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Original Research Article
**Field Performance and Differential Response of
Micro-propagated Potential F₁ Genotypes of
*Gerbera jamesonii***

ABSTRACT

Aims: To evaluate gerbera hybrids with respect to mass propagation under *in vitro* conditions and their characterization under field conditions for floral traits for selection of promising gerbera lines for commercial utilization.

Study design: Field performance and differential response of micro-propagated gerbera were evaluated in randomized block design.

Place and Duration of Study: CSIR-IHBT, Palampur (HP), India 2012-2015.

Methodology: F₁ genotypes of gerbera were developed through controlled crossing program and subjected to *in vitro* micro-propagation to achieve quick multiplication. Mature seeds obtained from different cross combinations were used for the establishment of *in vitro* gerbera cultures. Seeds were cultured on Murashige & Skoog (MS) basal medium and the developing micro-shoots from seeds were further cultured on MS media supplemented with different doses of growth regulators to achieve shoot proliferation.

Results: Highest number of micro-shoots, number of leaves and leaf length were observed in M3 proliferation medium (MS supplemented with 1mg/l 6- Benzylaminopurine + 0.030 mg/l Indole Butyric Acid (IBA) + 0.025 mg/l Naphthalene Acetic acid) which gave best proliferation among the gerbera genotypes. The half strength MS medium supplemented with 0.4mg/l IBA was found best for *in vitro* rooting. Also, there was differential response of hybrid gerbera genotypes to micro-shoot proliferation.

Conclusion: Characterization of two hybrid F₁ genotypes (23-1 and E-3) under field conditions with respect to floral traits in comparison to parental genotypes provided information about new gerbera lines with high micro-propagation potential for commercial utilization.

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Keywords: *Gerbera jamesonii*, *in vitro* proliferation, root initiation, 6- Benzylaminopurine, IBA, NAA

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1. INTRODUCTION

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Gerbera (*Gerbera jamesonii*) is an important commercial cut flower of the trade having extensive demand throughout the world due to its numerous colors, shapes and prolonged vase life. The plant is ideal for beds, borders, pots and rock gardens. It has a great export potential and ranks fifth among top cut flowers in the international market [1]. There is an increasing demand of quality gerbera cut flowers, planting material and new types of varieties for export as well as in domestic markets. *Gerbera* is out crossing in nature and the possibility of genotype fixation by clonal propagation unfolds a large potential for novel cultivar development. New cultivars of gerbera are developed by hybridization of diverse types to achieve genotypic recombination, which requires information about the genetic diversity among the parental genotypes, especially in order to create novel genotypes based on combination of desirable traits that can be easily fixed by vegetative propagation. In this context, with an aim of varietal development, selective breeding of gerbera (for desirable flower colors and complete double types) is being done under an ongoing gerbera breeding program at CSIR-Institute of Himalayan Bioresource Technology, Palampur, Himachal

Pradesh, India [2,3]. The parents were selected based on prior information with respect to variations for flower color [4], shape (double, semi-double and single), size, and good performance under protected cultivation.

Although conventional vegetative propagation of gerbera, by division of suckers is comparatively easy to perform, only limited plants can be developed from one plant and it takes 10–12 months to attain the next cycle of division [5]. Floriculture industry requires about nine plants of gerbera per square meter for clonal plantation under protected cultivation and a huge number of clonal plants are required every year when gerbera cultivation is to be done on commercial scale. Under such a situation it is difficult to produce large number of clonal plants of a promising genotype within a short period of time through vegetative propagation.

In order to meet the industrial demand, we need micro-propagation for rapid and mass multiplication of elite gerbera genotypes under *in vitro* conditions. However, response of different genotypes and the genetic control of component traits constitute crucial factors for the success of mass propagation program. At least two component traits, viz., proliferation rate and *in vitro* root induction possibly influence the response of a genotype to mass propagation. Therefore, the present study was undertaken to evaluate gerbera hybrids with respect to mass propagation under *in vitro* conditions and their characterization under field conditions for floral traits in comparison to parental genotypes for selection of promising gerbera lines for commercial utilization.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

To evaluate response of F_1 gerbera genotypes to micro-propagation, seeds obtained through the crossing program were used as explants for establishing cultures for *in vitro* clonal multiplication. Twelve F_1 genotypes (23-1, 24-1, 24-2, 24-3, 24-4, A-6, B-2, D-3, E-1, E-2, E-3 and Y-1) generated in this study were evaluated for *in vitro* response and characterized for floral characteristics under poly-house conditions in the present study (Table 1).

