

Water relations in calla lily flower stems harvested at different opening stages⁽¹⁾

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ABSTRACT

Cut flowers are a well established product and require conservation techniques that help keep postharvest quality for marketing. In this context, the objective of this study was to evaluate different opening stages of calla lily (*Zantedeschia aethiopica*) cut stems and their influence on postharvest. Calla lily stems were harvested in the morning, according to the following opening stages: closed spathe, semi-closed spathe (1/3 open), semi-open spathe (2/3 open) and fully open spathe. Once selected and standardized, stems were placed in a controlled room at 21 ± 2 °C and relative humidity of $75 \pm 5\%$, for eight days. The evaluations were conducted daily, observing water pH, commercial quality analysis, width and length of the spathe, fresh weight of stem, water absorption and transpiration. The experimental design was completely randomized, with four treatments (opening stages), five replicates and two stems by plot. The model used was split plot in time, with harvest stages as plots, and evaluation days as subplots. Calla lily harvested at closed spathe and semi-closed spathe (1/3 open), showed spathe opening, although it did not achieve fully spathe expansion, had higher water uptake and hydration of flower stems, and increased water retention capacity by floral tissues until saturation, followed by a period of weight reduction caused by transpiration rates greater than absorption.

Keywords: *Zantedeschia aethiopica*, harvest stages, commercial quality, water balance.

RESUMO

Relações hídricas em hastes florais de copo-de-leite colhidas em diferentes estádios de abertura

O segmento das flores de corte tem exigido técnicas de conservação que contribuam para manter a qualidade floral pós-colheita para a comercialização. Nesse contexto, objetivou-se avaliar as relações hídricas ocorrentes em diferentes estádios de abertura de hastes florais de copo-de-leite (*Zantedeschia aethiopica*) na pós-colheita e a sua influência na vida de vaso. Hastes florais de copo-de-leite foram colhidas no período da manhã baseando-se nos seguintes estádios de abertura da espata: fechada (cartucho), 1/3 aberta, 2/3 aberta e totalmente aberta. Depois de selecionadas e padronizadas, as hastes florais foram dispostas em sala com temperatura ambiente de 21 ± 2 °C e umidade relativa de $75 \pm 5\%$, pelo período de 8 dias. As avaliações foram realizadas diariamente, observando-se pH da água, análise de qualidade comercial, largura e comprimento da espata, massa fresca da haste, absorção hídrica e transpiração. Foi utilizado o delineamento experimental inteiramente casualizado, com quatro tratamentos (estádios de colheita), cinco repetições e duas hastes por parcela. O modelo utilizado foi em parcela subdividida no tempo, sendo que os estádios de abertura constituíram a parcela e os dias de avaliação, a subparcela. Hastes florais de copo-de-leite quando colhidas nos estádios de abertura fechadas e 1/3 abertas apresentam abertura da espata, apesar de não atingirem a expansão completa, observou-se maior absorção de água pelas hastes, hidratação das flores e aumento da capacidade de retenção de água pelos tecidos florais até a saturação, seguido por um período de decréscimo de massa fresca em virtude da taxa de transpiração ser maior que a de absorção. Sendo recomendada a colheita neste ponto para mercados específicos ou de maior distância devido à maior durabilidade comercial observada.

Palavras-chave: *Zantedeschia aethiopica*, estágio de colheita, qualidade comercial, balanço hídrico.

1. INTRODUCTION

An optimal flower harvest stage can ensure or increase postharvest longevity. Each species and even cultivar has specific harvest stages, which may influence metabolic processes. For example, some flowers can be harvested at the bud stage (roses, gladioli, iris), since they continue to develop after harvest. Others, such as orchids, anthuriums and gerberas, do not fully complete flower opening when early harvested (NOVAK et al., 1991).

For calla lily, harvest time is determined by the opening of the spathe, which should be fully extended, with the tip still facing up and absence of pollen (ALMEIDA et al., 2007, 2008, 2009). However, early-harvested flower stems can also be used by the consumer market as a new option

for decoration, since arrangements are conventionally prepared using inflorescences harvested according to the optimal harvest stage (PAIVA and ALMEIDA, 2012).

