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Effects of Gibberellic Acid on Postharvest Quality and Vaselife Life of Gerbera Cut Flowers (*Gerbera jamesonii*)

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Abstract: Laboratory trials were carried out to investigate the effect of gibberellic acid (GA_3) on the postharvest quality and vase life of gerbera cut-flowers. Freshly cut flower stems of gerbera cultivar 'Ida Red', with two outer disc florets open were put in flower vases containing 0, 2.5, 5, or 7.5 mg L^{-1} of GA_3. The treatments were arranged in a Completely Randomized Design with four replicates. Gerbera cut-flowers held in GA_3 at 2.5, 5 or 7. 5 mg L^{-1} significantly delayed flower senescence by increasing the number of disc florets open, delayed petal fading and abscission. Gibberellic acid at 2.5, 5 or 7.5 mg L^{-1} significantly reduced dry matter content in the flower heads and stems of gerbera cut-flowers. Gerbera cut-flowers held in 2.5, 5 or 7.5 mg L^{-1} GA_3 had significantly higher water content in the flower heads and stems, hence maintaining flower turgidity, reduction in bent neck and flower senescence and increased flower quality after 14 days of holding compared to flowers held in distilled water. Gibberellic acid at 2.5, 5 or 7.5 mg L^{-1} has the potential to be used as a gerbera cut-flower preservative solution.

Key words: Bent-neck, dry matter, flower water content, postharvest quality, senescence, GA_3

INTRODUCTION

Gerbera, also known as Transvaal daisy or Barberton daisy *Gerbera jamesonii* (Bol. *ex* Adlam) is a member of the composite family. Composite is a large family containing numerous important genera in the floricultural industry such as *Aster*, *Calendula*, *Centauria*, *Chrysanthemum*, *Cosmos*, *Dahlia*, *Dendranthema*, *Helianthus*, *Pericallis*, *Solidago*, *Tagetes* and *Zinnia*. Gerberas are valued for their brightly coloured daisy like flowers. Flowers are available in a wide range of colours, including yellow, orange, pink, crimson, red, purple and white. *Gabera jamesonii* is native to South Africa (Transvaal and Natal Provinces) and Swaziland. The other species of Gerbera are *G. viridifolia*, *G. aurantiaca*, *G. linnaei*, *G. anandria*, *G. aspleniifolia* and *G. kunzeand*[1]. Gerbera is most commonly used worldwide as a cut flower; however, dwarf hybrids lines exist which are suited for potted or bedding plants[2]. Stems are pulled, not cut and the base of stem should be removed before hydration.

Several commercial floral preservatives have been formulated for gerberas. Some firms dip the flower heads for a few minutes in 0.1 mM benzyladenine (BA) to maintain flower weight and senescence[1]. Gibberellic acid did not delay leaf senescence in most plant species and its content in tissues was not correlated with senescence[3]. Foliar sprays of promalin (GA_{4+7} plus BA) are reported to prevent postharvest leaf chlorosis and delays senescence of Easter lilies (*Lilium longiflorum* Thunb. Nellie White)[4] and Oriented hybrid lilies (*Lilium* Cv. Strargazer)[5]. The use of accel ($BA+GA_{4+7}$) at 25 mg L^{-1} BA equivalent was reported to delay flower senescence, prolonged the vase life and enhanced post harvest quality of Alstroemeria cut flowers[6].

Botswana is more dependent on the import of cut flowers especially from South Africa. Gerbera cut flowers are grown by only a few farmers in Botswana especially around Gaborone. In Botswana, due to the high temperatures and low humudity, the postharvest vase-life of gerbera is 2-3 days. The short postharvest vase-life of gerbera, limited supply of water, lack of knowledge about gerbera and floriculture in general, handling, transportation and marketing of cut flowers are constraints to gerbera cultivation in Botswana. The problem with gerbera cut-flowers is the short postharvest vase life[7]. In line with the Botswana government policy of diversification, cultivation of gerbera and other high valued horticultural crops (floriculture) under controlled environment (greenhouses) should be promoted.