Table 1. List of gerbera genotypes involved in the study

S.No.	Genotypes	Remarks	Shape	Colour
1.	IHBT-Gr-01 (P1)	Parent	Single	White (RHS 155 C)
2.	IHBT-Gr-02 (P2)	Parent	Semi-Double	Red-Purple (RHS 58 D)
3.	IHBT-Gr-03 (P3)	Parent	Double	Yellow-Orange(RHS158 C)
4.	IHBT-Gr-04 (P4)	Parent	Semi-Double	Orange-Red (RHS 40 A)
5.	IHBT-Gr-05 (P5)	Parent	Single	Red-Purple (RHS 66 B)
6.	IHBT-Gr-06 (P6)	Germplasm	Single	Red-Purple (RHS 58 D)
7.	IHBT-Gr-07 (P7)	Parent	Single	Red (RHS 52 C)
8.	23-1 (P2 x P3)	Hybrid F_1	Double	Yellow-Orange (RHS 16 C)
9.	24-1 (P3 x P4)	Hybrid F_1	Semi-Double	Orange

69	10.	24-2 (P3 x P4)	Hybrid F ₁	Single	Orange-Red
70	11.	24-3 (P3 x P4)	Hybrid F ₁	Double	Orange-Red
71	12.	24-4 (P3 x P4)	Hybrid F ₁	Semi-Double	Yellow-Orange
72	13.	Y1 (P3 x P7)	Hybrid F ₁ *	Double	Yellow
73	14.	E-1 (P1 x P7)	Hybrid F ₁ *	Double	White
74	15.	E-2 (P1 x P7)	Hybrid F ₁	Single	White
75	16.	E-3 (P1 x P7)	Hybrid F ₁	Double	White (RHS 155 D)
76	17.	A-6 (E1 x Y1)	Hybrid F ₁	Double	Yellow
77	18.	B-2 (P1 x P5)	Hybrid F ₁	Single	Red
78	19.	D-3 (P4 x P2)	Hybrid F ₁	Semi-Double	Orange-Red

79 *used as parents in breeding program

80 Seeds were washed with few drops of Tween-20 to remove the surface dust particles with
81 constant shaking for 5-6 minutes and washed thoroughly with distilled water (6-7 times). The
82 seeds were surface sterilized with 0.1% mercuric chloride solution for 2 minutes under
83 aseptic condition in laminar air flow cabinet and rinsed 4-5 times with autoclave distilled
84 water. The seeds were cultured aseptically on basal MS medium [6]. The pH of the medium
85 was adjusted to 5.8 with 1N NaOH and agar (8g/l) was used for solidification of medium. The
86 media were dispensed into tissue culture flask and each contained 100ml of culture medium.
87 The flasks were autoclaved at 121°C at 15 psi for 20 minutes and then allowed to cool at
88 room temperature before culturing the seeds. Cultures were given a 16 h photoperiod with
89 light intensity of 37.40 mmol-2 s⁻¹ which was maintained by using photosynthetically active
90 radiation (PAR) light sources and fluorescent tubes. Temperature in the culture room was
91 maintained at 25 ± 2°C.

92 After germination, the apical meristems of seedlings were transferred to shoot proliferation
93 medium supplemented with 6- Benzylaminopurine at higher levels (BAP - 1.0 mg/l) than
94 Indole 3- butyric acid (IBA - 0.030 mg/l) and Naphthalene acetic acid (NAA - 0.025 mg/l)
95 along with 30g/l sucrose for initiating micro-shoots in hybrid gerbera genotypes. When
96 multiple shoots are formed in the cultures, individual shoots are separated using fine scalpel
97 under laminar air flow and subcultures done at regular intervals of four weeks on shoot
98 proliferation medium to attain rapid *in vitro* multiplication. To study the effect of different
99 concentrations of BAP (0.5 (M1), 0.75 (M2), 1.0 (M3), 1.5 (M4) mg/l) and fixed
100 concentrations of IBA (0.030 mg/l) and NAA (0.025 mg/l) an experiment was laid out
101 employing completely randomized design with five explants per flask per treatment and
102 replicated thrice (5 explants x 4 treatments x 3 replications = 60 explants per genotype).
103 Data were recorded for number of micro-shoots per plant, leaf number and leaf length in
104 proliferation medium.

