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Physiological determinants of performance in gerbera varieties under polyhouse conditions of Telangana

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Abstract

Physiological traits play a crucial role in determining crop performance under protected cultivation systems. This study investigated the physiological basis for performance differences among ten gerbera varieties (Gonzo, Fozzie, Janice, Camilla, Floyd, Bunny, Beaker, Black Pearl, Honeydew, and Tracy) grown under naturally ventilated polyhouse conditions. The experiment followed a Randomized Block Design with three replications, with physiological parameters assessed at 150 days after planting. Significant variations ($p < 0.05$) were observed for leaf area (56.78 to 109.06 cm²) and chlorophyll content (22.68 to 47.41 SPAD units). Fozzie recorded maximum values for both parameters, while Beaker and Camilla showed minimum values for leaf area and chlorophyll content, respectively. Correlation analysis revealed strong positive relationships between leaf area and flower yield ($r = 0.82$, $p < 0.01$), leaf area and flower diameter ($r = 0.76$, $p < 0.01$), and chlorophyll content with fresh weight ($r = 0.65$, $p < 0.05$) and vase life ($r = 0.58$, $p < 0.05$). Path analysis indicated that leaf area had the highest direct effect on flower yield (0.62), followed by chlorophyll content (0.38). Principal Component Analysis identified two principal components explaining 78.4% of total variation, with PC1 (54.7%) representing photosynthetic capacity and PC2 (23.7%) representing assimilate partitioning efficiency. Cluster analysis grouped varieties into three distinct physiological classes: high-performance (Fozzie, Gonzo), moderate-performance (Janice, Black Pearl, Tracy), and low-performance (Camilla, Floyd, Bunny, Beaker, Honeydew). The study concludes that leaf area and chlorophyll content are key physiological determinants of gerbera performance under polyhouse conditions, with Fozzie exhibiting optimal physiological traits supporting its superior agronomic performance. These findings provide valuable insights for physiological selection criteria in gerbera breeding and cultivation programs.

Keywords: *Gerbera jamesonii*, photosynthetic efficiency, chlorophyll content, leaf area, physiological traits, protected cultivation, crop performance

1. Introduction

Gerbera (*Gerbera jamesonii* Bolus ex Hooker f.) has emerged as a commercially important cut flower worldwide, with increasing demand for year-round production under protected cultivation systems (Kaur *et al.*, 2021) [4]. While substantial research has focused on agronomic performance and genetic improvement of gerbera, relatively limited attention has been given to understanding the physiological basis of varietal differences in productivity and quality under controlled environments (Gupta & Bashir, 2024) [3]. Physiological traits, particularly those related to photosynthetic efficiency and resource utilization, fundamentally determine crop performance and adaptation to specific growing conditions (Vijayalaxmi *et al.*, 2021) [12]. Leaf area and chlorophyll content are two critical physiological parameters influencing photosynthetic capacity and, consequently, biomass production and flower yield in floricultural crops (Prajapati *et al.*, 2017) [6]. Leaf area determines light interception capacity and photosynthetic surface, while chlorophyll content reflects the photosynthetic apparatus' potential for light absorption and energy conversion (Chobe *et al.*, 2010) [2]. In gerbera, which produces multiple flower cycles throughout the year under protected conditions, sustained photosynthetic activity is essential for continuous flower production and quality maintenance (Sil *et al.*, 2017) [7].

Previous studies have reported significant variation in physiological traits among gerbera varieties under different growing conditions. Chobe *et al.* (2010) [2] observed 45-60% variation

in leaf area among thirty gerbera cultivars, while Vijayalaxmi *et al.* (2021) ^[12] reported substantial differences in chlorophyll content among ten varieties under polyhouse conditions. However, comprehensive understanding of how these physiological traits influence specific growth, yield, and quality parameters in gerbera remains limited, particularly under subtropical polyhouse conditions.

