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# Effects of cold storage on post harvest keeping quality of Gloriosa (*Gloriosa superba* L.) flowering stems

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## ABSTRACT

**The impact of cold storage and floral preservatives on *Gloriosa superba* quality attributes of fresh weight, petal and leaf colour, chlorophyll fluorescence and vase life were investigated during the vase life period. Wet storage (4 °C for 7 d) of fully opened *Gloriosa* flowers markedly improved flower keeping quality when stems were kept in 'Standard Vase Solution', as compared to dry stored flowers. However, a sharp decrease in fresh weight and vase life was observed at 4 °C after 10 days of cold storage. Chlorophyll fluorescence values ($F_0$, $F_m$ and $F_v$) increased up to day 3 and then decreased over the vase period. Compared to other treatments, flowers kept at 4 °C (wet storage) for 7 days maintained a higher chlorophyll fluorescence yield (0.76) during vase period. There was a significant decrease of chlorophyll fluorescence yield with increasing storage temperature. Results proved that flower colour was affected by increasing temperature in the storage. Wet cold storage (4 °C for 7 d) and use of selected floral preservatives played an important role in postharvest flower quality of *Gloriosa*.**

**Key words:** Gloriosa, vase life, floral preservatives, cold storage

## INTRODUCTION

As consumers acquire a taste for new and different flowers, gloriosa (*Gloriosa superba* L.) is becoming a popular cut flower in the floricultural market. It belongs to the family *Liliaceae* and is generally called as 'Glory Lily' or 'Climbing Lily'. *Gloriosa* is a herbaceous, tall and stout climbing herb. Flowers themselves change colour from greenish yellow, orange, scarlet and crimson from blooming to fading respectively. A native of India, it has been cultivated and used as a popular medicinal plant (Oudhia, 2002). *Gloriosa* flowers for florists should be harvested in almost fully opened stage (Nowak and Rudnicki, 1990).

Cold storage is essential to delay flower senescence and quality deterioration in postharvest chain and when it is needed to regulate the supply of flowers to the market. It is necessary to investigate appropriate postharvest treatments in bringing fresh special cut flower materials from the grower to the market place. Low temperatures provide many advantages to extend vase life by reducing respiration and internal breakdown of tissues by enzymes, reducing water loss and wilting, slowing the growth of lethal micro-organisms, reducing the production of ethylene and providing 'time' for proper handling, packaging and marketing. However, previous studies have shown that *Gloriosa* is not an ethylene sensitive flower (Elgar, 1998). It is clear that temperature is the major factor affecting storage and vase life of flowers because of its influence on the respiration rate of flowers, moisture loss and physical damage. Thus, cooling is necessary to reduce metabolic activities of flowers.

No studies on the effect of cold storage and postharvest quality of *Gloriosa* cut flowers have been reported. The lack of information hinders the development of *Gloriosa* postharvest treatments to prevent

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quality deterioration. In the present study, we investigated the effects of cooling temperature, storage duration, sensitivity of flowers for 'Standard Vase Solution' - 'SVS' (van Meeteren *et al*., 1999) during vase period of *Gloriosa*.

## MATERIALS AND METHODS

A series of pot experiments were conducted to study the effects of cold storage and vase solutions on postharvest quality of *Gloriosa*. Plantings were established in a plant house at the University of Natural Resource & Applied Life Sciences, Vienna, Austria. Rhizomes of micro-propagated plants were obtained from a commercial source, planted in large plastic containers (30cm(L) × 30cm(W) × 30cm(D)) using 'Torboflor' standard substrate mixture + Perlite (1:4 ratio), and placed in the plant house. Fully opened flowers were harvested with two to three leaves, immediately placed in clean buckets containing tap water and flower buckets were transported to the institute laboratory. There, the stems were trimmed to a length of 15 cm before using for experiments.