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Research on the postharvest handling of cut flowers grown under Botswana conditions need be undertaken, because floriculture and postharvest handling and preservation of cut-flowers in Botswana are at an infant stage. Therefore, any treatment that will increase the vase life of gerbera cut flowers will enhance its production and postharvest handling and vase life. Therefore, the objective of this study was to investigate the effect of gibberellic acid (GA_3) on the vase life and postharvest quality of gerbera cut flowers.

MATERIALS AND METHODS

Experimental site: Two laboratory trials were carried out to investigate the effect of gibberellic acid (GA_3) on the postharvest quality and vase life of gerbera cut-flowers. Flowering stems of gerbera cultivar 'Ida Red' were harvested when two outer disc florets were open on 6th August 2002 and 28th October 2002 at a commercial farm in Gaborone, Botswana. The mother plants were grown from meristem culture. Shoots between 50 and 70 cm were pulled from the mother plants in the morning, packed and received the same day in the Plant Physiology Laboratory at the Department of Crop Science and Production, Botswana College of Agriculture.

Procedure and experimental design: The flowers were immediately unpacked and the lower 2 cm were cut off under water to avoid air embolism. The cut stems were then placed in a 10 L plastic buckets containing a solution of 5% sucrose at 38-43°C for two hours, in order to rehydrate the flowers. Ten stems were used for each treatment. The stems of the flowers were placed in plastic vases containing gibberellic acid at 0, 2.5, 5 and 7.5 mg L^{-1} GA_3 (ProGibb is a liquid concentrate containing 4% w/w a.i L^{-1} GA_3- Abbott Laboratories, North Chicago, IL 60064, USA). The vases containing GA_3 at various concentrations were arranged in a Completely Randomized Design with 4 replicates. The control flowers were held in distilled water. The vases also contained 5% sucrose and 0.23% sodium hypochlorite. Trials were carried out in a laboratory at an ambient temperature of 27±2°C and 40-55% RH and continuous lighting with cool-white Sylvania Fluorescent lamps (65 W, 240 V) at an intensity of 4160 J S^{-1}.

Dependent variables determined: The vase life of gerbera cut flowers was determined by counting the number of disc florets open after 7 and 14 days, number of stems showing colour fading and petal fall at 7 and 14 days and number of stems with the physiological disorder bent neck after 7 and 14 days. Dry weights of the flower heads and stems were determined using 5 cut flowers per replicate. The flower heads were cut at the neck and weighed separately from the stems. The flower stems were weighed using Mettler PM 400 digital balance to determine the fresh weight after 14 days of holding. The flower heads and stems were put in brown paper bags and oven dried at 70°C to constant weight (72 h) using Term-O-Mat incubator, then reweighed for dry weight. Water content of flower heads and stems was determined by subtracting dry weights from their corresponding fresh weights. The dry weights and water content are reported in percentages due to the different fresh weights of flower heads and stems of each replicate.

Data analysis: Analysis of variance was performed on the data collected using the general linear models (Proc GLM) procedure of the statistical analysis system program package. Proc univariate procedure was carried out on residuals to support the assumptions of normality made by the researcher. Where a significant F-test was observed, treatment means were separated using the Least Significant Difference at $p= 0.05$.

RESULTS

In trial 1, GA_3 at 5 and 7.5 mg L^{-1} increased the number of rows of disc florets of gerbera open after 7 days compared to flowers held in distilled water (Table 1). However, after 7 days of holding, 2.5 mg L^{-1} GA_3 had no effect on the opening of gerbera disc florets. After 14 days of holding in trial 1, gerbera cut-flowers held in vase solutions containing GA_3 2.5, 5 or 7.5 mg L^{-1} had significantly higher number of rows of disc florets open compared to the control (Table 1). There were significant differences among GA_3 concentrations with respect to their ability to open disc florets of gerbera after 14 days of holding (Table 1). In trial 2, gerbera cut flowers held in vase solutions containing GA_3 at 2.5, 5 and 7.5 mg L^{-1} for 7 and 14 days, respectively, had significantly higher number of rows of disc florets open compared to the flowers held in distilled water (Table 2). In trial 2, flowers held for 7 days in GA_3 at 5 and 7.5 mg L^{-1} had no significant differences with respect to opening of disc florets, but had significantly higher disc florets open compared to flowers held in 2.5 mg L^{-1} GA_3 (Table 2). After 14 days of holding gerbera cut-flowers in 2.5 or 5 mg L^{-1} GA_3, there were no differences in their ability to increase the rows of disc florets open, but flowers held in 7.5 mg L^{-1} GA_3 had significantly higher number of disc florets open compared to flowers held in 2.5 or 5 mg L^{-1} GA_3 (Table 2).

