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# Effects of Different Storage Periods on The Vase Life of Goldenrod (*Solidago x Hybrida*) Cut Flower

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**Abstract**

Goldenrod (*Solidago x hybrida*) is one of the most traded cut foliage in the world, used as a popular filler in flower arrangements and bouquets. In cut flower, it is desirable to have a long post-harvest storage period and vase life. However, long storage periods shorten vase life. Managing the storage period is important to prevent quality and quantity loss of the product. In this study, it was aimed to determine the effects of different storage periods on the vase life of cut goldenrod flower. *Solidago x hybrida* cv 'Golden Glory' was used as plant material in the study. The flowers were stored dry at different periods (0, 5, 10 and 15 days) in a cold storage (2-4 ºC) and then their vase life was measured. The vase life of the flowers used as control was measured without storage. In the study, chlorophyll density in leaves (SPAD) and relative fresh weight at pre and post storage stages were measured. In the research, the longest vase life was found with no-storage application (control) with 15.27 days. This was followed by 12.13 days of application stored for 5 days. Extending the storage period resulted with significant leaf yellowing and reduction of vase life. The results showed that the longest vase life of cut goldenrod flowers was at no-storage application condition. However, although storing for 5 days decreased the vase life of the flowers by 20% compared to the control, it was concluded that cut goldenrod flowers could be stored for 5 days.

**Keywords**: Solidago, goldenrod, vase life, storage, leaf yellowing, cut flower

## INTRODUCTION

Plant parts with and/or without flowers such as fruity and fruitless branches, shoots and leaves are frequently used to prepare all kinds of flower arrangements such as baskets, bouquets, and wreaths to provide freshness and color diversity to improve appearance (Özzambak, 2009; Kazaz, 2012; Mabini and Acedo, 2013). Solidago is well known in the world and in Turkey for a long time, but its use as a cut flower is recent. The name “Solidago” is the combination of the Latin words “solid” meaning firm and “ago” meaning to strengthen. It was translated into Turkish as "Altınbaşak" in the " Büyük Bitkiler Klavuzu" in 1952. About 100 goldenrod species naturally grow in the North America and intersection zone of the Europe-Asia Continent (Anonymous, 2008; Kazaz and Karagüzel 2010). *Solidago x hybrida* is among the most traded cut foliage in the world (Ergür et al., 2016). This flower has conical clusters formed by long-lasting and voluminous flowers and is widely used in bouquets and arrangements with its durable and long stem structure. Leaf yellowing is an important problem in cut flower species such as *solidago, lilium, chrysanthemum, alstromeria and matthiola*. Leaf yellowing reduces the quality of flowers and shortens the vase life (Philosoph-Hadas et al., 1996; Hassan et al., 2003; Çelikel, 2013). The economic value of many ornamental plants is directly related to leaf color, and yellowed leaved flowers does not have commercial value. Unfavorable environmental conditions (water loss, temperature, nitrogen deficiency, insufficient light, diseases and pathogen attacks), ethylene, plant growth regulators, genetic structure, chlorophyll and carotenoid pigments are affective on leaf yellowing (Nowak and Rudnicki 1990; Van Doorn, 1997; He et al., 2002; Looze and Van Staaveren, 2003; Ferrante et al., 2004; Shiva, 2006; Woltering, 2008; Christiansen and Gregersen, 2014; Penfold and Buchanan, 2014). Leaf yellowing can be controlled by the use of plant growth regulators at various concentrations (Thomas and Stoddart, 1980, Thimann, 1985). High temperatures increase respiration, sugar/starch consumption, ethylene synthesis, and leaf yellowing. Low temperatures, on the other hand, limit the slowdown of respiration, the reduction of water losses through transpiration, destruction reactions, ethylene biosynthesis, and pathogen attacks (Çelikel and Reid, 2002; Teixeira, 2003; Armitage and Laushman, 2003). The term vase life refers to the length of time from when the flower stem are placed in the vase solution until the loss of their appeal and aesthetic value (Halevy and Mayak 1981; Fanourakis et al. 2013). In the cut flower industry, vase life is an important quality criterion and affects consumer satisfaction and demand for flowers. Amounts of cut flower products get lost due to different reasons from the producer to the consumer in the world. Although it varies according to the species and varieties, globally 25% of the cut flowers produced are lost during the storage and transportation process. Many studies show the positive effects of storage at temperatures above freezing. Dry storage is preferred for long-term storage, and storage in water containing a preservative solution is preferred for short-term storage. Many cut flower species are stored at 0$^{o}$C just above the freezing point during their storage. Since tropical flowers show cold damage at temperatures below 10 $^{o}$C, they are stored above 10 $^{o}$C during storage and transportation (Jones and Moody 1993; Sacalis, 1993; Reid, 2002; Kazaz et al., 2003; Macnish et al., 2009; Çelikel, 2020). The protection of the commercial value of the cut flowers grown in Turkey is important for the development of ornamental plants sector and the country's economy. Cut goldenrod cultivation and its export is becoming more widespread in Turkey. *Solidago x hybrida* 'Golden Glory' variety is one of the popular varieties produced both in Turkey and in the world. Knowing the post-harvest storage strength and vase life of the variety is important for the sector. For this reason, the effects of different storage periods on the vase life of the cut goldenrod flower were investigated in this study.