Standard Vase Solution (Van Meeteren *et al*., 1999) was prepared according to published recommendation ($NaHCO_3$ 125mg/l, $CaCl_2.2H_2O$ 99mg/l, $CuSO_4.5H_2O$ 1.2mg/l) using deionised water at 20 5 °C. An Eppendorf cup (11.5cm(L) × 8.5cm(W) × 2cm(D)) which was used to place *Gloriosa* flower stem, filled with approximately 25 ml of the desired vase water solution. During the vase period, each vase had to be re-filled with the desired vase solution according to water consumption rate of flowers.

The effects of storage temperatures at 4 °C and 13 °C and durations of 7, 10 and 14 days on flower quality and longevity were studied. The wet stored flower stems were placed in similar size Eppendorf cups with their stem bases dipped in 'SVS' floral preservative solution. Then they were enclosed in polythene bags to reduce water loss during the cold storage period. Dry stored flowers were wrapped in soft papers, and then enclosed in polythene bags. After cold storage, they were unwrapped, weighed, re-cut and placed in SVS. Flowers were held at room temperature (20 5 °C) and ambient indoor fluorescent light conditions (15 mol $m^2sec^{-1}$) and evaluated daily. Holding solution was added as and when needed during the vase period. Experimental design was (2×2×2) factorial in CRD with 3 replicates.

The fresh weights of these flowers were measured before cold storage, after storage and during vase period in all treatments. Flower quality was evaluated regularly, observations on notable changes in quality were recorded, and vase life of each flower was determined by using standard criteria including petal wilting, curling, petal drop, whole flower or leaf wilting and discoloration patches on leaves. Flowers having any of the above symptoms were considered dead.

Three fully grown leaves on the terminal shoot of each flower stem of all treatments were randomly selected for each experiment, for measuring chlorophyll fluorescence with a portable chlorophyll fluorometer (MINI PAM, Walz, Effeltricht, Germany). The fluorescence was measured through an optical fibre bundle with the terminal end in close contact with the leaf surface. The optimal quantum yield in photo system II is equal to $F_v/F_m = (F_m-F_0)/F_m$, where $F_m$ and $F_0$ denote maximum and minimum fluorescence in dark adapted tissue, respectively (Schreiber and Bilger, 1993). $F_v$ was calculated using the above equation.

The changes in colour of flower petals and leaves during flower vase life were measured on randomly selected individuals (3 petals and 3 leaves per flower stem) with a chroma meter (Minolta, Model CR-200b; Minolta, GmbH Ahrensburg, Germany). Measurements were used as indirect estimate of the chlorophyll loss during vase period of Gloriosa flowers. Colour was recorded using the CID-*L*a*b** uniform colour surface (CIE-*Lab*) (Clydesdale, 1978). Results were expressed in *L** indicating lightness, *a** and *b** indicating colour intensity and calculated hue angle ($h^0$ - arctangent *b*/a**) and chroma ($C^*$-$(a^{*2} + b^{*2})^{1/2}$) which relate to visual perception (McGuire, 1992).

All data were statistically analysed by using the SPSS software package (SPSS 11.0 for windows, standard version, Chicago,USA,

1996). Samples consisted of 3 replicates for each treatment in all experiments. Data were presented as mean SE or SD. Comparison of means was done using Tukey HSD at Alpha 0.05 level. Moreover correlations among variables were calculated by the Pearson method and retained as significant when $P<0.05$.

## RESULTS AND DISCUSSION

### Changes in fresh weight and vase life

Fresh weight change and vase life of cut gloriosa stems were markedly reduced by increasing cold storage temperature, duration and the storage system (Tables 1 and 2). The highest fresh weight change (36.16 %) was observed in flowers under wet storage at 4 °C for 7 days than other treatments. Wet stored flowers increased their fresh weight at both temperatures (4 °C and 13 °C) in varying amounts. However, dry stored flowers showed significantly lower ($P$=0.05) weight both storage and during vase period.

