The genotype CSIR-IHBT-Gr-PS-03 produced a maximum number of leaves and flowers per plant. The genotype CSIR-IHBT-YS-20 was observed with higher stalk length. Significant GEI interaction for flower diameter allows stability analysis of genotypes. The Eberhart and Russell model of based stability analysis confirmed that the genotype CSIR-IHBT-MS-12 had shown stable performance over environments for trait flower diameter. Therefore, it was confirmed that the genotype CSIR-IHBT-MS-12 was ideal with higher mean performance and stability for flower diameter over the environments. Thus, this genotype can be used further in gerbera breeding and improvement programs.

Keywords: Gerbera, multi-environments, flower diameter, Stability, G × E interaction.

INTRODUCTION

Gerbera jamesonii is one of the most important cut flower belonging to the family Asteraceae. It is commonly known as the Barberton daisy, Transvaal daisy, or African daisy (Ahlawat *et al.*, 2012). Tropical Asia and Africa are considered primary centers of origin (Sujatha *et al.*, 2002). It ranks fourth among the cut flowers (Singh and Srivastava 2008). China and India are the two main countries that contribute the maximum in their production. It is extensively grown in the North Eastern States, Maharashtra, Chhattisgarh, and Karnataka (Barooah and Talkkukdar 2009). It is a highly valuable cash crop as compared to other floriculture crops (Barooah amd Talkkukdar 2009). It has about 30 species and out of all the species, *Gerbera jamesonii* is the only one that is being grown commercially on a large scale. The annual flower outputs range from 15 to 30 flower sticks per plant and this depends on the cultivar's performance (Naz *et al.*, 2012). It is a small evergreen herbaceous plant with a single inflorescence on lengthy thin stalks (Bose *et al.*, 2003). The leaves are 12-20 cm in length and 5-7 cm broad (Bhargava *et al.*, 2013; Maitra *et al.*, 2020). It is highly demanded in both national and international markets (Singh *et al.*, 2017). It is used for both fresh and dried floral arrangements, decorative purposes, landscaping as well as in the cosmetics industry due to longer vase life (Das *et al.*, 2012; Singh and Mandhar 2002). The flowers come in a variety of hues, such as yellow, white, red, orange, pink, maroon, and crimson (Singh *et al.*, 2017). It is a high-value cut flower used as fresh and dry flower, aesthetic decoration, making of bouquet with high demand in the domestic as well as export market (Maitra *et al.*, 2024). It is one of the most cultivated cut flower crops in tropical and sub-tropical environment (Maitra *et al.*, 2020; Roosta *et al.*, 2024). It is widely cultivated and has significant market value due to their popularity as ornamental plant and their medicinal uses. The global market includes various segments such as cut flowers, potted plants and medicinal products (Chaturvedi *et al.*, 2023). It reproduces sexually by seed and asexual means by using branch divisions. It is not propagated by seed due to the demand for uniform plant stature and colour (Ibrahim and Yassin 2020). To achieve uniform plants the *in-vitro* propagation techniques have been utilized (Son *et al.*, 2011). It is the most effective way to regulate the continuous supply of high-quality planting materials (Zheng *et al.*, 2022).

Gerbera is commercially cultivated in different climatic conditions of the world (Lhoste, 2002; Maitra *et al.*, 2020). The flower head is comprised of outer whorls that are thin, long, and prominent known as ray florets, and small tubular whorls on the inner side known as disc florets. Physiological disorders can arise under high-temperature circumstances hence a partly regulated atmosphere is required for cultivation (Mishra & Pathania, 2000; Ahlawat *et al.*, 2012; Sarmah *et al.*, 2014) It may be cultivated in tropical and subtropical environments (Sarmah *et al.*, 2014). The environment has a significant impact on flower growth (De and Kumar 2017). Heat waves are responsible for the growth of morphological characters and soil temperature influences the head diameter and length of the flowering stem in gerbera (Aderson *et al*., 2023).

Out of all *in-vitro* propagation methods, micropropagation is one of the best method of mass multiplication of planting material which assures quick, true-to-type, disease-free, and year-round availability of gerbera planting materials (Singh and Srivastava 2008; Singh *et al*., 2016). There is greater demand for tissue culture plants as compared to conventional plant production (Kumar *et al*., 2012). Therefore, the micro propagation technique has proved helpful in evaluating a large number of genotypes in multi-environments as it shortens the time between two successive generations (Naz *et al.,* 2012; Talla *et al.,* 2019). Hybridization followed by clonal selection is a technique for varietal improvement in this crop and this is based on only the variability, which is present in the genotypes. Environments can cause changes in genetic factors such as heritability, and variance and result in higher flower production (Barreto & Jagtap 2006). G × E interactions are important for the stability analysis of genotypes over fluctuating environments. According to (Baker, 1988; Trethowan *et al.,* 2001), the genotype's mean performance varies among environments and results in crossover (qualitative) G × E interaction. The idea of stability is beneficial for the identification of stress environment factors (Baker and Leon 1988). The goal of stability is to produce a variety with stable performance and wide adaptation (Cooper and De-Lacy 2018). The genotype, environment, and their interaction determine crop production and crop yield. The genotype performances vary among different environments due to significant GEI. There is a huge demand for gerbera in national and international countries. To meet the increasing demand in both domestic and international markets, it's crucial to evaluate new cultivars of gerbera based on qualitative and quantitative characteristics under variable environments. Western Himalayas, unique agro-climatic conditions present both opportunities and challenges for cultivating gerbera flowers. In the present study, a multi-environment investigation of different gerbera genotypes was performed for floral traits to identify the best-performing genotypes of gerbera under tropical and sub-temperate regions of the Western Himalayas.

MATERIAL AND METHODS

A. Planting Material

The rooted seedlings of eight genotypesCSIR-IHBT-Gr-PS-03, CSIR-IHBT-Gr-RSD-8, CSIR-IHBT-YS-20, CSIR-IHBT-MS-12, CSIR-IHBT-Gr-1, CSIR-IHBT-Gr-3, CSIR-IHBT-Gr-4, and CSIR-IHBT-Gr-7 were obtained by using micro propagation. These seedlings were transplanted at different environments and characterized for floral traits.