## MATERIALS and METHODS

The study was carried out in 2022 in the "vase life determination room" and "cold storage room" of the Department of Horticulture, Faculty of Agriculture, Ankara University. 'Golden Glory' cultivar belonging to Goldenrod (*Solidago x hybrida*) species was used as plant material in the study (Figure 1).

**Figure 1.** *Solidago x hybrida* cv 'Golden Glory'.

The flowers were harvested during the commercial harvest maturity (when 5-10% of the flowers were opened) early in the morning (08.00) at 70 cm stem length and flower were packed in plastic sleeve to minimize water loss which were produced in the greenhouse (in Antalya, Turkiye) of the producer company that produces cut goldenrod. Materials were packaged and placed in perforated cardboard boxes and brought to the laboratory (in Ankara, Turkiye) within 10 hours where the study will be carried out (Figure 2). Before storage, all flowers were pulsed for 6 hours in buckets containing pure water at a temperature of 21±2 $^{o}$C. Afterwards, the flowers were stored dry in a cardboard box in a cold store at 2-4 $^{o}$C.

**Figure 2.** Sorting and packaging of *Solidago x hybrida cv* 'Golden Glory'.

### Measured Factors

### Vase Life

The vase life of the flowers was measured in a vase life room with 21±2$^{o}$C temperature, 65±5% relative humidity, 1000 lux light and 12 hours day (Ueyama and Ichimura, 1998; Ferrante et al., 2007; Lü et al., 2010).

In the vase life room, the bottoms of the flowers were cut obliquely from 1 cm and placed in vases containing 750 ml of distilled water length (Figure 3). As a visual parameter in determining the vase life of flowers; leaf senescence, inflorescence, leaf senescence + inflorescence were evaluated separately. The vase life of the flowers was terminated if any of the following criteria were met.

1- Leaf yellowing in ≥50% of leaves

2- Fading, browning, closing in ≥50% of opened flowers

3- Leaf yellowing in ≥50% of leaves + wilting, browning, closing in ≥50% of opened flowers.

**Relative Chlorophyll Exchange Rate During Storage (%)**

All the stems used in the study were measured before and after storage. The measurement of chlorophyll change in the leaves was conducted with the Minolta brand SPAD-502 chlorophyll measuring device on the leaves at 30, 40 and 42 cm height from the base on the branch. Chlorophyll determination was calculated with the help of the following formula presented in Equation 1.

$$RCE\ (\%) = (C_t / C_{t=0}) \times 100 \quad (1)$$

*Ct*: Chlorophyll value after storage (0., 5., 10., ve 15. day)

*Ct=0*: Chlorophyll value before storage (0. day)

**Relative fresh weight (RFW) During Storage (%)**

In order to determine the relative fresh weight changes in the stems during storage, relative fresh weight measurements were conducted on all stems before and after storage. The stem weights used in the experiment were measured on a digital scale sensitive to 0.01 grams. Relative fresh weight measurements were calculated with the help of the following formula presented in Equation 2. (He et al., 2006; Lü et al., 2010).

$$RFW\ (\%) = (W_t / W_{t=0}) \times 100 \quad (2)$$

*Wt*: Weight of stem after storage (0., 5., 10., ve 15. day)

*Wt=0*: Weight of stem before storage (0. day)


**Figure 3.** Vase life determination room.

**Statistical analysis**

The experiment was established according to the randomised design with 3 replications where 5 flowers in each replication, with a total of 60 flowers. SAS statistical software was used in the analysis of the obtained data. The differences between the means were evaluated at the $p \leq 0.01$ level using the Duncan's multiple range test and the correlation data using the Pearson's correlation coefficient.