Both early (when flower stems are not fully expanded) and late harvest (when flower stems have begun the senescence process) affect longevity (CUQUEL et al., 2009). Thus, the vase life of calla lily flower stems can be changed with harvest stage and the maintenance of tissue hydration levels, which is one of the most important factors for a normal metabolic activity and plant organ development (BOROCHOV et al., 1982).

Water balance involves physiological processes of absorption, transport, water loss and ability of tissues to retain it (DIAS-TAGLIACOZZO et al., 2005). In flowers kept in water, water stress occurs when transpiration

⁽¹⁾ Received in 19/12/2014 and approved in 17/11/2015

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becomes higher than water absorption (VAN DOORN, 1996).

In several cut flowers, wilting and senescence of petals are associated with a deficiency in water absorption by the stems. Wilting can be a normal physiological process, part of natural senescence, and it may also be caused by the obstruction of connective tissues on the flower stem basis, causing the reduction in water flux (PAULL et al., 1985). The physical obstruction of xylem vessels can be through microorganisms or embolism (VAN DOORN, 1996).

Water quality is critical to extend flower life. For more postharvest longevity, the optimum pH ranges between 3 and 4, which prevents the proliferation of bacteria and blocking of conducting vessels, by increasing water

absorption and the maintenance of stem turgor (GAST, 2000).

Therefore, the objective of this study was to evaluate the water absorption and transpiration in calla lily stems harvested at different opening stages, and its influence on postharvest.

2. MATERIAL AND METHODS

Calla lily flower stems from a commercial production in Ribeirão Vermelho, Minas Gerais State, Brasil, were collected in the morning, at 4 different opening stages of the spathe: closed (cartridge), 1/3 open, 2/3 open and fully open (Figure 1).



Figure 1. Harvest stages of calla lily flower stems: (1) closed spathe (cartridge), (2) 1/3 open, (3) 2/3 open and (4) fully open.

They were then transported dry for one hour, to the laboratory, where the stem basis was immersed in water and kept at 21° C. Once selected and standardized at 35 cm, they were weighed to determine fresh weight, and two stems were prepared in each plastic pot containing 1 L of tap water, which was completed daily. The pots were sealed with a plastic bag around the stem to prevent water loss by evaporation.

The flower stems were placed in a room, at room temperature (21 ± 2° C) and relative humidity of 75 ± 5%, for a period of eight days. Assessments of water pH, commercial quality, width and length of the spathe, fresh weight of the stem, water absorption and transpiration, were performed daily.

The width and length of the spathe were measured with the aid of a ruler and, in both, the curvature was taken into consideration, as a pattern determined by Almeida et al. (2008). The width measurement was made considering the reference spadix tip. On the other hand, the length was measured, considering the spathe tip.

The absorption rate was obtained by determining the volume of consumed water, in mL stem⁻¹ day⁻¹, and the transpiration rate was estimated in g stem⁻¹ day⁻¹, according to Van Doorn and Vaslier (2002), with modifications:

$$T = Vc - (MHf - MHi)$$

T: transpiration rate (g stem⁻¹ day⁻¹);
Vc: consumed solution volume (g);

MHi: early stem weight (g);

MHf: late stem weight (g).

Changes in fresh weight were determined by daily weighing of flower stems, and the value was determined according to He et al. (2006), with modifications:

$$VMF = (Mf \times 100) / Mi$$

VMF: variation in fresh weight (%);

Mi: stem fresh weight on the first day of evaluation (g);

Mf: stem fresh weight on the day of evaluation (g).

The water balance was calculated by the difference between absorption rate and transpiration rate, and was expressed in mL stem⁻¹ day⁻¹, according to He et al. (2006).

The analysis of commercial quality of the stems was based on the pattern determined by Almeida et al. (2008):

Class A1: turgid inflorescences, with inclined spathe tip and no roughness or necrosis;

Class A2: turgid inflorescences, with the spathe tip slightly rolled down and absence of roughness or necrosis;

Class B: turgid inflorescences, with the spathe tip slightly rolled down, presence of roughness, absence of necrosis;

Class C: wilted inflorescences, with the spathe tip rolled down and presence of necrosis.

From assessments of flower stem quality, it was determined that the sum of the days in which they remained in classes A1, A2 and B represent the vase life of these inflorescences; stems classified as A1 indicate the best

quality, and those classified as C were considered as a waste.

