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

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

DOI: https://doi.org/10.65041/BiologicalForum.2025.17.3.7

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

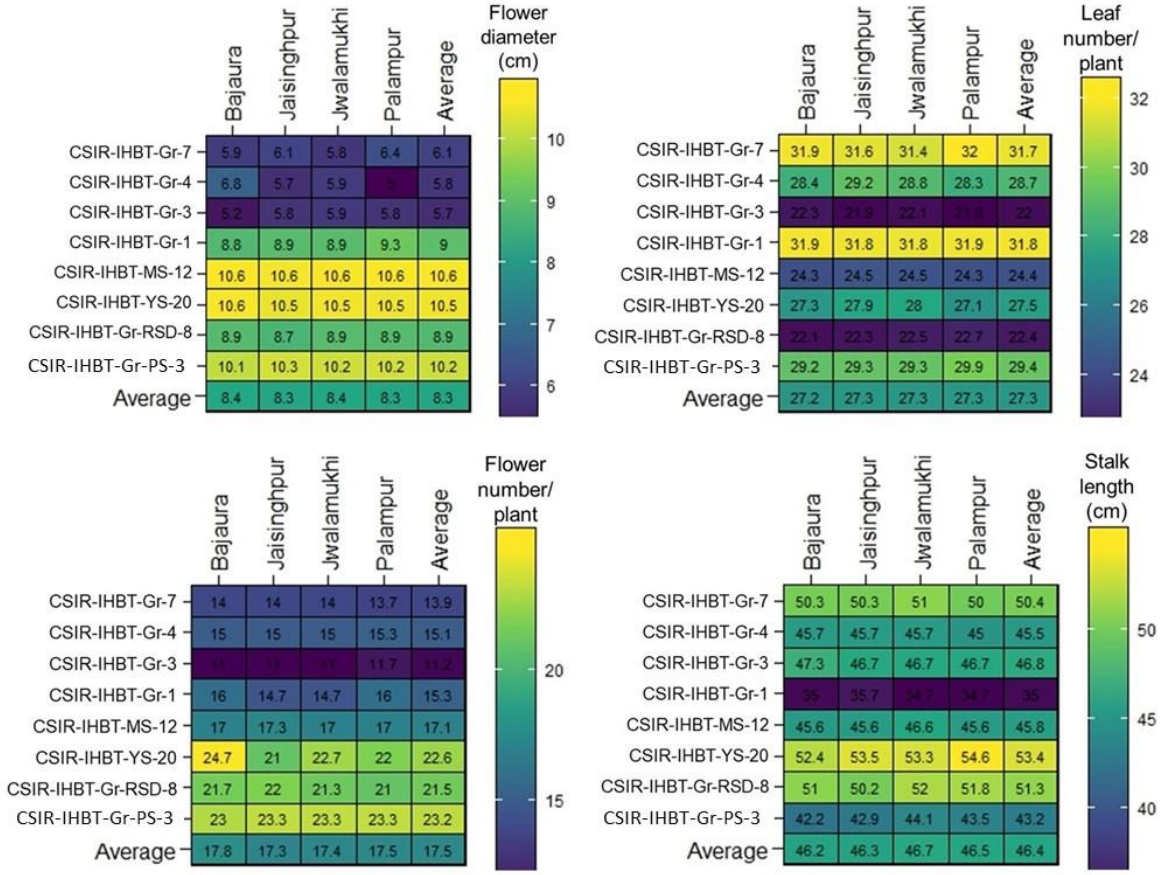

Fig. 2. Heatmap depicting mean performances of all the genotypes at all tested locations.

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 e*t 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).

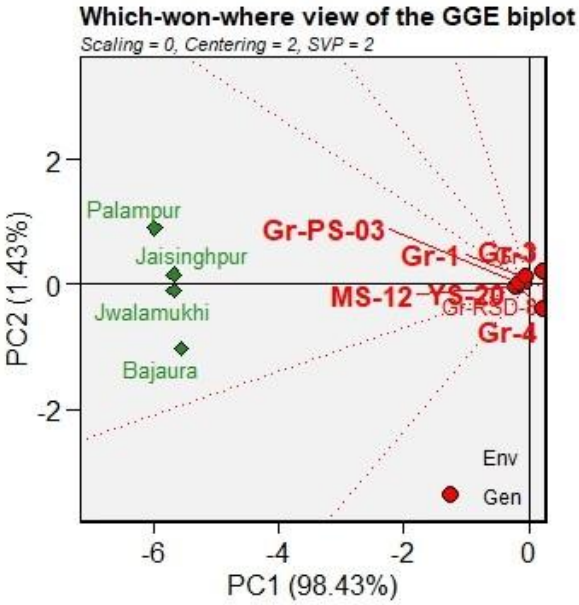

Fig. 3. "Which-won-where" type GGE biplot for flower diameter representing the genotype main effect plus G×E interaction.

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.

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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.