## RESULTS and DISCUSSION

### Vase Life (Days)

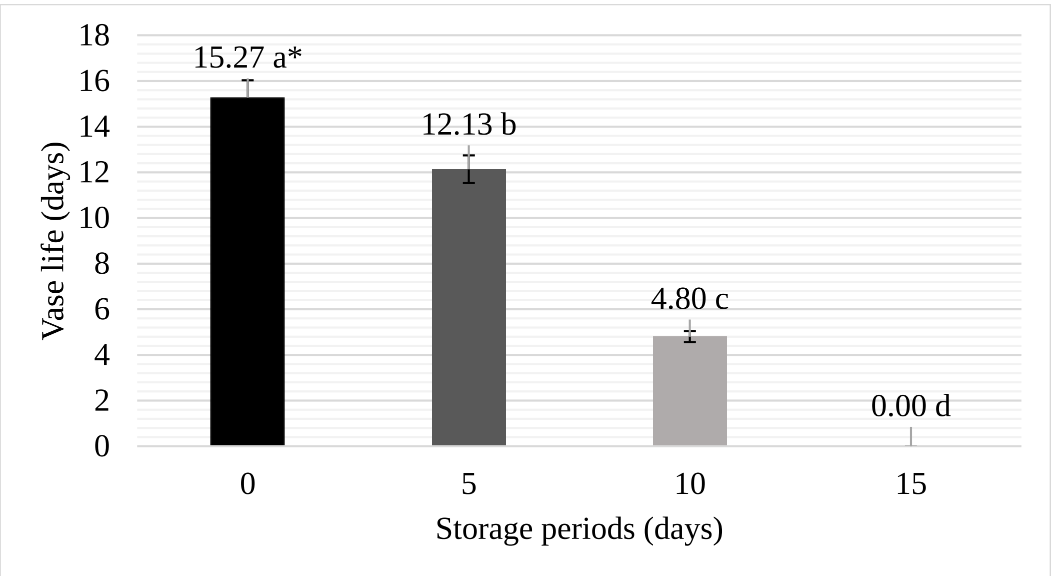
The effects of different storage periods on vase life are presented in Table 1 and Figure 4. According to the findings obtained in the study, the storage periods was found to be statistically significant on the vase life of cut goldenrod ($p \leq 0.01$).

**Table 1.** The effects of different storage periods on the vase life of *Solidago x hybrida* cv 'Golden Glory'.

| Storage period (days) | Vase life (days) |
|---|---|
| 0 (Control) | 15.27 ± 0.88[a*] |
| 5 | 12.13 ± 1.80[b] |
| 10 | 4.80 ± 1.78[c] |
| 15 | 0.0 ± 0.00[d] |

* The difference between the means with different letters is significant ($p \leq 0.01$).

The longest vase life was determined in the flowers at no-storage application (control) (15.27 days), followed by applications that flowers were stored for 5 days (12.13 days), stored for 10 days (7.43 days), and stored for 15 days (0 days). Prolongation of the storage period resulted in a significant shortening of the vase life of the cut goldenrod flowers compared to the control. Goldenrod flowers stored for 5, 10 and 15 days preserved their opening forms similar to first day. However, the leaves of the flowers stored for 10 days turned yellow partially, and the leaves of the flowers stored for 15 days turned completely to yellow. These leaf yellowing resulted with shortened vase life. Since more than 50% damage occurred on the leaves of goldenrods stored for 15 days, their vase life was accepted as 0 days. According to the control treatment, the vase life of the flowers decreased by 20% in 5 days of storage, 70% in 10 days of storage and 100% in 15 days of storage periods. The results showed that the longest vase life was in flowers that were no-stored. However, although the vase life of flowers stored for 5 days decreased by 20% compared to the control, this showed that goldenrod flowers would be stored for up to 5 days. Similarly, it has been reported that long and dry storage causes damage to cut flowers and shortens their vase life (Jones and Faragher 1991; Ahmad et al., 2012; Schiappacasse et al., 2014).