In trial 1, GA_3 had a non significant decrease in the number of wilted cut stems of gerbera after 7 days (Table 1). In trial 2, GA_3 at 2.5, 5 or 7.5 mg L^{-1} significantly lowered the number of wilted gerbera cut flower stems compared to flowers held in distilled water

Table 1: Effect of GA_3 on postharvest quality and vase life of gerbera cut-flowers (trial 1)

GA_3 concentrations ($mg\ L^{-1}$)	Rows of disc florets open after 7 days	Rows of disc florets open after 14 days	Number of stems wilted after 7 days	Number of stems with colour fading after 7 days	Number of stems with 50% petal fall after 7 days	Number of stems with bent neck after 7 days
0	3.48b	8.08b	3.75a	3.75a	1.25a	3.25a
2.5	3.73ab	9.88a	1.75a	1.75b	0.00b	1.00b
5	3.85a	9.60a	1.50a	2.00b	0.00b	2.00ab
7.5	3.88a	9.35a	1.50a	1.50b	0.25b	1.50ab
Significance	*	**	NS	*	***	*
LSD	0.32	1.07	2.28	1.6	0.46	1.96

*, **, ***, NS, significant at p=0.01, 0.001, 0.0001, or non-significant, respectively. Means separated by the protected LSD at p=0.05; means within columns followed by the same letter(s) are not significantly different

Table 2: Effect of GA_3 on postharvest quality and vase life of gerbera cut-flowers (trial 2)

GA_3 concentrations ($mg\ L^{-1}$)	Rows of disc florets open after 7 days	Rows of disc florets open after 14 days	Number of stems wilted after 7 days	Number of stems with colour fading after 7 days	Number of stems with 50% petal fall after 7 days	Number of stems with bent neck after 7 days
0	3.18c	7.15c	4.50a	3.75a	1.00a	3.00a
2.5	3.55b	8.98b	1.25b	1.50b	0.00b	0.75b
5	3.75a	8.93b	1.25b	0.75b	0.00b	0.75b
7.5	3.88a	10.15a	1.50b	1.00b	0.00b	0.75b
Significance	****	**	***	***	****	*
LSD	0.19	1.09	1.53	1.6	0.25	1.07

*, **, ***, **** significant at p=0.05, 0.01, 0.001, 0.0001, respectively. Means separated by the protected LSD at p=0.05; means within columns followed by the same letter are not significantly different

Table 3: Effect of GA_3 on bent neck, dry matter and water content of gerbera cut-flowers (trial 1)

GA_3 concentration ($mg\ L^{-1}$)	Number of stems with bent neck after 14 days	Dry matter content (%) of flower heads after 14 days	Dry matter content (%) of flower stems after 14 days	Water content (%) of flower heads after 14 days	Water content (%) of flower stems after 14 days
0	6.00a	76.50a	57.00a	23.50c	43.00b
2.5	5.25a	68.00b	48.30b	32.00b	51.80a
5	6.50a	59.00c	48.30b	41.00a	51.80a
7.5	7.75a	58.00c	49.00b	42.00a	51.00a
Significance	NS	****	***	****	***
LSD	2.28	4.82	4.34	4.82	4.34

, *, NS, significant at p=0.001, 0.0001, non-significant, respectively. Means separated by the protected LSD at p=0.05; means within columns followed by the same letter are not significantly different

Table 4:Effect of GA_3 on bent neck, dry matter and water content of gerbera cut-flowers (trial 2)