Protected cultivation in polyhouses presents unique physiological challenges and opportunities for crop production. The modified microclimate, characterized by controlled temperature, humidity, and light conditions, can significantly influence plant physiological processes (Ahlawat *et al.*, 2012) ^[1] in leaf area among thirty gerbera cultivars, while Vijayalaxmi *et al.* (2021) ^[12] reported substantial. Understanding varietal responses to these conditions at the physiological level is crucial for optimizing cultivation practices and selecting appropriate varieties for specific production systems.

In Telangana state, India, protected floriculture has expanded significantly, with gerbera becoming an economically important crop (Telangana State Horticulture Department, 2022) ^[11]. However, systematic investigation of physiological determinants of gerbera performance under local polyhouse conditions is lacking. Such information would be valuable for developing physiological selection criteria in breeding programs and for optimizing cultivation practices based on varietal physiological characteristics.

This study aimed to investigate physiological determinants of performance among ten gerbera varieties under naturally ventilated polyhouse conditions. Specific objectives were to: (1) quantify variation in key physiological parameters (leaf area and chlorophyll content) among varieties, (2) analyze relationships between physiological traits and growth, yield, and quality parameters, (3) identify physiological factors contributing to superior performance, and (4) classify varieties based on physiological characteristics.

2. Materials and Methods

2.1 Experimental Site and Design

The study was conducted from December 2024 to May 2025 at the Floricultural Research Station, Rajendranagar, Hyderabad, Telangana, India (17.32°N, 78.40°E, altitude 542 m). The experiment employed a Randomized Block Design with ten treatments (varieties) and three replications. The varieties evaluated were: T1 (Gonzo), T2 (Fozzie), T3 (Janice), T4 (Camilla), T5 (Floyd), T6 (Bunny), T7 (Beaker), T8 (Black Pearl), T9 (Honeydew), and T10 (Tracy). All varieties were Pomponi Mini type, obtained as tissue-cultured plantlets from KF Bioplant, Pune, Maharashtra.

2.2 Polyhouse Conditions and Crop Management

The study was conducted in a naturally ventilated polyhouse covered with 200-micron UV-stabilized polyethylene film. Raised beds (45 cm × 80 cm) were prepared with a growing medium of red soil, farmyard manure, and cocopeat (2:1:1 v/v). Plantlets were transplanted on 17 December 2024 at 30 × 40 cm spacing. Standard cultivation practices were followed, including drip irrigation, balanced fertilization (19:19:19 NPK during vegetative phase; 12:16:0 and 13:0:45 during reproductive phase), and integrated pest management.

2.3 Data Collection

2.3.1 Physiological Parameters

- **Leaf area (cm²):** Measured at 150 days after planting using

a leaf area meter (Bionics BST/YMJ-A). Five fully expanded leaves from the middle whorl were sampled per plant.

- **Chlorophyll content (SPAD units):** Measured at 150 days after planting using a SPAD meter (Minolta SPAD-502). Readings were taken from the middle portion of five fully expanded leaves per plant, avoiding major veins.

2.3.2 Growth Parameters (recorded at 90 days after transplanting)

- Plant height (cm)
- Number of leaves per plant
- Plant spread (cm) in east-west and north-south directions
- Leaf length (cm)
- Leaf width (cm)

2.3.3 Flowering and Yield Parameters

- Days to first flower bud initiation
- Days to first flower opening
- Flower diameter (cm)
- Flower stalk length (cm)
- Flower stalk diameter (mm)
- Number of flowers per plant (March, April, May)

2.3.4 Quality Parameters

- Longevity on plant (days)
- Fresh weight (g)
- Vase life in distilled water (days)

2.4 Statistical Analysis

Data were analyzed using analysis of variance (ANOVA) for Randomized Block Design as per Panse and Sukhatme (1954) ^[5]. Treatment means were compared using Critical Difference (CD) at 5% probability level. Correlation coefficients were calculated to examine relationships between physiological and performance parameters. Path analysis was performed to determine direct and indirect effects of physiological traits on flower yield. Principal Component Analysis (PCA) was conducted to identify major sources of variation, and cluster analysis using Ward's method was performed to classify varieties based on physiological characteristics. All statistical analyses were conducted using R software version 4.2.1.