B. Micropropagation

Seeds of different genotypes were obtained through hybridization. The hybrid seeds of genotypes were used as explants for micropropagation. Murashige and Skoog's medium (MS medium) was prepared for micropropagation. The main components of media preparation were sucrose and MS media. The medium was solidified using agar (8g/l) and its pH was modified to 5.8 using 1N NaOH. Each tissue culture bottle contained 100 milliliters of culture medium. The media flasks were placed in the autoclave for 20 minutes at 121°C and 15 pressures for sterilization. After that, they were allowed to cool at ambient temperature. The seeds were disinfected by Tween-20 and then thoroughly rinsed with distilled water at least five to seven times. The seeds were surface sterilized for two minutes in a laminar airflow cabinet by using a 0.1% mercuric chloride solution in an aseptic manner and then thoroughly rinsed with distilled water at least five to seven times. The disinfected seeds of different genotypes were cultured in MS medium. Fluorescent tubes and photosynthetically active radiation light sources were used to sustain a 16-hour photoperiod for the cultures. The culture room's temperature was kept at 23±2°C. Once the seedlings germinated, their apical meristems were moved to a shoot proliferation medium supplemented with 6-Benzyl amino purine (BAP - 1.0 mg/l) at a higher concentration in comparison to other shoot proliferation medium (Singh *et al.*, 2016). To initiate micro shoots in gerbera 30g/l sucrose was used. To achieve rapid *in vitro* multiplication, shoots were regularly sub-cultured on the shoot proliferation medium and on the rooting medium to initiate the rooting process. For the rooting medium, half-strength MS salts, 0.4 mg/l IBA, 15 g/l sucrose, and 6 g/l agar were used. The plantlets of gerbera with roots were taken out of culture flasks and properly cleaned with running tap water to get rid of the agar. To preserve humidity, the plant lets were subsequently moved to plastic trays filled with sand and covered with plastic bags. They were moved in sleeves for soil cultivation after three weeks of acclimatization. All acclimatized plants of eight genotypes were transplanted in field conditions.

Table 1: Detail of genotypes used in the study.

Sr. No.	Genotype	Parental lines
1.	CSIR-IHBT-Gr-PS-03	Gr-01× Gr 07
2.	CSIR-IHBT-Gr-RSD-8	Gr-04× Gr-07
3.	CSIR-IHBT-YS-20	Gr-03× Gr-01
4.	CSIR-IHBT-MS-12	Gr-04× Gr-07
5.	CSIR-IHBT-Gr-01	CSIR-IHBT-Gr-01 (Parental line)
6.	CSIR-IHBT-Gr-03	CSIR-IHBT-Gr-03 (Parental line)
7.	CSIR-IHBT-Gr-04	CSIR-IHBT-Gr-04 (Parental line)
8.	CSIR-IHBT-Gr-07	CSIR-IHBT-Gr-07 (Parental line)

C. Experimental site and data observation

The field experiment was conducted during the year 2019-20 and 2020-21. Eight genotypes were selected and evaluated over four different locations: Palampur, Bajaura, Jaisinghpur, and Jwalamukhi. All eight genotypes were planted at a spacing of 30 cm × 30 cm. Trials were laid out in randomized block design with three replications. All agronomic practices were performed from time to time. Data were recorded for different agro-morphological and floral traits *viz*., flower diameter (cm), flower number/plant, leaf number/plant, and stalk length (cm). All the data were recorded at the commercial stage of flower harvest. Five randomly selected plants from each genotype were examined to gather data on quantitative features such as the number of leaves and flowers on each plant. The data over two years was studied separately to assess the overall performance of the gerbera genotypes. Analysis of variance and stability analysis were performed to access the best-performing genotype from multiple environments.

Table 2: Details of floral features of new gerbera F_1 selections.

Sr. No.	Genotype	Flower colour	Flower shape	Disc colour	Flower type
1.	CSIR-IHBT-Gr-PS-03	Pink	Single	Green	Standard
2.	CSIR-IHBT-Gr-RSD-08	Red	Semi-double	Green	Mini
3.	CSIR-IHBT-YS-20	Yellow	Single	Green	Standard
4.	CSIR-IHBT-MS-12	Maroon	Single	Green	Standard

Fig. 1. Potential gerbera genotypes with high *in vitro* proliferation (left to right: CSIR-IHBT-Gr-PS-03, CSIR-IHBT-Gr-RSD-8, CSIR-IHBT-YS-20 and CSIR-IHBT-MS-8).

D. Statistical analysis

The data was analysed by two-factor ANOVA using genotypes and environments as factors and stability was analysed using the Eberhart and Russell model (Eberhart & Russell 1966). All the analysis was performed by using the software OPSTAT (Sheoran et al., 1998). The heatmaps showing the mean and average genotype performances at each site were made using RStudio's "geplot" function. The GGE biplot analysis was carried out to confirm the results of stability analysis using RStudio's "GGE" function (RStudio, 2022).

RESULTS AND DISCUSSION

A. Pooled analysis of variance

A combined analysis of variance for gerbera genotypes evaluated over four environments was carried out (Table 2), which indicated that genotypes, environments, and genotype x environment interaction were the causing factors for the difference in morphological and floral character's performance over all locations. The variation in floral characters over the four environments indicated the influence by the environment on genotypic performances. The genotypic main effect was significant for all traits like flower diameter, leaf number, flower number, and stalk length. Genotype and environment interaction was significant ($p \leq 0.05$) for flower diameter. The significant difference for genotype main effect and genotype × environment interaction indicated that genotype performances for floral traits and vegetative traits varied over all the environments. The significant genotype and environment interaction was observed only for flower diameter which further allows stability analysis for this trait. Therefore, significant GEI revealed that the genotype performs distinctively over all environments and indicated that stability analysis must be performed to identify the stable genotype over all the environments. Our results are in line with an earlier report, observed the significant mean sum of squares for all the traits and indicated the existence of variation among gerbera genotypes. The reason for variation among traits was mainly due to the genotypic main effect and genotype × environment interaction (Barooah and Talkkukdar 2009). A comparable combination analysis approach was used to identify the trait with a significant G×E interaction for stability analysis (Soresa and Nayagam 2019). The strategy of combined analysis was performed in dahlia (Manjula *et al.,* 2017); tuberose (Kishalayee and Talukdar 2020); mungbean (Asfaw *et al.*, 2012; Ullah *et al.,* 2011); rice (Kibanda and Luzi-Kihupi 2007).