A completely randomized design was used, with four treatments (harvest stages), five replicates and two stems per plot. The model used was split plot in time, in which the opening stages were the plot and the days of evaluation, the subplot. The data obtained in the experiment were pooled and submitted to the Tukey test at 5% probability for qualitative data, and analyzed with the aid of the R software (R DEVELOPMENT CORE TEAM, 2006).

3. RESULTS AND DISCUSSION

The pH of the maintenance solution (water) ranged between 7.0 and 7.35. While the maintenance of cut flowers

in solution with pH between 3-4 favors the blocking reduction of conducting vessels (GAST, 2000), the highest pH probably did not influence water absorption, the quality of calla lily stems and proliferation of bacteria. Ahmad et al. (2013) also observed that the vase life of Calla (*Zantedeschia L.*) was not affected by the high pH of water (8.1), showing that this species can be less sensitive to a reduction in water absorption as a function of pH, which is observed in other species when it is high.

It was observed that the number of days in which calla lily flower stems remained in class A1, A1+A2 and A1+A2+B was higher for the closed harvest stage, followed by stages 1/3 open and 2/3 open, and differences were not observed between them. However, the open harvest stage had a lower longevity (Table 1). Besides having a greater longevity, the inflorescences collected in the closed harvest

Table 1. Number of days in which calla lily flower stems remained in qualitative classes A1, A1+A2, A1+ A2+B, as a function of harvest stage, stored at room temperature (21 ± 2 °C) and relative humidity of $75 \pm 5\%$, for a period of 8 days.

Harvest stages	Days*		
	Class A1	Class A1+A2	Class A1+A2+B
Closed	7.2 a	7.2 a	8.0 a
1/3 open	5.8 a	6.3 a	7.8 a
2/3 open	5.9 a	6.1 a	7.5 a
Open	3.9 b	3.9 b	4.9 b

*Means followed by the same letter in columns do not differ by the Tukey test at 5% probability.

stage also remained in the classification A1 for more days (7.2 days).

Harvested flower stems remained closed about 3 days longer in class A1, A1+A2, A1+A2+B, when compared to open flower stems. Flower stems harvested 1/3 open and 2/3 open also remained within the commercial standard for a longer time, when compared to flower stems harvested open.

Increased longevity for early-harvested flower stems was also observed for lily (BARBOSA et al., 2006). In addition, it decreases the difficulty in transportation, since they take up less space in the vehicle, are more easily packed and suffer

less damage (PAIVA and ALMEIDA, 2012).

Unlike other species, calla lily does not complete the total process of spathe opening when early harvested (PAIVA and ALMEIDA, 2012). Although there is a significant increase in longevity, the consumer should consider that the inflorescence aspect is different and can also be an interesting option. For the spathe expansion in the direction of width (Figure 2) and length, it can be observed, by the measurement of such dimensions, that these values change with the senescence process and harvest stage.

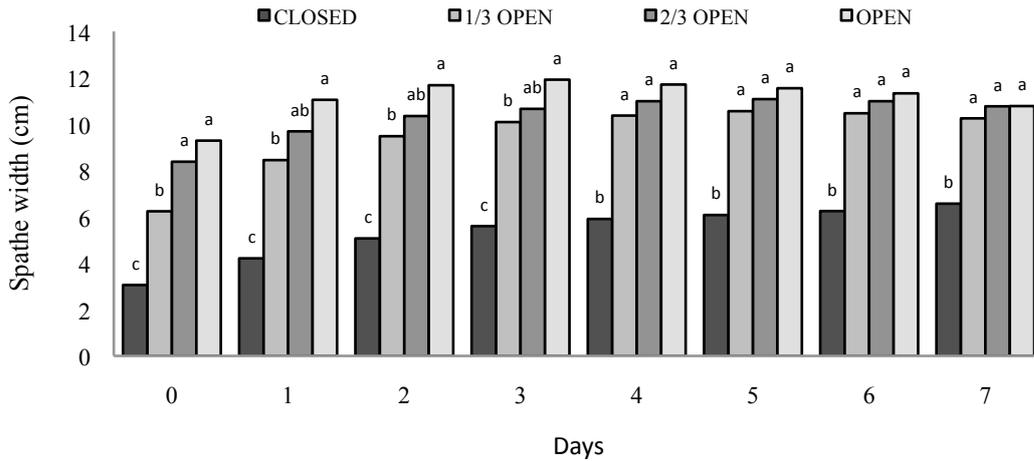


Figure 2. Spathe width of calla lily flower stems as a function of harvest stage and days after harvest. Means followed by the same letter for each day of evaluation do not differ by the Tukey test at 5% probability.