GA_3 concentration ($mg\ L^{-1}$)	Number of stems with bent neck after 14 days	Dry matter content (%) of flower heads after 14 days	Dry matter content (%) of flower stems after 14 days	Water content (%) of flower heads after 14 days	Water content (%) of flower stems after 14 days
0	6.00a	78.00a	64.00a	22.00c	36.00c
2.5	4.25b	70.50b	60.25b	29.50b	39.75b
5	3.25b	62.25bc	59.25b	34.75ab	40.75b
7.5	3.00b	59.25c	52.00c	40.75a	48.00a
Significance	***	***	***	****	***
LSD	1.38	6.03	3.57	6.03	3.57

, *, significant at p=0.001, 0.0001, respectively. Means separated by the protected LSD at p=0.05; means within columns followed by the same letter(s) are not significantly different

after 7 days (Table 2). There were no significant differences among GA_3 concentrations with respect to their ability to reduce wilting (Table 2).

In both trials 1 and 2, Holding gerbera cut flowers in vase solutions containing GA_3 at 2.5, 5 or 7.5 mg L^{-1} significantly delayed cut flower senescence as measured by petal fading and abscission after 7 days compared to flowers held in distilled water (Table 1 and 2). There were no significant differences among GA_3 concentrations with respect to their ability to delay petal colour fading and abscission in gerbera cut-flowers (Table 2).

GA_3 at 5 or 7.5 mg L^{-1} in trial 1, 14 days after harvesting, resulted in a non-significant reduction on the number of gerbera cut flowers stems with the physiological disorder bent neck (Table 3). In trial 2, GA_3 at 2.5, 5, or 75 mg L^{-1} significantly reduced the number of gerbera cut-flowers stems with the physiological disorder bent neck after 14 days (Table 4). There were no GA_3 concentration differences in their ability to reduce the physiological disorder bent neck (Table 4).

Gerbera cut-flowers held in vase solutions containing GA_3 at 2.5, 5 or 7.5 mg L^{-1} had significantly lower dry matter content of flower heads but higher water content than those held in distilled water in both trials 1 and 2, after 14 days of holding (Table 3 and 4). The lower dry matter content and higher water content in the flower heads decreased with increasing GA_3 concentration (Table 3 and 4). There was no significant difference

between 5 or 7.5 mg L^{-1} GA_3 in lowering dry matter retention and increasing turgidity (water content) in the gerbera flower heads (Table 3 and 4). However, flowers held in GA_3 at 2.5 mg L^{-1} had significantly higher dry matter content and lower water content than flowers held in 5.0 or 7.5 mg L^{-1} GA_3 (Table 3 and 4).

In trials 1 and 2, 14 days after harvest, gerbera cut-flowers held in GA_3 at 2.5, 5 or 7.5 mg L^{-1}, had significantly lower stem dry matter and higher stem water content than flowers held in distilled water (Table 3 and 4). In trial 1, there were no GA_3 concentration differences in their ability to lower stem dry matter content and increase stem content (Table 3). In trial 2, gerbera cut flowers held in 7.5 mg L^{-1} GA_3 for 14 days, had significantly lower stem dry matter content and higher stem water content than flowers held in either 2.5 or 5 mg L^{-1} GA_3 (Table 4). There was no significant difference between 2.5 and 5 mg L^{-1} GA_3 in their ability to lower stem dry matter content and increase stem water content (Table 4).

DISCUSSION

The flower is a heterogenous organ, composed of floral parts each of which may be at a different physiological developmental stage. Gibberellic acid is an endogenous phytohormone present in different concentrations in different floral parts and developmental stages. Gibberellic acid (GA_3) significantly increased the number of disc florets open because GA_3 decreased the dry matter in the flower heads and stems. Gibberellins are reported to increase hydrolysis of starch, fructans and sucrose (constituents of dry matter) into glucose and fructose[8], which were utilized by the flowers for disc floret opening, hence a reduction in dry matter contents in the flower heads and stems. The increased reducing sugars in the flower heads and stems of gerbera cut flowers, may increase the osmotic potential of the flower head and stems, thus improving their ability to absorb water and maintain their turgidity, which may explain the increase in water contents of gerbera cut flower heads and stems observed in the present study. Maintenance of turgidity is important in extension of longevity of gerbera cut flowers. The final stages of flower development are characterized by a decline in the content of carbohydrates and dry weight of petals[6,9,10]. Reducing sugars and not sucrose has been observed to be the main constituents of the sugar pool of mature petals[11,12]. The changes in sugars are accompanied by starch hydrolysis[13].