**Table 1: Effect of storage temperature on percentage fresh weight change, vase life, flower osmotic potential and Brix value for wet stored cut gloriosa flowers. Data are means ± SE (n=3)**

| Wet Storage | % weight change | Vase life (d) | Osmolality (mmol/kg) | °Brix |
|---|---|---|---|---|
| 4°C-7 d | 36.16 ± 0.1 | 12.61 ± 0.26 | -12.04 ± 0.55 | 8.24 ± 0.41 |
| 13°C -7d | 8.08 ± 0.38 | 10.33 ± 0.32 | -11.78 ± 0.43 | 8.84 ± 0.26 |
| 4°C -10 d | 9.80 ± 0.2 | 8.27 ± 0.88 | -11.23 ± 0.24 | 8.45 ± 0.18 |
| 13°C -10 d | 5.18 ± 0.54 | 6.54 ± 0.53 | -11.79 ± 0.81 | 8.62 ± 0.60 |

Interestingly, flowers kept under wet storage at 4 °C for 7 days, showed an increase of fresh weight up to day 3 and then started to decrease till the end of vase life. However, flowers in all other treatments (4 °C - 10 d, 13 °C - 7 d & 10 d) gradually decreased their fresh weight over the vase period (data not shown). Our study showed that flowers under dry storage (wrapped in newspapers andolythene) at both 13 °C or 4 °C temperature, decreased their fresh weight significantly ($P$=0.05), even when kept in the vase solution during vase period (Table 2). Wet storage for longer period (>10 d) was detrimental for the better performance of flowers during vase period (data not shown). Post-storage performance of the gloriosa flowers depended on storage temperature, duration and storing method.

We observed that for the lower storage period (<5 d), for both wet and dry gloriosa flowers kept in 4 °C did not show any significant differences in fresh weight changes, colour or chlorophyll fluorescence changes (data not shown). However, the above mentioned quality parameters were negatively affected by increasing the temperature and duration of storage. Mor (1989) found that flowers exposed to lower water content in storage performed better during vase period and thereby recommending to keep rose flowers dry during storage. However, gloriosa cut flowers showed better performances during vase period, if they are kept under wet storage. Omolality and brix values showed no statistically differences among the storage temperature, duration or storage method (Table 1 & 2).

**Table 2: Effect of storage temperature on fresh weight during cold storage, vase life, flower osmotic potential and Brix value for dry stored cut gloriosa flowers. Data are means ± SE (n = 3)**

| Dry storage | % weight change | Vase life(d) | osmolality (mmol/kg) | °Brix |
|---|---|---|---|---|
| 4°C - 7 d | -5.01 ± 0.04 | 8.06 ± 0.5 | -12.04 ± 0.55 | 8.12 ± 0.20 |
| 13°C - 7 d | -13.0 ± 0.11 | 6.48 ± 0.65 | -11.78 ± 0.43 | 8.36 ± 0.54 |
| 4°C - 10 d | -10.18 ± 019 | 5.10 ± 0.46 | -12.65 ± 0.15 | 8.51 ± 0.39 |
| 13°C-10 d | -27.06 ± 0.49 | 5.94 ± 0.74 | -11.31 ± 0.28 | 8.01 ± 0.33 |

The rose flowers showed loss of petal dry weight after cold storage and therefore, Mor (1989) suggested that wet-stored rose flowers had higher respiration rates than the dry-stored flowers, which resulted in poor performance after cold storage. Waithaka *et al*. (2001) observed that there were no significant differences between wet (250 ppm 8-hydroxyquinoline citrate with 2 % sucrose) and dry storage (spikes wrapped with newspapers and polythene) for improving the keeping quality of cut tuberose in cold storage.