105 To initiate rooting, shoots were transferred to rooting medium with half strength of MS salts,
106 supplemented with varying concentration of IBA (0.1, 0.2 and 0.4 mg/l), 15 g/l sucrose and
107 6g/l agar were used. In case of rooting medium, days taken for root initiation were recorded.
108 Rooted plantlets of gerbera were removed from culture flasks and washed thoroughly with

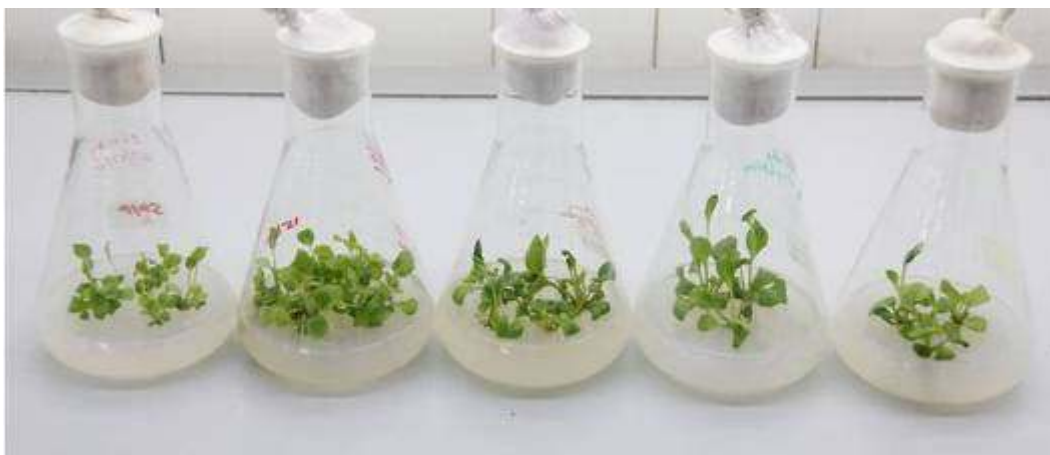
109 running tap water to remove agar. The plantlets were then transferred to plastic trays
110 containing sand and covered with plastic bag to maintain humidity. After 3 weeks of
111 acclimatization they were transplanted in sleeves for further cultivation in soil.

112 Data were analyzed using F-test to evaluate the response of different hybrid gerbera
113 genotypes under proliferation medium. The data regarding different proliferation media and
114 rooting media were analyzed using Student's t-test. All tissue culture experiments were laid
115 out in a Randomized Block Design and the significance of differences between means was
116 estimated at 5% level of significance.

117 In the field experiment conducted during 2013-14 and 2014-15, two hybrid genotypes of
118 gerbera 23-1 and E-3 which performed well under *in vitro* conditions were evaluated along
119 with parental genotypes IHBT-Gr1, IHBT-Gr2, IHBT-Gr3 and IHBT-Gr7. All the six genotypes
120 were planted polyhouse in randomized block design with four replications and data were
121 recorded for different agro-morphological and floral traits viz., leaf number per plant, plant
122 spread (cm), number of suckers per plant, leaf length (cm), leaf width (cm), flower color,
123 flower shape, disc color, flower number per plant, scape length (cm) and flower diameter
124 (cm). Data were collected on five flowers of each genotype in each replication. All the data
125 were recorded at the commercial stage of flower harvest; the stage at which the stigmata of
126 the ray florets have been exerted [7]. Flower color of selected gerbera genotypes along with
127 parental lines was compared using the Royal Horticultural Society's (RHS) color chart [8].
128 Flower shape (single - with whorls of only ray florets, semi-double - with separate whorls of
129 ray florets and smaller-sized transition florets and complete double with ray florets covering
130 the entire disc) [9] and disc color (light green / dark brown) were observed on visual basis.
131 Data with respect to quantitative traits leaf number per plant, plant spread (cm), number of
132 suckers per plant and flower number per plant were recorded on yearly basis on five random
133 but competitive plants of each genotype while leaf length (cm), leaf width (cm), scape length
134 (cm) and flower diameter (cm) were recorded on five mature leaves and five flowers of each
135 genotype. The data over two years was studied separately to assess overall performance of
136 the gerbera genotypes. Analysis of variance was conducted to work out significance of
137 variability for different agro-morphological and floral traits.

