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Effect of Substrate for Extending Post-Harvest Sustanability and Freshness in Commercial Varieties of Gerbera (*Gerbera jamsonii*)

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ABSTRACT

Gerbera is an important cut flower that is famous for its attractive and wonderful colors. The gerbera is produced in all around the globe especially in South East Asian country of Japan and in Netherlands in Europe. The short vase life of gerbera is limiting factor in earning full profit from gerbera cut-flower sale. The standardization of suitable substrate for extending vase life of gerbera is not present. The gerbera was placed in substrates 6-Benzyleadenine, Silicic acid and Silver nitrate (20, 40, 60, 80 and 100 ppm) with sucrose (5, 10, 15, 20 and 25g), respectively. The cut flower response was observed by observing the time (days) for sustaining the freshness of cut flowers. Net fresh weight (g) after 15 days according to the formula and Dry weight of the flower (Flower head + flower stem) were taken on placing flowers at 50^{o}C in incubator for 36 hr. The environment of laboratory during research was 20^{o}C. The best response for extending the freshness was observed in cv. Bonnie (Orange) that performed excellent when placed in medium level of 6-Benzyleadenin (20-40ppm with 10-15g/l of Sucrose). The results of 6-Benzyleadenin (20-40ppm with 10-15g/l of Sucrose) are recommended to common retailers for extended storage life of gerbera cut-flower prior to sale. The present substrate is easy to use and non-toxic for extending the vase life/freshness of gerbera cut flower.

Keywords: Gerbera, Freshness, Substrates, Vase life, Sustainability

INTRODUCTION

Gerbera (*Gerbera jamsonii* L.) is one of the most famous and beautiful cut-flower of tropical and subtropical climate (Minerva & Kumar, 2013). China produces gerbera in open farming conditions on 6204 ha. followed by Netherlands (169), Turkey (116), Japan (92), Mexico (87) and Taiwan (77) in protected conditions (Laura, 2020). Generally Gerbera is propagated through division of rhizomes, seeds and shoot tips cutting in *in vivo* conditions (Son *et al.,* 2011). Various commercial verities of gerbera are propagated through seeds however variations in subsequent generations are significant. Due to which seed propagation method is not followed at commercial farms for raising population in further years. Hetrozygosity loses uniformity, color, number of petals and size of flower in subsequent generations (Ludwig *et al.,* 2008). Gerbera is mainly used as cut-flower due to its attractive colors, significant stem length, amazing petal shape and extended vase life these are also the indices that make it famous in national and international markets of Europe and America (Parathasarathy & Nagaraju, 1999). Pakistan did not grow gerbera on significant area for commercial purposes due to lack of hybrid seed production for desirable commercial purposes. Entire seeds and plants are imported from Netherland, China and India for small scale commercial purposes. Pakistan floriculture industries are lacking for gerbera breeding and hybrid seed production at local level.

Post-harvest senescence is the major factor limiting the marketing of most cut flower

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species. Silver ion (applied in silver thiosulfate form), Silicic acid, GA_3, 6-Benzyleadenine (BA) are the ingredients that are widely used to postpone aging of ethylene-sensitive flowers. These substances inhibits the synthesis of ethylene (Sevindik *et al.,* 2018), thereby delaying wilting. However, concerns have been voiced about the application of silver because this is a heavy metal that may be toxic to the environment (Rezvanypour & Osfoor, 2011). The BA that is the Cytokinin that trigger the growth in plants especially in *in vitro* environment. It causes the cell proliferation as well. In post-harvest environment the growth regulator act as an antagonistic agent against the senescence as well (Lewis *et al.,* 2011). Silver nitrate and silicic acid specially used for preventing culture decline in in vitro environment. While in post-harvest environment the silver nitrate stops the production of ROS from the system and keeps the tissues in active form due to which the plants maintain their freshness as well (Li *et al.,* 2018). The use of these substances for extending the post-harvest freshness of cut-flowers is evident in international literature.