Rudnicki *et al*. (1989) recommended wet

storage for carnations. The effects of cold storage methods on flower keeping quality differ with flower species. According to our results, we would suggest to use wet storage conditions along with an effective floral preservative solution for gloriosa flowers. Pre-storage pulsing of cut flowers with sucrose or a floral preservative has already been reported (Halevy and Mayak, 1979) to improve flower keeping quality after cold storage by manipulating cell membrane integrity and reducing their sensitivity to ethylene during cold storage. Here we continuously treated flowers with SVS during the storage period for wet storage conditions and it markedly affected the flower quality during post-storage period. According to our results, flowers stored under wet conditions at 4 °C for 7 days gave significantly ($P$=0.05) higher vase life (12.61 d) than other treatments. Vase life values decreased significantly ($P$=0.05) after 7 days of wet and dry storage period at both temperatures (Table 1 & 2). It clearly showed the negative impact of dry storage on gloriosa vase life.

## Chlorophyll fluorescence

Flower stems kept at 4 °C under wet storage conditions for 7 d showed higher chlorophyll fluorescence values ($F_0$, $F_m$ and $F_v$) up to third day of the vase period and then values declined. However, $F_0$, $F_m$, $F_v$ and yield values tended to show higher values towards the end of vase life than initial values. Results showed better performances of *Gloriosa* flower stems kept at 4 °C (wet storage - 7 d) in vase period till end of vase life. In contrast, stems kept at 13 °C showed a lower yield (0.73) at the end of vase life. Flower stems stored at 4 °C showed the highest chlorophyll fluorescence yield value (0.76) at the end of vase life (Table 3). Higher initial chlorophyll fluorescence ($F_0$) of flower stems kept in 13 °C did not increase fluorescence yield during vase period. Stems stored under wet and dry storage at 4 °C and 13 °C for 10 d resulted continuous decline of all parameters studied (data not shown). Variable fluorescence ($F_v$) of stems at 4 °C under wet storage for 7 d showed a higher correlation (0.69**) with yield (Table 4 than stems stored at 13 °C under wet storage (0.66**). Moreover, storage method had a significant and positive correlation (0.32*) with flower stems stored at 4 °C, but negatively correlated (-0.41**) with flower stems stored at 13 °C (Table 4).

Our experiment clearly showed the relationship of changes in chlorophyll fluorescence parameters with the storage temperature. Keeping flower stems under low temperature resulted in lower yield at the beginning as metabolic rates were reduced in cold storage. When cut stems were placed in a floral solution after cold storage, they absorbed nutrients and water from the floral solution.

**Table 3: Effect of storage temperature and method for variation of chlorophyll fluorescence parameters during vase period. Data are means ± SE of three replications**

| Treatment | $F_o$ | $F_m$ | $F_v$ ($F_m$-$F_o$) | Yield($F_v$/$F_m$) |
|---|---|---|---|---|
| **4$^0$C wet 7 d** | | | | |
| Initial | 481.10 ± 9.97 | 1781.60 ± 49.01 | 1300.50 ± 39.52 | 0.73 ± 0.006 |
| Day 3 | 564.66 ± 7.17 | 2314.84 ± 42.37 | 1750.18 ± 30.14 | 0.76 ± 0.004 |
| End-vase life | 547.83 ± 7.48 | 2293.40 ± 39.25 | 1745.57 ± 35.10 | 0.76 ± 0.003 |
| **13$^0$C wet 7d** | | | | |
| Initial | 578.23 ± 9.12 | 2296.67 ± 39.22 | 1718.44 ± 31.99 | 0.75 ± 0.002 |
| Day 3 | 608.07 ± 9.71 | 2145.93 ± 39.15 | 1537.86 ± 29.89 | 0.72 ± 0.001 |
| End-vase life | 591.13 ± 6.89 | 2189.87 ± 35.16 | 1598.73±29.35 | 0.73 ± 0.002 |