138 139 **3. RESULTS AND DISCUSSION** 140

141 In the tissue culture experiments, initially the seedlings raised on MS basal medium of twelve
142 hybrid genotypes viz. 23-1, 24-1, 24-2, 24-3, 24-4, A-6, B-2,D-3,E-1, E-2, E-3 and Y-1 when
143 cultured on proliferation medium supplemented with BAP (1.0 mg/l) + IBA (0.030 mg/l) and
144 NAA (0.025 mg/l) gave a differential response with respect to micro-shoot formation during
145 first three sub-cultures. Of these, only five genotypes (23-1, 24-4, A-6, E-3 and D-3)
146 responded well in the proliferation medium and taken forward for experimentation to
147 evaluate their proliferation potential under varying concentrations of BAP and different
148 concentrations of IBA for rooting (Fig. 1). Since sufficient micro-shoot proliferation in other
149 genotypes was not achieved to the same extent in the first three sub-cultures, they were
150 excluded from the experiment so as to homogenize the experimental data set of 60 explants
151 per genotype. The data on effect of concentrations of BAP on micro-shoot multiplication
152 recorded after one month of culture is given in Table 2. The maximum number of micro-
153 shoots (12.73), leaves (44.7) and leaf length (3.48 cm) were produced in the medium M3
154 containing 1 mg/l BAP+ 0.030 mg/l IBA+ 0.025mg/l NAA followed by M2 medium with
155 0.75mg/l BAP+ 0.030 mg/l IBA+ 0.025mg/l NAA.



156

157 **Fig. 1. Differential response of different gerbera genotypes to *in vitro* proliferation**
158 **(genotypes from left to right 24-4, 23-1, E-3, D-3 and A6)**

159	Table 2. Effect of BAP on number of micro-shoots, number of leaves and largest leaf length in five different genotypes of gerbera																		
160	Media	Number of micro-shoots per explant						Number of leaves per explant						Largest leaf length (cm)					
161		E-3	23-1	24-4	D-3	A-6	Mean	E-3	23-1	24-4	D-3	A-6	Mean	E-3	23-1	24-4	D-3	A-6	Mean
162	M1	9.0	10.3	5.0	5.4	4.8	6.9	31.7	31.8	21.5	23.9	18.9	25.5	2.1	2.6	2.2	2.9	2.1	2.4
163	M2	10.4	10.6	5.2	5.7	5.1	7.4	32.8	33.3	23.4	25.1	21.1	27.1	2.1	2.7	2.4	3.0	2.3	2.5
164	M3	11.6	12.7	5.6	5.9	5.4	8.2	44.7	41.5	30.0	32.7	22.8	34.4	2.2	2.9	2.3	3.4	2.2	2.6
165	M4	11.2	11.5	5.1	5.6	4.9	7.6	34.2	34.4	22.4	28.9	19.5	27.8	2.2	2.8	2.2	3.2	2.2	2.5
166	Mean	10.5	11.3	5.2	5.6	5.0		35.8	35.2	24.3	27.6	20.5		2.2	2.8	2.3	3.1	2.2	
167	CD	1.86	1.70	0.41	0.31	0.42		9.53	6.84	6.14	6.34	2.78		0.12	0.20	0.14	0.41	0.14	

Currently, *in vitro* propagation is the preferred method for quick multiplication of the planting material [10, 11, 12, 13, 14]. Gerbera plants have been regenerated from calli derived from a variety of explants [15, 16, 17, 18, 19]. Adventitious shoots have also been regenerated from the flower buds of Gerbera plants grown in the greenhouse [20, 21]. However, in this study, seeds were available which were developed through crossing under an ongoing gerbera breeding program and used for *in vitro* propagation. Accordingly, standardization of culture medium with optimum concentration of growth regulators is critical for evaluating micro-propagation response of the different genotypes involved in the study.

To further understand the response of potential gerbera genotypes, data generated as per randomized block design in tissue culture experiment were analyzed and maximum micro-shoot formation was observed in 23-1 followed by E-3 (Table 2), whereas more leaves were formed in E-3 as compared to 23-1 (Fig. 2). Analysis of variance of the shoot proliferation data indicates significant genotypic variations (Table 3). Overall, among the five gerbera genotypes evaluated for proliferation potential, 23-1 and E-3 have significantly better response than other genotypes under *in vitro* conditions. The present investigation suggests that number of micro-shoots leaf number and leaf size are independent traits which are affected by media conditions and contribute to overall shoot proliferation in gerberas. Considerable variations were obtained for shoot proliferation parameters indicating genotypic specificity of gerbera accessions to these component traits of *in vitro* propagation. Genotypic response to *in vitro* propagation has also been reported in other plant species such as sugarcane [22] and *Phoenix dactylifera* [23].