Table 3: Pooled analysis of variance (2019-20 and 2020-21) for morphological and floral traits.

Source of Variation	Degree of freedom	Mean sum of square			
		Flower diameter (cm)	Leaf number/plant	Flower number/plant	Stalk length (cm)
Replication	2	2	2	2	2
Environment	3	0.02*	0.10	1.15	1.38
Genotype	7	56.24*	182.11*	237.53*	395.47*
G × E	21	0.32*	0.27	1.29	1.07
Error	62	0.14	0.62	2.51	1.95

*significant at $p \leq 0.05$

B. Mean performance of genotypes and environments

The mean performance of gerbera genotypes for morphological and floral traits over all environments were presented in Table 3 and Fig. 1. The significant mean difference in genotypes was observed for all traits like flower diameter, leaf number/plant, flower number/plant, and stalk length over all environments. Genotype CSIR-IHBT-Gr-1 was observed with the highest number of leaves per plant (31.82) followed by CSIR-IHBT-Gr-PS-03, CSIR-IHBT-Gr-4, and CSIR-IHBT-Gr-7. The highest flower number/plant was observed in CSIR-IHBT-Gr-PS-03 (23.25) followed by CSIR-IHBT-Gr-RSD-8 and CSIR-IHBT-YS-20. The largest flower diameter was recorded from genotype CSIR-IHBT-MS-12 (10.62) followed by CSIR-IHBT-YS-20. Genotype CSIR-IHBT-YS-20 was shown with the longest stalk length (53.43) followed by CSIR-IHBT-Gr-7, and CSIR-IHBT-Gr-RSD-8. However, based on mean performance the genotype CSIR-IHBT-MS-12 was found superior to the other genotypes for flower diameter (Fig. 1). Environment -2 has shown maximum mean performance for trait flower diameter. The trait flower diameter is of economic importance in gerbera. Therefore, environment-2 could be considered suitable for the commercial cultivation of gerbera. The variation in the mean performance of gerbera genotypes for floral traits was mainly due to the genetic makeup of genotypes and environmental influence (Chobe *et al.*, 2010). (Vasudevan and Rao 2010) have reported inherent varietal characteristics may be the cause of the variation in the genotype's mean performance of gerbera. Larger ray florets were the cause of the increased flower size (Naik *et al.*, 2006). The existence of additive genes in each cultivar may be the cause of the variations in stalk length. The increased number of leaves per plant contributed to the maximum production and accumulation of photosynthates, which in turn produced larger-sized flowers. This could account for the increase in economic floral traits (Barooah & Talkkukdar 2009). The results of the present study are similar to the Deke and Choudhury results, who evaluated the mean performance of gerbera genotypes and observed significant differences in morphological and floral traits of the Red gem genotype in contrast to other genotypes (Deka and Choudhury 2015). The present results are in line with other researcher's results that observed the significant mean value difference among gerbera genotypes for morphological and floral traits and reported that the variation in genotypes was due to environmental influence and the genetic makeup of genotypes (Anand *et al*., 2013; Hedau *et al.*, 2012) The morphological and floral traits of gerbera genotypes showed observable variations (Hemlata *et al*., 1992; Mahanta and Paswan 2003; Reddy *et al*., 2003; Singh and Ramachandaran 2002). The significant variation in the mean performance of gerbera genotypes for floral traits under different environmental conditions was also observed (Deepa *et al*., 2011; Pattanashetti, 2009). The genotypic makeup and performance of the cultivars might be responsible for the superior growth of morphological parameters of gerbera. The results of study showed a similar trend to the findings of Singh *et al*. (2017); Rangnamei *et al.* (2019); Sairam *et al.* (2022). The significant difference among gerbera cultivars representing to number of leaves per plants has also observed in earlier studies by (Sil *et al.*, 2017; Maitra *et al.,* 2020). The superior performance of flower stalk length and flower diameter may be due to strong relationship between growth attributes and genotypic expression (Magar *et al*., 2010; Mahmood *et al.,* 2013). The genetic makeup of the plant was responsible for higher yields of gerbera cultivars as previously recorded by Biswal *et al*. (2017); Singh *et al*. (2017); Thirugnanavel *et al.* (2019) ; Sairam *et al.* (2022). The cultivar with higher stalk length has extended vase life in gerbera (Paikray *et al.,* 2022). These above-mentioned previous reports are similar to the current study results. A similar approach of mean comparison among genotypes over environments was observed in mungbean (Asfaw *et al*., 2012; Ullah *et al.*, 2011); rice (Kibanda and Luzi-Kihupi 2007).

Table 4: Mean performance of genotypes for morphological and floral traits.

Genotypes	Flower diameter (cm)	Leaf number/plant	Flower number/plant	Stalk length (cm)
CSIR-IHBT-Gr-PS-03	10.20*	29.41*	23.25*	43.18
CSIR-IHBT-Gr-RSD-8	8.87*	22.40	21.50*	51.26*
CSIR-IHBT-YS-20	10.53*	27.55*	22.58*	53.43*
CSIR-IHBT-MS-12	10.62*	24.43	17.08	45.83
CSIR-IHBT-Gr-1	8.99*	31.82*	15.33	35.01
CSIR-IHBT-Gr-3	5.66	22.04	11.17	46.83*
CSIR-IHBT-Gr-4	5.84	28.68*	15.08	45.50
CSIR-IHBT-Gr-7	6.06	31.70*	13.92	50.42*
Overall Mean	8.35	27.25	17.49	46.43
C.D.	0.31	0.64	1.30	1.14

*Significantly ($p \leq 0.05$) higher than the overall population mean; CD-critical difference