In the present study, the dry matter retention and high water content of flower heads and stem in the gerbera cut-flowers was important in avoiding the development of the physiological disorder bent neck. In gerbera cut-flowers a high level of turgidity is necessary for the opening of the disc florets. GA_3 treated cut-flowers had higher water content in the flower heads and stems than flowers held in distilled water. The increase in water content in gerbera cut-flower, flower-heads and stems was due to the effect of GA_3 in reducing water loss (transpiration) as evidenced by the significant reduction of gerbera cut flower stems which wilted. Gibberellins increase water uptake in plant tissues by making the cell's water potential more negative. As a result of the decrease in water potential, water enters more rapidly, causing cell expansion and diluting the sugars in the tissues[8]. The hydrolysis of starch into reducing sugars due to GA_3 results in accumulation of sugars. The sugars improve the water balance and osmotic potential of gerbera cut flowers and therefore delayed flower senescence. Generally the senescence and wilting of the petals determine the longevity of the cut flowers. When the amount of transpiration exceeds absorption, a water deficit and wilting develops. Gibberellic acid in the present study increased water uptake and reduced transpiration. Phytohormones have been implicated in the regulation of flower senescence[14].

The reduction in water uptake, coupled with continuous transportation, leads to water deficit and reduced turgidity in the cut flowers. This may cause the stem to bend under the weight of the flower. The bending occurs often below the flower, a phenomenon known as bent neck[15]. Bending resistance depends on the development of secondary thickening and lignification of the vascular elements in the peduncle area subtending the flower head. In the present study GA_3 significantly reduced the number of gerbere cut flower stems with bent neck because GA_3 reduced water loss and increased water uptake, therefore improving the water balance and mechanical strength of the stems due to turgidity.

Gibberellic acid delayed petal abscission and colour fading because of GA_3 decreased flower head and stem dry matter of gerbera flowers thereby promoted hydrolysis of starch, fructans and sucrose into fructose and glucose which delayed petal abscission and colour fading (senescence). The GA_3-induced hydrolysed sugars possibly maintained the supply of respirable substrates, especially in petals, thus promoting respiration and extending the vase life of gerbera flowers. It has been reported that the main effect of applied sugar in extending cut flower vase life was to maintain mitochondrial structure and functions[16,17]. However, the effect of sugars on mitochondria may not be a specific effect and may stem from its general protective effect on membrane integrity. The mitochondria remain functioning until the final stages of senescence[8,18]. In view that senescence is a programmed process regulated by internal hormonal

balance, then reducing sugars interaction with phytohormones may modulate the regulatory process. It has been shown that sucrose enhanced the effect of cytokinins in delaying senescence of flowers and reduced the effect of ethylene in promoting it[19]. There is a possibility of sucrose supplied in the vases interacting with GA_3 and hence delaying the senescence of gerbera cut flowers possibly by either altering the sensitivity of the tissue to ethylene or by delaying the natural rise in ethylene production, or both. Ent neck in gerbera cut-flowers by increasing the dry matter partitioning to the stems. In conclusion, GA_3 increased the vase life of gerbera cut flowers, improved gerbera flower quality by increasing cut flower water uptake and reduced water loss, therefore maintaining turgidity and delayed flower senescence. Gibberellic acid also delayed the development of bent neck which normally occurs after 2-3 days. Gibberellic acid further promoted dry matter (starch) hydrolysis into reducing sugars in the stem and flower heads, leading to enhanced vase life and quality of gerbera cut flowers via improved water balance. Gibberellic acid at between 2.5-7.5 mg L^{-1} has the potential to be used as a gerbera cut flower preservative.

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