Fig. 2. Growth of gerbera genotypes 23-1 and E-3 (left and right, respectively) after one month in proliferation medium

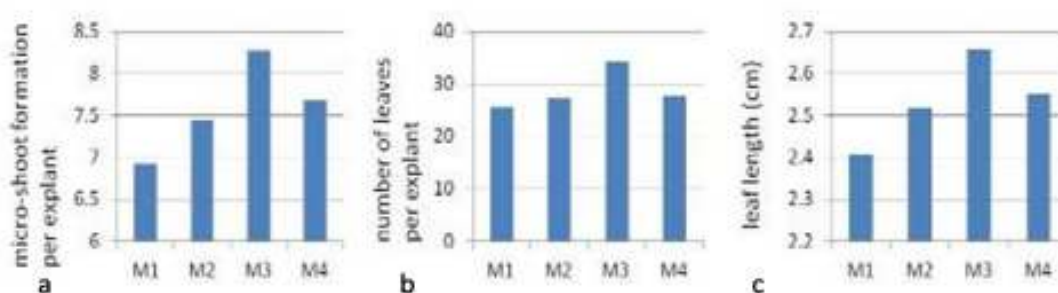
Table 3 ANOVA test for the differences in micro-shoot formation per explant, number of leaves per explant and leaf size among five different genotypes of gerbera

S. No.	Source of variation	Variance	F- value
1.	micro-shoot formation per explant	38.22	136.12*
2.	number of leaves per explant	180.27	53.06*
3.	leaf size (cm)	0.70	58.13*

*Significant at $P = .05$

Based on Student's t-test, media M3 and RM3 were significantly better from the other media for shoot proliferation and root induction in gerbera. Different combinations of cytokinin and auxins have been used to achieve multiple shoot induction in Gerbera [24, 25, 26]. In the

present studies, among the different concentrations of BAP in combination with IBA and NAA, the MS medium supplemented with 1 mg/l BAP was found to be best medium as compared to others because it results in maximum number of shoots and shoot length, whereas high concentration of BAP (1.5 mg/l) induced negative effect on plant growth (Fig. 3). These results are in conformity with that of Mariam *et al.* in 2010 [27] who obtained highest shoot number in gerbera with 1mg/l BAP. Highest multiplication rates [28] were observed in gerbera with 3 mg/l BAP which are contrary to the present finding. Genotypic specificity to growth regulators may possibly be the reason for such large variations in response to concentrations of growth regulators. The gerbera genotypes which did not respond well under initial tissue culture experiment need to be evaluated for higher doses of BAP so as to ascertain their growth regulator requirements for effective micro-propagation. There are reports [29, 30] that the cultivars varied widely in their growth regulator requirements at multiplication phase. In the present study, among different genotypes evaluated for micro-propagation, genotypes 23-1 and E-3 were observed best because micro-propagation rate was found to be high in these two genotypes.



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219 **Fig. 3** Comparison of proliferation media (M1-M4) for (a) micro-shoot formation per
220 explant, (b) number of leaves per explant and (c) leaf size (cm) in gerbera

221 Rooting was obtained in all the root induction media, but the main difference was time taken
222 for root initiation. Earliest response for root initiation was observed in RM3 medium (Fig. 4).
223 IBA plays important role in root induction in tissue culture plants. IBA has been reported as
224 the best medium for root induction in Gerbera [19]. The root initiation and root development
225 were better in MS medium with higher concentration of IBA as compared to lower
226 concentration in all the five varieties used in the present study. 100% rooting in red yellow
227 and white varieties was obtained the cultured on half MS containing 0.2 mg/l IBA within 15-
228 20 days of root initiation [31]. Successful rooting was obtained from *in vitro* cultured gerbera
229 shoots in MS medium containing 1.5mg/l IBA [27]. The results obtained in our study confirm
230 the earlier reports. However, response to root initiation in rooting media was observed to be
231 at par among the gerbera genotypes. A large number of rooted plantlets of gerbera were
232 successfully hardened by removing them from culture flasks, washed thoroughly under
233 running tap water to remove agar and then transferred to plastic trays containing sand and
234 covered with plastic bag to maintain humidity. After 2-3 weeks of acclimatization they were
235 transplanted in sleeves for further cultivation in soil (Fig. 5). The new gerbera genotypes
236 were characterized with respect to floral traits and showed high to moderate growth
237 response to *in vitro* proliferation as compared to other gerbera genotypes and have good
238 potential for commercialization (Fig. 6).