The bulk import of gerbera is done monthly or fortnightly as the preservation of cut-flower is highly necessary to earn proper return from investment. Cut flowers lose their water soon after harvesting and water balance is a major factor determining quality and vase life of cut flowers (Da-Silva 2003). Normal way of preservation of gerbera sticks is to keep them in sweet water prepared with anonymous and unstandardized formulations of Soft drinks of Coca-Cola and 7Up. The soft drink are used due to which the medium become acidic with low pH that helps to extent in preservations of gerbera sticks up to 8-10 days. The market sellers also keep flowers in freezer due to which injury prevails. The injured petals are generally become black and removed as it affects the beauty of the flowers. Dropping of heads, lowering the brightness of color of petals, softening of stem are the key indicators of gerbera cut-flower death in vase or preservation environment. The freshness of cut-flowers in market is a key source of customer's attraction and product price. The post-harvest handling of cut-flower directly aims at preventing flowers from biotic (Fungus) and abiotic (food supply, water quality, light, temperature and maturity of flowers) factors (Greer, 1999). Post-harvest substrate must be non-toxic, free from microbes, plant friendly and nutritive as cut-flowers need nutrients after harvest (Shanan, 2012). Various growth regulators and nutrient mixtures are used for post-harvest substrate such as 6-Benzyleaminopurine and Murashing&Skoog (1962). The present research was done to standardize the post-harvest substrate for local floral retailors in the market.

MATERIALS AND METHODS

The present research has been carried out in post-harvest laboratory of Horticultural research institute for floriculture and landscaping, Islamabad (HRI). The gerbera plants of hybrid varieties (cv. Alberino (Red), cv. Bonnie (Orange) and cv. Devil (Yellow)) were planted in germplasm unit of HRI in 12" pot size for cut-flower harvest for further research on post-harvest life. The soil substrate for gerbera plants comprised equal volume of leaf manure and silt. The plants of gerbera age, 6 month were purchased from commercial nurseries of Lahore were shifted into pots during the month of October. Substrate for pots for transplanting of hybrid gerbera plants was leaves manure+silt (1:1). The plants were harvested during the month of December and January 2020 and placed in the various solutions for observing the vase life. The solutions are as mentioned in table 1.

The temperature of the lab was standardized at 20^{o}C for present research. The cut flower response was observed by observing the time (days) for sustaining the freshness of cut flowers, Net fresh weight (g) after 15 days according to the formula as given below and Dry weight of the flower (Flower head + flower stem) were taken for placing flower at 50^{o}C in incubator for 36 hr. The Statistical analysis was done according to the factorial CRD experimental design with LSD-test after ANOVA (Steel&Torrie, 1960)**.**

Net Fresh wt.(g) =Final wt. of flower (includes water/substrate uptake)-Initial fresh wt.

RESULTS

The results ($P<0.05$) revealed cut-flower health in various concentrations of PGRs and other substances (Table I). The Data was analyzed statistically the F-test and ANOVA carried out (Supplementary data) revealed that all the interactions (Variety, duration in Substrates, level of substrates and substrate type) were significantly affecting the post-harvest attributes of the gerbera cut-flowers. The interaction with different substrate (Gibberellic acid (GA_3), 6-Benzyladenine (BA), Silicic acid (SSA) and Silver Nitrate (SN)) and varieties (cv. Bonnie (Orange), cv. Devil (Yellow) and cv. Alberino (Red)) showed significant difference in time of head drop of gerbera cut flowers (Table III).

Table I: Concentration of Silver Nitrate (ppm), GA_3 and SSA (ppm) and addition of Sucrose (g) for observing the plant response in substrate for extending freshness (Sharma *et al.,* 2018)

Gibberellic acid GA_3 (ppm)	6-Benzyladenine	Silicic acid SSA (ppm)	Silver Nitrate (ppm)	Sucrose (g)	pH of solution
Control: Clean Tap water	**Control: Clean Tap water**	**Control: Clean Tap water**	**Control: Clean Tap water**	**Clean Tap water**	**5.8-6**
20	20	20	20	5	-Do-
40	40	40	40	10	-Do-
60	60	60	60	15	-Do-
80	80	80	80	20	-Do-
100	100	100	100	25	-Do-

Table II: Mean plant health in various varieties of gerbera under poly-tunnel house

	cv. Bonnie (Orange)	cv. Devil (Yellow)	cv. Alberino (Red)
flower Stem Length of (cm)	22.24±0.40A	21.51±0.24B	22.56±0.48A
Flower head Diameter (cm)	9.04±0.21A	9.04±0.18B	9.31±0.18B
Class of flower	Class-III	Class-II	Class-III

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean.