Regarding spathe width, it was possible to observe the influence of harvest stage, as well as that of the days after harvest. An expansion occurred in flower stems, when they were harvested closed throughout the evaluation period, reaching a maximum width of 6.57 cm on day 7. Despite this expansion, the spathe did not reach the same size of those harvested in more developed stages.

Analyzing spathe width of flower stems harvested open, they showed higher expansion, compared with

stems collected 1/3 open until the third day after harvest. It was also possible to observe a maximum value of 11.92 cm on day 3 and 10.56 cm on the fifth day, respectively, with subsequent reduction, indicating the occurrence of senescence. The days in which the spathe started the bending process are equivalent to the days in which the stems remained in class A1+A2 (Table 1).

Observing spathe length (Figure 3), it was influenced by harvest stages and evaluation period, which corresponds to the period after harvest.

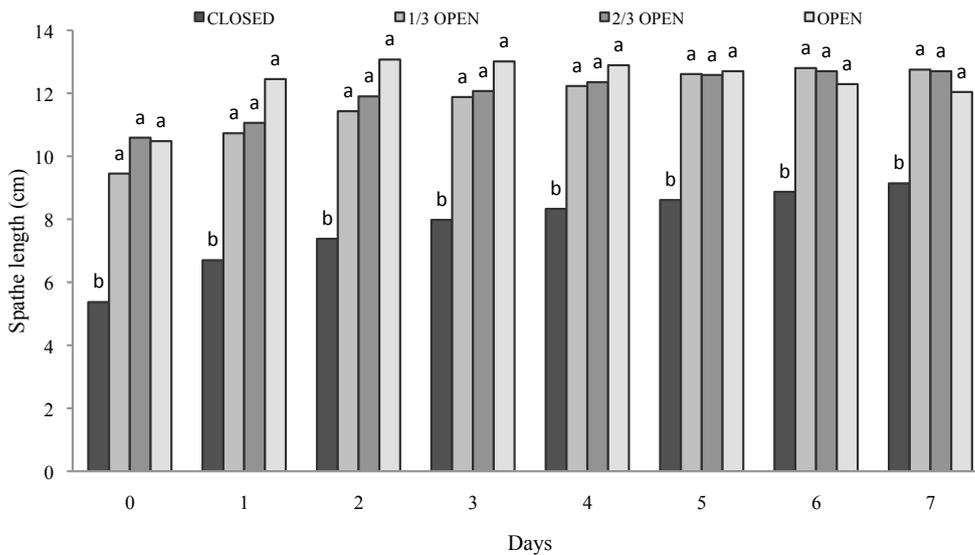


Figure 3. Spathe length of calla lily flower stems as a function of harvest stage and days after harvest. Means followed by the same letter for each day of evaluation do not differ by the Tukey test at 5% probability.

Flower stems harvested closed showed expansion throughout the evaluation period, reaching a maximum length of 9.14 cm on day 7 after harvest. The flower stems harvested semi-open (1/3 and 2/3 open) showed maximum values of 12.80 and 12.70 cm, respectively, on the sixth day. In both stages, a similar spathe expansion behavior was observed.

For flower stems harvested open, the spathes showed a maximum length of 13.07 cm on the second day after harvest, wilting after this period. In the senescence

process of calla lily inflorescences, it is possible to observe a reduction in the dimensions of the spathe, corresponding to wilt, and subsequent necrosis at the edges and the tip of the calla lily inflorescence (ALMEIDA et al., 2009).

Although flower stems harvested closed did not reach full expansion, they had a gradual increase in spathe size, remaining for more days in expansion. There was no necrosis in the spathe edges, unlike what was observed in other harvest stages (Figure 4).