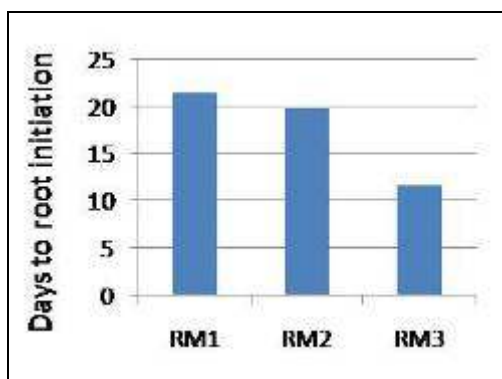


Fig. 4 Mean differences of rooting media (RM1-RM3) for days to root initiation in gerbera



Fig. 5. (a) Root initiation in gerbera cultures, (b) and (c) hardening of rooted plantlets in trays and (d) transfer of plantlets in sleeves in hardening chamber



Fig. 6. Potential gerbera genotypes 23-1 (left) and E-3 (right) with good field performance and high micro-propagation rate

The floral description and agro-morphological performance of genotypes is mentioned in Tables 1 and 4. Significant variability was observed among the F_1 genotypes 23-1 and E-3 as compared to parental lines Gr1, Gr2, Gr3 and Gr7 for the agro-morphological and floral traits. The extent of variability based on analysis of variance estimates for different traits (Table 5) suggests that there is wide scope for improvement of agro-morphological as well as floral traits in gerbera through a breeding program. Data generated for quantitative traits

over two years were analyzed separately and not pooled because *Gerbera jamesonii* is a perennial plant species and the observations made were not repetition but continuation of the same experiment. Significant genotypic variations were recorded for the agromorphological and floral traits although variations among the replicates were not significant which is expected considering that the plants of each genotype have clonal origin and the experiment was undertaken under controlled poly-house conditions. Based on mean performance of hybrid gerbera genotypes with the respective parents, E-3 was superior to at least one parental genotype for traits plant spread in a year, leaf length (cm) and leaf width (cm), while it was at par to parental genotypes for the other traits. In case of 23-1, the genotype was superior to at least one parental genotype for leaf width (cm), number of flowers per plant in a year and scape length (cm). Comparison of data for the two years suggests that some of the traits tend to stabilize over the years (leaf number per plant/year, leaf length, leaf width, flower number per plant/year and flower diameter), while others become more variable (plant spread, number of suckers per plant/year and scape length). As is evident from the data, characters such as plant spread, number of suckers per plant/year and scape length are associated with overall growth of the plants and may not completely express during first year of plant growth.

Table 4. Mean performance of gerbera genotypes over two years

S. No.	Source of variation	IHBT-Gr-01		IHBT-Gr-07		E-3	
		2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
1.	Leaf number per plant/year	31.25	33.15	32.05	33.05	29.3	31.85
2.	Plant spread (cm)/year	57.75	58.45	48.95	49.45	63.25*	63.8*
3.	No. of suckers / plant/year	2.45	4.45	2.7	6.25	2.75	5.7
4.	Leaf length (cm)	32.55	32.60	23.0	23.75	34.25*	33.425*
5.	Leaf width (cm)	11.55	11.3	7.17	7.075	12.87*	11.975*
6.	Flower no. per plant/year	21.15	22.95	17.6	19.55	18.8	21.8
7.	Scape length (cm)	34.6	33.55	50.05	49.05	39.3	40.75
8.	Flower diameter (cm)	8.22	8.25	7.55	7.775	8.05	8.225
*Significant at $P = .05$							
S. No.	Source of variation	IHBT-Gr-02		IHBT-Gr-03		23-1	
		2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
1.	Leaf number per plant/year	20.85	23.7	22.75	24.45	25.4	28.65
2.	Plant spread (cm)/year	66.05	66.55	66.25	66.8	65.85	66.55
3.	No. of suckers / plant/year	2.3	4.5	2.45	5.15	2.8	5.75
4.	Leaf length (cm)	37.2	37.31	36.35	35.68	38	37.46

290	5.	Leaf width (cm)	12.17	11.67	14.67	14.6	16.2*	15.22*
291	6.	Flower no. per plant/year	13.95	16.35	12.75	14.75	23.5*	23.4*
292	7.	Scape length (cm)	32.8	31.95	32.6	31.5	45.4*	44.75*
293	8.	Flower diameter (cm)	9.65	9.72	9.35	9.55	10.85	10.75