Table III: Mean response of gerbera cultivars against various post-harvest substrates in sustaining the freshness of cut-flower

		cv. Bonnie (Orange)	cv. Devil (Yellow)	cv. Alberino (Red)	Mean
Time for head drops (Days)	Fresh Tap water	5.43±0.98	6.45±1.12	4.56±1.23	5.48±1.12
	Gibberellic acid	11.72±1.31ef	11.11±1.38f	12.00±1.30ef	11.61±0.76D
	6-Benzyleadenine	24.29±1.32a	23.12±0.91ab	22.35±0.65abc	23.25±0.58A
	Silicic acid	20.40±0.42c	21.79±0.42bc	20.51±0.51c	20.90±0.27B
	Silver Nitrate	14.11±1.48de	12.78±1.18def	14.67±1.21d	13.85±0.74C
	Mean	17.63±0.84A	17.20±0.81A	17.38±0.69A	
Net Fresh wt. (g) of cut flowers	Gibberellic acid	13.21±0.41f	13.80±0.42f	14.10±0.48ef	13.71±0.25C
	6-Benzyleadenine	19.92±0.44a	19.05±0.36ab	19.80±0.35a	19.59±0.23A
	Silicic acid	17.73±0.61bc	17.66±0.78bc	17.08±0.57cd	17.49±0.38B
	Silver Nitrate	13.03±0.79f	13.85±0.94f	15.64±0.33de	14.18±0.44C
	Mean	15.98±0.45B	16.09±0.43AB	16.66±0.33A	
Dry wt. (g) of cut flowers	Gibberellic acid	6.55±0.34	6.53±0.27	7.07±0.26	6.72±0.17B
	6-Benzyleadenine	9.81±0.26	10.09±0.55	10.16±0.27	10.02±0.22A
	Silicic acid	9.81±0.26	10.16±0.32	9.96±0.20	9.98±0.15A
	Silver Nitrate	5.56±0.52	6.65±0.55	6.56±0.35	6.26±0.28B
	Mean	7.93±0.29B	8.36±0.30A	8.44±0.24A	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean.

The longest duration of remaining fresh was observed in the variety of cv. Bonnie (Orange) (24.29 days), followed by cv. Devil (23.12 days) and cv. Alberino (Red) (22.35 days) in 6-Benzyladenine. The Net fresh weight (g) was also significant in 6-Bnzyladenine that was 19.92 (g), 19.05 (g) and 19.80 (g) in cv. Bonnie, Devil and Alberino, respectively while Dry weight (g) of cut flowers was also significant in 6-Benzyladenine in cv. Bonnie (9.81), cv. Devil (10.09) and cv. Alberino (10.16). The interaction amongst the post-harvest attributes, varieties and various levels of the post-harvest treatment with substrate was observed significant (P<0.05) (Table IV).

Table IV: Mean response of gerbera cultivars against various levels of post-harvest substrates for sustaining the freshness of cut-flowers

Plant attributes	Varieties	Fresh Tap water	(10ppm) +Sucrose 5g	(20ppm) +Sucrose 10g	(40ppm) +Sucrose 15g	(60ppm) +Sucrose 20g	(80ppm) +Sucrose 25g	(100ppm) +Sucrose 30g
Time for head drops (Days)	cv. Bonnie (Orange)	6.45±1.54d-e	17.62±2.09b-e	20.80±2.00a	21.25±2.29a	17.59±1.22b-e	14.51±2.23ef	14.01±1.67f
	cv. Devil (Yellow)	5.67±0.98ef	16.25±2.51c-f	20.18±1.18ab	20.02±2.24ab	15.52±1.83def	16.62±1.95c-f	14.60±1.73ef
	cv. Alberino (Red)	5.97±1.12df	18.12±1.86a-d	16.10± 1.94c-f	19.10±1.56abc	17.44±1.41b-e	17.11±1.74b-f	16.42±1.83c-f
	Mean	6.03±1.32C	17.33±1.22B	19.03±1.04A	20.13±1.16A	16.85±0.86B	16.08±1.13BC	15.01±0.99C
Net Fresh wt. (g) of cut flowers	cv. Bonnie (Orange)	9.23±2.12cf	15.72±1.20abc	14.97±1.17c	16.87±1.09abc	17.04±0.87abc	15.36±1.33bc	15.90±1.04abc
	cv. Devil (Yellow)	9.45±1.23bc	15.03±1.53c	16.86±0.80abc	16.92±1.27abc	16.28±0.66abc	16.25±0.95abc	15.21±0.93bc
	cv. Alberino (Red)	8.32±2.32ac	16.52±0.52abc	15.71±1.09abc	17.53±0.80a	16.47±0.75abc	17.27±0.96ab	16.43±0.68abc
	Mean	9.01±2.31C	15.76±0.66B	15.85±0.59B	17.11±0.60A	16.59±0.43AB	16.29±0.63AB	15.85±0.51B
Dry wt. (g) of cut flowers	cv. Bonnie (Orange)	4.98±1.34bc	6.88±0.90d	7.64±0.72bcd	8.27±0.62a-d	8.76±0.45abc	7.52±0.70cd	8.53±0.75abc
	cv. Devil (Yellow)	6.35±2.12bc	7.48±1.08cd	7.69±0.42bcd	9.12±0.62ab	8.95±0.88abc	9.09±0.68ab	7.82±0.53a-d
	cv. Alberino (Red)	6.46±1.43cd	8.12±0.57a-d	8.26±0.67a-d	8.77±0.58abc	9.24±0.34a	8.60±0.63abc	7.66±0.63bcd
	Mean	5.93±2.12C	7.49±0.50C	7.86±0.35BC	8.72±0.35A	8.98±0.34A	8.40±0.39AB	8.01±0.37BC