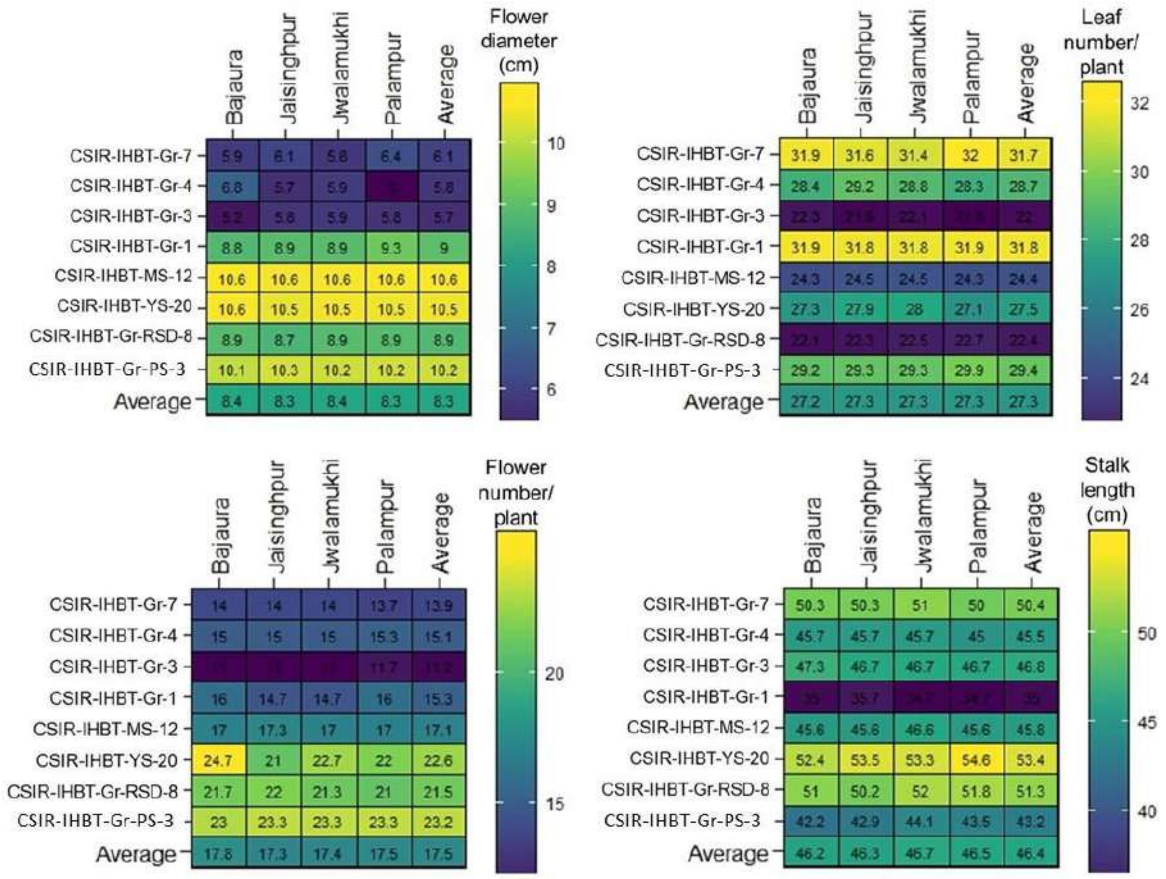

Fig. 2. Heatmap depicting mean performances of all the genotypes at all tested locations.

C. Stability analysis through Eberhart and Russell model

The trait having significant G×E interaction namely flower diameter was considered for analysis of stability parameters (Table 4). Mean performance, regression (b_i), and squared deviation (S^2d_i) for flower diameter are presented in Table 4. The value of the regression coefficient ranged from -7.69 to 22.43 for trait flower diameter. Genotype CSIR-IHBT-MS-12 has been observed with a high mean value for flower diameter with a significant regression coefficient close to unity (b=1) and zero divergence, which reflected the stability of this genotype in multi-environments. The five genotypes showed above-average mean values for flower diameter along with a regression coefficient greater than unity (bi <1.0) and zero divergence. It directly indicated that these genotypes are suitable for favorable environments. As suggested by (Finlay and Wilkinson 1963; Freeman and Perkins 1971) stability is absolutely a hereditary component like qualitative and morphological traits. Thus, genotype CSIR-IHBT-MS-12 can be used in further gerbera breeding programs and recommended for commercial cultivation in different geographical locations. Stability analysis is used to identify the stability across locations and seasons. The current study's stability parameter results are consistent with the other researchers' results, they observed significant variation in the traits and identified a stable genotype for floral traits in the gerbera (Naik *et al.*, 2006; Wankhedeb and Gajbhiyue 2012). The significant variation in the genotypes for flower number/plant, flower diameter, and stalk length (Mahmood *et al.*, 2013). They also reported that the genotype Alberno showed better floral and morphological features than the other genotypes in gerbera. The stable genotype was identified under various kinds of environmental conditions by using stability analysis (Tiawar *et al.*, 2011). A stability study was also carried out in horticultural crops (Koli et *al.*, 2016; Namita *et al.*, 2014; Yadav *et al.*, 2014). In line with the current findings, similar results have been observed in various floricultural crops, which include carnation (Bansal *et al.*, 2019; Misra *et al.*, 2003), marigold (Naik *et al.*, 2019; Patil *et al.*, 2011) chrysanthemum (Priyanka, 2012) and gladiolus (Desh Raj and Misra 1998).

Table 5: Stability analysis of flower diameter using Eberhart and Russell model.

Genotypes	Flower diameter (cm)			
	Mean	b_i	S^2d_i	R
CSIR-IHBT-Gr-PS-03	10.20*	-2.80	-0.05	F
CSIR-IHBT-Gr-RSD-8	8.87*	2.23	-0.04	F
CSIR-IHBT-YS-20	10.53*	2.32	-0.05	F
CSIR-IHBT-MS-12	10.62*	0.92	-0.05	S
CSIR-IHBT-Gr-1	8.99*	-3.69	-0.01	F
CSIR-IHBT-Gr-3	5.66	-7.69	0.02	F
CSIR-IHBT-Gr-4	5.84	22.43	0.29	F
CSIR-IHBT-Gr-7	6.06	-5.72	0.00	F

*, higher than the overall mean; b_i , regression coefficient; S^2d_i , deviation; R, stability responses as (F, suitable for favorable environment and S, stable)

D. Genotype main effect plus G×E interaction

The which-won-where type GGE biplot analysis was used to confirm the best-performing stable genotype for flower diameter over the tested environments. The first two principal components (PC1 and PC2) of the GGE biplot provided a total variability of 99.86% (98.43% and 1.43%, respectively) (Figure 2). The polygon and vertices of GGE biplots were used to analyse the presence of mega environments and the relationship between genotypes and environments. In terms of floral diameter, the genotypes CSIR-IHBT-MS-12 and CSIR-IHBT-Gr-PS-03 were found near the vertices of the polygon. The perpendicular lines that are drawn from the GGE biplot's origin to each side of the polygon divide it into five distinct environmental areas. All genotypes at the corner of the polygon are believed to be the best performers among those environments. All the tested locations come under one region and make a mega environment. It proved that the combined impacts of every tested location produced the best habitat for the flower diameter. The findings demonstrated that genotype CSIR-IHBT-MS-12 performed best and showed consistent expression under all tested environments because it lies in the mentioned region.