294 *Significant at $P = .05$

295

296 **Table 5. Analysis of variance for quantitative traits among new gerbera hybrid**
 297 **genotypes and their parental lines during 2013-14 and 2014-15 under poly-house**
 298 **conditions**

299	S. No.	Source of variation	2013-14		2014-15	
300			Variance	F- value	Variance	F- value
301	1.	Leaf no. per plant/year	85.81	367.09*	72.43	185.25*
302	2.	Plant spread (cm)/year	189.34	472.31*	190.21	498.80*
303	3.	No. of suckers/plant/year	0.16	5.66*	2.12	21.68*
304	4.	Leaf length (cm)	123.00	421.41*	104.66	471.24*
305	5.	Leaf width (cm)	38.32	388.85*	33.60	306.44*
306	6.	Flower no. /plant/year	67.94	323.36*	51.48	137.89*
307	7.	Scape length (cm)	209.45	750.73*	217.42	497.28*
308	8.	Flower diameter (cm)	6.04	97.88*	5.23	62.73*

309 *Significant at $P = .05$

310

311 4. CONCLUSION

312

313 On the basis of the present study a suitable protocol for shoot regeneration, multiplication
 314 and root induction has been identified for mass multiplication of gerbera plants. The MS
 315 medium supplemented with 1mg/l BAP + 0.030mg/l IBA + 0.025mg/l NAA produced
 316 maximum micro-shoots, leaf number and leaf length. Half strength MS medium with 0.4mg/l
 317 IBA was observed to be the best medium for early root initiation of *in vitro* raised micro-
 318 shoots of gerbera. The protocol can be utilized for mass multiplication of new gerbera
 319 genotypes on a commercial scale. Characterization of new hybrid F_1 genotypes of gerbera in
 320 comparison to parental genotypes under field conditions suggests the scope of improvement
 321 of gerbera for desirable floral traits such as double flower shape, standard size of flowers
 322 and various colours through breeding program which will result in new varietal types for
 323 cultivation in future.

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330 REFERENCES

331

332 1. Tjia B. Cooperative extension services. International Food and Agricultural Science,
333 University of Florida, 2001; 1-5.

334 2. Singh S, Dhyani D and Karthigeyan S. Characterization of variability in F₁ progeny of
335 inter-varietal cross of gerbera (*Gerbera jamesonii* Bolus ex. Hooker F). Journal of
336 Ornamental Horticulture 2009; 12(4): 225-231.

337 3. Singh S, Dhyani D and Kumar Ashok. Flower colour variations in gerbera (*Gerbera*
338 *jamesonii*) population using image analysis. Indian Journal of Agricultural Sciences 2011; 81
339 (12): 1130-1136.

340 4. Singh S, Kumar A and Dhyani D. Inheritance of pigment markers associated with
341 flavonoid and carotenoid pigmentation in flowers of *Gerbera jamesonii*. Canadian Journal of
342 Plant Breeding 2013; 1(3): 110-114.

343 5. Peper H, Brandis AV, Dopke H. Clonal propagation of gerberas can be profitable. Result
344 from Ahlem on the culture and clonal propagation of gerberas. Taspo 1971; 105, 7.

345 6. Murashige I, Skoog F. A revised medium for rapid growth and bioassay with tobacco
346 tissue cultures. Physiol. Plant 1962; 15, 473-487.

347 7. Meeteren U Van. Water relations and keeping-quality of cut gerbera flowers. I. The cause
348 of stem break. Scientia Horticulturae 1978; 65-74.

349 8. RHS colour chart. Published by the Royal Horticultural Society, 80 Vincent Square,
350 London, SW1P 2PE. 1995.

351 9. Drennan D, Harding J, Byrne TG. Heritability of inflorescence and floret traits in gerbera.
352 Euphytica 1986; 35: 319-330.

353 10. Reynoird JP, Chriqui D, Noin M, Brown Sand Marie D. Plant propagation from *in vitro*
354 leaf culture of several gerbera species. Plant Cell Tissue and Organ Culture 1993; 33: 203-
355 210.

356 11. Aswath C, Choudhary ML. Rapid plant regeneration from *Gerbera jamesonii* Bolus callus
357 cultures. Acta Botanica Croatica 2002; 61:125-134.

358 12. Xi M, Shi JS. Tissue culture and rapid propagation of *Gerbera jamesonii*. Journal
359 of Nanjing Forestry University 2003; 27: 33-36.