**Table 4: Pearson correlation co-efficient among $F_0$, $F_m$, $F_v$ fluorescence yield and wet storage of flowers kept at 4$^0$C and 13$^0$C Significant correlations between factors are indicated as * (P = 0.05) and ** (P = 0.01)**

| | $F_v$ - 4$^0$C | Yield - 4$^0$C | $F_v$ - 13$^0$C | Yield - 13$^0$C |
|---|---|---|---|---|
| Wet storage | 0.22 | 0.32* | -0.24** | -0.41** |
| $F_o$ | 0.85** | 0.52** | 0.47** | -0.17 |
| $F_m$ | 0.99** | 0.68** | 0.89** | 0.57** |
| $F_v$ | - | 0.69** | - | 0.66** |

This influenced to maintain physiological and metabolic activities of the cut stem. This promoted to continue gloriosa flower development and to show better performances during vase period. In contrast, flowers kept at higher temperatures (13 °C) had higher

chlorophyll fluorescence at the beginning of the experiment because they were able to maintain a higher metabolic rate in storage. In comparison to flowers kept at 4 °C, they did not show significantly higher performances ($P$=0.05) in the vase and resulted senesce within short period. It may be due to higher metabolic activities in storage period and thus decline of food reserves during vase period. Our results suggest that chlorophyll fluorescence could be used to evaluate the flower quality of gloriosa kept in cold storage.

The loss in fluorescence during vase period appears to reflect a loss in chloroplast function with advancing senescence (Mir *et al*., 1998a) over time. Hence, chlorophyll fluorescence has been suggested as a potential non-destructive tool for quality measurement of horticultural produce (Song *et al*., 1997). This can be applied to gloriosa cut flowers during the vase period. Reduction in both chlorophyll content and chlorophyll activity as measured by net $O_2$ evolution was responsible for low levels of chlorophyll fluorescence during senescence (Mir *et al*., 1998a). Thus, the decline of fluorescence yield is a measure of advanced senescence. Our results showed that chlorophyll fluorescence is a good indicator for identifying gloriosa flower senescence symptoms in the vase period after keeping flowers in cold storage. Floral preservatives and tap water did not significantly ($P$=0.05) affect any changes in chlorophyll fluorescence for a shorter period, in the case of flowers placed in vase solutions.

**Petal color**

Chroma values (colour intensity) of flower stems kept under wet storage conditions in both temperatures (13 °C and 4 °C) showed a similar pattern, having a low value at senescence. The petal colour intensity declined throughout the vase period even when stems were placed in a floral solution. However, a slight variation was observed in stems kept at 4 °C (-4.98 %) than those kept at 13 °C (-7.10 %). Petal hue angle of stems kept at both treatments increased (4 % at 4 °C, 2.5 % at 13 °C) during vase period indicating an improvement of red hue of petals (Table 5). A clear visual colour change was observed after cold storage, indicating that higher colour intensity and red hue of flowers kept at 4 °C than those kept at 13 °C. Petal colour changed approximately 3 days after placing in floral solutions, from its original red-orange to a red-brown shade of flowers kept at 13 °C for 10 days (data not shown). In contrast, petal colour of stems kept at 4 ° C for 7 days remained unchanged in first 3 days. By the end of vase life, flowers kept at 13 °C showed discoloration of the petal and brown patches on petals, while flowers stored at 4 °C showed only a very slight lightening of their original red-yellow/orange colour. There were no significant differences ($P$=0.05) in petal hue angle between initial and final values of stems stored in both temperatures.

**Leaf colour**

The chroma value of gloriosa stems kept at 4 °C and 13 °C, increased during vase period. However, the differences were not significant ($P$=0.05). A higher chroma (colour intensity) variation (20.35 %) of stems kept at 13 °C under wet storage than stems placed at 4 °C under wet storage (5.91 %) was observed. There was a positive correlation with the visual observations. Although, vase life was shorter, leaves of the stems placed at 13 °C showed a bright, dark colour at senescence. All physiological activities declined in cold storage and therefore, stems kept at 4 °C showed a lower chlorophyll production even in vase period. Leaf hue of stems kept at 4 °C showed a negative value (-3.6 %) at the end of vase life (Table 5). In contrast, hue of leaves kept at 13 °C gave significantly a higher value (-0.98) at the termination of storage period than the value observed in early stage of the vase life (-1.04). Experimental results and visual observations indicated that flower colour was affected by increasing cold storage