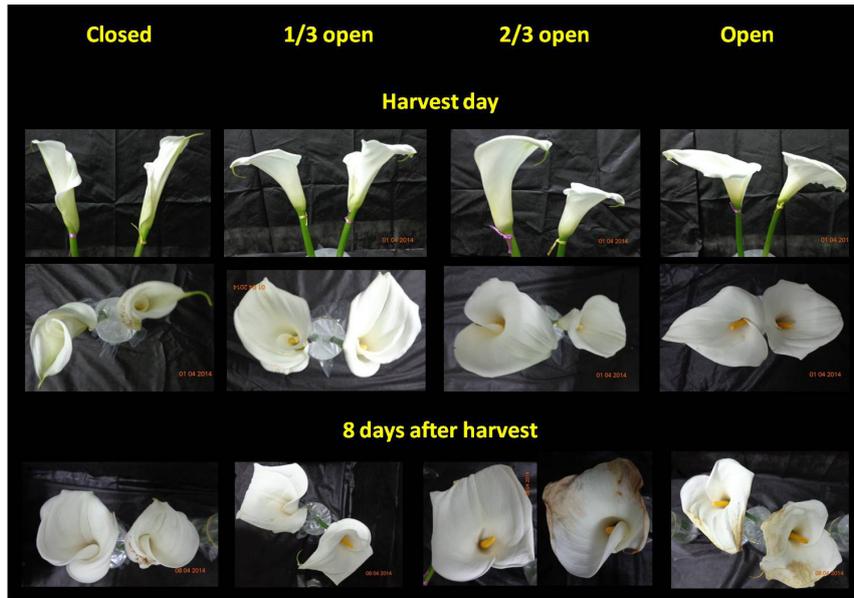


Figure 4. Spathe expansion of calla lily flower stems as a function of harvest stage and days after harvest

For all harvest stages, there was a reduction in the fresh weight of calla lily flower stems after day 3 (Figure 5). Stems harvested at the stages closed and 1/3 open showed an increase in absolute fresh weight values,

higher than other treatments until the third day after harvest, with a weight gain of up to 5%. From the fourth day, there was a reduction in weight of 2% until the last day.

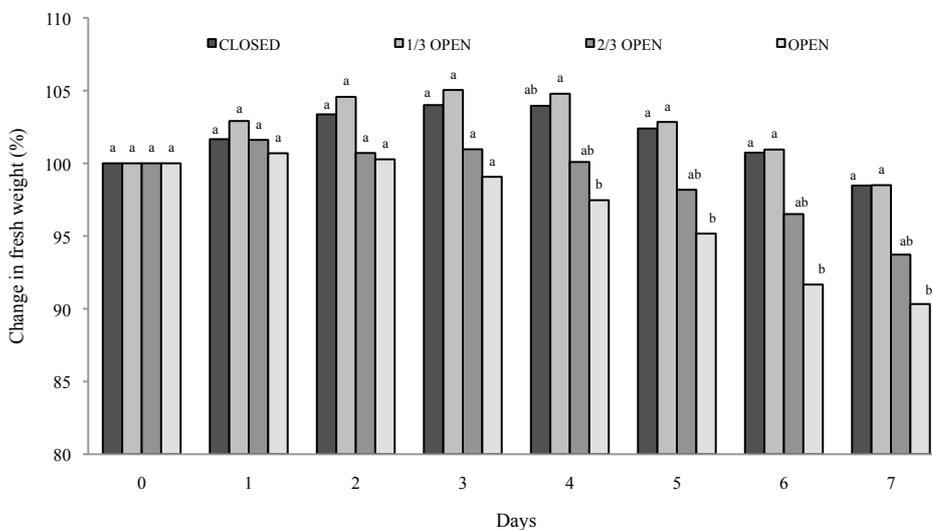


Figure 5. Percentage change in fresh weight of calla lily flower stems as a function of harvest stage and days after harvest. Means followed by the same letter for each day do not differ by the Tukey test at 5% probability.

Stems harvested 2/3 open showed a weight gain of only 1% on the first day after harvest. After this period, it was possible to observe an accelerated decline in fresh weight, with a loss of 7% on the last day, without statistical significance, but of biological relevance, since it was correlated with quality evaluation.

The greatest fresh weight loss occurred in the open harvest stage, presenting an statistical difference from day 4 and coming to a reduction in fresh weight of 10% on day 7. High tissue hydration levels are generally associated with increased vase life of cut flowers, whereas losses between 10 and 15% of their fresh weight can lead to tissue death (MORAES et al., 1999).

Flower stems harvested with fully open spathe had a greater fresh weight loss than stages closed, 1/3 and 2/3 open. Therefore, more open stems develop and reach maximum quality faster, with accelerated senescence.