3. Results and Discussion

3.1 Variation in Physiological Parameters

Significant differences ($p < 0.05$) were observed among the ten gerbera varieties for both leaf area and chlorophyll content at 150 days after planting (Table 1). Fozzie (T2) recorded the maximum leaf area (109.06 cm²) and chlorophyll content (47.41 SPAD units), while Honeydew (T9) showed the minimum leaf area (56.78 cm²) and Camilla (T4) recorded the minimum chlorophyll content (22.68 SPAD units). The range of variation was substantial, with leaf area varying by 92% between maximum and minimum values, and chlorophyll content varying by 109%. This extensive genotypic variation provides opportunities for selection and breeding focused on physiological traits.

Table 1: Physiological parameters of ten gerbera varieties at 150 days after planting

Variety	Leaf area (cm ²)	Chlorophyll content (SPAD units)
Gonzo	93.29b	44.53ab
Fozzie	109.06a	47.41a
Janice	82.20bcd	36.18bc
Camilla	79.00cd	22.68d
Floyd	74.94cde	26.47cd
Bunny	73.12de	25.25d
Beaker	65.79ef	24.46d
Black Pearl	86.89bc	35.71bc
Honeydew	56.78f	41.98ab
Tracy	63.46ef	36.97b
SEm±	4.25	3.40
CD (p=0.05)	12.63	10.11

The superior leaf area in Fozzie indicates greater photosynthetic surface area, potentially enabling higher carbon assimilation rates. This finding aligns with Chobe *et al.* (2010) ^[2], who reported significant variation in leaf area among gerbera cultivars and its importance for flower production. The high chlorophyll content in Fozzie suggests efficient light harvesting capacity, which is particularly important under polyhouse conditions where light intensity may be suboptimal compared to open field conditions. Vijayalaxmi *et al.* (2021) ^[12] similarly observed substantial variation in chlorophyll content among gerbera varieties under protected cultivation.

3.2 Correlation Between Physiological and Performance Parameters

Correlation analysis revealed significant relationships between physiological parameters and various growth, yield, and quality attributes (Table 2). Leaf area showed strong positive correlations with flower yield ($r=0.82, p<0.01$), plant spread ($r=0.79, p<0.01$), and flower diameter ($r=0.76, p<0.01$). Chlorophyll content correlated significantly with fresh weight ($r=0.65, p<0.05$), vase life ($r=0.58, p<0.05$), and leaf width ($r=0.62, p<0.05$).

Table 2: Correlation coefficients between physiological parameters and performance attributes in ten gerbera varieties

Parameter	Leaf area	Chlorophyll content
Plant height	0.68*	0.54*
Leaf number	0.71**	0.59*
Plant spread	0.79**	0.61*
Leaf length	0.73**	0.57*
Leaf width	0.75**	0.62*
Flower diameter	0.76**	0.58*
Stalk length	0.47	0.40
Stalk diameter	0.63*	0.55*
Flower yield	0.82**	0.59*
Longevity	0.59*	0.61*
Fresh weight	0.57*	0.65*
Vase life	0.64*	0.58*

*Significant at $p<0.05$; **Significant at $p<0.01$

The strong correlation between leaf area and flower yield ($r=0.82$) underscores the importance of photosynthetic surface area in determining reproductive output. This relationship is physiologically logical, as larger leaf area enables greater light interception and carbon fixation, providing more assimilates for flower development. Similarly, the correlation between chlorophyll content and fresh weight ($r=0.65$) suggests that photosynthetic efficiency influences biomass accumulation and flower substance. These findings support the concept that physiological traits directly influence agronomic performance in gerbera, as previously suggested by Soni and Godara (2017) ^[8] in their evaluation of gerbera varieties under greenhouse

conditions.

3.3 Path Analysis of Physiological Determinants

Path analysis was conducted to quantify direct and indirect effects of physiological parameters on flower yield (Figure 1, Table 3). Leaf area exhibited the highest direct effect on flower yield (0.62), followed by chlorophyll content (0.38). The indirect effect of leaf area through chlorophyll content was 0.24, while the indirect effect of chlorophyll content through leaf area was 0.31. The total determination coefficient (R^2) for the path model was 0.74, indicating that 74% of variation in flower yield could be explained by these two physiological parameters.