**Table 5: Effect of temperature for colour change during vase period of Gloriosa stored for 7 days under wet cold storage.**

| Plant part | Initial Chroma | End of vase Chroma | % Chroma change | Initial Hue | End of vase Hue | % hue change |
|---|---|---|---|---|---|---|
| Flowers ($4^0$C) | 33.91 ± 4.32 | 32.22 ± 5.62 | -4.98 | 0.50 ± 0.12 | 0.52 ± 0.09 | 4.0 |
| Leaves ($4^0$C) | 17.42 ± 3.29 | 18.45 ± 4.48 | 5.91 | -0.98 ± 0.03 | -0.01 ± 0.08 | -3.6 |
| Flowers ($13^0$C) | 27.19 ± 5.36 | 25.26 ± 7.76 | -7.10 | 0.40 ± 0.09 | 0.41 ± 0.15 | 2.5 |
| Leaves ($13^0$C) | 18.67 ± 5.67 | 22.47 ± 4.46 | 20.35 | -1.04 ± 0.03 | -0.98 ± 0.36 | 5.77 |

Data are means ± SD (n = 3)

temperature (Data not shown for dry stored stems and 10 d storage period). Low temperature in storage resulted an increase in leaf colour intensity and hue angle of flower stems, except stems kept at 4 °C. The colour intensity of petals and leaves were gradually decreased throughout the vase period however, they did not show statistically differences among storage temperature, duration or method (data not shown).

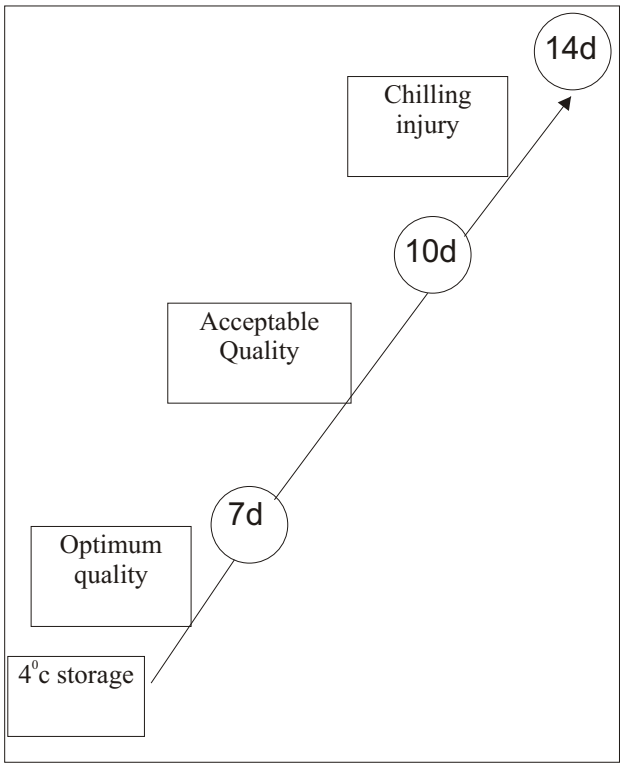


Figure 1: Changing quality of *G. superba* during cold storage

## CONCLUSION

Our results suggest a proven method to maintain gloriosa flower keeping quality in the postharvest chain. Experiments showed that adding a floral preservative positively affected flower quality or longevity during the cold storage and hence the vase period. The mechanism of beneficial effect of wet storage on physiological and metabolic performances of cold stored gloriosa flowers remains to be investigated. Increasing storage duration decreased the vase life and increased chilling injury for both leaves and flowers (Figure 1). According to measured quality attributes, we suggest to store cut gloriosa flower stemsunder wet storage with a selected floral preservative solution for example at 4 °C for a period of 7 days.

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