Similar results were found by other researchers, who worked on sweet potatoes and resulted that the 80 (109), 68 (120), Ayamurasaki, and Awachyl found stable genotypes (Mustamu *et al.*, 2018). GGE biplot and Eberhart and Russell regression model results predicted that CSIR-IHBT-MS-12 was the best performer in all tested locations. Comparable studies employing GGE biplot analysis have been carried out in many crops, with an emphasis on grain yield and quality characteristics (Enyew *et al.*, 2021; Gupta *et al.*, 2023; Krishnamurthy and Wood 2018; Singh *et al.*, 2024). Some genotypes of stevia present at the central region of the polygon and showed low genotype and environmental effect because of higher yield than other genotypes (Amien *et al.*, 2022).

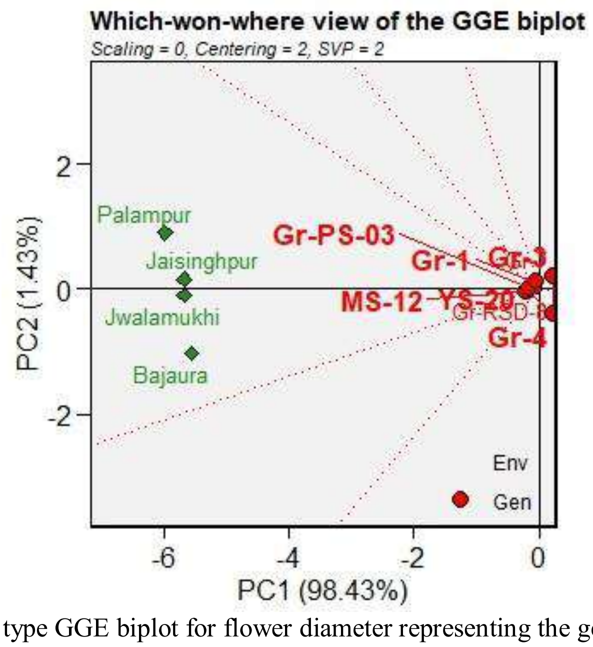

Fig. 3. "Which-won-where" type GGE biplot for flower diameter representing the genotype main effect plus G×E interaction.

CONCLUSIONS

It could be concluded from the present study that higher significant genotypic variation was observed for floral and vegetative characters of gerbera genotypes over the environments. The genotype CSIR-IHBT-MS-12 has shown superior mean performance and stability for yield trait like flower diameter under western Himalayan conditions. The genotype CSIR-IHBT-YS-20 has also shown superior mean performance for stalk length. Thus, genotype CSIR-IHBT-MS-12 and CSIR-IHBT-YS-20 can be recommended to farmers for commercial cultivation of gerbera under Western Himalayan conditions. Also, the identified genotype could be used in future breeding programs.

FUTURE SCOPE

The present attempt directly indicates that genotype CSIR-IHBT-MS-12 will improve the yield contributing trait flower diameter under Western Himalayan conditions. Higher flower diameter, stability, and adaptability of this genotype will directly enhance the commercialization of gerbera. Commercialization will improve the economy of farmers and the livelihood of smallholder farmers which lead to greater benefits for future generations.

Acknowledgement. The authors are grateful to the Director of CSIR-IHBT Palampur India for his unwavering support and for providing the necessary facilities required for this work. The authors acknowledge the Council of Scientific and Industrial Research (CSIR) Government of India for financial support. This research work has been undertaken under the CSIR network project HCP-0007. The CSIR-IHBT communication number of this paper is 5744
Conflict of Interest. None.

REFERENCES

Aderson, S., Lisanea, M., Nildo, D., Hans, R. and Cristiane, G. (2023). Climate Variations in Greenhouse Cultivated with Gerbera and Relationship with External Conditions. *Engenharia Agriola Jaboticabal*, *31*, 857–867.

Ahlawat, T., Barad, A. and Giriraj. (2012). Evaluation of Gerbera Cultivars under Naturally Ventilated Poly house. *Indian Journal of Horticulture*, *69*, 606–608.

Amien, S., Maulana, H., Ruswandi, D. and Nurjanah, S. (2022). Stevia (*Stevia Rebaudiana* B.) Genotypes Assessment for Leaf Yield Stability through Genotype by Environment Interactions, AMMI, and GGE biplot analysis. *Sabrao Journal of Breeding and Genetics*, *54*(4), 767–779.

Anand, M., Sankari, A. and Arulmozhiyan, R. (2013). Evaluation of Commercial Cultivars of Cut Gerbera (*Gerbera jamesonii* Bolus ex Hooker F.) under Polyhouse in Shevaroy Condition of Eastern Ghats. *Journal of Horticulture Science*, *8*(2), 199–203.

Asfaw, A., Gurum, F., Alemayehu, F. and Rezene, Y. (2012). Analysis of Multi-Environment Grain Yield Trials in Mung Bean *vigna radiate* (L.) Wilczek based on GGE Bipot in Southern Ethiopia. *Journal of Agriculture Science and Technology*, *14*, 389–398.

Baker, H. and Leon, J. (1988). Stability Analysis in Plant Breeding. *Plant Breeding*, *101*, 11–23.

Baker, R. (1988). Tests for Crossover Genotype × Environment Interactions. *Canadian Journal of Agricultural Crops*, *68*, 405–410.