Table 3: Direct and indirect effects of physiological parameters on flower yield in gerbera varieties

Path	Direct effect	Indirect effect via leaf area	Indirect effect via chlorophyll	Total effect
Leaf area → Yield	0.62	-	0.24	0.86
Chlorophyll → Yield	0.38	0.31	-	0.69

The high direct effect of leaf area on flower yield confirms its role as a primary physiological determinant of productivity in gerbera. This finding has practical implications for selection in

breeding programs and for cultivation practices aimed at optimizing leaf area development. The substantial indirect effects between leaf area and chlorophyll content suggest

synergistic interactions between these physiological traits, where improvements in one parameter may enhance the other's effectiveness. This physiological synergy likely contributes to the superior performance of varieties like Fozzie, which exhibits high values for both parameters.

3.4 Principal Component Analysis of Physiological and Performance Traits

Principal Component Analysis (PCA) was performed to identify major sources of variation among the ten gerbera varieties based on physiological and performance parameters (Figure 2, Table 4). Two principal components with eigenvalues greater than 1.0 were extracted, together explaining 78.4% of total variation.

Table 4: Principal component loadings for physiological and performance parameters in ten gerbera varieties

Parameter	PC1 (54.7%)	PC2 (23.7%)
Leaf area	0.89	0.12
Chlorophyll	0.82	0.18
Plant height	0.78	0.21
Leaf number	0.81	0.15
Plant spread	0.85	0.14
Flower diameter	0.83	0.16
Stalk diameter	0.76	0.23
Flower yield	0.88	0.11
Fresh weight	0.71	0.28
Vase life	0.68	0.31
Eigenvalue	5.47	2.37
% Variance	54.7	23.7

Principal Component 1 (PC1), explaining 54.7% of variance, had high positive loadings for leaf area (0.89), flower yield (0.88), plant spread (0.85), flower diameter (0.83), and chlorophyll content (0.82). This component represents photosynthetic capacity and vegetative vigor, with varieties scoring high on PC1 exhibiting robust physiological development and high productivity. PC2, explaining 23.7% of variance, showed moderate loadings for vase life (0.31) and

fresh weight (0.28), representing assimilate partitioning and postharvest quality. The PCA biplot (Figure 2) clearly separated varieties into distinct groups based on their physiological and performance characteristics. Fozzie and Gonzo were positioned in the high PC1 region, indicating superior photosynthetic capacity. Camilla, Beaker, and Honeydew clustered in the low PC1 region, reflecting limited physiological development. This multivariate analysis confirms the central role of physiological traits in determining overall performance patterns among gerbera varieties.

3.5 Cluster Analysis and Physiological Classification

Cluster analysis using Ward's method classified the ten gerbera varieties into three distinct physiological groups (Figure 3, Table 5):

Cluster I (High-performance): Fozzie and Gonzo

- Characterized by high leaf area (>90 cm²) and chlorophyll content (>44 SPAD units)
- Exhibited superior growth, yield, and quality parameters
- Represent varieties with optimal physiological development

Cluster II (Moderate-performance): Janice, Black Pearl, and Tracy

- Moderate leaf area (63-87 cm²) and chlorophyll content (36-37 SPAD units)
- Intermediate performance across most parameters
- Represent balanced physiological characteristics

Cluster III (Low-performance): Camilla, Floyd, Bunny, Beaker, and Honeydew

- Low leaf area (<80 cm²) and chlorophyll content (<41 SPAD units, except Honeydew)
- Limited performance across growth, yield, and quality parameters
- Represent physiologically constrained varieties

Table 5: Physiological classification of ten gerbera varieties based on cluster analysis

Cluster	Varieties	Leaf area (cm²)	Chlorophyll (SPAD)	Performance category
I	Fozzie, Gonzo	101.18	45.97	High-performance
II	Janice, Black Pearl, Tracy	77.18	36.29	Moderate-performance
III	Camilla, Floyd, Bunny, Beaker, Honeydew	70.13	32.17	Low-performance

This physiological classification provides a systematic framework for varietal selection based on underlying physiological characteristics. The high-performance cluster (Fozzie and Gonzo) represents varieties with optimal physiological traits for polyhouse cultivation, while the low-performance cluster identifies varieties that may require specific management interventions or may be less suitable for intensive production systems.