The absorption rate of the different harvest stages of calla lily was higher on day 1 after harvest, followed by a decrease over time (Figure 6), while in the opening stage 1/3, a higher absorption occurred. The same behavior was observed for lotus flowers (*Nelumbo nucifera*), in which the water absorption rate was relatively high during the first day of vase life (IMSABAI et al., 2013). This indicates that the high initial water absorption is to compensate for water loss during the harvest period.

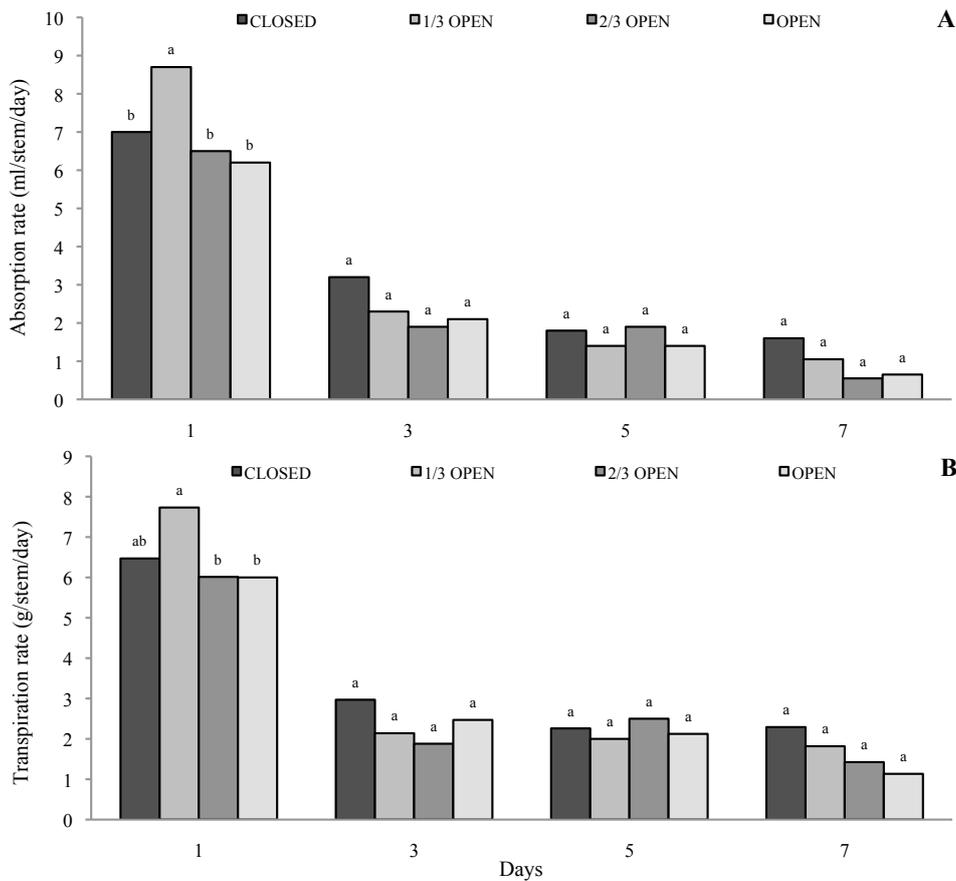


Figure 6. Absorption rate (A) and transpiration rate (B) of calla lily flower stems as a function of harvest stage and days after harvest. Means followed by the same letter for each day do not differ by the Tukey test at 5% probability.

From the third day, there was no difference in water absorption for the different opening stages. However, in general, the highest water absorption was observed at harvest stages closed and 1/3 open, and the lowest absorption, at stages 2/3 open and fully open. The higher absorption for early harvest stages can be justified by the need to maintain tissue hydration levels, so that full spathe development occurs. All harvest stages showed a lower absorption rate on the last day that corresponds to the end of stem vase life.

The absorption rate of cut flowers is dependent on many

variables, is determined by pre- and post-harvest factors, and is related with genetic, physiological and anatomical characteristics of each species (NOWAK and RUDNICKI, 1990). Although the absorption rate decreases after some time of water storage, the water absorption observed in postharvest indicates that there was no physical obstruction of xylem vessels by microorganisms or embolism.