Bansal, S., Gupta, R., Chandel, A., Dhimaan, S., Sankhyan, N. and Devi, S. (2019). Stability Analysis of Carnation (*Dianthus caryophyllus*) Varieties using Stability Models. *Journal of Pharmacognosy and Phytochemistry*, *8*, 1544–1548.

Barooah, L. and Talkkukdar, M. (2009). Evaluation of Different Gerbera (*Gerbera jamsonii* Bolus ex Hooker F.) Cultivars under Agroclimatic Conditions of Jorhat. Assam. *Journal of Ornamental Horticulture*, *12*(2), 106–110.

Barreto, M. and Jagtap, K. (2006). Assessment of Substrates for Economical Production of Gerbera (*Gerbera jamesonii* Bolus ex Hooker F.) Flowers under Protected Cultivation. *Journal of Ornamental Horticulture*, *9*, 136–138.

Biswal, M., Palai, S. K., Chhuria, S. and Sahu, P. (2017). Evaluation of Exotic Cultivars of Gerbera (*Gerbera Jamesonii* L.) Under Naturally Ventilated Polyhouse in Western Odisha. *Journal of Krishi Vigyan*, *5*(2), 70-76.

Bhargava, B., Dilta, B., YC, G., Dhiman, S. and Modgill, M. (2013). Studies on Micropropagation of Gerbera (*Gerbera jamesonii* Bolus). *Indian Journal of Applied Research*, *3*(11), 8–11.

Bose, T., Yadav, L., Pal, P., Parthasarthy, V. and Das, P. (2003). *Commercial Flower*. Bhuban i Mitra Publishers.

Chaturvedi, P., Singh, D. and C. John Wesley (2023). Varietal Evaluation of Gerbera Under Shade Net Condition in Prayagraj Agroclimatic Condition. *Biotech Today*, *13* (1), 53-59.

Chobe, R., Achankar, P. and Warade, S. (2010). Studies on Genetic Variability and Heritability in Gerbera. *Asian Journal Horticulture*, *5*(2), 256–258.

Cooper, M. and De-Lacy, I. (2018). Relationships among Analytical Methods used to Study Genotypic Variation and Genotype-by-Environment Interaction. *International Journal Current Microbiology and Applied Science*, *7*, 3336–33343.

Das, C., Shammy, F., Habiba, S., Islam, M. and Jamaluddin, A. (2012). Growth and Yield Performance of Exotic Potted Gerbera Cultivars (*Gerbera jamesonii* L.) in Bangladesh. *Bangladesh Research Publication Journal*, *7*(1), 16–20.

Deepa, M., Reddy, S. and Kulkarni, B. (2011). Evaluation of Gerbera (*Gerbera jamesonii*) under Different Conditions for Growth and Quality Parameters. *Research Journal Of Agricultural Sciences*, *2*(3), 50–53.

Deka, K. and Choudhury, M. (2015). Evaluation of Gerbera (*Gerbera jamesonii* Bolus) Cultivars for Growth and Flower Characters under Assam conditions. *Journal of Agriculture and Veterinary Science*, *8*, 28–30.

Desh Raj, A. and Misra, R. (1998). Stability Analysis in Gladiolus Floral Characters. *Journal of Ornamental Horticulture*, *1*, 61–65.

Eberhart, S., & Russell, W. (1966). Stability Parameters for Comparing Varieties. *Crop Sciences*, *6*, 36–40.

Enyew, M., Feyissa, T., Geleta, M., Tesfaye, K., Hammenhag, C. and Carlsson, A. S. (2021). Genotype by Environment Interaction, Correlation, AMMI, GGE Biplot and Cluster Analysis for Grain Yield and Other Agronomic Traits in Sorghum (*Sorghum bicolor* L. Moench). *Plos One*, *16*(10), 1–22.

Finlay, K. and Wilkinson, G. (1963). The Analysis of Adaptation in the Plant Breeding Programme. *Journal of Agricultural Research*, *14*, 742–754.

Freeman, G. and Perkins, J. (1971). Environmental and Genotype Environmental Components of Variability VIII. Relation Between Genotype Grown in different