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean.

Table V: Cumulative Correlation amongst pre and post-harvest attributes in various varieties of Gerbera

Plant Attributes	Length of stick (cm)	Flower diameter initial (cm)	Total days for head drop	Total fresh wt. (g)	Total dry weight (g)
Flower stem length of (cm)	1.000				
Flower head diameter (cm)	0.278*	1.000			
	0.018				
Time for head drop (Days)	0.285*	0.111	1.000		
	0.015	0.354			
Fresh wt. (g) of cut flowers	0.358**	0.017	0.597**	1.000	
	0.002	0.889	0.000		
Dry wt. (g) of cut flowers	0.539**	0.107	0.657**	0.829**	1.000
	0.010	0.370	0.020	0.010	

Upper values indicated Pearson's correlation coefficient; Lower values indicated level of significance at 5% probability. * = Significant (P<0.05); ** = Highly significant (P<0.01)

The three factor statistical analysis revealed the most optimum level of substrate independently from the type of substrate that showed that 40 ppm +10g of sucrose is the best for prolonged days of freshness (20.13 days), highest fresh weight (17.11g) and highest dry weight (8.72g) of the cut-flower (Table IV). Cumulative correlation amongst pre and post-harvest attributes in various varieties of gerbera (Table V) showed dry weight (g) and fresh weight (g) (0.829), Dry weight and time for head drop (days) (0.657), while total fresh weight (g) and time (days) for head drop in gerbera (0.597) showed significant correlation. The strong correlation amongst fresh weight (g) and Dry weight (g) with Time (days) of freshness and fresh weight (g) are critical that depicts that healthy plants may survive longer in post-harvest substrate then a weak and small flower.

Comparative Analysis of Substrate, Level of Substrate and Plant Response for Extending Freshness in Gerbera Varieties

The overall interaction of three factor statistical analysis has been shown in the form of Fig (1-3). The figure showed that cumulative interaction of mean time for sustaining the freshness was prolonged by the various levels of 6-Benzyladenine (Fig 1), the same trends was also observed in the case of Fresh weight of flower (Fig 2) and dry weight of the flowers (Fig 3) in cut-flower of gerbera varieties. The time for head drop was significantly high when flowers were placed in the various concentrations of 6-Benzyladenine (Fig 1) while fresh weight (g) and dry weight of flowers were also observed to be highest in various concentrations of 6-Benzyladenine substrate.