For this experiment, senescence was the possible cause of reduction in water absorption by calla lily.

The transpiration rate observed in the flower stems showed a decrease over time. Similarly to the absorption

rate observed on day 1, stem transpiration was high for all harvest stages at the same time assessment and, in the opening stage 1/3, it was possible to observe a higher transpiration. The higher absorption and transpiration rates on the first day are related to metabolic stress caused by stem cutting, which is reduced upon stem hydration.

From the third day, it was not possible to observe a significant difference in transpiration for the various opening stages. However, the highest transpiration rate occurred at harvest stages closed and 1/3 open. According to Taiz and Zeiger (2013), most of the water absorbed by the plant is lost to the atmosphere by stomatal transpiration, and this process is regulated by complex and dynamic interactions of internal and external factors.

Transpiration rates can be influenced by internal factors, such as ripening stage, besides external and environmental factors, such as temperature, relative humidity, air

movement and atmospheric pressure (VILAS BOAS, 2000). According to Yiotis and Psaras (2011), numerous stomata on the epidermis of peduncle and petiole tissues of *Zantedeschia aethiopica* were observed. Environmental factors were controlled and kept constant during the experiment, without abrupt changes in temperature, relative humidity, or the presence of forced air circulation, thus minimizing their impact on transpiration rates.

The observed results demonstrate a direct relationship between absorption rate and transpiration rate (Figure 6), since the most hydrated flower stems had greater water loss.

The water balance (difference between absorption and transpiration rates) for harvest stages closed, 1/3 open and 2/3 open turned negative from the fifth day after harvest (Figure 7). It is observed that, for these harvest stages, stem fresh weight (Figure 5) does not decrease until the fourth day, suggesting that there was no severe water stress during this period.

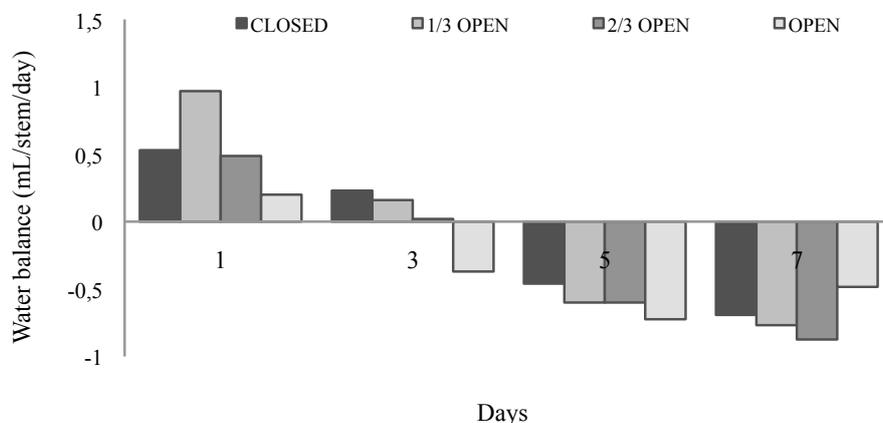


Figure 7. Water balance of calla lily flower stems as a function of harvest stage and days after harvest.

Although the water balance of the harvest stage 2/3 open was not negative on the third day after harvest, it was very close to zero. On the other hand, for the harvest stage fully open, there was a reversal of fluid balance, becoming negative from the third day. This period in which transpiration rate exceeds absorption rate is equivalent to the reduction in fresh weight (Figure 5), limiting flower longevity, leading to spathe wilting. This loss can be attributed to the transpiration process, as well as to the deficiency in water absorption by the stems (DIAS-TAGLIACOZZO et al., 2005).

Water stress was also responsible for induction of premature senescence in other cut flowers like carnation (*Dianthus caryophyllus* cv. White Sim) (BOROCHOV et al., 1982) and anthurium (*Anthurium* cv. Ozaki Red) (PAULL and GOO, 1985).

4. CONCLUSIONS

The flower stems harvested at stages closed and 1/3 open presented spathe opening, although not completely expanded; there was a higher absorption of water by the

stems, flower hydration and increased water retention capacity by tissues, remaining longer in commercial quality. Thus, they are better suited to more distant markets, with long transportation periods.

ACKNOWLEDGMENTS

The authors would like to thank FAPEMIG, CNPq and CAPES for the financial support and grants provided.

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