Environments and Measurement of These Environments. *Heredity*, *27*, 15–23.
Gupta, A., Kumari, M., Sharan, H., Kumar, A., Vikrant, Chauhan, R., Kumar, A., Singh, S. and Singh, S. (2023). Multi-Environment Investigations Using GGE Biplot and Regression Model for Higher Spike Yield and Essential Oil Content in Lavender (*Lavandula angustifolia*). *Journal of Essential Oil Bearing Plants*, *26*(5), 1220–1235.
Hedau, N., Singh, B. and Mishra, P. (2012). Evaluation of Gerbera Genotypes under Protected Conditions. *Agricultural Progress*, *44*, 336–337.
Hemlata, B., Patil, A., & Nalwaadi, U. (1992). Variability Studies in Chrysanthemum. *Progressive Horticulture*, *25*, 55–59.
Ibrahim, Abdulhameed, M. and Yassin, M. (2020). Direct Shoot Regeneration by in Vitro Culture of the Gerbera (*Gerbera Jamesonii* Bolus) Capitulum Explants. *Plant Cell Biotechnology and Molecular Biology*, *1*, 1–9.
Ibrahim, M. and Yassin, M. (2020). Direct Shoot Regeneration by In -Vitro Culture of the Gerbera (*Gerbera Jamesonii* Bolus) Capitulum Explants. *Plant Cell Biotechnology and Molecular Biology*, *21*, 1–9.
Kibanda, J. and Luzi-Kihupi, A. (2007). Influence of Genetic and Genotype X Environment Interaction on Quality of Rice Grain. *African Crop Science Journal*, *15*, 173–182.
Kishalayee, G. and Talukdar, M. (2020). Field Performance of Single Cultivars of Tuberose For Growth and Floral Characters under Assam Conditions. *International Journal of Current Microbiology*, *9*(4), 1936–1931.
Koli, N., Bagri, R., Meena, B. and Kumhar, B. (2016). Studies on Stability Parameter and Sustainability Index for Selecting Stable Genotypes of Sugarcane (*Saccharum officinarum L.*). *Electronic Journal of Plant Breeding*, *7*, 137–139.
Krishnamurthy, M. and Wood, F. (2018). Promoting Effective Searches and Use of Information by DNP Students: Getting the Write Start. *Nurse Educator*, *43*(2), 63–64.
Kumar, R., Deka, B. and Venugopalan, R. (2012). Genetic Variability and Trait Association Studies in Gerbera (*Gerbera Jamesonii*) for Quantitative Traits. *International Journal of Current Microbiology*, *82*, 615–619.
Lhoste, A. (2002). Cut gerbera : Varietal Experiments in Mediterranean Climate. *PHM - Revue - Horticole*, *435*, 24–27.
Mahanta, P. and Paswan, L. (2003). Recent advances in Indian floriculture. *Assessment of Comparative Performance of Some Gerbera (Gerbera Jamesonii Bolus) Cultivars under Open Condition and Plastic Rain Shelter in Assam Condition*, Nation. Symp. Recent. Adv. in Indian Flori.TRICHUR 12-14 Nov., Proc. Indian Soc. Orna. Hortic., pp 91-92.
Mahmood, M., Ahmad, N. and Khan, A. (2013). Comparative Evaluation of Growth, Yield and Quality Characteristics of Various Gerbera (*Gerbera jamesonii* L.) Cultivars Under Protected Condition. *Journal of Ornamental Plants*, *3*, 235–241.
Magar, S. D., Warade, S. D., Nalge, N. A. and Nimbalkar, C. A. (2010). Performance of Gerbera (*Gerbera jamesonii*) Under Naturally Ventilated Volyhouse Condition. *International Journal of Plant Sciences*, *5*, 609-612.
Maitra, S., Tanmoy, S., Masina, S. and Sandipan, P. (2020). Evaluation of Gerbera (*Gerbera jamesoniil*.) Cultivars for Growth, Yield and Flower Quality Under Protected Cultivation. *Indian Journal of Natural Sciences*, *10*, 20271–20276.
Maitra, S., Sairam, M. and Santosh, D. T. (2024). Evaluation of the Growth, Flower Quality, Yield and Vase Life of Gerbera (*Gerbera Jamesonii* L.) Cultivars Under Open Ventilated Saw-Tooth Type Polyhouse. *Research on Crops*, *25*(1), 104-109.
Manjula, B., Nataraj, S., Pruthvi, P., Ganisetti, A. and Ayesha, N. (2017). Evaluation of Dahlia Genotypes (*Dahlia variabilis* L.) for Growth, Yield and Quality Traits Under Hill Zone of Karnataka. *Environment and Ecology*, *35*, 3158–3171.
Mishra, R. and Pathania, H. (2000). For North Indian Condition Hitech Green House and Production Strategies for Cut Flowers. *Indian Horticulture Journal*, *45*(1), 13–17.
Misra, S., Gupta, Y. and Rao, A. (2003). Correlation and Path-Coefficient Studies In Carnation. *Journal of Ornamental Horticulture*, *6*, 24–28.
Mustamu, Y. A., Tjintokohadi, K., Grüneberg, W. J. and Karuniawan, A. (2018). Selection of Superior Genotype of Sweet-Potato in Indonesia Based on Stability and Adaptability. Chilean Journal of Agriculture research *78*, 461–469.
Naik, H., Chauhan, N., Patil, A., Patil, V. and Patil, B. (2006). Comparative Performance of Gerbera (*Gerbera jamesonii*) Cultivars Under Naturally Ventilated Polyhouse. *Journal of Ornamental Horticulture*, *9*(3), 204–207.
Naik, P. V., Seetaramu, G. K., Tejaswani, M. G., Sadanand, G. K., Shivashankara, K. S. and Kalmath, B. S. (2019). Evaluation of marigold genotypes for flowering and quality parameters under upper Krishna project command area in Karnataka State. *International Journal of Chemical Science*, *7*(4), 1567-1570.
Namita, R., Mulge, R. and Kumar, A. (2014). Stability Assessment in Okra- Abelmoschus esculentus- L. Moench. *Indian Journal of Research*, *3*, 1991–2250.
Naz, S., Naz, F., Taeiq, A., Aslam, F., Ali, A., and Athar, M. (2012). Effect of Different Explants on In Vitro Propagation of Gerbera (*Gerbera jamesonii*). *African Journal of Biotechnology*, *11*(37), 9048–9053.
Paikray, D. K., Sagar, L., Nayak, D. K., Patel, S. Biswamayeel, D. K., Pradhan, A. Jena, S. Sairam, M. Santosh, D. T. and Maitra, S. (2022). Evaluation of Gerbera (*Gerbera Jamesonii* L.) Hybrids Based on Morphological Characteristics Under Controlled Environment Conditions. *International Journal of Natural Sciences*, *13*, 41368-72.
Patil, K., Kulkarni, B., Reddy, B., Kerure, P. and Ingle, A. (2011). Yield and Quality Parameters as Influenced by Seasons and Genotypes in Marigold (*Tagetes erecta* L.). *Research Journal of Agricultural Sciences*, *2*(2), 344–347.
Pattanashetti, C. (2009). *Evaluation of Gerbera Cultivars Under Protected Conditions*. M.Sc. Thesis,University of Agricultural Sciences, Dharwad, Dharwad.
Priyanka, B. (2012). *Genotypic Stability Analysis in Chrysanthemum (Dendranthema grandiflora Tzevlev)*. M.SC. Thesis Kittur Rani Channama College of Horticulture, University of Horticultural Sciences, Bagalkot.
Rangnamei, K. L., Kumar, M., Kikon, E. L., Meena, K. L., Rajkhowa, D. J., Namei, A. and Pungding, L. (2019). Evaluation of Different Gerbera Cultivars for Growth and Flower Characteristics Under Naturally Ventilated Polyhouse Under Nagaland Condition. *Journal of Agriculture Research*, *6*, 166-169.
Reddy, B., Kulkarni, B., Manjunath, H. and Shiragur, M. (2003). Performance of Gerbera Cultivars Under Naturally Ventilated Greenhouse. *Potential and*