DISCUSSION

Morphological Response of Gerbera Cut-Flower In Post-Harvest Environment

The Number of days for sustaining the freshness of flowers, fresh weight (g) of flowers (head+stem) and dry weight (g) of the flower (head+Stem) are very important attributes to observe and judge the post-harvest freshness of the flowers (Sharma *et al.,* 2018). Cut-flower or fresh cut flower is a unique commodity that remains alive after harvest (Hassani & Alimirzaii, 2017). The turgidity of the cut-flower sustains for a few hours if post-harvest measures are not taken and deteriorates with the passage of time (Bayat & Aminifard, 2017). Cut flowers have relevantly high rate of ethylene production and transpiration as well (Alves *et al.,* 2017). The production of ethylene effects the freshness of the cut flowers by chlorosis /darkening of leaves, dropping of heads of flowers and senescence, abscission, epinasty, and chlorophyll depletion in leaves (Costa *et al.,* 2016). The levels of such responses depend on the degree of sensitivity of the cut flower that differ among species and cultivars (Pattyn *et al.,* 2021). The use of various substrates is evident for sustaining the freshness and longevity of flowers in storage and transportation timing. These substrates are Gibberellins, Cytokinins, Silver nitrate and Silicic acid (Khunmuang *et al.,* 2019 and Da-Costa *et al.,* 2021).

The Role of Sucrose in Extending Post-Harvest Life of Gerbera Cut-Flowers

The Excision of flowers from plant stops the continuous flow of nutrients and water that are connect since they are grown while the upper parts are still living and have the great chances to deteriorate the longevity as well. The one cause of hasten the senescence events are lack of supply of organic substances such as Carbohydrates (Santos *et al.,* 2016). The sucrose is the key component of metabolism that regulate the osmotic potential play part in signal transduction and gene expression (Santos *et al.,* 2016). The key purpose of Photosynthesis is to form the sucrose through various forms of Chlorophyll. The Carbohydrates play the part in plant development in two ways, amongst 1: Structural building of the plant cell such as building of cell wall in the farm of polysaccharides, 2: translocations in plants and support the growth. The buds have highest level of sucrose that become utilized in further stages of floral development until the opening of petals and anthesis as well (Van-Doorn & Kamdee, 2014). The flowers such as Gerbera did not have enough reserves of Carbohydrates/Sucrose that showed early deterioration of flowers and did not contain market value for elongated duration (Seman & Rafdi, 2019). The use of sucrose in post-harvest substrate play part in prolonging the longevity and freshness (Van Doorn & Kamdee, 2014). Exogenous supply of sucrose helps cut-flower for respiration in addition with substrate (Pun & Ichimura, 2003). The sucrose added with substrate is reduced prevent the formation of invertases and sucrose synthase mechanism and dissociate into releasing glucose and fructose. This may slower the metabolism of the floral stems angel diversion and deterioration as well that may be due to high metabolism rate and failing lack of generation of sucrose (De *et al.,* 1996).