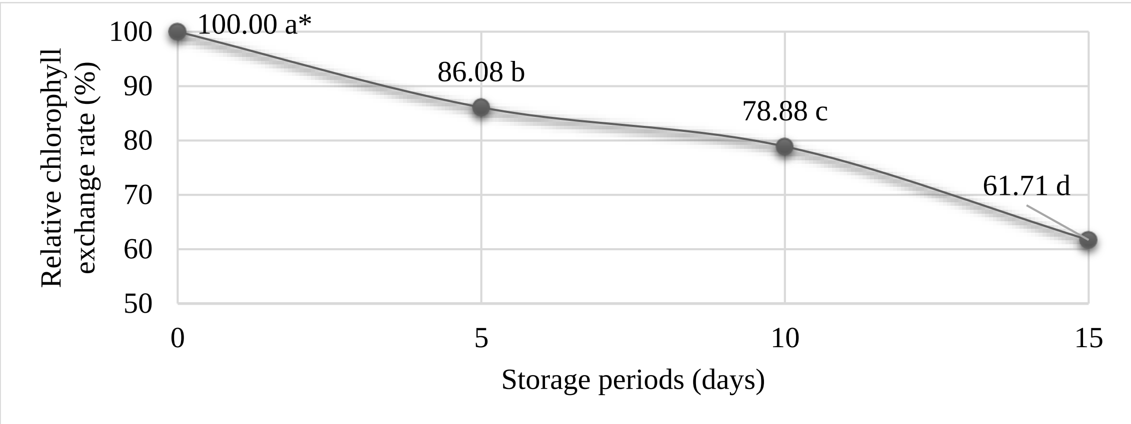

* The difference between the means of values with different letters is significant ($p \leq 0.01$).

**Figure 4.** The effects of different storage periods on the vase life of *Solidago x hybrida* cv 'Golden Glory'.

**Relative Chlorophyll Exchange Rate During Storage (%)**

The effects of different storage periods on leaf yellowing are presented in Figure 5 and Figure 6. Chlorophyll density in *Solidago x hybrida* cv 'Golden Glory' leaves showed a decreasing during the storage period. This decrease in the content of chlorophyll was found to be statistically significant ($p \leq 0.01$).

The chlorophyll content measured as 100% on the first day of the flowers was 86.08% on the 5th day, 78.88 on the 10th day and 61.71% on the 15th day. Although the chlorophyll concentration in the leaves of the flowers with a storage period of 5 days was statistically significant, this was not reflected in the visual quality. Instead, the leaf yellowing with storage period 10 days was reflected on the visual quality, but did not reach a level that would end the vase life. Leaf yellowing greater than 50% occurred in the leaves of the flowers stored for 15 days, which resulted with termination. This yellowing in the leaves can be explained by the continuation of the metabolic activities of the flowers and the breakdown of chlorophyll in the leaves as a result of aging. Chlorophyll measurements supported this result. It has been reported that changes in the amount of ethylene synthesis, respiration, transpiration, genetic structure and plant growth regulators in the plant affect the yellowing of the leaves (Thomas and Stoddart, 1980; Thimann, 1985; Philosoph-Hadas, 1996; Hassan et al., 2003; Sağlam, 2015;).




* The difference between the means with different letters is significant ($p \leq 0.01$).

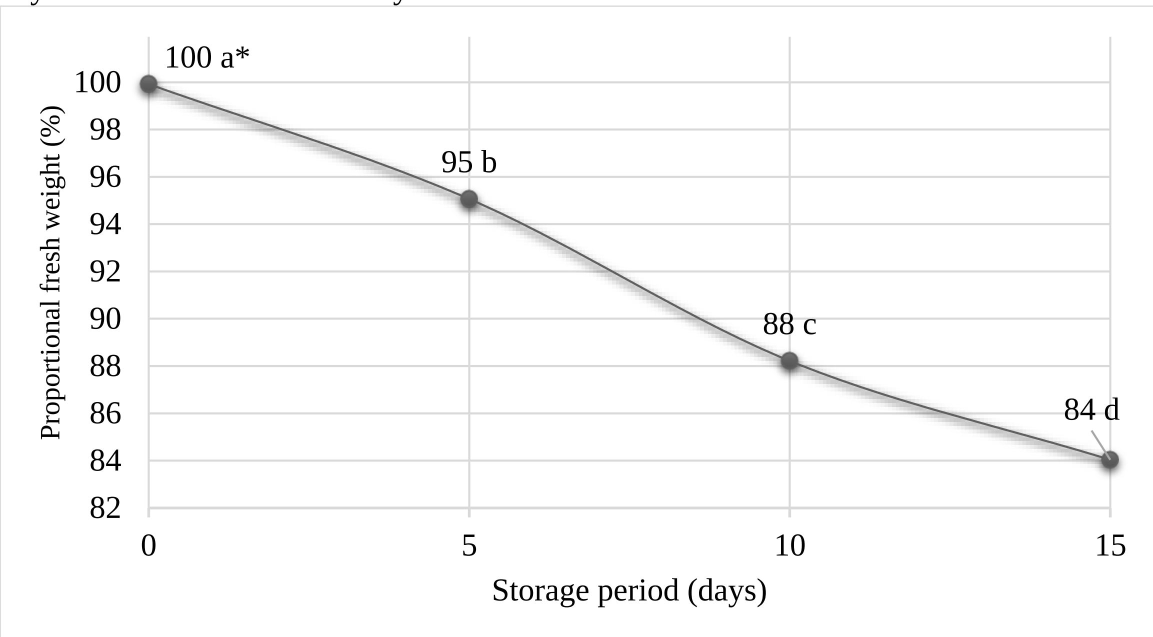
**Figure 5.** Changes in the chlorophyll content in leaf of *Solidago x hybrida* cv 'Golden Glory' at different storage periods.