Prospects for Protective Cultivation, 91–92.
Roosta, H., Nili, F., Pourkhaloee, A. and Askari, N. (2024). Effects of Supplemental Light Quality and Foliar Application with Calcium on Photosynthetic Parameters and Flower Stem Strength of Cut Gerbera (*Gerbera Jamesonii* 'Bayadere'). *International Journal of Horticultural Science and Technology*, *11*(1), 69-82.
Rstudio (2022). Rstudio: Integrated Development For R. *Rstudio, Pbc, Boston, Ma*.
Sarmah, D., Kolukunde, S. and Mandal, T. (2014). Evaluation Of Gerbera Varieties For Growth and Flowering Under Polyhouse in the Plains of West Bengal. *International Journal of Scientific Research*, *3*(12), 135–136.
Sairam, M., Maitra, S., Shankar, T., Sagar, L. and Santosh, D. T. (2022). Performance of Different Gerbera (*Gerbera Jamesonii* L.) Cultivars Under Protected Cultivation in South Odisha Conditions. *Crop Research*, *57*(3), 211-215
Sheoran, O., Tonk, D., Kaushik, L., Hasija, R. and Pannu, R. (1998). Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory. In *Statistics & Computer Applications by D S Hooda & R C Hasija Department of Mathematics Statistics CCS HAU Hisar*.
Sil, M., Sarkar, M. M., Raghupathi, B. and Mondal, S. (2017). Varietal Evaluation of Gerbera (*Gerbera Jamesonii*) Grown in a Polyhouse. *International Journal of Current Microbiology and Applied Sciences*, *6*, 810-14.
Singh, B. and Srivastava, R. (2008). Varietal Evaluation of Gerbera as Influenced by Growing Conditions. *Journal of Ornamental Horticulture*, *11*(2), 143–147.
Singh, K. P. and Mandhar, S. (2002). Performance of Gerbera Cultivars Under Fan and Pad Cooled Greenhouse Environment. *Journal of Applied Horticulture*, *4*(01), 56–59.
Singh, K. P., & Ramachandaran, N. (2002). Comparision of Greenhouses having Natural Ventilation and Fan Pad Evaporative Cooling Systems for Gerbera Production. *Journal of Ornamental Horticulture*, *5*, 15–19.
Singh, M., Nara, U., Kaur, K., Pandey, V., Pathak, D., Sangha, M. K. and Singh, P. (2024). Exploring GGE biplot, Stability Index, Correlation, and Clustering Analysis for Growth and Seed Yield-Related Traits in Celery (*Apium graveolens* L.). *Journal of Applied Research on Medicinal and Aromatic Plants*, *40*, 100546.
Singh, P., Bhardwaj, A., Kumar, R., & Singh, D. (2017). Evaluation of Gerbera Varieties for Yield and Quality under Protected Environment Conditions in Bihar. *International Journal Current Microbiology and Applied Science*, *6*(9), 112–116.
Singh, S., Ram, R., Kaundal, S., Sharma, A., Kumar, A. and Dhyani, D. (2016). Field Performance and Differential Response of Micro-Propagated Potential F1 Genotypes of *Gerbera jamesonii*. *American Journal of Experimental Agriculture*, *10*(1), 11.
Son, N., Mokashi, A., Hegde, R., Patil, V. and Lingaraju, S. (2011). Response of Gerbera (*Gerbera jamesonii* Bolus) Varieties to Micropropagation. *Karantaka Journal of Agricultural Sciences*, *24*, 354–357.
Soresa, D. and Nayagam, P. (2019). Genotype and Environment Interaction Effect on Yield and Yield Components in Desi-type Chickpea (*Cicer arietinum* (L.). *African Journal of Agricultural Research*, *14*(25), 1073–1080.
Sujatha, K., Gowda, J. and Khan, M. (2002). Effect of Different Fertigation Levels on Gerbera Under Low-Cost Greenhouse. *Journal of Ornamental Horticulture*, *5*(1), 54–59.
Talla, S., Ebenezer, M., Manga, S., Aileni, M. and Mamidala, P. (2019). Efficient TDZ-Induced Regeneration from Capitulum Explants of *Gerbera jamesonii* an Ornamental Plant With High Aesthetic Value. *Plant Biosystems*, *153*, 679–685.
Tiawar, D., Pandey, P., Singh, R., Singh, S. and Singh, S. (2011). Genotype × Environment Interaction and Stability Analysis in Elite Clones of Sugarcane (*Saccharum officinarum* L.). *Journal of Plant Breeding and Genetics*, *53*, 93–98.
Thirugnanavel, A., Deka, B. C. and Rangnamei, K. (2019). Effect of Different Growing Media on Gerbera Varieties Under Low Altitude Conditions of Nagaland. *Green Farming*, *10*, 1- 4.
Trethowan, R., Crossa, J., Ginkel, M. and Rajaram, S. (2001). Relationships Among Bread Wheat International Yield Testing Locations in Dry Areas. *Crop Sciences*, *41*, 1461–1466.
Ullah, H., Hussain, I., Iltafullah, Hidayat, U. and Amin, I. (2011). Genotype × Environment Interaction, Heritability and Selection Response for Yield and Yield Contributing Traits in Mungbean. *African Journal of Biotechnology*, *10*(4), 475–483.
Vasudevan, V. and Rao, V. (2010). Evaluation of Gerbera (*Gerbera jamesonii* Bolus ex Hooker F.) Genotypes Under Mid Hill Conditions of Garhwal Himalayas. *Journal of Ornamental Horticulture*, *13*(3), 195–199.
Wankhedeb, S. and Gajbhiyue, R. (2012). Performance of Gerbera Varieties for Flowering, Yeld and Quality Parameters Under Shade Net. *Indian Journal of Horticulture*, *69*, 98–100.
Yadav, A., Yadav, I. and Yadav, C. (2014). Stability Analysis of Yield and Traits in Chickpea (*Cicer Arietinum* L.). *Legume Research-An International Journal*, *37*, 641–645.
Zheng, X., Wang, J. and Li, M. (2022). Factors Affecting Organogenesis in *Gerbera jamesonii* Bolus Cultures In Vitro. *Journal of Jiangsu Forestry Science and Technology*, *29*, 29–31.

How to cite this article: Romika Thakur, Mohar Singh, Niketa Yadav, Ramesh Chauhan, Bhavya Bhargava, Satbeer Singh and Sanatsujat Singh (2025). Morphological Evaluation of Gerbera Genotypes in Different Environments under Western Himalayan Conditions. *Biological Forum, 17*(3): 40-48.