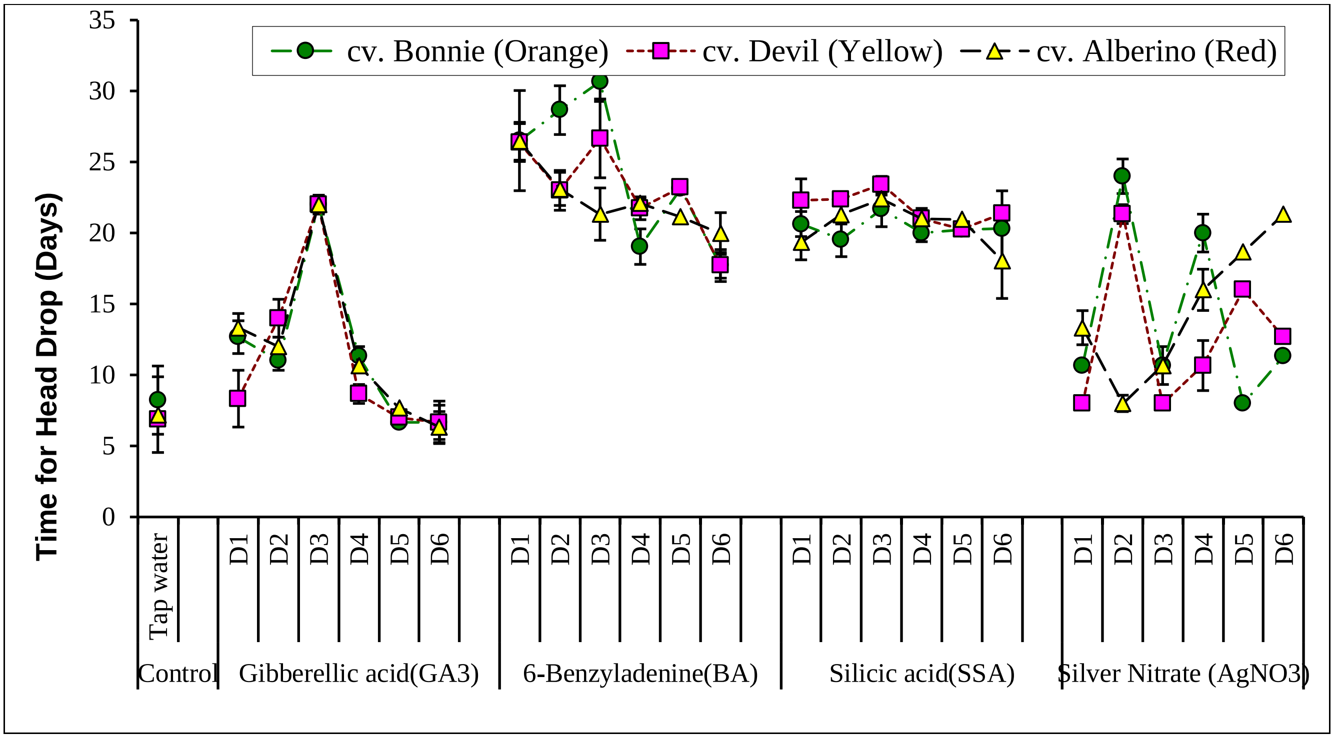

Fig 1: Comparative analysis of varieties for sustaining freshness (Time for Head Drop (Days)) in various levels of substrates