**Figure 6.** The effects of different storage periods on leaf yellowing *Solidago x hybrida* cv 'Golden Glory' a) 0 (control) days storage, b) 5 days storage, c) 10 days storage, d) 15 days storage.

**Relative fresh weight (RFW) During Storage (%)**

During dry storage, relative fresh weight loss occurred in *Solidago x hybrida* cv 'Golden Glory' flowers compared to the first day (Figure 7). These relative fresh weight losses were found to be statistically significant ($p \leq 0.01$).

Relative fresh weight measured as 100% before storage were measured as 95% on the 5th day, 88% on the 10th day and 84% on the 15th day. As the storage period increased, the relative fresh weight of the flowers decreased. The resulting relative fresh weight loss can be explained by the flowers losing water through respiration and transpiration. In parallel with this study, it was reported that the relative fresh weight of the flowers decreases as the dry storage period of cut flowers increases (Joyce et al., 2000; Makwana et al., 2015).




* The difference between the means with different letters is significant ($p \leq 0.01$).

**Figure 7.** The effects of storage periods on relative fresh weight of *Solidago x hybrida* cv 'Golden Glory'.

Correlation data of the features examined in the study are presented in Table 2. The relationship between storage periods, vase life, relative fresh weight and chlorophyll content was significant ($p \leq 0.01$). A negative correlation was found between vase life, relative fresh weight and chlorophyll content as the storage periods increased. A positive correlation was found between the decrease in relative fresh weight and chlorophyll content and vase life.

**Table 2.** Correlation results of storage periods, vase life, relative fresh weight and chlorophyll content in *Solidago x hybrida* cv 'Golden Glory'.

| | | Storage Period | Vase Life | Relative fresh weight | Chlorophyll Content |
|---|---|---|---|---|---|
| **Storage Period** | Pearson Correlation | 1 | -,967** | -,934** | -,887** |
| | Sig. (2-tailed) | | ,000 | ,000 | ,000 |
| | N | 60 | 60 | 60 | 60 |
| **Vase Life** | Pearson Correlation | -,967** | 1 | ,898** | ,843** |
| | Sig. (2-tailed) | ,000 | | ,000 | ,000 |
| | N | 60 | 60 | 60 | 60 |
| **Relative fresh weight** | Pearson Correlation | -,934** | ,898** | 1 | ,824** |
| | Sig. (2-tailed) | ,000 | ,000 | | ,000 |
| | N | 60 | 60 | 60 | 60 |
| **Chlorophyll Content** | Pearson Correlation | -,887** | ,843** | ,824** | 1 |
| | Sig. (2-tailed) | ,000 | ,000 | ,000 | |
| | N | 60 | 60 | 60 | 60 |

**. The correlation is significant at the $p \leq 0.01$ level.

## CONCLUSIONS

In this study, it was aimed to determine the effects of different storage periods on the vase life of *Solidago x hybrida* cv 'Golden Glory'. The longest vase life was determined at no-storaged flowers. Extending the storage period shortened the vase life and damaged the leaves. The leaf yellowing rather than the flowers in the spikes was effective in ending the vase life of the cut *Solidago x hybrida* cv 'Golden Glory' . The results showed that cut goldenrod flowers can be stored for up to 5 days. However, for longer vase life and storage, new studies should be performed with applications to prevent leaf yellowing, different temperatures and storage conditions.

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