360 13. Prasanth M, Sekar K. Studies on age of explant on callus induction in gerbera cv.
361 Mammot. Scientia Horticulturae 2004; 9: 207-211.

362 14. Kumar S, Kanwar JK, Sharma DR. *In vitro* regeneration of *Gerbera jamesonii* Bolus from
363 leaf and petiole explants. Journal of Plant Biochemistry and Biotechnology 2004; 13: 73-75.

364 15. Zheng XF, Wang JH, Li MY. Factors affecting organogenesis in *Gerbera jamesonii* Bolus
365 cultures *in vitro*. Journal of Jiangsu Forestry Science and Technology 2002; 29: 29-31.

- 366 16. Modh FK, Dhaduk BK, Shah RR. Factors affecting micropropagation of gerbera from
367 capitulum explants. Journal of Ornamental Horticulture 2002; 5: 4-6.
- 368 17. Tyagi P, Kothari SL. *In vitro* regeneration of *Gerbera jamesonii* (H. Bolus ex Hook f.)
369 from different explants. Indian Journal of Biotechnology 2004; 3: 584-586.
- 370 18. Ray T, Saha P, Roy SC. *In vitro* plant regeneration from young capitulum explants of
371 *Gerbera jamesonii*. Plant Cell Biotechnology and Molecular Biology 2005; 6: 35-40.
- 372 19. Kumar S, Kanwar JK. Regeneration ability of petiole, leaf and petal explants in gerbera
373 cut flower cultures *in vitro*. Folia Horticulturae 2006; 18: 57-64.
- 374 20. Pierik RLM, Jansen JLM, Maasdam A, Binnendijk CM. Optimization of gerbera plantlet
375 production from excised capitulum explants. Scientia Horticulturae 1975; 3: 351-357.
- 376 21. Laliberte S, Chretien I, Veith J. *In vitro* plantlet production from young capitulum explants
377 of *Gerbera jamesonii*. Horticulture Science 1985; 20: 137-139.
- 378 22. Cheema K L, Hussain M. Micropropagation of sugarcane through apical bud and axillary
379 bud. International Journal of Agriculture and Biology 2004; 2: 257-9.
- 380 23. Al-Khayri J M, Al-Bahrany A M. Genotype dependent *in vitro* response of date palm
381 (*Phoenix dactylifera* L.) cultivars to silver nitrate. Scientia Horticulturae 2004; 99: 153-62.
- 382 24. Murashige T, Sepra M, Jones JB. Clonal multiplication of gerbera through tissue culture.
383 Hort. Sci. 1974; 9: 175-180.
- 384 25. Schiva T, Lercari B, Giusta R. Micropropagation of Gerbera: variable response to *in vitro*
385 culture. Annali-dell'Istituto-Sperimentale-per-la-Floricoltura 1982; 13: 56-61.
- 386 26. Barbosa MHP, Pasqual M, Pinto JEBP, Arello EF, Barros IDe, Barros I. Effects of benzyl
387 amino purine (BAP) and 3-indole acetic acid (IAA) on *in vitro* propagation of Gerbera
388 (*Gerbera jamesonii* Bolus ex Hook) cv. Appelbloesem. Pesquisa Agropecuaria Brasileira
389 1993; 28: 15-19.
- 390 27. Mariam A, Mahmed A, Igbal A. Evaluation of micro and macro propagation techniques of
391 Gerbera (*Gerbera Jamesonii*) under different conditions. Second RUFORUM Biennial
392 Meeting 2010; 20 - 24 September.
- 393 28. Shailaja VP. Studies on *in vitro* propagation of *Gerbera jamesonii* Bolus. M.Sc. Thesis,
394 University of Agricultural Sciences, Dharwad 2002. (India): pp??
- 395 29. Pierik RLM, Steegmans HHM, Verhaegh JAM, Wouters AN. Effect of cytokinin and
396 cultivar on shoot formation of *Gerbera jamesonii in vitro*. Netherlands J. Agric. Sci. 1982; 30:
397 341-346.
- 398 30. Harel D, Kuzmicic I, Jug-Dujakovic M, Jelaska S. The effect of genotype on Gerbera
399 shoots multiplication *in vitro*. Acta Bot. Croatia 1993; 52: 25-32.
- 400 31. Akter N, Hoque MI and Sarker RH. *In vitro* propagation in three varieties of gerbera
401 (*Gerbera jamesonii* Bolus.) from flower bud and flower stalk explants Plant Tissue Culture
402 and Biotechnology 2012; 22(2): 143-152.