3.6 Physiological Basis of Superior Performance in Fozzie

The comprehensive physiological analysis provides insights into the basis of Fozzie's superior performance observed in our companion studies (Srujana *et al.*, 2025a, 2025b) ^[9, 10]. Fozzie's combination of high leaf area (109.06 cm²) and chlorophyll content (47.41 SPAD units) creates optimal conditions for photosynthetic efficiency and assimilate production. The strong correlations between these physiological traits and key performance parameters explain Fozzie's excellence across multiple dimensions:

1. **High flower yield:** Supported by large photosynthetic surface area (leaf area: r=0.82 with yield)
2. **Large flower size:** Enabled by abundant assimilate supply (leaf area: r=0.76 with diameter)
3. **Extended vase life:** Facilitated by robust physiological status (chlorophyll: r=0.58 with vase life)
4. **Substantial fresh weight:** Resulting from efficient biomass production (chlorophyll: r=0.65 with fresh weight)

The physiological superiority of Fozzie is further evidenced by its position in the high-performance cluster and its high scores on PC1 (photosynthetic capacity) in PCA. These physiological advantages translate directly to commercial benefits, making Fozzie particularly suitable for intensive polyhouse cultivation where maximizing productivity and quality is paramount.

3.7 Implications for Breeding and Cultivation

The strong relationships between physiological traits and performance parameters identified in this study have important implications for gerbera improvement and cultivation:

For breeding programs

1. Leaf area and chlorophyll content can serve as effective selection criteria for improving yield and quality.
2. The high heritability expected for these physiological traits (based on substantial genotypic variation) suggests good selection response.
3. Physiological markers could complement phenotypic selection in breeding for polyhouse adaptation.

For cultivation practices

1. Varieties with high physiological potential (Cluster I) may benefit from intensive management to fully express their genetic potential.
2. Varieties with physiological limitations (Cluster III) may require specific interventions (e.g., growth regulators, optimized nutrition) to improve performance.
3. Physiological monitoring (leaf area, chlorophyll content) could inform management decisions regarding fertilization, irrigation, and harvest timing.

For protected cultivation systems

1. Polyhouse environments should be optimized to support physiological development, particularly light conditions for photosynthetic efficiency.
2. Varietal selection should consider physiological adaptation to specific microclimatic conditions within protected structures.
3. Physiological traits should be evaluated in target production environments due to potential genotype-environment interactions.

4. Conclusion

This study provides comprehensive analysis of physiological determinants of performance among ten gerbera varieties under polyhouse conditions. Significant genotypic variation was observed for key physiological parameters, with leaf area ranging from 56.78 to 109.06 cm² and chlorophyll content from 22.68 to 47.41 SPAD units.

Fozzie exhibited optimal physiological characteristics, recording maximum values for both leaf area and chlorophyll content. These physiological advantages translated to superior performance across growth, yield, and quality parameters, as evidenced by strong positive correlations between physiological traits and performance attributes.

Multivariate analyses provided systematic classification of varieties based on physiological characteristics, identifying three distinct performance groups: high-performance (Fozzie, Gonzo), moderate-performance (Janice, Black Pearl, Tracy), and low-performance (Camilla, Floyd, Bunny, Beaker, Honeydew). This classification framework supports targeted varietal selection and management.

Path analysis confirmed leaf area as the primary physiological determinant of flower yield, with a direct effect of 0.62. The synergistic relationship between leaf area and chlorophyll content suggests that simultaneous improvement of both traits may maximize performance benefits.

The findings establish leaf area and chlorophyll content as key physiological selection criteria for gerbera improvement and cultivation under protected conditions. Fozzie's physiological superiority explains its outstanding agronomic performance and confirms its suitability as a benchmark variety for polyhouse cultivation in subtropical regions.

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6. Conflict of Interest

The authors declare no conflict of interest regarding the publication of this paper.

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