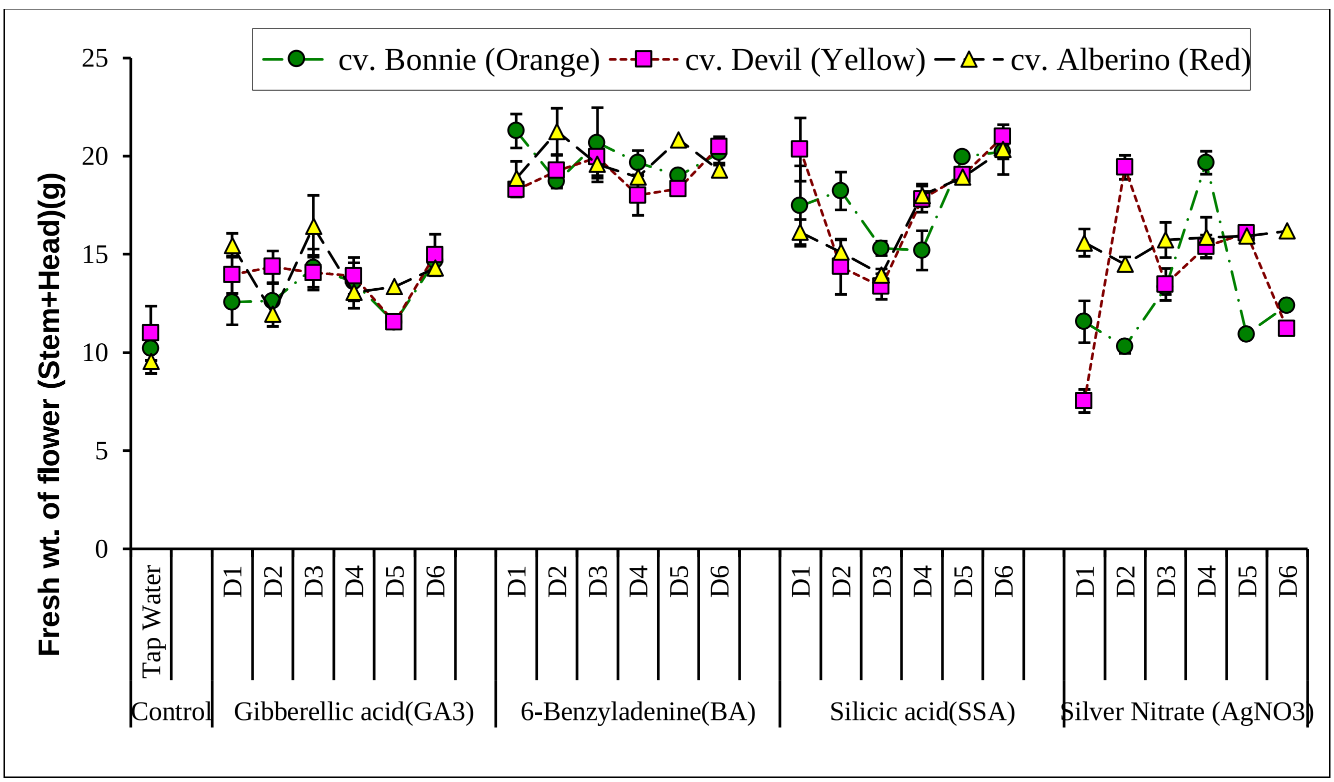

Fig 2: Comparative analysis of Gerbera varieties for maintaining Fresh wt. of flower (g) (Stem+Head) in various levels of substrates

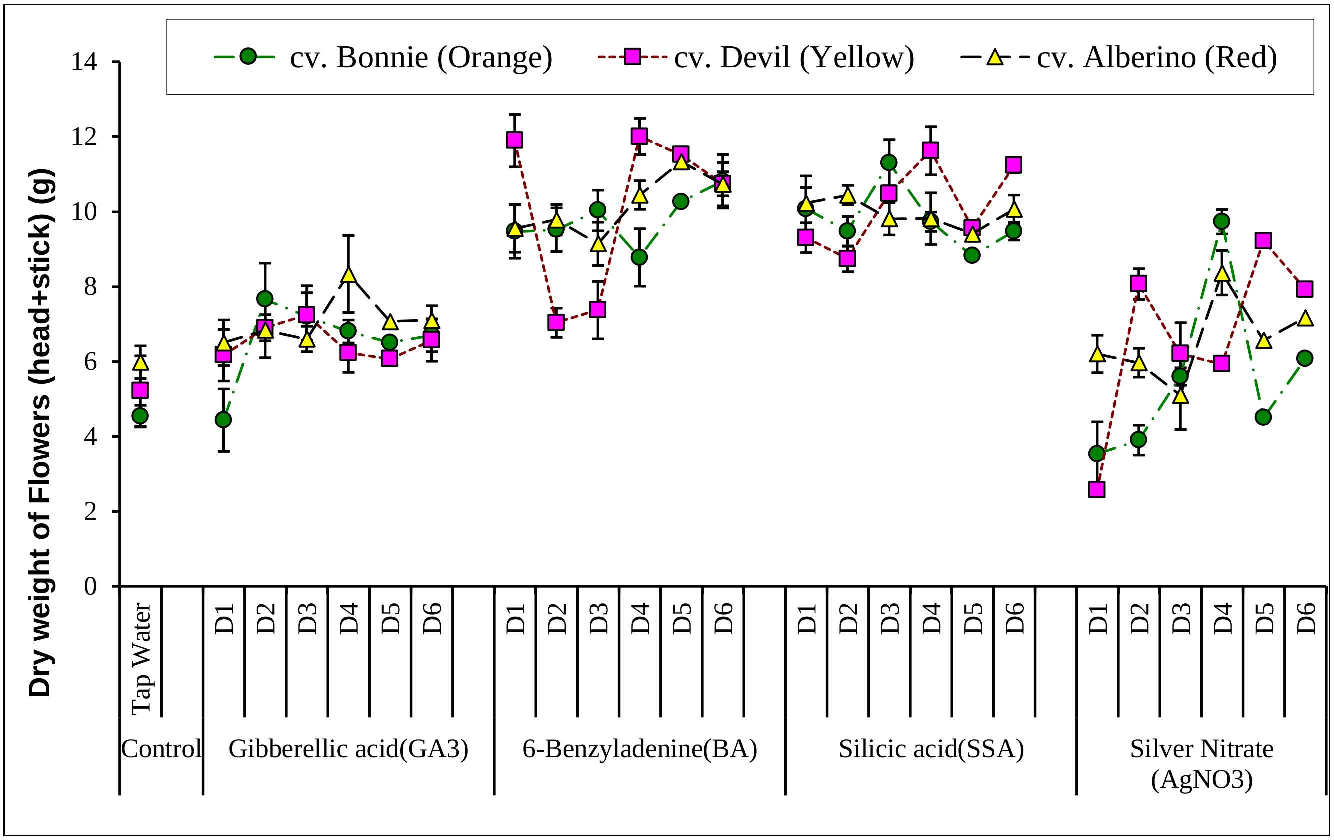

Fig 3: Comparative analysis of Gerbera varieties for maintaining Biological yield of cut-flowers (Dry wt. of flower (g) (Stem+Head)) in various levels of substrates

The Response of Gibberellins/Gibberellic Acid in Post-Harvest Environment of Gerbera Cut-Flowers

Gibberellins or Gibberellic acid (GA_3) are used as an antagonistic agents for resisting the ethylene production as well (Kumar *et al.,* 2014). The GA_3 also slow down the senescence activities in cut-flower in storage but it is not very effective compared with other substances used for preservation of commodity in storage. In higher amount the GA_3 shall fasten the senescence activities and promote the ripening and flower botrytis as well (Ta *et al.,* 2021). The use of GA_3 is great as post-harvest substrate in flowers that are harvest at farm maturity and are closed prior to marketing because GA_3 helps in opening of flower that is evident in various studies (Rahman *et al.,* 2016).

The Response of 6-Benzyleadenine/Cytokinins Acid in Post-Harvest Environment of Gerbera Cut-Flowers

Senescence accompanied with number of changes focused on starting cellular structural degradation at cytological, molecular and physiological, for that degradation numerous phytohormones involved (Wojciechowska *et al.,* 2018); leaf senescence includes gradual Chlorosis and Necrosis, mainly due to the over plant's age and/or the transforming into the reproductive phase. The plant hormones control the endogenous and exogenous signals which regulate the senescence program (Mayta *et al.,* 2019). However, petal senescence is differs because of the abundance of secondary metabolites. However several phytohormones are regulate the petal senescence, that phytohormones act synergistically and antagonistically (Ma *et al.,* 2018). Cytokinins (6-BA) are not only paly role in regulation of plant growth and developmental processes, but also their exogenous applications help in improve the plant yield (Li *et al.,* 2016) Cytokinins play the role as an antagonistic hormone against Absicic acid (ABA) (Shu *et al.,* 2018). 6-benzyladenine (BAP) known as the master growth modulator: it develop the resilience by controlling of the production of free radicals against abiotic or water stress (Ma *et al.,* 2018; Kamran *et al.,* 2021). In general, the exogenous application of 6-BA causes delay in the petal senescence. The exogenous application of cytokinin in potted plants and cut flowers was observed to delay leaf yellowing and decrease ethylene biosynthesis in plant systems (Iqbal *et al.,* 2017).

The Response of Silver Nitrate Acid in Post-Harvest Environment of Gerbera Cut-Flowers

The silver nitrate also plays a role in prolonging the freshness of cut flower when applied exogenously in the form of spray or in substrate for placing the cut flower for commercial purposes (Darvishani & Chamani, 2013). The silver nitrate is mobile substance in plant that is decomposed by sunlight exposure to the plants (Abbasi *et al.,* 2017). The silver nitrate did need any other substance to transfuse in the plant body such Cytokinins (Abbasi *et al.,* 2017). The silver nitrate is readily moved towards Corolla and elongate the freshness as well (Mohammadi *et al.,* 2014). The silver nitrate play role in fresh and dry weight of cut-flowers (Mohammadi *et al.,* 2014).

The Response of Silicic Acid in Post-Harvest Environment of Gerbera Cut-Flowers

The Silicic acid play a significant role in preventing the horticultural commodities to decay (Asghari & Aghdam, 2010). It play the role of antagonistic agent against the production of ROS and trigger the plant mechanism for AOX production. Generally the Silicic acid prevent the flowers from attack the biotic agents in post-harvest environment (Aghdam *et al.,* 2009). Exogenous application through spray and in the form of substrate further prevent the plants from chilling injury as well (Aghdam *et al.,* 2009). It maintain the water balance in plant tissue in storage environment hence the freshness sustain for commercial purposes.

CONCLUSION

Gerbera is an important cut-flower and have a great commercial value in retail flower markets. The present study can be disseminate amongst the local retailers for saving large amount of money invested to import the flowers out of season. The overall summary of results revealed that various levels of 6-Benzyleadenine play great rose in extending the freshness of cut flowers in storage environment where temperature is not exceeded above 20^{o}C. The best suited variety for better and log vase life is cv. Bonnie that sustain the freshness for more number of days compared with all other varieties. The present research is done on limited scale however the present research can also be extended by adding more attributes related to Biochemical changes occurring in the petals also.

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